Economics of Science, Technology and Innovation

Gunnar Eliasson

Advanced Public Procurement as Industrial Policy

The Aircraft Industry as a Technical University

Springer

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Preface

This study is about the macroeconomic effects of positive externalities or industrial spillovers around advanced production. The case explored is the "technology dividend" around Swedish aircraft industry, and in particular around the aircraft manufacturer Saab, and the major industrial project of the JAS 39 Gripen multirole combat aircraft. The project is partly an updating of my book (in Swedish) *Technology Generator or a National Presige Project*[1] from 1995, but extends the analysis in several directions. The study includes a chapter on spillovers from advanced production in an industrially developing economy, South Africa, that has acquired the JAS 39 Gripen for its Air Force. There is also a chapter in which the results for Sweden are discussed in the wider context of advanced public procurement in Europe.

The text has been organized such that the main chapters have been written for academic readers. Two supplements include the technical details of data collection, mathematical models, and calculation methods.

The first chapter is brief and focused on the results. It has the character of an extended executive summary.

The second chapter summarizes the entire story; problems, results, and methods.

This project would not have been possible without the generous support of a number of people. First of all great thanks go to all those people with crowded calendars in Swedish industrial firms that have set aside time to respond to my questions. Most of them have been listed at the end of the book. Several of them have read large parts of, or entire earlier versions of my manuscript, added important insights and helped me weed out a large number of factual errors. Among them, I want to mention Carl-Henrik Arvidsson, Billy Fredriksson and Lennart Källqvist at Saab in particular.

Some of my academic colleagues have also read the manuscript at different stages of completion. Some have been very helpful in going through particular technical aspects of my empirical method. From others, finally, I have benefitted significantly from brief discussions of particular arguments that I have ventured. On all these counts I want to mention (in alphabetical order) Pontus Braunerhjelm and Anders Broström, both at the KTH Stockholm; Richard Day at USC in Los Angeles; Åsa Hansson, Lund University; Erik Mellander at IFAU in Uppsala; Pierre Mohnen at Merit in Maastricht; Ishaq Nadiri at NYU; Erol Taymaz at the Middle East Technical University (METU) in Ankara; Lars Werin earlier at Stockholm University and Clas Wihlborg, Chapman University, Anaheim in particular.

Djursholm, Sweden Gunnar Eliasson
January 15, 2010

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About the Author

Gunnar Eliasson is Professor Emeritus of Industrial Economics/Dynamics at the Royal Institute of Technology (KTH) and a Senior Researcher at the Swedish Entrepreneurship Forum and at the Ratio Institute in Stockholm. He was previously the President of the Industrial Institute for Economic and Social Research (IUI) in Stockholm and before that the Chief Economist and Director of the Economic Policy Department at the Federation of Swedish Industries. From 1994 to 1996 he was the President of the International Joseph A. Schumpeter Society. His current research is focused on the economics of the firm and management, technology, entrepreneurship and economic development, and on the competence demands on the labor markets of the New Economy. He is the father of the Swedish micro- to macrosimulation model, MOSES, and the theory of the Experimentally Organized Economy and of Competence Blocs. He has published many books and journal articles in the fields of industrial economics, the theory of the firm, business economic planning and management, labor and education economics, and simulation modeling. Among his books are *Business Economic Planning* (1976), *Technological Competition and Trade in the Experimentally Organized Economy* (1987), *The Knowledge Based Information Economy* (1990), *Firm Objectives, Controls and Organization* (1996), and *The Birth, the Life and the Death of Firms* (2005). Together with his wife, Ulla, he has authored a study on the fifteenth century art markets in Northern Italy and Florence (1997).

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List of Interviews

The interviews with business firms and other agencies on which most of the empirical content of this book is based have been conducted in stages over a long period.

1. For the 1995 book in Swedish (Eliasson 1995:171f), 33 interviews were conducted during 1994 and 1995. They have been directly useful as bench marks for the later interviews with the same firms.
2. During two interview visits to South Africa in 2000, 15 interviews (14 firms and 23 individuals) were carried out (listed below).
3. The main body of interview material on which this book rests was compiled during 2008 and 2009 in Sweden, Europe and South Africa. It includes the results from 37 interviewed persons on 37 occasions with IG JAS firms, 3 of them per telephone. In addition, 20 individuals in 10 outside spillover-receiving firms have been interviewed on 14 occasions, including three interviews with the Government customer FMV, one by telephone. Nine firms and nine individuals were interviewed in South Africa in 2008 (listed below). The number of firms, business units, and agencies interviewed thus adds up to 49. They are all listed below. The large numbers depends on the considerable historical data collection needed for the quantitative part of the study.

In addition I have drawn on interview material on firms included in this analysis, but compiled for other studies, notably my study on “insourcing” of production (Eliasson 2005c) and on corporate headquarter location (Eliasson 2008a), both for Invest in Sweden Agency (ISA) and two studies on the networked defense (Eliasson 2005d) and on disaster preparedness that I was actively involved in, carried out within the Swedish Academy of Engineering Sciences (IVA), covering altogether 21 firms related to firms included in this study.

I have also recently started a complementary spillover study on Gripen weapons development within Saab Bofors Dynamics (SBD) that will be reported on separately. Two of these interviews have also been used in this context and are listed below. The spillover multiplier calculations (See Supplements 1 and 2) are based on official data from public investigations, official statistics or annual reports of companies and on partly confidential data obtained during interviews. I am preparing a separate document on some of this statistical detail that was simply not reasonable to document in this volume, to make it possible to repeat the calculations, or to follow up with updated calculations as more data become available with time. I will make this documentation available for research purposes to the extent data is not confidential.

IG JAS Group

Saab Group

Jan Ahlgren, former Director of Communications, Saab Aerosystems
Stefan Andersson, Director Development, Saab Aerosystems
Thomas Karlsson, Director of Business Development, Saab Aerosystems
Carl-Henrik Arvidsson, Director Business Development, Saab Aerosystems
Katarina Björklund, Director Business Development, Saab Aerosystems
Gustaf Håkan Borin, Saab International Technology Korea, Seoul, South Korea
Robert Carlsson, Chief Accountant, Saab Bofors Dynamics
Christer Dahlberg, CEO IG JAS and VP Business Development, Saab Aerosystems
Anders Florenius, former Group Senior VP, Corporate Communications, Saab
Billy Fredriksson, former Chief Technical Officer, Saab Military Aircraft
Lars Gissler, former VP Procurement, Saab AB
Gunnar Holmberg, Director Business Development, Saab Aerosystems
Henrik Höjer, Director Program Management, Gripen International
Per Hoving, Director Industrial Cooperation, Saab Aerosystems, retired
Tommy Ivarsson, former VP Head of Strategy, Saab Military Aircraft
Bengt Janer, Saab Gripen International, Brazilia, Brazil
Dan Jangblad, Group Senior VP, Strategy and Business Development, Saab
Pontus Kallen, General Manager, Saab Aerosystems
Lennart Källqvist, Senior VP, Corporate Strategy and Development, Saab
Gert Malmberg, Senior VP, Business Development and Strategy, Saab Bofors Dynamics
Johan Noren, Saab Microwave Systems
Håkan Rosen, Saab Ventures
Peter Sandehed, Group Senior VP, Corporate Treasury and Management, Saab
Åke Svensson, CEO Saab AB
Göte Strindberg, Saab Aerostructures
Eva Söderström, Programme Manager, Gripen South Africa
Virgel Åkerman, Systems engineer, Safety Systems, Saab

Ericsson

Håkan Eriksson, Senior VP and Chief Technical officer
Leif Hedenström, Director Management Information

Bengt Halse, Head of strategic data link activity (Ericsson Microwave Systems) in Mölndal, later CEO of Saab AB, now retired
Curt Sigvardsson, formerly with Ericsson, now retired
Richard Smedberg, Manager Financial Planning and Analysis

Volvo Aero Corporation (VAC)

Bengt-Olof Elfström, Head of Research and Development, Chief Technical Officer
Bengt Lundgren, Director Industrial Cooperation
Hasse Nilsson, Marketing Director
Thomas Sätmark, Senior VP, Corporate Development

Other

Applied Composites AB (Acab), Linköping

Lars Hultman, Workshop Engineer
Kenneth Karlsson, Marketing Director
Sören Poulsen, Manager Radomes and Antennas
Torgny Stenholm, CEO

Autoliv

Jan Olsson, VP Research
Hans-Göran Patring, Group VP, Human Resources
Dan Persson, President, Autoliv Sweden
Mats Ödman, Group VP, Corporate Communications

Bodycote (from 2009 Exova), Karlskoga

Lars-Gunnar Svensson, Project Manager

Combitech AB

Niclas Foch, VP

Dassault Aviation

Gilles Marcoin, VP Affairs Union Europeenne
Gilles Appollis, Deputy VP. International General Directorate

FMV

Arne Heden, Director of Air and Space procurement Command
Staffan Näsström, former Chief of Operations, also Special Advisor to the Ministry of Defence, retired

Modig Machine Tool, Virserum

Percy Modig, CEO

SEB, Stockholm

Erik Belfrage, Advisor to the Chairman, on the Board of Saab

Sectra, Linköping

Jan-Olof Brüer, CEO

Svensk Tryckpressgjutning, Vimmerby

Sven Hjelte, CEO

South Africa (Interviews in 2000 and 2008, Two Visits Each Year)

Åke Albertsson and Eva Söderström both at Saab have been very helpful in organizing these interviews
Per Erlandsson, Chief Executive Officer, *Saab South Africa*, Centurion (2008)
Chris Coetzee, *Denel Saab Aerostructures*, Kemplon Park (2008)
Paul Gerber, Group manager Business Development, *Grintek*, Centurion (2000)
Brian Greyling, Program Director, *Aerosud*, Pretoria (2008)
Paul Hatty, *Hatty and Associates and Industrial Consultants*, Johannesburg (2000)
John Holdt, *Denel Aviation* (2000)
Derek Jones, *ABB South Africa*, Sunninghill (2000 and 2008)

Boenie Louw, *Tshwane South College*, Centurion (2008)
Thivash Moodly, CEO *TMI Dynamatics*, Ganteng (2008)
Tom O´Donnel, *Volvo South Africa*, Pretoria (2000)
Vanan Pillay, Director Industrial Partnership and Government procurement, *Department of Trade and Industry (DTI)*, Pretoria (2000)
Christer Petren, General Manager *Saab and BAE Systems*, Saxonwold (2000)
Bengt Saven, CEO *Denel Saab Aerostructures*, Kemplon Park (2008)
Harold Timm, Senior General Manager, *Ericsson South Africa*, Johannesburg (2000)
Jörn von Treskow, *Ericsson sub-Saharan Africa*, Johannesburg (2008)
John Williamson, executive VP, *BAE Systems*, Centurion (2008)

Avitronics (Pty), Centurion (2000)

Ben Ash, Managing Director
Ulf Ericsson, Director Business Development

CSIR, Pretoria (2000)

Reine Biesenbach, Head: International Business Development
Oliver Damm, Manager: National Product Development Center, Manufacturing and Materials Technology
Philip Haupt, Business Area Manager, Manufacturing and Materials
Erlank Pienaar, Manager: Electronic Countermeasures

Denel Aviation (2000)

Theo Kleynhaus
Grant Sampson

Marieholm Industry AB (MIAB), Sandton (2000)

Vesa Peurakari, Managing Director
Terje Bark Andersen, Division Manager Telecom

Scania South Africa, Mondeon (2000)

Ulf Grevesmül, CEO
Tord Holmström, Finance Director
Sune Rask, Assembly Manager

List of Cases

The case documentations are an important part of my analysis to give empirical content and substance to the spillover multiplier estimates and the more principal reasoning. The cases come in two forms, (1) as specific and rather brief technology stories and (2) as longer and more general presentations occupying entire numbered sections. They have all been numbered as (also see Table 4 on page 51):

Cases under *Core technologies*

Case 1: Civilian aircraft
Case 2: Aircraft engines and commercial gas turbines

Cases under *Related industries*

Case 3: Innovative start ups around Saab
Case 4: Secondary-related engineering spillovers from the development and modifications of aircraft engines

Cases under *Engineering general*

Case 5: Hydraulic engines, etc.
Case 6: Integrated production, lifelong support, and maintenance-free products.
Case 7: Creating an advanced and attractive industrial competence bloc rich in spillovers (Sect. 4.3.5).

Cases under *Industry General* and serendipitous discovery

Case 8: Digital Mobile Telephony: Ericsson (Sect. 4.4).
Case 9: Ericsson HP Telecom (Sect. 4.5).
Case 10: The emergence and disappearance of a Swedish computer industry (Sect. 4.6).
Case 11: The business information systems venture of Ericsson (EIS, Sect. 4.7).
Case 12: Medical technology spillovers (Sectra, Sect. 4.8).
Case 13: The Erieye surveillance system, Electrically directed antennae, and the MiniLink: the development of an early networked defense system moving Ericsson mobile telephony on (Sect. 5.2).

Case 14: Distributed and integrated production as a generic engineering organizational technology: the art of systems integration (Sect. 5.3).
Case 15: Safety-critical software engineering (Sect. 5.4).
Case 16: Manufacturing lightweight technologies, including Modig Machine Tool and ACAB.
Case 17: The Swedish automotive safety industry and Autoliv (Sect. 5.6).
Case 18: Maximizing functional flexibility and minimizing life cycle maintenance and service costs (Sect. 5.7).
Case 19: Space research and exploration (Sect. 5.8.1).
Case 20: Virtual and secure online design-encryption/Security (Sect. 5.8.2).
Case 21: Civil security (Sect. 5.8.3).
Case 22: Unmanned aircraft and future air transport (Sect. 5.8.4).
Case 23: Engineering consultancy (Combitech AB).
Case 24: Industrial competence bloc Formation in Linköping.
Case 25: Spillover opportunities missed (Sect. 5.10.1).

Other

Case 26: TMI Dynamics.
Case 27: Saab industrial school project in South Africa.
Case 28: Dassauilt Aviation, France.

Chapter 1
On the Cloud of Technology that Surrounds Advanced Production: A Summary of Results

This study is about the macroeconomics of positive externalities or industrial spillovers around advanced production.

It is a case study, using different methods to generalize from cases at the microproduction and market levels to economic value creation and macroeconomic growth.

I use the Swedish military aircraft industry as an illustrative case, and in particular the major industrial project of the Saab JAS 39 Gripen[1] multirole combat aircraft that has been procured by the Swedish Air Force. The supplier was the Industrial Group (IG JAS) of firms[2] specially formed in 1981 to take on the considerable technical risks associated with the program. The Saab JAS 39 Gripen project is unique in terms of level of technological sophistication, clear definition and availability of background material. Gripen was the first fourth generation "unstable" combat aircraft in the world that could be "flown by the computer" and that could also change mission in flight between fighter, attack and surveillance roles (Swing-Role capacity). Gripen was also the critical actor of a complex early networked defense system and featured advanced light weight technology to be able to land on, and take off from, regular roads. The project, furthermore was a procurement of considerable size for the Swedish economy and constituted an important reason for part of the procurement being negotiated under an innovative incentive contract (see further Sect. 8.4).[3]

1.1 The Spillover Multiplier

Four stories run through the text. There is (1) the overriding issue of advanced public procurement as a form of, perhaps the only form, of effective *industrial policy* and *a policy vehicle to overcome the considerable underinvestment in private R&D among the industrial economies* to be documented in this text. There are (2) the quantitative assessments of the magnitudes involved and the economic value of the technological spillovers, or the *spillover multiplier* that presents *the advanced firm as a technical university* or an *infrastructure asset* of the national economy. There are (3) the case presentations that give concrete content to the spillovers. Finally, (4) there are the strategic business and *property rights* issues associated with advanced

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product development that may generate spillovers of much greater economic value than the procurement value itself, “spilled technology” that the generator firm has to let go as a free public good because it cannot charge for it and appropriate its value for itself. The weak property rights that characterize intangible assets are a general theme that runs through the entire text. It is of course a shame if the local economy at large is not sufficiently entrepreneurial to commercialize the technological spillovers. To help build local commercialization competence therefore is a policy instrument for local government to assert property rights to technology spillovers that will otherwise be captured elsewhere, or get lost. And the logical conclusion is an argument for a joint exploitation of the spillovers between the producer and the public customer that both share the value created. Offset trade agreements in developing economies sometimes have that objective, but they could often be more rationally and efficiently formulated to the benefit of both parties. This is an issue explored in a separate Chap. 6 on the purchasing of the Gripen combat aircraft by South Africa.

Central to the quantitative part of my analysis is the concept of a *spillover multiplier*, defined as the ratio between the social value creation over and above opportunity costs that the military development project has created and the military investment itself. If that ratio is one, the entire development investment publicly procured has been returned to society in the form of net social value creation. This measure is of course highly abstract and really cannot be understood if the prior assumptions that have gone into the calculation are not understood. A number of technical problems are associated with that “understanding” that I will return to in Chap. 8 and Technical Supplement S2. The large number of case studies, furthermore, are there to give concrete empirical content, and therefore also credibility to the abstract econometric measurements.

1.2 Twelve Conclusions on How to Overcome the Underinvestment in Private R&D Among Advanced Industrial Economies

To facilitate for the reader to evaluate, for him- or herself, the evidence to be presented in this document, I present here a list of the main conclusions.

1. To realize a major industrial project such as the JAS 39 Gripen, and to satisfy a *demanding customer* a large number of technical problems have to be solved. The Gripen project therefore became a broad-based *technology driver* that has generated a flow of technology spillovers. A situation of *joint production* has been created since the *double product* of both the aircraft and the “cloud of spillovers” that surrounds aircraft development project are supplied.
2. Spillovers predominantly originate during the product development phase.
3. New products will never be better than the competence of customers to understand and to use them, and what they are willing to pay for. When it comes to complex and sophisticated products such as military aircraft the customer often also contributes

user knowledge. *Advanced customers therefore raise the quality of the technological spillover flow and represent a competitive advantage of a national economy.*

4. *Long-term competitive sustainability of an industry requires the local presence of one or more technology leading firms at its helm for the rest of industry to learn from.* Aircraft industry develops and manufactures an extremely complex product, developing and using top of the line industrial technology. *Aircraft industry therefore already today uses the many technologies of the future engineering industry. It operates as, and compares well in terms of performance with, a technical university, both in generating new and tested technologies and in supplying well-educated and experienced workers and engineers to industry at large.* In fact, while some advanced knowledge may be taught in principle in a university classroom many critical industrial competences, such as systems integration in which the aircraft industry excels, can only be acquired through direct experience from that production.
5. Since engineering industry will continue to serve, for the foreseeable future, as the industrial backbone and welfare creator of the advanced economies, the continued role of aircraft industry as a technical university for engineering industry should not be underestimated.
6. *Spillovers become available to industry at large in proportion to the local entrepreneurial capacity to identify and commercialize them.* Property rights to intangible assets play a role both in stimulating the development of spillover-rich products and services and in commercializing spillovers. Hence social value creation is supported by policies directed at enhancing the entrepreneurial capacity of the national economy and the *tradability of intangible assets* (see further on *competence bloc theory* in Sect. 2.4).
7. An entrepreneurial economy is characterized by a comprehensive and varied commercialization competence. This commercialization competence can only rarely be internalized within one firm hierarchy but requires trade in intangible assets across the market between the many specialized actors of a competence bloc that lists the minimum of actors with specialized competences needed to create, identify, and commercialize winning projects (see Sect. 2.4). Property rights and tradability in intangible assets are a critical part of the *commercialization competence* that *is an important ingredient of the competitive advantage of a national economy* and a determinant of long-term economic growth.
8. For "public goods and services" such as national defense, the services of which cannot be shopped for individually in the market, Government is the representative *customer* of the underlying private demand of its citizens for defense services. Government is, however, also the main beneficiary of the social value created by the spillovers. We have a case of *double customership*. Hence advanced *public procurement can be seen as an act of effective industrial policy*.
9. Today, and in the wake of a massive privatization of previously public production of private goods, defense industry, and military aircraft industry in particular, may be the only remaining industry where such public customership of considerable magnitude can be effectively exercised. Emerging markets, still partially in the public domain are civil security and infrastructure investments with very long time horizons, such as health-care technology platforms.

10. *The social value created around advanced production is potentially very large.* I introduce and define the *spillover multiplier* as the ratio between the estimated social value net of opportunity costs created and the development investment that has created them (see further Chap. 8 and Technical Supplement S2). According to my calculations based on identified spillover cases aggregated up to macro the JAS 39 Gripen development program has generated (in the Swedish economy) over and above opportunity costs an additional social return to society (a spillover multiplier) on the order of magnitude of *at least* 2.6 times the original development investment during the period from 1982 through 2007. This means an average investment per year of 0.17% of GNP, and a return to society of 0.43%.[4]

    To judge from studies on the difference between social and private rates of return (an alternative indirect method to calculate the spillover multiplier), notably on North American data, my calculations appear to be on the low side. These studies would support a spillover multiplier of at least 2–4, and even larger for the US economy, being more entrepreneurial than the Swedish economy. While the Gripen is a unique and highly sophisticated development project, the econometric estimates are based on much broader aggregate categories with significantly smaller spillover intensity. I would however still be careful and not use the highest numbers estimated mechanically. While my low-end case study-based estimates are well documented, the upper range estimates are easy to criticize on methodological grounds. My cautious low-end estimate, furthermore, is sufficient to make development programs of the JAS 39 Gripen combat aircraft type worthwhile and socially very profitable. Swedish society in fact got the aircraft development done for free and a lot more in addition.
11. The considerable *underinvestment* in private R&D that these numbers suggest,[5] offers a unique opportunity to restart an economy in stagnation or crisis through advanced public procurement of spillover-intensive development projects.

    For reasons to be elaborated further in Chap. 9 this could be considered a *modern version* of growth promoting *demand policy* that does not suffer from all the well-known allocational distortions[6] (negative spillovers) that are associated with Keynesian employment policies and the negative budget effects associated with such policy. *The public procurement is directed at procuring public goods and services that are privately demanded that would otherwise not be supplied.* Hence:
12. Industrial policy through advanced public purchasing is not an instance of R&D subsidies.

Quite the opposite. Government enters as a substitute customer in its noncontroversial role of creating a market for privately demanded public goods that (I repeat) would otherwise not be supplied. While government support of industrial R&D is an instance of subsidizing, government as a competent public customer of advanced public goods is not. The provision of publicly procured and privately demanded public goods and services just happens to spill technologies generously, and probably of better quality than would have been generated by the same amount of R&D subsidies provided without strings. This highlights the fact that *advanced customers* who appreciate sophisticated products and are both capable and willing to pay for them *are a competitive advantage of a national economy*, emphasized already by Burenstam-Linder (1961).

My proposal to overcome the underinvestment in private R&D through advanced spillover intensive public procurement furthermore is a matter of public investment. Because of the cloud of new technology created the prudent Secretary of the Treasury does not have to worry about any negative budget consequences, only about how to finance a socially highly profitable public investment and about getting his public accounts properly organized so that the investment categories can be clearly distinguished from the consumption categories.

Considering this it should no longer be a puzzle that a small industrial country such as Sweden with nine million inhabitants has been capable of developing one of the world's most advanced combat aircraft systems without draining its industry of engineering resources. This question was never asked during the cold war when defense requirements were top priority. It was raised when the Gripen project was considered around 1980. It was never answered and the military situation was then still unclear. Today there is an answer. The spillovers from the Gripen project have been so large and have represented such a large extra resource input in production that neither society nor industry suffered. On the contrary, both society and industry benefitted from the completion of the Gripen development project, perhaps several times over.

1.3 Joint Production and Joint Customership

Advanced products such as aircraft distinguish themselves by a number of characteristics. They are complex as products and produced under extremely complicated circumstances, but built not only to be robust and capable of weathering extreme conditions of use but also to have a very long life. This means that the purchase price is only a small part of the total user cost of the product and that the value of these products to the user is higher, the more of cost efficient maintenance that has been built into the product and the easier it is to service and modernize the product. This is also the reason why the military customer has been intensively involved in the product design throughout the development of the Gripen aircraft and thereby has contributed user competence to technology development. The multirole feature of the aircraft, for instance, means that there is only one version of the aircraft to service, which considerably reduces service and maintenance costs. To a significant extent thanks to a demanding customer, the Swedish Defense Materials Administration (Försvarets Materielverk, FMV), the Gripen aircraft therefore has an excellent record of easy serviceability in the field by conscript nonspecialist personnel and low-cost maintenance. I frequently refer to "maintenance free" products and the corresponding general engineering competence to develop such products as a technology that has originated in the military aircraft industry.

Advanced products such as aircraft thus distinguish themselves by an additional collective characteristic, namely a *cloud of technology* available to external users free of charge, but only in proportion to their competence (*receiver competence)* to commercialize them. The economic value of these technological spillovers may be greater than the development investment itself and should be viewed as an integral part of the product, a knowledge asset ready to exploit. We have a case of *joint production*. The supplier of the advanced product develops and manufactures both the product itself and the associated cloud of technology. The potential economic value to the users of the additional knowledge asset created, however, depends on the receiver's competence to commercialize the spillovers industrially. To the private producer the value also depends on the producer's innovative ability (*innovative pricing*) to charge for them. To understand the economic value of spillovers therefore a broad definition of technology has to be used, including in particular, both *management and organizational competence*.

This theoretical argument will be supported by the case of downstream industrial firm formation around Swedish aircraft industry.

Military aircraft industry, and military equipment production in general, has frequently been regarded as "walled off" from, and contributing little to the rest of industry in the USA (Kelley and Cook 1998),[7] a reputation that has played a role in the post-cold war economic political debate. This study will conclude the exact opposite for Swedish military aircraft industry.[8]

Joint production of products rich in spillovers is discussed in the context of *joint customership*, i.e., public purchasing of both products and the collective value generated by spillovers. It becomes an act of marketing and innovative pricing on the part of the producer to present a credible case for the social value of such spillovers, and to find a way of charging for them. Industrial participation programs can be made part of a sale to support the receiver competence of local producers to capture the spillover rents. In a situation of both joint production and joint customership such programs can be organized to create a positive sum game. I will show that *a potential win-win situation might exist between the two* that can be realized under the right management and market regimes. A well-designed, mutually beneficial incentive contract should make both parties to the trade winners. This latter form of innovative pricing should be particularly attractive for developing countries.

1.4 The Questions Raised

This introductory presentation, therefore, addresses five questions:

1. Why are spillovers interesting? Do they *exist*? How large are they?
2. How are spillovers *created*? The critical role of the *advanced customer.*
3. What do spillovers look like? The *case presentations.*
4. How are economically valuable spillovers identified, captured, and commercialized (Competence *bloc theory*).
5. What are the implications for business practice and policy and for government *policy* of public procurement?

The analysis of positive externalities or spillovers has a long history in economics, beginning with the British economist Alfred Marshall (1890), the authority at the time on the then modern Walrasian (neoclassical) economic model. Marshall was concerned about the shortcomings of that model in dealing with economies of scale, and as a consequence with economic development. As a solution he suggested what has later come to be called networking externalities within what he called *industrial districts* or clusters. Marshall's ideas from 1890 and 1919 are still modern today. The shortcomings of the standard economic model that he addressed still have to be overcome, and the solution Marshall suggested in 1890 to internalize the externality was in principle what has later come to be called (first by Romer 1986) "new growth theory." Even though modern economists have had a frustrating experience about giving Marshall credit for his very early contribution, what the new growth theory shows is that *externalities or spillovers, when endogenized within a more broadly defined economic model, become a source of economic growth.*

This is briefly the theoretical background of this study to be elaborated further in the main text. In practice, the phenomenon of positive externalities or spillovers can be briefly presented as the consequence of two accounting problems:

1. The resource input that gives rise to positive spillovers is booked on a different account than the value of the spillovers it has created.
2. Resources cannot be assigned to the observed output because they are attributable to the entire economic system (*networking externalities*).

There is also the question which public good type of producer generates spillovers. Many of the complex products and production processes that are rich in spillovers are outside the domain of private markets even though their services are privately demanded. To create a market for such public goods a public procurer has to step in as an intermediary (a *substitute customer*) between the private demand and the private producer. *The public procurer represents the citizens as private customers in expressing their demand in a market for public goods and services.* Many would say that this is the main task of democratic government that it should attend to successfully before it engages in other public efforts. The public procurer of complex products rich in spillovers then takes on the double role of acting as a substitute representative customer for a private demand and an industrial policy maker.

The existence of positive spillovers has been abundantly documented in economic literature and through case studies. The procurement of defense services is a typical such double policy act and military equipment such as combat aircraft has been, and will be documented to be particularly rich in spillovers. It may in fact be the only remaining industry with a sizable spillover generating capacity where industrial policy through public procurement can be effectively exercised, even though civil security and health-care technology may offer opportunities for supporting the development of goods and services of a public infrastructure type. As a consequence, advanced R&D intensive production and military aircraft industry are surrounded by the above-mentioned "cloud of technology" that is available for free in proportion to the ability of local entrepreneurs to identify, capture, and build a business on (to commercialize) them. I will demonstrate that the potential economic value of such spillovers is very large, and particularly large around military aircraft industry development and manufacturing.

Military aircraft production therefore is a form of joint production. The goods and services produced consist of a private and a social component, or of

1. The demanded equipment, the aircraft and
2. The cloud of technology the economic value of which depends on the local ability to commercialize it

Since the social value created depends positively on the local ability to commercialize the cloud of spilled technology the aircraft producer's effort may also include the complementary service of maximizing the private rent that may be extracted from the cloud by supporting its commercialization. This is particularly common in public purchasing of defense products of industrially developing countries with little or no own local commercialization competence. It is, however, also common among industrial countries. In such cases one must ask whether the producer of military equipment is also the most competent provider of the commercialization services. The supplier of military equipment may see it as a way of commercializing its own spillovers or a way of overcoming the weak property rights associated with the cloud. Because of weak appropriability the supplier therefore faces an interesting marketing and business policy problem (Innovative Pricing) when attempting to strengthen those property rights such that it can charge for at least part of the cloud it has created. The art of innovative pricing or of bundling spillovers with products is well known from software industry. Offset trade agreements is another example when customer and producer can jointly extract a profit from spillovers that would otherwise be captured by outsiders or get lost.

The general picture, however, is that those property rights cannot be effectively exercised by the private producer however inventive he is in the art of bundling of products and innovative pricing. The social value of the spillovers then depends on the local capacity of the economy to take commercial advantage of the spillovers on its own. *Since spillovers* take *on widely different forms the local capacity to capture them depends critically on the local existence of a broad-based commercializing industry*, notably entrepreneurs and venture capitalists the support of whom is to some extent the responsibility of Government policy. But before commercializers go into action the supply of positive spillovers has to be created, and this requires, as a minimum, the privately profitable development and manufacturing of the base product to be procured (the "military aircraft"). In the absence of this profitability there won't be any spillovers to commercialize.

1.5 The Nature of Spillovers

Econometric research has come up with abstract numbers on the size of spillovers, but tells little about their content (what) and *how* they have diffused through the economy, and nothing on the underlying dynamics. The case studies presented in this document put life into the abstract numbers. They also make it possible to *distinguish between spillovers in the form of technology supply and social value creation in the form of* *later commercialized output* (see further Sect. 2.4 and the competence bloc diagram in Fig. 2 on page 46). More specifically, the commercial outcome of spillovers in the form of net value creation is composed of civilian production; military exports, the origin of which can be traced to a particular procurement from the Swedish military; and spun off commercial ventures. In our specific calculation, only the development of the Gripen combat aircraft platform, excluding weaponry and manufacturing, is recognized as the spillover generator.[9] This definition means that case studies as well as the econometric estimations to be presented are measured in terms of ex post outcomes after the commercialization process has been completed. There is a whole range of civilian net value creation that can be directly linked to performance demands on the Gripen development specified by the government procurer, such as the need to lower the weight to half that of its predecessor (The Viggen) to allow the aircraft to land on, and take off, from reinforced regular highways and still carry the same weapons load. Light weight technologies therefore have become a specialty of Saab and Volvo Aero Corporation in entering civilian markets as subsystems producers. A similar example is the "maintenance free" technology necessary to be able to service the air craft and the engines in the field by regular nonspecialist conscript personnel and far away from repair workshops. This means that availability of the Gripen aircraft is very high and downtime very low compared to all competitor aircraft.

The computing and communications (C&C) technology content of the Gripen aircraft development – Gripen was the first fourth generation unstable aircraft piloted to a large extent by computers, and the first networked aircraft in the world (see further Technical Supplement S1) – means that generic spillovers to other industries are particularly intensive (see Sects. 2.3.2. and 5.2.4).

The Gripen development, however, also exhibits several fancy spillovers, and the most spectacular spillover, Ericsson mobile telephony, also illustrates the difficult problem of isolating the spillovers from the Gripen project from those of earlier military aircraft development. Ericsson happened to be the only telephone systems and equipment producer in the world (possibly including also Nokia) to have an in-house military radio technology in the early 1980s. Without that, Ericsson would not have been the world leader in mobile systems development today, and most likely not an autonomous telecommunications company, I conclude in Chap. 4 (Sect. 4.4). If not a truly serendipitous discovery, Ericsson mobile telephony still is a peripheral capture of military aircraft technology spillovers that was almost lost to the company (see Sect. 4.4). Military radio technology defined the first platform for Ericsson's entry into the mobile telephony market when its top management had finally understood its commercial potential. Gripen dependent antennae and microwave technology defined the later successful Ericsson advance into a 100% mobile systems producer.

1.6 Social Value Creation: The Magnitudes Involved

Technically the spillover values captured in the economy show up in the form of differences between measured social and private returns. There is a large theoretical and econometric literature on how to estimate those differences that will be surveyed in the main text and in the technical supplements, and the differences are generally found to be very large for advanced and R&D-intensive production. On the whole, Jones and Williams (1998) conclude that social returns to private R&D investments are at least twice to four times the private returns, and probably more, and imply significant *underinvestments in private R&D* in the US economy. Conservative estimates suggest, Jones and Williams say, "that optimal R&D investment is at least two to four times actual investment."[10] I would add that this may even be the low end since in Chap. 3 I report on even larger estimates. Moretti (2002), furthermore, shows that while most of the estimated spillovers come from high technology, R&D intensive plants, spillovers from low-tech plants are virtually zero.

On this I conclude from the econometric studies presented in Chap. 3 and in the Technical Supplements that the economic value of spillovers around Swedish military aircraft industry has been very large. The sophisticated and demanding public customer, furthermore, has played a particularly important role behind the intensity of the spillover generation around the JAS 39 Gripen development. An innovative *incentive contract* (see Sect. 8.4) and the contribution of user competence has made all the difference. Strict customer demands on the Gripen aircraft, furthermore, and notably on light weight of the aircraft to be capable of landing on, and taking off from regular roads and extreme performance characteristics in combination, the in-air flexibility in combat roles (swing-role capacity) and the need to integrate new electronics and software with mechanical functions, have all contributed to an enhanced spillover intensity compared to earlier generations of Swedish combat aircraft. Much more than the entire development investment has in fact been returned to society in the form of additional social value creation, and several Swedish companies owe their existence to these spillovers. Those spillovers have been particularly important for the long-term development of Swedish engineering industry for which the aircraft industry has served importantly as a technical university providing both educated and experienced engineers and technologies proven to be practically useful and directly applicable. In addition, several technologies, to be documented in the main text, originating in the aircraft industry have served as technological platforms for new business start ups in entirely different markets.

More specifically, I also conclude that the spillover intensity has increased from the Saab Viggen "third generation" of Swedish combat aircraft to the "fourth generation" JAS 39 Gripen multipurpose aircraft, mostly because of its larger electronics and software content, and despite the fact that procurement conditions for the Gripen aircraft were more parsimonious. Paradoxically the same advanced spillover intensity appears to have its origin in the increased share of off-the-shelf standard components and subsystems used. Again, also here cost considerations forced (Swedish) aircraft industry early in the direction that engineering industry at large is now moving, and not only toward increased outsourcing but also toward the use of standard components and systems available in the market. The military aircraft producers in fact learned early to design advanced, high performance products from standard, off-the-shelf components and subsystems. Hence, general engineering knowledge diffusion has become relatively more important compared to the industrial impact of particular and relatively well-defined technological innovations. This should mean that the long-term systems dynamics leverage on the entire economy (the spillover multiplier) has increased in importance (see further below in this section).

On the social values created around the JAS 39 Gripen R&D investments I have brought together material from external studies and my own estimates to construct a range. At the minimum end, using a method similar to that of Fölster (1993), the current estimate of the social values created by the JAS 39 Gripen R&D investment from 1980 through 1992 is at least 1.5 times the original development investment.[11] This compares with Fölster's (1993) estimate of 1.15. The reason for the difference is that Fölster's forecasts of social value creation for the period 1992 through 1998 (obtained from the firms) were significantly lower than my estimates based on actual records, the explanation being Ericsson's phenomenal and not expected surge into mobile telephony during those years. Continuing my calculations through 2007 I have documented a spillover multiplier of *at least* 2.6 times over and above the original development investment in the form of additional social value creation based on some 45 interviewed and/or researched spillover-receiving firms. This is a smaller number than the 208 firms Fölster (1993) questioned in a postal survey. The difference, furthermore, is that I have interviewed and studied my smaller number of firms individually and evaluated their dependence on the Gripen project, rather than asking firm management to make their own assessment as Fölster (1993) did.

My larger estimate depends to some extent on the larger electronics content in the post 1992 development investments in the JAS 39 Gripen but most importantly on the fact that some spillovers, notably into Ericsson mobile telephony have taken longer to develop, and continue to grow in importance. This is, however, still a low-end estimate. A large number of small firms that have benefitted from Gripen spillovers have not been identified and therefore are not included. Furthermore, it has not been possible to directly estimate long-term dynamic systems effects and peripheral technology diffusion throughout the entire industry beyond 2007. The missing firms are small firms and won't add much to the spillover multiplier. Long-term dynamic systems effects and peripheral technology diffusion throughout the economy are not possible to estimate using my case study aggregation to macromethod. Those systems effects may, however, be very large (see below).

These micro-based estimates are however small compared to what you arrive at when deriving the social values created indirectly from estimated differences between social and private rates of return to the private investment. Applying the econometric estimates on the social returns to private R&D investments in the USA, notably the summary evaluation of Jones and Williams (1998), such peripheral spillovers can to some extent be captured, and I then come up with much higher estimates of the spillover multiplier for a US type economy, or two to four times as a minimum, probably extending into an upper range of some five times the original development investment. The difference probably depends to a large extent on the fact that peripheral technology diffusion is particularly sensitive to the local commercialization competence. In an entrepreneurial economy of the US type you would therefore expect the spillover multiplier to be larger than in Sweden. Furthermore, the probability of losing spillovers is much lower within the larger capture area of the US economy compared to that of Sweden (More on this in the European discussion in Chap. 7). One reason for the large differences between social and private rates of return estimated on US data therefore must depend on the higher incidence of peripheral technology diffusion in the US economy through new firm establishment and that peripheral technology diffusion is particularly sensitive to the local commercialization competence.

The numbers on the US economy may however still be underestimates because the underlying econometric models used do not properly pick up long-term dynamic systems effects on the allocation of resources. Those effects may be large. As mentioned, my own simulation analysis of those effects on the Swedish micro- to macromodel suggests that another 30% should be added to the spillover multiplier to capture the long-run effects (see Sect. 3.3.2 and Technical Supplement S2). My cautious estimate of the spillover multiplier for Sweden of at least 2.6 takes us above the absolute lower end of the US estimates.

On the whole, however, my conclusion is that even though JAS 39 Gripen spillover value creation won’t reach US levels because the Swedish economy does not possess the US entrepreneurial capacities to capture spillovers, I would not hesitate to use a multiplier of 4 to 5 for Sweden in a social profitability calculation on this or a similar public procurement project. But it is not necessary to go that high since “at least 2.6” will be sufficient to make a project of the JAS 39 Gripen type socially very profitable. The case studies, furthermore, suggest that spillovers from the future developments of the Gripen platform that are more intense in their use of electronics and software technologies, for instance the Next Generation Demonstrator (See Technical Supplements S1 and S2), will be even larger.

To put it bluntly. These numbers should be sufficient to motivate the public procurement of domestic technology platforms for advanced military aircraft on a large scale. And those who don’t like this conclusion and rather want to see the money go to technical universities and/or government-run laboratories or institutions (The “Arrow 1962 proposition”) will find that the evidence is against them. This may be considered a strong proposition that needs further empirical testing to convince. True. To compare the spillover multiplier of technical universities and advanced firms is also the further research agenda that I propose in Technical Supplement S3.

1.7 Competition Between Alternatives

Physical manufacturing and assembly of Gripen aircraft are excluded from my spillover estimates. One reason is that technology spillovers mainly occur during the development phase, even though physical employment effects may be larger during manufacturing and assembly. Another reason is to achieve comparability with the econometric studies that relate spillovers to R&D investments and with the alternatives discussed around 1980, namely (1) to modify the older Swedish Viggen combat aircraft or (2) to purchase the aircraft from abroad, modify it, and in both cases manufacture it in Sweden. The local Swedish technology spillovers under these alternatives would then have been much smaller than (3) developing an entirely new and very advanced aircraft. Since, even in this third alternative, the aircraft would have been manufactured in Sweden the comparison is much simplified. Most of the spillover value would be lost under alternatives (1) and (2).

Around 1980 a decision had been taken to equip the Swedish Air Force with a new combat aircraft so the problem was reduced to which design to choose. Today, however, the decision might also include the problem to consider what else can be done with the budgeted money, and two additional alternatives might be discussed; return the money to the tax payers in the form of lower taxes, or spend it on subsidizing other forms of R&D to compensate for the loss of the technology cloud. The latter proposal was in fact a standard industrial policy proposal of the "linear neo schumpeterians" and innovation systems theorists (Lundvall 1992; Nelson 1993) during the 1980s and the 1990s to stimulate innovation and growth.

It is obvious that the size of the spillover flows makes all the difference. With no need for a new combat aircraft and no awareness of the spillovers, the natural alternative would be to return the money to the tax payers and let the citizens decide through their private spending decisions what to do next.

With a large spillover flow, on the other hand, the policy maker faces a public infrastructure investment decision. Abstaining from developing a new combat aircraft also means foregoing the cloud of technology associated with its development, the economic value of which being much larger than the development investment itself.

Also, the private demand increase from returning the money to the tax payers is not likely to be directed toward expenditures that will raise product development and spillover flows to levels of sophistication even in the neighborhood of those associated with a new combat aircraft. So the approach for those concerned about technology development and growth should perhaps be to compare, on the one hand, a product development investment of a public good type in an advanced firm that will serve as a technical university, recognizing only the spillover flows, and, on the other, a similarly sized public investment in one or several traditional technical universities or public technical research laboratories. Such a comparison of infrastructure value creation has not been done, and should be done (see further Technical Supplement S3). But let us still consider such a decision as if it had been taken around 1980 and for the sake of the argument forget the use value of the combat aircraft Gripen, and discuss investing the entire JAS 39 Gripen development budget in (technical) university organized R&D, or in any of the many public technical R&D-sponsoring public organizations that have been heralded as being part of the innovation systems of a national economy. This would most probably, and for reasons given in the main text, have been a large misallocation of resources compared to developing the military aircraft. The Gripen development project not only takes R&D much closer to a functioning product than university research will ever be capable of achieving. It has also to some extent been commercially tested, which academic research rarely is.[12] The Gripen development furthermore, and most importantly, means that a large number of technologies have been integrated to achieve particular product functionalities, which a university, due to its organization into narrow and isolated specialties, is incapable of achieving (see further Technical Supplement S3 where improvements in that respect are discussed). Industrial product development always requires extensive technology integration. Sophisticated technology integration defines a general engineering industry technology. Technical university research on the other hand, due to its organization and purpose will be limited to supporting the specific technology development that becomes useful only for firms (read large firms) that possess the capabilities of engineering that integration themselves. I would expect a much smaller social return to have been the outcome if this last alternative of investing the resources in general university research had been decided on.[13] To calculate how much smaller would, however, require further study. We know already that the investments in education earn quite low private returns compared to the returns to private investment in industrial R&D and that spillovers are low or non existent (Mellander 2002, Lindahl and Canton 2007).

1.8 Competitive Bidding and Competition Policy

There is one more principal problem to deal with. The industrial organization (I/O) literature is clear on how to organize public purchasing. Public purchasing should to the extent possible be subjected to competitive bidding. In the USA, it has been common that two or more competing aircraft producers develop one flying prototype each for the public customer to compare and evaluate. Thus, for instance, with its F-35 Lockheed Martin won the competition for the Joint Strike Fighter (JSF) procurement over Boeing. Such competitions, even though extremely costly, may also be motivated by the spillovers the aircraft development generates. Consensus opinion appears, however, to be that they are too costly even for the USA to be continued.

The point I want to make here though is that the efficiency benefits (disregarding the spillovers) of competitive bidding rest squarely on the assumptions of the neoclassical I/O model, which is based on a sharp dichotomy between supply (the producer) and demand (the customer). *When the producer and the customer cooperate over a long gestation period to improve upon the product,* and arrange to share both risks and gains through an incentive contract *the standard conclusions on competitive bidding no longer hold*. Mechanical competitive bidding, furthermore, tend to favor low-cost outcomes at the expense of noncontractable quality (Hart and Vishny 2001), and there is no ready made alternative rule set to guide the purchasing process other than to stay away from stereotyped competitive bidding. The JAS 39 Gripen procurement was to some extent based on an incentive contract (Sect. 8.4).

The customer contribution to a joint product development is based on technical product and user knowledge on the part of the customer. The customer may even take on part of the development itself and outcontract the rest. The Swedish military procurement agency FMV has used what they call *functional procurement*, meaning that it takes on responsibility for some of the development work related to particular product functionalities, and parcels out other jobs in the market. This was easier in the past when FMV was responsible for coordinating and integrating the development work for military aircraft. Today the complete systems integration (platform, weaponry, real time information, communication and command system, etc.) attempted defines the performance characteristics of the aircraft as a weapon. In the case of JAS 39 Gripen that responsibility was taken on by the IG JAS group, with Saab being responsible for coordinating and integrating it all.

So there are ways to place privately financed product-oriented industrial research in a competitive market environment that filters the projects technically and economically and takes them close to the market and even some way toward commercialization. Firms learn in the market by being challenged by better solutions that tell them it can be done and force them to come up with something even better. The challenge the IG JAS Group faced during the procurement process when being offered the much less attractive alternative to modify and manufacture an aircraft developed abroad contributed to an improved design and a lower competitive price for the Gripen aircraft. The bottom line of this, of course was that the IG JAS Group of firms felt competent that they could carry the extremely advanced and demanding development project through to successful completion. They were confident because of a long earlier learning history of increasingly more sophisticated such projects (see Technical Supplement S1). Similarly, and as a consequence, *firms that have not been forced by competition to solve their technical problems in the economically best way*, therefore, *rarely offer something for other firms to learn.*

Understanding the numbers and those conclusions, however, requires that we also understand the nature of spillovers and it has been one of the main points of this study to make the spillover flows as concrete as possible. The case studies also go a long way both to support the quantitative estimates and in giving concrete empirical content to the numbers.

So before we go on to the main text let me flesh out the abstract argument with some illustrations from the main text of the case of Swedish military aircraft industry. The message is that aircraft industry already today uses the technologies of future engineering industry and therefore operates as an advanced technical university that takes its R&D investment close to the market in the form of functioning and tested products, develops new technologies and industrial practices that can only be developed in a working industrial environment and that allows its engineers and workers to become familiar with the most advanced manufacturing techniques. In that capacity, the aircraft industry is more critical as a source of industrial knowledge than existing technical universities in Sweden. The existence and industrial vitality of the Swedish aircraft industry may therefore be what is needed to keep the Swedish engineering industry alive and competitive over the foreseeable future as the industrial back bone of economic welfare creation. For the time being, at least, I can see no other industrial candidates on the horizon capable to fill in if the Swedish engineering industry engine begins to sputter. And when it comes to public procurement of privately demanded public goods and services there seems to be no good alternative to defense products.

The numbers tell why. The cases will help to understand how.

The case study presentations of the chapters to follow have been organized to give concrete content to the “cloud of spillovers” of Fig. 1 (on page 35).

1.9 The Contents of the Spillover Cloud

Without a Swedish military aircraft developer Sweden today would not have advanced civilian producers of aircraft and aircraft engine subsystems for international markets (Saab and Volvo Aero Corporation (VAC), inner circle of *core technologies* of Fig. 1 on page 35 and Table 4 on page 51).

A large number of aircraft and aircraft engine-*related technologies* (next wider circle in Fig. 1, See page 35) have been spilled and commercialized from civilian and military aircraft and aircraft engine development. Concrete examples are aircraft and aircraft engine servicing, maintenance and modification, hydraulic engines that have found their way early into heavy truck and construction equipment development, automobile frame designs that collapse in a safe and structured way (Saab Automobile), the world's perhaps most sophisticated automotive safety industry, etc.

Perhaps most difficult to pin point and also most important when it comes to large volume effects on production is the next diffusion stage in Fig. 1 (on page 35) of *general engineering technologie*s. They have become especially important in the JAS 39 Gripen development because of its large electronics and software content. Over the last two to three decades aircraft industry has shifted its core technology base into the intersection of sensors, electronics, and hydraulic systems integrated with mechanical devices and new materials through software. Almost the entire engineering industry is now following aircraft industry in that direction. Thus, for instance, the landing gear of the JAS 39 Gripen (using early Saab-developed ABS technology) packs as much computing power as the early versions of the entire previous generation Viggen combat aircraft.

Critical software engineering of the integrated electronics and mechanical architectures is what gives mechanical products of today their often uniquely flexible and customized functional features. Critical software engineering is an early specialty of Saab aircraft engineering, and of the Gripen in particular, that is now finding a multitude of applications in engineering industry at large.

Distributed and integrated production (systems integration) has been the mainstay of military aircraft manufacturing, and that technology is now also rapidly diffusing into, and revolutionizing engineering manufacturing processes at large. It is the technology mover of the globalization of production that no advanced industrial economy can now afford to be without. Virtual design methods are also paving the way for a geographical distribution of the design work. Expensive mock-up models and special pilot aircraft to be tested, furthermore, are no longer necessary. The prototype Saab 2000 civilian aircraft was the first aircraft that rolled off the production line.

The *light weight structure technologies* pioneered by the Gripen project to make it possible for the aircraft to land on, and take off from regular roads, has become increasingly important for the engineering industry at large as fuel economy and environmental concerns have increasingly mattered for the economics of its products. Saab has also capitalized on some of these Gripen-related spillovers through developing a sizable engineering consulting activity, *Combitech AB*.

The fourth outer layer in Fig. 1 (on page 35) adds winning *serendipitous technologies*. Even though commercial discovery may be more a matter of chance than in the inner circles this outer periphery of the spillover cloud may be what matters most in the very long run, and notably in an entrepreneurial economy. Discovery entrepreneurship usually takes a long time to materialize in the form of industrial winners. Two already established winners stand out; Ericsson mobile telephony (Cases 8 and 13) and the Swedish automotive safety industry, including Autoliv (Case 17).

Ericsson Sweden sports an astonishing and almost immediate success story. Without an early experience from military radio technology (in the early 1980s Ericsson was alone among the telecommunications companies to have both radio and telecommunications competence in-house) Ericsson would not be the major player in the world in *mobile telephone systems* it is today, and probably not even an autonomous player. The discovery of odd new technologies within a large and conservative business hierarchy in fact is a low probability occurrence. Nondiscovery almost occurred in the Ericsson case. However, once discovered the size, management experience, and financial resources of Ericsson could be focused on rapidly taking mobile radio-based telephony on to industrial scale production and distribution. This early military radio technology supported Ericsson's early entry into the mobile telephone systems market and JAS 39 Gripen-related wireless data communication and antenna technologies have so far helped keeping Ericsson as the leader in this extremely competitive global market.

While the Ericsson story is about the conversion of an already established large company in its entirety onto a new technology base, the Swedish automotive safety industry and Autoliv is an entirely new creation. Because of the pioneering work on aircraft safety systems and the close contacts between Saab and the two Swedish automobile companies Saab Automobile and Volvo Car, aircraft safety technology migrated early through the movement of aircraft safety engineers into automobile design and development (Case 17).

The outer circle in Fig. 1 (on page 35) is also populated by a number of extremely sophisticated business spin offs from Gripen and earlier military aircraft and weapons technology development.[14] Medical technology is prominently represented as are product developments in entertainment and automotive traffic control.

The story of serendipitous discovery in the outer circle would also not be fully told if the missed opportunities and outright failures have not been mentioned, the most spectacular being Ericsson's failed venture (EIS) into the business information systems market (Case 11) that pulled an early, promising Swedish and Saab-based computer industry with it (Case 10).

1.10 The Advanced Industrial Environment

One final and additional spillover category has to be mentioned here, namely the evolution of a specialized industrial district capable of sustained endogenous growth (Case 7). One way of dealing with complex systems products is to break the product down into a number of less complex systems and components the development and manufacturing of which are distributed over a market of specialized subcontractors and consultants. *Integrated production*, therefore, *has developed into an advanced way of working together with many subcontractors in the market and of integrating all component systems into a consistent whole*. Distributed and integrated production of complex systems products much more than specialized production also integrates technology and economics. The term industrial in practice *stands for the integration of technology and economics*.[15] The large and technologically advanced systems integrating company, therefore, also functions both as a competent and demanding customer to subcontractors and as an entrepreneurial catalyst in creating a local industrial environment. Saab's need for computer scientists stimulated local entrepreneurs to set up shop. In the Saab case we can also point to its influence on the academic orientation of the Institute of Technology of Linköping that was established in 1969 and was the first technological university in Sweden to introduce computer science on its teaching agenda. And Linköping University was the Swedish pioneer in establishing a department of industrial economics. Linköping University got a head start in those fields over the other conservative technical and general universities.

In the years that followed, a large number of high technology businesses have been established around Saab and the Linköping Institute of Technology and have been located there because of the combined presence of the two (see further Sect. 4.3.5, Case 7). Even though not necessarily based on defined aircraft technologies they have all benefited from the demanding customership of a major industrial player, the rich spillover flow of the entire industrial district and the abundant supply of human capital related to Saab technologies. I won't say anything about the direction of causality (this should be subjected to further research; see Technical Supplement S3). The standard a priori assumption in this respect of academic studies, however, is that causality runs from the university and university entrepreneurship to industry. This may not be entirely true as witnessed in the Linköping story where causality may well have run from Saab, inspiring the creation of an industrially minded technical university, to the creation of a rich and well-balanced entrepreneurial mix between academe and industry.

1.11 Policy Implications

The concrete case presentations of the main text will demonstrate concretely

- *How* the advanced customer contributes to product technology development.
- *How* a well-designed incentive contract can improve productivity and cost performance.
- *How* the development of advanced products generates greater social value (spillovers) than the development investment itself.

- *That* the development of military aircraft is a particularly potent such spillover generator.
- *That* spillovers are predominantly generated during the product development phase of projects that are financed under a private profitability constraint.
- *That* contrary to civilian product development public procurement of advanced products is supported by double incentives, because the public customer enjoys both the product being developed and the social spillover values being generated.
- *That* the magnitude of the social spillover value created depends on the capacity of the local (national) economy to capture the spillovers, to commercialize them and to build businesses on them.
- *That* there is a wider perspective to recognize if the customership is supranational, covering the Scandinavian countries or Europe at large, and if the procurement cannot be directed to national producers.
- *That in* the latter case the spillover pick up area widens, reducing the risk for the area as a whole of losing winners and raising the potential economic values created. But it will also be difficult or impossible to predict the geographical (national) "fall out" of the spillovers.
- *That*, as a consequence, the optimal concerns of the supranational authority ("Brussels") should be to force (through incentives and rules) the national authorities to refocus their policy attention (1) away from demanding a "fair" return in the form of defense orders, toward (2) supporting the national economic capacity to pick up and commercialize spillovers, i.e., to help build an entrepreneurial economy. With large potential spillovers from sophisticated procurements, if Brussels is unable to enforce (1) a lower spillover intensity, and a losing proposition for the entire wider area ("Europe") will be the consequence.

Some further conclusions should finally be mentioned:

1. The industrially most potent technology spillovers operating in the long term do not take the form of well-specified new (and patentable) technologies that can be directly transferred to civilian use, but occur when competent *people with military production experience move between jobs and apply their competence to the solving of civilian production problems.*
2. Aircraft *spillover benefits come mainly in the form of innovative product development*, not as improvements in manufacturing process efficiency, except, of course, that many new product developments are investment goods, for instance machine tools that raise process efficiency when installed in production.
3. The intensive use of electronics and computing and communications technology in the JAS 39 Gripen compared to previous combat aircraft generations has not only raised the quality of the spillover flow and its intensity, but also changed the character of the spillover flows, from the transfer of specific and well-defined

applications to generic technologies and industrial practices and experience (for instance the distributed and integrated production technology mentioned above). Such spillovers are more difficult to identify and illustrate with concrete applications. The effects are more diffuse and longer term but they are potentially much larger. Indeed, the technologies spilled around aircraft industry have become critical to master for many firms in the sophisticated end of engineering industry.

4. The existence of a "local" full fledged aircraft industry is normally associated with the parallel existence of an advanced subcontracting industry. In general the development of complex products and excellence in systems integration (such as telecom systems, truck development and manufacturing, automotive, etc) require the existence of a *supporting market of specialist subcontractors*.

1.12 Complete Competence Blocs are Spillover Generators and Advanced Learning Environments

The participant systems coordinator and the specialist subcontractors all support each other and benefit from each other's existence, not least as demanding customers, defining competence blocs that have to reach above minimum critical levels to be self sustained. The clouds of technologies generated within those competence blocs define the values to be shared by all participant firms, and hence their incentives to establish there, stay there, and grow. Together all firms in such a competence bloc also subject each other to competition. Those actors that survive this competition will however not only have access to, and benefit from, the cloud of technologies. They also contribute to the competence bloc by creating their own clouds of technologies.

Understanding this also gives us an understanding of how advanced product development at the microlevel through the creation and exploitation of the spillover cloud contributes to macroeconomic growth.

The valuation of the clouds therefore presents us with a particularly interesting pricing problem for the production of advanced spillover intensive goods and services. The business art (Innovative Pricing) is to

1. Find a way of claiming ownership to the cloud and
2. Maximize its value

which in the case of advanced public procurement often requires that the supplier and customer work closely together to create not only a better product, but also to increase the social value (the spillover multiplier) and to find an alternative formula for both parties to share in that value creation. For *the private supplier* this also means that "s/he" *has to engage in marketing the social value that may be created, not only to the public customer, but also to the constituency of private citizens, the voters.*

1.13 Macroeconomic Growth

The large macroeconomic effects estimated imply that:

- Sophisticated and wealthy customers constitute a competitive advantage of the national economy.
- Improved entrepreneurship and commercializing competence reduce the risk of losing winners in the spillover flow to the national economy.
- The knowledge embodied in the commercializing industry also constitutes a competitive advantage for the advanced industrial economies.
- The situation is different for industrially developing economies. They need help both to capture and to commercialize the spillovers that are associated with large industrial procurement projects. This constitutes the rationale for value sharing within an industrial participation or offset trade contract (Cf. Chap. 6 on South Africa).
- Even the firms in advanced industrial economies depend on access to the global pool of technology, and a large part of their competitiveness rests on their competence to access and exploit that pool (receiver competence). In fact, Swedish military aircraft industry during the early post WWII period was a vehicle for accessing very advanced US industrial technology and was therefore instrumental in advancing Swedish engineering industry at large to the prominent position (Carlsson et al 1979) almost lyrically presented in Pavitt and Soete (1981).

I therefore conclude this introductory chapter by repeating that military aircraft projects are complex industrial ventures that develop and integrate a broad range of sophisticated technologies that in different combinations have later been found to be used in civilian engineering industry. The military products furthermore are designed to work in rugged and extreme environments and still to have an extremely long life. The Gripen, in particular, has been designed with a view to easy servicing and flexibility in upgrading and, hence, for both a long life and low lifetime costs. This latter easy modernizing feature is particularly important today when the electronics and software that define the functionalities of the aircraft need to be turned over several times during the life of the aircraft. A number of technical design problems therefore had to be solved to meet customer specifications. Such project development therefore drives technology development across industries, but notably in engineering industry. I can therefore conclude that:

- Military aircraft industry already today uses the technologies of future engineering industry.
- Engineering industry is, and will continue to be, over the foreseeable future, the backbone of welfare creation among the rich industrial economies. Engineering industry itself has gone through an interior revolution, partly created by those technologies that are developed in, and used by aircraft industry that motivates the term: The Old Industry in the New Economy.
- Aircraft industry in practice functions as an advanced technical university for this critical growth promoting industry of Western economies, and it is this knowledge about advanced industrial practices that is critical, not its underlying principles.

- The large spillover multipliers estimated, furthermore, reflect a large *underinvestment in private R&D* in those leading industries. If it could be overcome it would significantly reduce, perhaps eliminate the reasons for concerns among the rich industrial economies for competition from low-wage economies such as China.
- Public procurement of sophisticated products can therefore be seen as a form of industrial policy (Joint production/joint customership).
- This is particularly important when it comes to the procurement of public goods and services such as military equipment where private markets do not develop spontaneously, because the private customers, the citizens, cannot shop individually for such collective goods and services.
- It is difficult, probably impossible, to find another industry operating in the markets for public goods and services that rivals military aircraft in generating spillovers. This is also the reason why policy makers in the industrial countries keep being concerned about the sustained competence development of this industry.
- Developing economies constitute a special case since they also lack a competent receiver industry capable of picking up spillovers and putting them to industrial use. They need help and this fact also constitutes a rational foundation of offset trade.
- In the wider European context the analysis changes (see Chap. 7). The spillover pick up area of political interest widens and the potential growth effects increase, even though their geographical market allocation is difficult (impossible) to predict. To optimize the policy outcome the national policy maker should now take on the broader public policy role of a facilitator to make sure that the spillover pick up rate from large European procurement projects (public as well as private, military as well as civilian) is maximized within the EU region. The best way to do that is to make sure that *only the best economic contractors obtain the public orders, to suppress all attempts by national policy makers to negotiate for public orders and employment* and to *encourage the member countries to compete for spillovers from the projects through being entrepreneurial*. If the EU becomes successful on that score it might even gain a competitive advantage on the US where Federal Government has not been successful in restraining regional and state politicians from negotiating local employment favors in large Federal procurement projects.

1.14 Notes

1. A note on notation. JAS 39 Gripen appears under different names in different texts. In this text the name "JAS 39 Gripen" and for short "Gripen" will be used. The term *production* appears one or more times on almost every page. In order to avoid confusion "production" will be used to signify all value added creating activity within a firm across the entire value chain, including both development and physical manufacturing. Whenever needed for clarity of exposition I write "development and manufacturing" instead of production. The terminology is

however not clear. Advanced production also has a dominant *engineering* content which conventionally covers product development up through the prototype and testing phases, and possibly an early part of manufacturing, and sometimes even some of the maintenance activities and product upgrading after the product has been delivered.

2. Mainly Ericsson, Saab, and Volvo Aero Corporation with Saab as the coordinating firm. See further Technical Supplement S1.
3. For easy reading references to the main text are given like this without further comment.
4. The opportunity cost has been defined as the alternative production value that the resources now gone into Gripen development would have created elsewhere. “Elsewhere” has been defined as the average productivity of Swedish engineering production that same year. For the exact calculation method, discount rate assumption, etc. see Chap. 8 and Technical Supplement S2.
5. Discussed further in Technical Supplement S3.6.
6. See Hansson (2007, 2009). This is not entirely true. Even though the public good (“defense”) is privately demanded, it is provided for free, but financed over a public budget. Dishonest Swedes might enjoy the free defense service, but still try to avoid paying for it by avoiding the tax. But the allocational distortions are smaller than paying unemployed workers over public budgets to dig, and then fill, holes in the ground. See further policy Chap. 9.
7. Also see Alic et al. (1992), Gansler (1989), and Markusen and Yudken (1992).
8. It should be noted again here, and for the policy discussion to follow in Chap. 9 that spillovers are not subsidies.
9. I am currently involved in a complementary study on spillovers from weapons development by Saab Bofors Dynamics for the Gripen aircraft.
10. For an explanation and qualification of that statement see Technical Supplement S2.
11. See Table 2B in Technical Supplement S2. The exact calculation method is described in Chap. 8 and in Technical Supplement S2. I have used the higher than recommended real discount rate of 4% to achieve comparability with Fölster (1993) for the 1980 through 1992 period, but this lowers the calculated social rate of return of the Gripen development. Since technology spillovers take so long to be commercialized and grow into sizable industrial production there has been a problem to keep Gripen spillovers separate from earlier military development investments, for instance the Viggen. I describe how this has been done through interviews in Chaps. 4 and 5. If all military development is included the spillover effects become much larger. To obtain a net effect, furthermore, I have assumed that the alternative use of the resources now engaged in Gripen development, in the absence of Gripen, would have been employed at the average productivity registered for Swedish engineering industry, data that have been available on an individual firm basis from the Planning Survey of the Federation of Swedish Industries. See further Technical Supplement S2. The numbers only cover Gripen aircraft platform development including weapons integration, but not the development of the weapons. I am currently preparing a similar study on the spillover multiplier for the weapons development.

12. Let me add one qualification to that argument already here. University research and especially academic research outside technical universities, of course, has different objectives than being economically useful to society. True. But technical university research of today draws such large resources that any request for additional public funding should be subjected to exactly that comparison of economic usefulness. See further on suggested future research in Technical Supplement S3.
13. One objective to that statement that has been raised several times during seminar discussions of this document has been that this is a European conclusion. The US technical universities such as MIT are much more socially useful. Possibly. Again, another reason for further study. See Technical Supplement S3.
14. If not based on Gripen technologies they have not been counted in the spillover multiplier estimate. See further Technical Supplement S2.
15. Even though the original Latin meaning of industrious is hard working and diligent.

Chapter 2

The Art of Defining, Pricing, and Marketing Advanced Multidimensional Products that Spill Technology

Advanced engineering products such as aircraft distinguish themselves by a number of characteristics. Most obvious is that they are complicated as products to develop and manufactured under very complicated circumstances. They have also been designed to be robust, safe, and capable of operating under extremely demanding conditions, and to still have a very long life. This means that the purchase price of the product is only a part of the total user cost over its life cycle. The value of these products to the user furthermore, is larger, the more cost-efficient repair and maintenance features that have been built into them, and the easier they are to service and modernize. Hence, the value of the product to the user should be based on the user value and the cost of the user services it delivers over its long life cycle. Producers of such advanced products have also begun to follow the logic of this characterization, changing the property rights characteristics of their product; they increasingly own it and sell their services; hence, minimizing lifetime cost for the same use of the product and maximizing their net income of the product by postponing some of the charges to later stages of product life, and the aftermarket of servicing and updating the product.

Some military products such as aircraft, however, take so long to develop that considerable financial commitments and risks cumulate between initiation and delivery. Payments are therefore normally made in installments as defined milestones are passed. Also this changes the ownership characteristics of the product.[1] The military customer therefore owns an increasing part of the product as its development edges closer to final product and delivery. Also this early involvement in the design and engineering process means that the lifetime cost of the product to the user is being considered and minimized already in the product design.[2] In both cases, the customer is normally intimately involved in the product design and often contributes significant user knowledge, thereby directly influencing the definition of the product.

Civilian procurement of aircraft and aircraft engines and of other complex systems products with a long life has increasingly adopted a similar ownership logic. For the same reasons as in military procurement the large development risks and financial demands are forcing the large commercial aircraft makers Boeing and Airbus and aircraft engine makers GE, Pratt & Whitney, and Rolls Royce to demand significant risk sharing and financial contributions of their subcontractors

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(see further Chap. 5). The role of the *competent customer in shaping new technology* development therefore must be addressed in any analysis of economic growth, and, as we will see, the changing relative roles in that respect between public and private customers have to be specially considered.

In general, I argue, there will be no more sophisticated products developed than there will be customers who understand the usefulness of the products and are willing to pay for them. As concluded already by Burenstam-Linder (1961); *a sophisticated and wealthy customer base represents a competitive advantage*[3] *of the economy.*

Economic and political commentators have often neglected these positive industrial externalities of defense production altogether.[4] This neglect of well-established facts to a large extent depends on the ignorance of factual circumstances embodied in the models that economists have used for decades to structure their thinking, and to voice their opinions on. Models on industrial development that leave no room for spillovers cannot explain economic development. Hence, when the world changes and there suddenly seems to be no need for military aircraft, analysts and politicians suddenly become ready to scrap it all, aircraft and spillovers. This is one reason for presenting in this book the second and never-planned industrial role of military aircraft development and production, namely *aircraft industry as a technical university*. The magnitude and degree of sophistication of the development of a combat aircraft such as JAS 39 Gripen drives technology development over a broad range. The extreme technical requirements placed on the developers of such products are normally significantly above the current levels of competence and practice over a wide range making it necessary to solve many technical problems along the way to satisfy the customer's requirements, technical solutions that have a general application area in industry at large.

As will be seen in Chap. 6 devoted to the South African purchase in 1995 of 26 Saab 39 Gripen Aircraft and 24 BAE Systems Hawk trainer jets from the joint venture between Saab and British Aerospace,[5] the additional "procurement" of modern industrial technology (a spillover benefit) to help turn an isolated South African arms industry into a modern commercial engineering industry was an explicit part of the deal.

The role of military industry in economic development has, however, been a controversial topic. Some literature argues that the industrial wealth of Western economies would not have developed without the critical support of technologies developed for military ventures and defense.

In a fairly influential article Dunne (1990) distinguishes between three theoretical schools each of which embodies a voice of the economic significance of military production entered by assumption and used extensively to support argument in one or the other direction, two of them being decidedly negative to military production by prior assumption. *First*, the neoclassical model features a frictionless reallocation of constantly fully employed resources from one industry to another, so if you do not want or need the military products you can almost costlessly move the resources over to other politically more desired production. This pure neoclassical model is the standard of "modern" economic analysis. It ignores spillovers altogether and it is often used to argue against them. The introduction of spillovers, or positive externalities in this model already by Marshall 1890, however, was an attempt to remedy a serious shortcoming of the pure neoclassical model, a modification that resurfaced in the 1980s under the title of "new growth theory" (see below and Technical Supplement S2). All the spillover econometrics referred to in this text rests on the neoclassical assumptions.

The *second*, now old-fashioned Keynesian macromodel offers an opportunity for Government to increase total demand through increased military spending thereby raising the utilization of the resources of the economy and creating multiplier accelerator growth and more employment. Even though that model in its standard form is completely misleading in an economic growth analysis it keeps being referred to in arguments to create employment through military spending. There is also a related export stimulation argument.

Only the *third* Marxist model has something positive to say on military production. The Marxist economic model views capitalism as having an inborn tendency (a technological property) to produce a surplus the absorption of which is constrained by an insufficient effective demand for commodities. Under this theory military spending is needed to overcome underconsumption and to keep economic development going. This, so far, is also a view that Batchelor and Wilett (1998) tend to lean on through parts of their book on the defense industrial adjustment in South Africa (see further Chap. 6).

These theoretical presentations illustrate how the choice of one particular set of assumptions, or a greatly simplified model, can decidedly influence one's thinking and conclusions. This to some extent always has to be the case within academia the rationale of which is to formulate and communicate ("teach") principles, a task that requires great simplification and makes the arguments hover safely above reality. That task sets academe apart from industry, which is organized to earn a profit from developing and manufacturing goods and services that function. Industrial practice therefore has to accommodate all the complexity that is needed to achieve that.

Within most economic models there is little positive to say on a weapons industry if you don't need its products. However, two additional theoretical views that Dunne (1990) never mentions can be offered by changing the assumptions of the simplified models somewhat toward more realism. The spillover theory (*fourth*) that I will refer to extensively in the text (see further Chap. 3) is arrived at through some slight modifications of the neoclassical model, modifications based on Marshall's (1890) early criticism of the original neoclassical model and more recently embodied in growth theory. Since the mid-1980s Marshall's criticism has appeared (unrecognized, however) in what has come to be called "new growth theory." This theory introduces industrial knowledge as a factor behind economic development. The modifications of the neoclassical model needed to view the technical and industrial knowledge accumulated within an advanced military industry as a knowledge asset are minor. This knowledge asset can, however, only be expanded through further knowledge accumulation within the same industry or through knowledge accumulation in equally advanced industries. This extended neoclassical model, as we shall see, will be the methodological basis for one calculation of the spillover effects to come, and one critical factor behind that calculation is what you assume about the returns from further investments in knowledge accumulation (read R&D); Are they increasing or decreasing? (see Technical Supplements S1 and S2 and Chap. 8). The economic value of spillovers will now be seen to be potentially very large, and worth more, or much more than the cost of the original development of the military product.

But there is a *fifth* Schumpeterian evolutionary type model that I will also rely on in expounding on the spillover economics of a modern capitalistically organized market economy. This model rests on some further relaxations of the assumptions of the neoclassical model which turn the negative conclusions on military procurement upside down because of the dynamics introduced. We keep all basic assumptions of the neoclassical model, except for its technical definition of an equilibrium determined outside (externally to) the economy,[6] but the analysis now gets quite complicated (see further Eliasson 2005a:74ff).

The neoclassical model is a measurement and calculation theory that has little explanatory power when it comes to understanding the dynamics of a capitalistically organized market economy. Actors are assumed to be almost fully informed about everything that matters to optimize their economic decisions, and hence lie inactivated in equilibrium. There is nothing more of value for society to capture beyond what they know. They take prices offered in the market for given (price taking assumption). The link back to prices from changes in the physical allocation of resources is however absent. There is no place for the unpredictable entrepreneur with special insights who discovers industrial opportunities no other person has seen, and no economic mistakes are made by assumption. The neoclassical model is structured such that it can be located on an externally known (by the policy maker) equilibrium. It is therefore very centralistic in its policy advice. While this may be a required property of a calculation model for central government it does not help understanding the dynamics that goes on in the economy. Above all the analyst/planner using such a model will miss a number of factors that play important roles in the behavioral dynamics of a real economy that pop up as spillovers and explain economic growth. However, simply by removing the assumptions that make all actors fully informed and all markets constantly cleared clears the way for new insights. Then the entrepreneur and all the well-known specialist actors that are needed to commercialize innovations surface and decidedly change the framework of understanding and analysis.

Within this new model economic world that I have created the policy maker will become aware of the fact that s/he risks missing an industrial opportunity of enormous dimensions if she/he simply allows the defense industry to go.

2.1 The Pricing of Complex and Multidimensional Systems Products

The multidimensionality of advanced products is only one complicating factor. Advanced products such as aircraft also distinguish themselves by another collective characteristic, namely a "cloud of new technology" (spillovers) more or less available to external users free of charge, but only to the extent they possess the *receiver competence* (Eliasson 1986:47f, 1990a; Cohen and Levinthal 1990) needed to commercialize them. The producer of these technological services would be happy to be able to charge for the spillovers. Spillovers are, in fact, a part characteristic of the product but they cannot be charged for directly because of weak property rights, i.e., if the firm cannot come up with an *Innovative Pricing* (IP) method (Jonason 1999, 2001; Eliasson and Wihlborg 2003). In studying the production and supply of advanced products we are therefore confronted with an interesting pricing problem. Industrial participation programs, including offset trade agreements can be organized to benefit both the customer and the producer by sharing the value created from the spillovers the supplier has created. This is in contrast to the conventional view that offset trade is only a cost to the supplier.

The above characteristics of advanced systems products are usually associated with the public procurement of, for instance, military aircraft (Eliasson 1995), submarines (Eliasson 1999) or public telecommunications systems. Three circumstances, however, have made the public dimension of these spillovers more general and private. (1) Previously public, or semipublic activities, like telecommunications are increasingly becoming privatized. (2) Traditional private industry is increasingly using very advanced and complex systems products of the kind we are talking about, for instance large commercial aircraft or telecom systems. Many parts of the media and entertainment industry, large and complex private banking payment systems, internet-based trading systems and advanced, global transport coordination systems belong here. It is to be expected that the health-care industry will soon move into this category of advanced systems builders (Eliasson 2007). Products for the growing markets of civil security also belong here. The existence (3) of an advanced industry, such as a complete aircraft industry in one country therefore not only serves as a source of technological development and learning (a "technical university"). It also becomes a positive "brand" that signals the existence of competence, a brand that spills over to the entire industry of the country, that, if cleverly used allows related firms to charge extra for their own products. We will pay special attention to that possibility below.

The increased mixing of public and private goods and services production using common technologies have brought change to previously specialized customs production of, for instance, military aircraft. With common components and sometimes also common subsystems military aircraft producers are increasingly composing their products from components supplied "off the shelf." Going from tailor made inhouse components and subsystems to commoditized products from the shelf characterizes the shift from the third to the fourth generation of military aircraft, i.e., in Sweden from the Saab 37 Viggen, first delivered in 1971, to the JAS 39 Gripen, first delivered in 1996.[7] South African arms industry (discussed in Chap. 6) provides an interesting "anomaly" in this respect. Because of the UN arms embargos in 1963 and 1977 South African arms industry developed its own arms manufacturing capacity built largely on proprietary technology, own industrial standards and the need to manufacture practically all components within South Africa. This was neither an economical organization of production nor a good way to achieve internationally competitive product performance. Similarly product obsolescence will occur more rapidly because the larger costs of remanufacturing and upgrading components and subsystems.[8] South African arms producers, even though innovative and efficient in their own ways, therefore moved further and further away from the manufacturing practices that developed in the international engineering industry. An important part of the Saab South African purchase deal of 26 JAS 39 Gripen aircraft in 1995 therefore included explicit technology transfer to support South African industry in getting out of its "proprietary technology lock-in" and to adjust to modern industry standards and practices (see further Chap. 6). The new practice of commoditization means increased economies of scale for specialized subcontractors and in general a greater potential value of spillovers.

In this chapter, I define the nature of the spillover problem strictly and discuss – in principal terms – the dependence of the commercial value of the total product (the aircraft plus the cloud of spillovers) on the competence of the local industry to commercialize the spillovers and to capture the rents. In Chap. 3, I present a survey of related theoretical and entrepreneurial literature. Special attention is paid to the commercialization of spillovers and the macroeconomic consequences. A key concept emerging from this analysis is *the advanced firm as a technical university* providing educated and experienced engineers and workers to industry at large and *production technology for future engineering industry.*

Chapter 4 covers the same theme empirically in the form of a case study of Swedish aircraft industry and its ex post impact on the Swedish economy, an advanced industrial economy. I trace the origin of observed spillovers ex post, which means that they have mostly originated in the third generation 37 Viggen development program.

To isolate the spillovers from the JAS 39 Gripen project a different method has to be used, since most of the spillover flow has yet (after 2007) to be realized in the form of volume industrial activity. The only parts that we can observe with certainty are the projects that have failed or been picked up by foreign firms. In this context, I will also touch upon spillovers around foreign military aircraft industry such as Dassault and the Eurofighter project, even though no case studies have been carried out on them within this project. Chapter 5 is therefore devoted to assessing and quantifying the *future* macroeconomic consequences of the JAS 39 Gripen development program that was initiated in 1980 and that is expected to stretch into the 2040s.

Chapter 6 is devoted to a similar case study analysis of technological spillovers around aircraft industry in an industrially less-developed economy; South Africa. Here the capacity of the local economy to commercialize spillovers is in focus. South Africa is a developing economy with at places very advanced inhouse technology. South African firms, however, have a limited experience from commercializing technology. Their ability to participate in the emerging global production networks is therefore correspondingly limited. Such participation demands the use of common standards, precision manufacturing, sophisticated quality controls and the strict honoring of delivery commitments. Part of the South African purchase of the Saab JAS 39 Gripen system and the accompanying offset deals were explicitly negotiated to provide support for those conversion and commercialization ambitions. How this has been done makes up the main story of Chap. 6. We therefore pay special attention to joint customership programs in which the producer engages for a profit together with the customer and local firms in the commercialization of spillovers from its own business deal.

Chapter 7 briefly introduces the European perspective and addresses the additional benefits of public procurement in, and the macroeconomic consequences of, an enlarged European spillover pick up area. In Chap. 8 a general method to calculate the private and social benefits from industrial development programs is presented verbally, or the social and private profitability of public purchasing. I estimate the macroeconomic effects on the JAS 39 Gripen development on Swedish industry. The methods are presented and discussed in more precise mathematical terms in Technical Supplement S2 which also includes further references to the spillover literature.

Advanced public purchasing of, for instance, military aircraft has certain unique and interesting features; the product and the spillovers are produced under a regime of *joint production*. However, we also have a situation of *joint customership* in the sense that the Government (the country) is both buying the product and benefitting from the associated spillovers as a collective good. Hence, *the advanced firm* in practice functions *as a private technical university* supplying both technology and experienced labor to the economy at large (Eliasson 1996b). The book therefore concludes (in Chap. 9) with a summary assessment of the macroeconomic effects of public purchasing and advanced firms functioning as technical universities in terms of their usefulness to industry at large. In that assessment I also discuss how their academic "competitors" compare on the same terms. With public purchasing, an indirect public funding of that "private university" occurs to the extent Government pays extra for the cloud of spillovers such that a satisfactory private profitability is achieved. Government and society, however, obtain the joint product at a very low price as a partly free spillover. Innovative pricing in this case amounts to the ability of the advanced firm/producer to demonstrate credibly the value to a user or to society of the total product, to bundle the spillovers with the product and to charge for the whole package, including an extra charge for the spillovers. If this extra charge has been successfully negotiated, the producer may be said to have strengthened the property rights to the spillovers it has produced through innovative pricing. Public procurement often represents such a form of joint consumption and customership.

On the surface it may look as if the producers of advanced aircraft are selling the intangible spillovers they produce as a byproduct at rock bottom zero prices. However, if the producer can offer support in commercializing these spillovers to the public buyer (for instance, in the form of an offset trade arrangement) there would be an extra economic value creation for society. That extra value will have to be shared between the supplier and the public customer, since otherwise the commercialization support will not be forthcoming. Offset trade therefore represent a form of innovative pricing, and needs to be supported by appropriately designed incentive contracts.

2.2 The Joint Manufacturing of Products and Intangible Spillovers

Any product can be defined in terms of its (FRs)

1. User functional requirements.
    (a) Performance
    (b) Availability
2. Life cycle costs,[9] that depend on the development and manufacturing process [(A) × DP].
    (a) Acquisition costs
    (b) Life support costs for use, repair, servicing, and maintenance
3. Flexibility of product design over time (updation, modernization).
4. Intangible spillovers.

When purchasing contracts are negotiated focus is on (1) and (2). Life support costs are increasingly becoming an issue, notably in private purchasing (of, for instance, large aircraft engines) where the producer increasingly owns the product and charges for the services of its use. The more the user is involved in the product design the greater his concern about product life cycle costs. In fact, as much as 70–80% of manufacturing productivity (Suh 1990:41) is determined at early design phases. Flexibility demands of the customer (3) often are a difficult task for the producer. Since such a large part of total product costs can be reduced by measures taken at an early design stage, the costs for engineering flexibility in future product updation should be correspondingly reduced. Hence, the art or technology of simultaneously minimizing the costs of life cycle maintenance and service and of future functional flexibility must have great priority in designing products such as aircraft with a very long service life.[10] Integrated production is a method to achieve that (see Sect. 5.3).

The matrix (A) can be structured to represent the various processes that link design parameters (DP) to desired functional requirements (FRs). One point is that there are many such designs, (A)s, and the art of clever design is to know about, and know how to apply the best.[11] This principal design architecture can be further developed to accommodate built in product flexibility, when not all FRs are known initially, but can be to some extent anticipated. Holmberg (2003) has done that in a fashion that takes the design process close to the cost–benefit analyses of real options theory (Trigeorgis 1996). Holmberg (2003) has also developed Suh's search for an optimal design architecture through an iterative process where existing knowledge feeds into a concept creation process that is validated and then adds to the knowledge base, and so on.

There are two types of uncertainty associated with the development and manufacturing of an advanced product.

1. Performance up to FR (*technological uncertainty*).
2. Calculability of costs, or the control of factor prices and of the (A) × DP relationships (e*conomic uncertainty*).

If the customer desires new functionalities that require radically new technology development greater uncertainty is associated with the matrix A and (1). Normally the producer then has no method of reliable calculation. *When the producer has no information advantage over the purchaser a (technological) risk-sharing contract is the common solution.* In fact, in advanced public military purchasing, the customer is often a significant user knowledge contributor who understands the product technology and the production organization well. Once product technology (A) is under control, costs of development and production become more easily calculable. Here, the producer has the information advantage. The balance between (1) and (2) is, of course, reflected in the contract.

With much new, untested product technology and flexibility in design (that is in determining the FRs) there will be a drift toward *cost plus pricing* with a larger part than normal of the risk being taken on by the customer. Since new untested technology should be expected to spill more technology when developed, it would therefore be in the interest of a rational public purchaser to cover a larger share of the risk, since the public economic value of the spillovers would become larger.

When functional requirements (FRs) are standard, tested, and normal, calculable flexibility is asked for and we have a case for *design-to-cost pricing* or fixed cost pricing. The buyer negotiates a price for specific minimum product performance characteristics (FRs). The negotiation, or the competition, may also include what more the producer can offer at that price, for instance in the form of support in commercializing spillovers.

Various forms of *incentive contracts* define intermediate forms between the cost plus and design-to-cost pricing methods. Incentive contracts are designed to make the producer commit himself to a maximum feasible performance and to share the profit and losses with the procurer in relation to the negotiated price. Cost and delivery performance are the common benchmarks. Incentive contracts always have a bias in favor of one of the parties that depends on their relative competence to understand the technicalities and economics of the project. This is where the *competent customer* enters in his capacity not to require the impossible, but what is feasible to achieve, and some more in the negotiation. An *incentive contract* was used in an early phase of the Gripen negotiations (see Sect. 8.4).

Intangible spillovers (4) have normally been forgotten altogether even in the large and complex public procurement contracts we are studying, and are rarely entered directly into the contract, except sometimes as local employment commitments on the part of the seller or as offset trade commitments. Such commitments are, however, often inefficient arrangements for both parties to the contract, frequently unrelated to the main contract and of little long-term value to both parties.[12] Hence, the development of a rational way of calculating the costs and benefits of technological spillovers and the design of contracts that maximize the potential economic value of these spillovers to be shared by the supplier and the customer should be a prime concern for the producer of spillover-intensive products and services.

One would also expect the clever producer, facing a tough negotiation on the purchasing side to use his information advantage and accept a low price for well-defined FRs, but save on (2b) and resist demands on (3) and then capture part of the profit on later maintenance and upgrading. From the customer point of view this is, however, less efficient. The buyer and the producer could also negotiate a real option (of well-defined flexibility) at a price (see further Chap. 5).

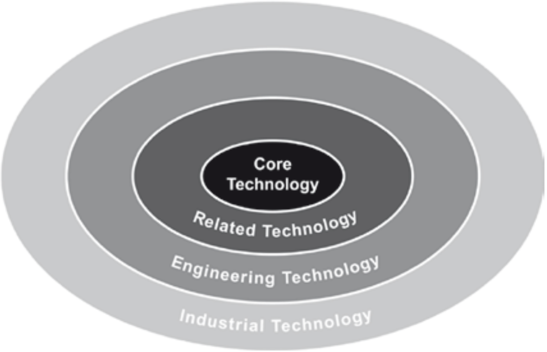
As a rule spillovers are determined by the product specification and not negotiable (excluding offset requirements), but the less of new technology development associated with achieving the FRs desired by the customer, the smaller the cloud of spillovers. Hence, the producer might get a better deal on the (1) and (2) sides if it can give a credible presentation of the value of the intangible spillovers under (4) and offer support to the public customer in capturing the spillovers, that may be large, or very large under the right incentive arrangements. The economic value of the spillovers to society, however, is not realized until it has materialized in the form of a profitable (sustainable) production activity. To a large extent this has to be the result of entrepreneurial activities in the market and especially so for an advanced industrial economy. But for a less-developed economy (see Chap. 6 on South Africa) lacking the infrastructure of commercializing agents the producer of spillover-intensive products may find it profitable not only to offer the product itself, but also to establish production based on some of the spillovers that come with the product. *A rational and informed public customer might therefore find it socially profitable to focus on achieving spillover value (4) and pay for the support in capturing the spillovers.*

Obviously, having an information advantage the outcome for the producer/seller improves with its ability *to present a credible story on the potential value of spillovers* (4). Risk sharing and incentive contracts become optimal when each party is equally informed about the value of spillovers. For instance, the Swedish Government defense procurement agency, or Defense Materials Administration (FMV) demanded[13] that the JAS 39 Gripen consortium should get the most efficient low-cost subcontractors, thus reducing the resources available to the subcontractors to develop new technology compared to earlier procurements. Consequently contracts often went abroad to foreign subcontractors of complex components that could modify already developed components, expand volume, and capture related technologies for themselves. With one exception only the large Swedish partners in the IG JAS group (Ericsson, Volvo, and Saab themselves) were willing or able to take on the risks of large development projects and finance them internally. This also meant that the by far dominant part of spillover values were created within those firms (See Supplement 2). An interesting question to ask is how well informed about the economics of advanced purchasing the public purchaser was when it squeezed the JAS 39 Gripen consortium so hard [under (2)] that less margin than before was available for product development, and, hence, most probably fewer spillovers were generated.

2.3 The Economic Nature of Intangible Spillovers

Advanced firms are surrounded by a cloud of new technology (Fig. 1) that they have generated as part of their ongoing business, that they unintentionally spill over free of charge to other firms in related industries, and that they can only appropriate for

Fig. 1 The four waves of spillovers (The technology cloud)



themselves to a limited extent because there are few ways of effectively claiming the property rights to those spillovers. It can to some extent be done through bundling the spillovers with the product to be sold (see Chap. 9 on policy). The economic value of these spillovers to firms and society, however, depends on the local receiver competence, or the local ability of whoever comes by to capture and commercialize them.

2.3.1 The Existence, Magnitude, and Economic Value of Spillovers

A large economic literature documents the existence of positive production/productivity effects of the cloud of spillovers around advanced firms, most of the literature originating in the USA. Chapter 3 includes a survey of this literature. Two results from these studies should be observed already here. *First*, advanced firms in these studies practically always mean firms that have a high R&D intensity in production. *Second*, practically all studies refer to positive relationships between high R&D intensity and productivity in own and related firms estimated on North American data. For firms and industries that are spillover intensive a related econometric literature also reports on very large positive differences between social and private returns to R&D investment. Such large econometrically determined differences mean that society benefits from private R&D investments that create, in fact, very large additional economic value. Jones and Williams (1998) are quite straightforward in their conclusion that advanced industrial nations such as *the USA* for those reasons *underinvests in industrial R&D,* a conclusion earlier drawn by Nadiri (1993). And the underinvestment is large. The optimal level of R&D investment is at least, Jones and Williams conclude, two to four times larger than the current level.

A few qualifications to these results should however, be mentioned already here (I will come back to the methodological problem later in Chap. 3 and in Technical Supplement S2). I distinguish between *spillovers as the technology supply* (technological spillovers) of a R&D process broadly defined and as social value creation as the output that has resulted when the technology has been filtered commercially through a competence bloc. The US is a market economy with less nonmarket influence, such as public sector production and subsidies to firms than in most other industrial countries, including Europe. Hence, R&D allocations in those mostly North American studies have been filtered by more efficient markets and by more efficient commercializing agents than would be reflected in a similar study on continental European data (Eliasson 1996b, 2003). A selection effect therefore afflicts these results in the sense that firms that have engaged in R&D spending with positive commercial outcomes tend to dominate statistics. This is so since failing R&D intensive firms have either reduced R&D spending, contracted operations, or dropped out of the market. An increase in R&D investment therefore does not necessarily increase long-run output. The spillovers first have to be identified as economically interesting and commercialized successfully. Spillovers that have been tested in the market therefore embody both technology and the economic or commercial knowledge that have gone into those selections. Competence contributions from the customer when it comes to specifying the appropriate design of the product improve both the technological and economic content of the spillovers. Competition from several suppliers for the same procurement contract also raises both the technical performance of the selected project and lowers its costs.

The policy method to raise spillovers from R&D spending in advanced firms hence is to support competition in the local economy (Eliasson 1996b). Technological spillovers – the common term – therefore, is a misnomer. The right term should be *industrial (knowledge) spillovers*, industrial signifying a dynamically integrated combination of technical and economic knowledge. I therefore introduce the distinction between technology supply, or the spillover intensity of the cloud, on the one hand side, and the share of the cloud that is commercialized and entered as the numerator in the spillover multiplier, on the other.

Some additional results from the empirical literature should also be noted here. The strongest economic filtering of technology is to be found in the financial markets. The strongest industrial spillovers therefore originate in R&D carried out in private firms, being privately financed. Publicly funded research carried out in private firms come in second, and the lowest spillover effects are recorded for publicly funded research in publicly run research laboratories (Nadiri and Mamuneas 1994; Eliasson 1997a:241f; Hall et al. 2010). Hence the largest spillover potential is achieved when the supplier carries both the technical and economic risks, preferably in projects conducted in cooperation with an involved and competent customer. When the customer is not involved and the Government contributes funding of R&D without any demands on specific outcomes, spillover intensity decreases. The lowest spillover intensity is recorded when the public funding agency also takes over the customer role and directs R&D spending. I have no further documentation on this, but if there is any substance in these results they need further empirical inquiry considering the vast public resources, especially in Europe, that are allocated in that way.[14] This, hence, is a negative result for university research and runs against the implicit suggestions of Arrow (1962a) that (static) efficiency in research allocation will be achieved when technical research is carried out in publicly run laboratories, and the results are made public to private industry for free (c.f. the story of *Daguerre* in Sect. 8.3.2). The empirical results thus rather support the theme emphasized in this book of "*the advanced firm as a technical university*" (Eliasson 1995, 1996b). Still, *the Arrow (*1962a*) proposition* has permeated much industrial policy discussion and associated publicly sponsored R&D programs for decades, and still lingers on in some literature and in many policy institutions. This is a technology supply-based policy advice based on economic models low on economics and often devoid of market recognition.[15]

2.3.2 Receiver Competence

The value of spillovers has a collective (social) and a private part. Both depend on the capacity of actors to build a business on them.

The capacity, or *receiver competence* to commercialize technology (Eliasson 1986:47f, 1990a; Cohen and Levinthal 1990) is both technical and economic. Hence, capturing the rent depends on (1) the possibility to link property rights to the spillovers, (2) the capacity to build a business on them and/or (3) the ability to charge for them (Innovative Pricing). Patent or copy rights are the most common designs to link property rights to spillovers. Vertical integration[16] or joint ventures (items 3 and 4 in Table 1) are common attempts to control or protect property rights and the external availability of spillovers during technology transfers, and to capture the rents based on asymmetric information or knowledge. Saab has done it (see next section) through starting companies on the basis of technologies developed around its military aircraft business. Another way is to build a new division to appropriate own spillover technology and later spinning it off as a separate company [for instance *Datasaab*, see Eliasson (1998b) and Dassault Systems (based upon the Catia system from French Dassault)]. A third way is to organize a joint venture with a group of internal innovators and contribute venture financing. The concern in all three cases is that of asymmetric information, or rather asymmetric knowledge, and the resources needed to achieve speed to market before competitors/imitators pick up the idea. Many large firms have therefore established their own venture capital arms to appropriate the rents from their own spillovers. The problem is, however, that a sophisticated venture capital industry, such as the one on the US west coast that consists of a varied assortment of firms defining together a broad range of specialized industrial experience, is needed to identify, select, and foster winners (Eliasson 2005a: Chap. 4). Internal venture capital firms, on the other hand, always, in one way or another are limited in their outlook by their own origin, which will rarely reflect what is needed to capture and commercialize the odd technologies that tend to emerge spontaneously from creative industrial research labs.

Compensation from successfully commercialized technologies comes in different ways. Capital gains on joint ownership arrangements is one form of compensation. Another is to allow an internal inventor/entrepreneur to do it on his own, and charge a license fee for what has been developed in the company, or just (which is not uncommon) to let the inventor/innovator take his/her idea and do it on his/her own. Then the innovator/entrepreneur will keep the profits in the form of capital gains if the spinoff is a success. But this path or diffusion channel (common in the USA, notably in Silicon Valley) is a high-risk path and depends critically on the support of a complete and viable competence bloc (item 2 in Table 1).

A corporate group composed of several companies operating in different markets, such as GE or the Swedish Investor group,[17] to which Saab belongs should have, if cleverly organized for it, a potential for commercializing spillovers from Saab. In the same way the Volvo Group has been quite successful in commercializing spillovers from the production of military aircraft engines. Such a capturing business could occur spontaneously, as in the case of Ericsson mobile telephony (see Chap. 4) or, be managed as a separate business.

Intangible spillovers come in different shapes. *First*, to exemplify from our case study, we have the closely related, within industry spillovers, one step beyond internal firm use (the *core industry* in the inner circle of Fig. 1). Here, we would expect to find spillovers between (both ways) aircraft manufacturers and aircraft engine manufacturers. The more fragmented by outsourcing the industry becomes the more important these spillovers, and the more urgent it becomes to find a way of mutual recognition and compensation. In public purchasing, we have a case of joint customership and it becomes easy for Government to motivate a higher price for the product as a compensation for spillovers. Silicon Valley and the South German luxury car production cluster offer similar examples of competence blocs populated with advanced firms that both benefit from the spillover source and contribute to it (Eliasson and Eliasson 1996, 2005a; Kelley and Cook 1998).

The next step (*second*) takes us further out to the second circle; *related* (to aircraft industry) *technology* including air navigation and safety, air traffic control, etc.; a rapidly growing IT-intensive industry. If unmanned air traffic becomes a reality this might constitute an important growth area, as will security industry in general. Recent firm interviews conducted within this project also indicate that the aircraft industry is moving in this direction.

Third, however, many devices and technological developments in the core aircraft industry have found profitable applications in the third *engineering general* circle. It is no coincidence that a Swedish computer industry originated among the advanced users of numerical calculation techniques (industrial simulation) among the Saab engineers. Already in the 1950s they constructed their SARA[18] computer. Digital computing was used in aircraft design work already for the 32 Lansen and the 35 Draken in the early 1950s and a fast and fully transistorized computer, the first in Europe, called Sank (or D2) was ready for the civilian market in 1960, less than a year after IBM in the USA. The Viggen combat aircraft was developed in the 1960s. When it was first delivered in 1971 it used on board computerization extensively. The on board computer, to begin with a central computer, not only became the prototype for Saab's commercial computer D21 (see further Sect. 4.6) but also laid a foundation for technology that would later be used to support distributed manufacturing. This was notably the case in later Viggen versions that used microprocessor technology and distributed computing extensively (see further below). This generic quality of aircraft technology makes it appropriate to say that *aircraft industry already today uses the technologies of future engineering industry* (Eliasson 1995, 1998a).

Finally we have the unpredictable serendipitous spillovers in the *industry general* outer circle. The word serendipity originated in Horace Walpole's (ca. 1754) *The Three Princes of Serendip* who had an aptitude for making fortunate discoveries accidentally. For instance, while it does not come as a surprise that a Swedish aircraft engine manufacturing activity developed within Volvo[19] as a spillover of Swedish aircraft industry, it is more difficult to understand that the digitalization of Ericsson mobile telephony owes a lot to military digital electronics development in the context of the Viggen and later JAS 39 Gripen projects (see below).

The ability to capture the spillovers in the different circles also requires different receiver competencies on the part of local industry and the econometric spillover studies to be further discussed in Chap. 3 tend to limit their attention by prior data classification to closely related industries. Hence, the more peripheral the spillovers that have been commercialized but not captured in those spillover studies the more underestimated the total magnitude of the effects. This will be more the case in an economy with a competent commercialization industry, such as the USA, than in other industrialized economies. (c.f. the social vs. private return estimates on this in Technical Supplement S2). The total economic outcome thus depends on the efficiency of available channels of diffusion (see Table 1) of the same spillovers and the capacity of local entrepreneurs to identify and commercialize them.

Receiver competence is thus critical for the value of spillovers. The more important receiver competence, the less of a problem of charging for the information. If the imitator is unable to pick up your idea (knowledge) without your help you can sell the knowledge over and over again because you have to provide user (receiver) competence each time. This bundling we call innovative pricing. Technology transfer programs and offset trade arrangements – if competently organized – are illustrations (item 5 in Table 1). The really valuable offset trade to the receiving country is offset trade that involves support in implementing the industrial user competence in the local economy.

2.3.3 Diffusion Channels

Table 1 lists the six main channels of technology diffusion. The most discussed channel is outright imitation – the Japanese, or now rather the Chinese way – (item 5),

Table 1 New technology is diffused (Source: Eliasson 1995)

1. When people with competence move (*labor market*)
2. Through new establishment by people who leave other firms (innovation and *entrepreneurship*)
3. When subcontractors learn from systems coordinating firm, and vice versa (*competent purchasing*)
4. Technology is acquired through strategic acquisitions of small R&D intensive firms (*strategic* acquisitions)
5. When competitors learn from technological leaders (*imitation*)
6. Through organic growth and learning in incumbent firms

when development costs are carried by US firms and the rents captured by the Japanese firms. Econometric research – as mentioned – lends support to the existence of that channel of diffusion. It is also a well-known fact that the bulk of R&D, and in international firms in particular, is devoted to sourcing new technology and that the ability of the firm to capture free-floating technologies (its receiver competence) is a critical competitive advantage of the advanced firm (Eliasson 1990a, 1991a; Kokko 1992; Lichtenberg and van Pottelsberg de la Potterie 1996). Some results, underlining the critical importance of receiver competence, are reported by Bernstein and Mohnen (1994). In their study of R&D activity in advanced US firms they looked at (1) effects of own R&D spending on productivity, (2) productivity effects in related US firms and (3) productivity effects in related Japanese firms. They found that the Japanese firms were better than the "closer" US firms to exploit technology developed in advanced US firms and "released" unintentionally as intangible spillovers.

Technology diffusion, however, it is necessary to emphasize in this context, only to a minor extent is about the diffusion of "solutions" already developed ("patents"). *The important form of diffusion occurs when people who have learnt to solve a particular type of technical problem, move on to another job to solve related problems there.* The most important avenue of technology or competence diffusion, therefore, is the *market for competence*, when people with competence move between jobs and firms (item 1). The same type of learning (item 3) occurs when firms/subcontractors learn from one another when working together.

Increasingly, firms also acquire complementary technology (item 4) through strategic acquisitions. This latter form of technology diffusion has increased in importance in the last decade as large specialized volume producers have found it increasingly difficult to innovate their technology base through own R&D investments (Eliasson and Eliasson 2005b).

Another form of diffusion and/or activation of technologies (item 2) occurs through spin offs from larger firms. In times of radical industrial restructuring this has been a triggering factor. It may have been more important than the movement of people, since it has often meant that winning technologies about to be shelved by conservative big business firms have been activated by understanding entrepreneurs. Most of Silicon Valley, in fact, has that origin. At the same time university entrepreneurship, meaning the industrial exploitation of university research results, while probably being less important (Eliasson 1997a, 2000b, 2005a: Chap. 4) has been more discussed in literature (Jaffe 1989; Nelson 1986; Stankiewicz 1986). University research to become industrialized requires strong complementary support of commercialization competence of a complete and broad-based competence bloc (next section).

Finally, research and internal learning in incumbent firms (item 6) is a not to be forgotten source of long-run growth because it involves considerable diffusion of technology both within the company and to outside companies through spillovers. A varied career within a firm and/or between firms is a carrier of knowledge and experience and an important form of executive learning.

2.3.4 Accessing the Global Pool of Technology

To summarize, the bulk of R&D expenditures in advanced firms is devoted to picking up internationally available complementary technology to integrate with their existing knowledge base, and only a small fraction is allocated on genuinely new technology development. The multinational firms are specialists in this field (Eliasson 1991a, 1997a:12ff), and, supporting this, Keller (2001) observes that recent research shows the major source of technical change leading to productivity growth among OECD countries to be foreign, not domestic. He also adds (op. cit.: p. 3) that learning through international economic activity might be particularly important for industrially less-developed economies, for instance through foreign direct investments (see further Chap. 6 on South Africa).

Klenow and Rodriguez-Clare (2004) have constructed what they call a hybrid model of some recent growth models including that of Jones (1995) and Jones and Williams (1998). Their model features a global technology frontier that is moved by R&D investment in all countries, that individual countries (or rather firms, I would say) can access in proportion to their receiver competence, being dependent on their own R&D. They find, through a series of calculations, that a high investment rate in physical and human capital explains the persistent differences in productivities and per capita income between countries, that complementarities among physical, human, and R&D capital are strong and that international knowledge externalities (the technology frontier) explain the fairly uniform rates of growth in the different economies irrespective of levels of per capita income. Without this global availability of knowledge, Klenow and Rodriguez-Clare conclude, the world GNP would be much smaller.

The notion of a *knowledge-based economy* (Eliasson 1987b, 1990b; OECD 1996) has become a particularly popular parable in the past decade when discussing technology or knowledge diffusion through markets, in contrast to the diffusion of information using modern computing and communications (C&C) technology.[20] Spillovers have been demonstrated to be particularly strong and more easily diffused in industries that are intensive in their use of C&C technology (Greenstein and Spiller 1996; Lichtenberg 1993; Mun and Nadiri 2002).

Part of the discussion has centered around the relative importance of tacit or noncodable knowledge versus codable knowledge or information. While information can easily flow through a wired economy tacit knowledge embodied in the heads of people requires personal contacts to be diffused and therefore tends to be more efficiently diffused within close metropolitan areas (Feldman and Lichtenberg 1997) and where labor markets are efficient in moving people on to better jobs. Hence, trade in advanced intermediate products and foreign direct investment tend to diffuse tacit knowledge more efficiently and explain international differences in productivity performance between countries.

The notion of tacit incommunicable knowledge, however, has not been well-received among traditional ("neoclassical") economists because tacit knowledge, as distinct from information, causes serious formal problems in the mathematical models they use.

A number of attempts to overcome this problem have been made. On this Mankiw (1995) rather believes that technical knowledge is generally available to all in an international pool. He wants to explain differences in the use of technical knowledge in terms of differences in complementary factor accumulation. Keller (2001) doesn't find this view particularly helpful in explaining productivity differences between countries. It should however be noted that commercialization competence is a critical complementary knowledge that is needed to commercialize freely available technical spillovers from R&D in advanced firms.[21]

Parente and Prescott (2000) want to explain the same differences in exploiting internationally available knowledge in terms of differences in actually used technical knowledge, something that can be explained in terms of differences in countries' resistance to the adoption of internationally available technology. Neither does this policy explanation find any sympathy with Keller (2001). Keller rather exhibits a strong preference for Quah's (2001a, b) weightless economy in which technical knowledge is disembodied, codified, and information globally available, while human capital is embodied, tacit, local, and difficult to communicate. This is quite speculative and to be on the safe side Keller (2001) suggests more research. Let me therefore note here that my interpretation of technological spillovers and the capacity of the local economy to identify and commercialize them combines the ideas of Mankiw (1995) and Quah (2001a, b) all being embodied in the competence bloc theory to be presented in the next section.

2.4 Competence Bloc Theory and the Critical Role of the Advanced Customer

Competence bloc theory deals with costly economic selection and growth. Selection implies the possibility of economic mistakes. Economic mistakes do not occur by assumption in the standard neoclassical economic model, except as costless stochastic random incidences. Competence bloc theory therefore has no role to play within the neoclassical model. To deal with costly selection a much broader theoretical framework than the neoclassical model has to be used, and this can be achieved through relaxing a few seemingly innocent but critical assumptions of the neoclassical model, essentially those assumptions that makes it a static equilibrium model where prices reflect, and (therefore) all actors can be fully informed about, everything there is to know.[22] We thus find ourselves in what I call the theory of the *Experimentally Organized Economy* (*EOE*) which is the home of competence bloc theory. Relaxing those neoclassical assumptions means that tacit knowledge becomes a reality, that difficult to communicate knowledge is no longer identical to codable information and that the economy will never come to rest in an exogenously determined equilibrium.[23] Competence bloc theory now has an economic role to play.

Creation, commercialization and diffusion of technology are largely a matter of costly transactions in tacit knowledge embodied in intangible assets over markets and, therefore, require both strong market support (economic *incentives*) and market

Table 2A The dominant selection problem (Source: Eliasson and Eliasson 1996)

Error type 1: Losers kept too long
Error type 2: Winners rejected

Table 2B Actors in the competence bloc (Source: Eliasson and Eliasson 1996)

Demand
1. Competent and active *customers*

Technology supply
2. *Innovators* who integrate technologies in new ways

Commercialization
3. *Entrepreneurs* who identify profitable innovations
4. *Competent venture capitalists* who recognize and finance the entrepreneurs
5. *Exit (Private Equity) markets* that facilitate ownership change
6. *Industrialists* who take successful innovations to industrial scale production

enforcement (*competition*). For the market dynamics of the experimentally organized economy to come into play a reasonable protection of intellectual property rights (Eliasson and Wihlborg 2003) and incentives to create and commercialize innovations have to be in place. Winning projects have to be exposed to a maximum of varied and competent evaluation to minimize the risk of losing a winner and of keeping losers for too long in the budget (Table 2A). A viable and complete competence bloc (Eliasson and Eliasson 1996, 2009; Eliasson 2009) is needed to perform this "optimization" of the selection process that results in the entry (Table 2B) of winning projects/firms and more competition from incumbent firms. The competent customer plays a both unique and critical role in that selection process.

2.4.1 Customer Competence Contributions

In the long term – such is the fundamental understanding of competence bloc theory – the quality of products will be limited from above by the quality of customers' understanding of the usefulness of the product, their willingness to pay, and their contribution of user knowledge to the development of new product technology.[24] *A competent and wealthy customer base constitutes a competitive advantage of an economy*.[25] The availability of specialist subcontractors within the competence bloc, furthermore, allows individual firms to enjoy economies of scale or networking externalities through the system. A complete competence bloc, hence, allows through an optimal mixture of market and hierarchical coordination a dynamically efficient combination of innovative ability and industrial-scale production (Eliasson and Eliasson 2005b).

In the end, this paper will highlight the different interests of the public and the private customer, in effect meaning that they regard the same product differently. A rational public customer should be concerned that the cloud of spillovers be commercialized locally to a maximum possible extent, indirectly making public procurement an instrument of industrial policy. The private customer cannot be expected to entertain the same social concerns, even though it may be interested in commercializing the spillovers, alone or together with a partner, to the extent it makes (private) economic sense.[26]

The availability of specialist subcontractors within the competence bloc allows individual firms to enjoy economies of scale through the system. A complete competence bloc, hence, allows through its mixture of market and hierarchical coordination a dynamically efficient contribution of both innovative ability and industrial scale efficiency.

2.4.2 Technology Supply

The complete competence bloc features competent *customers* (item 1 in Table 2B) that contribute technology to producers by participating in development work. This is typical of aircraft industry. *Innovators* in the competence bloc are technically defined. They combine old and new technologies into new composite technologies and are important actors in the creation process (item 2). It makes economic sense to give innovators a technical definition even though the pioneer of entrepreneurial economics Joseph Schumpeter (1911, 1942) was not clear on this point.[27]

Technological spillovers appear in the competence bloc and in my analysis as technology supply. But technology supply is not sufficient to guarantee economic growth. Technologies have to be identified and commercialized to result in economically and socially valuable output (industrial spillovers) or growth, and this is the phase when critical project selection by economic criteria occurs, large resources have to be mobilized and business mistakes are committed.

2.4.3 Commercialization

Entrepreneurs (item 3) have to be present in the own firm (“intrapreneurs”) or in the market to identify the commercial potential of the innovations offered. The entrepreneur, however, also needs funding, and for entrepreneurs in radically new industries the *venture capitalist* that provides the funds has to understand the commercial potential of what the entrepreneur has to offer to provide funding at reasonable costs. The venture capitalist in turn will want to *exit* (item 5) and return to new ventures, and hand over the task of taking winners to industrial-scale production and distribution to the *industrialist* (item 6). That last transaction may be thought of as taking place in the private equity markets.

Standard economics disregards these three functions in the commercialization process, or lumps them together in an undefined technical factor. Above all, little recognition in literature can be found for the large resource use associated with the commercialization of innovations, not least business mistakes.[28] In the theory of the experimentally organized economy (EOE) that I use to structure my analysis business mistakes become a normal cost for economic development. *First* of all, not until innovations have been selected by the entrepreneurs will large amounts of resources begin to be invested. *Second*, and perhaps more important, the rate of business failure at this stage is high. We are now talking about economic or business selection mistakes, rather than technical errors committed before a prototype product has been shown to function technically. To get the aircraft successfully into the air is one thing. To have developed the right aircraft for the user that "also works" is quite another thing, as the competitive outcome of the giant Airbus A 380 and Boeing's functionally different Dreamliner will eventually demonstrate.

The role of competent venture capital provision has slowly began to capture an academic interest, but largely as provider of early finance to newly established firms and as a complementary provider of management support, support that is generally available in the market. *Competence bloc theory features the venture capitalist as an industrially competent selector of entrepreneurs*, who reduces the incidence of business mistakes and charges for that competence service in the form of capital gains on his equity position. The other roles of the venture capitalists are secondary. Integrating the entrepreneurial, venture capital, exit market, and industrialization selection sequence is still missing in literature. It is captured in competence bloc analysis.

Ponder the following. In the early 1990s the Swedish industrial policy discussion was dominated by a concern about the "lack of entrepreneurship." This was a first realization that something serious had happened to the economy and standard Swedish macroeconomics was unable to tell anything meaningful about what was happening. However, not until the late 1990s was the argument brought onto the policy scene that perhaps the problem was not one of lacking entrepreneurs but one of missing industrially competent venture capitalists. Without industrially competent venture capitalists participating in the entrepreneurial selection process few successful entrepreneurs would get funding, and be seen. This was a more troublesome policy concern since ideological Sweden for decades had preferred to see no wealth accumulation through industrial entrepreneurship among private individuals, had taxed away profits with great gusto and returned some financial resources to industry in the form of selective grants and subsidies, directed by public hands and washed clean of industrial competence (see Eliasson 2003, 2005a: Chapter IV).

In competence bloc analysis an industrially competent venture capital industry figures as a competitive advantage for the national economy. This is the industry that had boosted US economic growth through the 1990s and most of the first decade of the new millennium. Policies directed at preventing private wealth accumulation through industrial entrepreneurship in continental Europe at large and in Sweden in particular have deprived those economies of an industrially competent venture capital industry capable of fostering the emergence and growth of new industry. European countries such as Sweden have therefore been relatively deficient in commercialization

Fig. 2 Decision and market structure of the competence bloc

capacity when it comes to capturing and building businesses on spillovers from advanced firms.[29]

Sweden may have been more successful in developing a private equity market of sorts, but private equity transactions are less demanding of industrial competence. This time the projects have already been sorted through the industrial competence filter of the venture capitalists and have been awarded a provisional economic quality grading by them.

The complete competence bloc has been put together in Fig. 2 to show how the technology supply and allocation processes map into the strategic, tactical, and operational decisions of a firm or a hierarchy.

At the operational level those selections have been made and the various skills needed to manufacture click in, such as skilled labor, shown at the bottom of the diagram.

2.4.4 The Allocation of Tacit Knowledge and the Limits of a Firm

Standard economics makes no distinction between knowledge and information. Knowledge is simply accumulated information. Standard economic theory therefore has great problems dealing with the transfer or diffusion of difficult to communicate tacit knowledge, as not only a costly process, but also a process fraught with economic mistakes. Standard economics treats business mistakes, if at all recognized, as stochastic noise. Hence, they are insurable in an actuarial sense, a notion that Knight (1921) rejected outright. In the real world a widely distributed portfolio of assets provides no such insurance coverage to the portfolio holder. To account for the tacit knowledge that cannot be fully commercialized in business decision making statistical insurance principles will not do. A different method and different principles are needed. Also, the further up at strategic business decision levels you go the more important tacit and difficult to communicate knowledge becomes.

Tacit knowledge can only be diffused through the interaction of knowledgeable people in hierarchies or in markets, not in coded form through, for instance, electronic communications channels. Competence bloc theory represents the dynamic interaction of people or groups of people embodying tacit knowledge. The competence bloc is inhabited by actors with the necessary tacit functional competences. They are driven by incentives and forced by competition to act in their self interest. If incentives are cleverly introduced into the economy through private contracts and institutional rules this competition will also be in the interest of a larger group of parties, including the nation. This was the idea of the invisible hand of Adam Smith (1776). Incentives and the competition process can be modeled even without defining the exact nature of tacit knowledge capital. Then, however, the exact outcome of the economic process cannot be calculated even in stochastic terms. This is what distinguishes the theory of the EOE from the standard neoclassical model,[30] namely that the maximum macroeconomic outcome cannot be calculated since everything that can be known and be reflected in the prices of the economy is not determinable and beyond analytical representation. (If the actors in the competence bloc chose to do something different in expectation of what all the different actors will do, a different set of prices will be the result and everybody will again revise their expectations and do something different and so on. In the nonlinear reality of a dynamic economy there will be an infinite regress and no convergence to an external, static equilibrium). All the different actors with multidimensional competences can do is to experiment their way through a largely unknown universe of opportunities (the Opportunities Space, Eliasson 2009).

In principle, the entire competence bloc can be internalized within one hierarchy. This was almost the case with IBM in its hey day during the early 1980s. IBM was even the competent customer of some of its own products, that it considered to be of such outstanding quality that it withheld them from the external markets, and potential competitors. In principle (again) the limits of a hierarchy or a firm will be set when the costs on the margin from coordinating businesses internally rises above those incurred when outsourcing and coordinating the production in markets (Coase 1937). Formulated so, there will be no such thing as a stable hierarchy or firm structure. The internal structures of a firm will constantly be in a state of flux, something every firm manager knows well from experience.

Internalizing too much of the value chain might raise static operational efficiency, but that improvement in cost efficiency is normally achieved only at the cost of lost innovative ability, and vice versa. A large and operationally oriented production hierarchy is rarely the habitat of innovative technology creation. Its capacity to discover innovations outside its routines is low and *the loss of winners the largest transactions cost* that is rarely part of neither internal management attention nor the economists' concern. However, by distributing the discovery process (and the competence bloc) over the market greater diversity of business evolution will be achieved as well as a smaller loss of winners. Total transactions costs will be reduced as a consequence (Eliasson and Eliasson 2005b).

Outsourcing of production and the sourcing of new technology in markets, however, carry other costs. Transactions in knowledge assets between actors in the competence bloc are market transactions. Market transactions in intangible knowledge assets (technology assets) require that they are tradable, meaning that the innovating firms can claim ownership to the technology they have created as tradable property (Eliasson and Wihlborg 2003). If not, it rather opts for internalizing the use of the technology, or establish property rights to the technology through bundling it with other products/services. Not well represented property rights to knowledge assets make trading in them risky and costly. This is one basis for understanding the role of spillovers in economic growth.

2.4.5 Critical Mass

The functions of the competence bloc support one another synergistically. Vertical *completeness* of the competence bloc therefore determines the dynamical functionality of the entire bloc. Without functioning exit markets the venture capitalist has no way of capturing the full profit potential of his venture, except through becoming an industrialist. And he is normally not the right person to do that. So the existence of competent industrialists to carry the winners selected at earlier stages determines the incentives of the entire system. But the entrepreneurs are dependent on the existence of venture capitalists and so on. The absence of one actor group tends to make the whole incentive structure of the competence bloc collapse.

However, *the creative supply of innovations cover a broader range than the supply of experience-based commercialization competence. So business mistakes are unavoidable* (Eliasson 2005a:40ff). The more horizontally varied a competence bloc the lower the incidence of business mistakes. One competent venture capitalist does not possess a sufficiently broad industrial competence range to understand and evaluate the entire supply of innovative propositions from an entrepreneurial society. *Many competing actors of each kind (in the competence bloc) are needed to maximize the exposure of each innovation to a competent evaluation.*

Furthermore, the more winners that are carried through the competence bloc the larger the potential for learning and creating new combinations of technologies (innovation potential). The competence bloc becomes a *spillover source*. When the *critical mass* for endogenous industrial development has been reached the competence bloc will become an *attractor* for new entrants looking for new complementary technology, but because of competition, only competent entrants that also contribute competence to the bloc, will survive. A vertically complete and horizontally sufficiently varied competence bloc that has reached critical mass will minimize the risk of losing a winner. Formulated differently, *a potential winner faces increasing returns to continued search for resources through the competence bloc.*

The competence bloc has an end product market definition. Technology or technology systems (Carlsson 1995), on the other hand, generate a supply of technology spillovers that are an input that enters an economic evaluation process through the innovation slot 2 in the competence bloc (Table 2B). After the commercial selection spillovers become industrial and economically valuable output.

2.4.6 Going from Micro to Macro (Aggregation)

After the spillovers have been identified and commercialized I go on to estimate their macroeconomic effects, or the spillover multiplier.

New technology introductions can take different forms. It has become common to postulate a production function of innovations that is fed with R&D investments. Most of the spillover literature and the literature on social and private rates of returns belong here, and even though I regard that literature as rather mechanical and free of dynamic considerations, this is where most econometric research is to be found. So I will draw on that literature in the next chapter. Another part of literature is, however, more dynamic and therefore more interesting in this context that is predominantly concerned with entrepreneurship and the entry of new firms. On the latter Jenner (1966) argues convincingly that the entry phenomenon should be approached much more broadly than in terms of the entry of firms. It should also include the launching of a new product within an existing firm, or in the market. Entry in any form, however, causes technical problems in standard economic modeling to the effect that Jenner (1966) was soon forgotten and entry, or the turnover of firms was neglected for a long time.[31] After decades of neglect and the post 1970s stagflation experience, innovative firm entry and the turnover of firms have been gradually recognized in parts of economic literature as a moving force behind economic growth (Eliasson et al. 2005; Eliasson 2007). And I have to integrate this Schumpeterian view with the more mechanical econometric studies to get the macroeconomics of spillovers relevantly addressed.

Table 3 offers one stylized way of representing that dynamic that I will return to in more detail in Chap. 3 and in the Technical Supplement S2 where I will also discuss the commercialization of spillovers through the entry and turnover of firms as a vehicle for economic growth.

Table 3 The four mechanisms of Schumpeterian creative destruction and economic growth (Source: “Företagens, institutionernas och marknadernas roll i Sverige,” Appendix 6 in A. Lindbeck (ed.), Nya villkor för ekonomi och politik (SOU 1993:16) and Eliasson (1996a:45))

1. Innovative entry enforces (through competition)
2. Innovative reorganization or
3. Rationalization or
4. Exit (shutdown)

New entry imposes competitive pressure on incumbent firms. Incumbent firms have to respond by innovative investments and reorganization of their businesses, or rationalize. If they fail to do that they eventually fail altogether and exit. The outcomes over the longer term are more productive and superior than earlier populations of firms. Macroeconomic growth occurs. Table 3 however, also tells that in estimating the growth effects of new technology introductions, for instance based on spillovers from advanced firms, the *opportunity cost* of production that would have been generated with those resources in the absence of spillovers has to be deducted. Such dynamical systems effects may in fact mean a negative growth effect in the short term since the negative competitive fall out is often immediate, while the positive effects take a long time in showing.

This S shaped effect curve (first a negative effect and then a positive effect), has been documented in recent econometric literature (Batisch and Fritsch 2008). I have also simulated similar S-shaped curves on the Swedish micro- to macro-model,[32] and this time the effects are sustained long term beyond 50 years in the sense that new competitive entry leaves a permanent positive net growth effect on the macro economy at least up to 75 years. To this I return in Chap. 3.

2.5 Aircraft Industry as a Spillover Source: A Preview of the Industry Case

The case of my spillover story is Swedish military aircraft development and manufacturing. Table 4 gives an overview of the spillover cases I have identified and classified on the four categories of the spillover cloud in Figure 1. The listed cases will be presented in detail in Chapters 4 and 5. An aircraft is an extremely complicated product with a very long life that requires an immensely complex and distributed production organization (Table 5). It therefore provides an excellent illustration of the economics of industry spillovers.

The product itself integrates advanced mechanical technology with electronics, sensors and new materials (Table 6) and the software that achieves that integration also determines the performance characteristics of the product and its flexibility in functional specifications. In this sense, aircraft industry already today uses the technologies of future engineering industry (Eliasson 1995). This is also one rational reason for the advanced industrial nation to be concerned about having an inhouse aircraft industry. It functions as a technical university that provides research, education, and training services free of charge to other firms in related industries and of a kind close to the most sophisticated manufacturing operations that the more theoretically inclined technical university is normally incapable of developing and providing (Eliasson 1996b).

The long life of the aircraft means that to enjoy its services as a user maintenance and repair services have to be delivered over its long life cycle and the product may have to be updated and modernized now and then. The increasing importance of software that integrates electronics and mechanical technologies has dramatically enhanced flexibility in that respect between the JAS 39 Gripen aircraft and the previous

Table 4 The spillover cloud around Saab military aircraft

Core technologies (see Fig. 1)
1. Saab civilian aircraft (Case 1)
2. Volvo Aero's transformation from military to civilian aircraft engine manufacturer (Case 2)

Related technologies
3. The early innovation market around Saab (Case 3)
4. Secondary related spillovers from development and modification of aircraft engines (Case 4)
5. Commercial gas turbines (Case 2)
6. Civil Security (Case 21)
7. Space technology, Saab Space and VAC (Case 19)

Engineering general
8. Hydraulic engines, VAC and VOAC (Case 5)
9. Manufacturing light weight technologies and high-speed machining, ACAB, and Modig Machine Tool (Case 16)
10. Integrated and flexible manufacturing (Cases 6, 14, 18)
11. Systems integration (Case 14)
12. "Maintenance-free" products (Case 6)
13. Engineering consultancy, Combitech AB (Case 23)

Industry general (serendipitous spillovers)
14. Digital mobile telephony, Ericsson (Cases 8, 13)
15. Telecom Control Systems, Ericsson–Hewlett Packard Telecom AB, EHPT (Case 9)
16. Swedish automotive safety industry, Autoliv (Case 17)
17. Computers and information systems (Cases 10, 11)
18. Medical technologies, Sectra (Case 12)
19. Electronic noise reduction (Saab A2 Acoustics)
20. Remote oil volume measurement in tankers (Rosemont Tank Radar)
21. Traffic toll systems (Kapsch Traffic Systems)
22. Individualized TV entertainment (Saab Trackab)
23. Creating specialized industrial competence blocs (Cases 8, 24)

Table 5 A military aircraft is

1. An extremely complicated product with
2. A very long life that is
3. Produced under very complex circumstances

Table 6 An advanced engineering product integrates

1. Advanced mechanical devices
2. Sensors
3. Electronics
4. Hydraulics and
5. New materials through
6. Software

generation of aircraft. In fact, the electronics of a modern military aircraft and a large commercial aircraft is normally replaced one or two times, sometimes three times during its often more than 50-year life span, and software reprogramming occurs many times in between. The definition of the product, hence, should include the features that lower maintenance and repair costs and facilitate upgrading and modernization.

But this is not enough. Compared to a university an industrial firm delivers technologies embodied in products that both function (are operational) and are more or less tested in a market for commercial viability and/or usefulness. This means that an aircraft that has gone through both a functional and a market test spills industrial knowledge that has a greater value for civilian production than spillovers that are only technological. This again means that technological spillovers (see Eliasson 1996b) is a misnomer. *The spillovers* documented econometrically around advanced US firms *are industrial, i.e., both technological and commercial*.[33] The commercial dimension of knowledge represents great economic value.

Two critical parts of a globally competitive engineering firm are (1) advanced product design and marketing competence and (2) ability to organize *integrated production* over global markets. Product design, international marketing and organizational competence are typically developed in industry. Complex integrated production was pioneered in (military) aircraft industry (Eliasson 1996b). Such generic industrial knowhow cannot be taught in classroom. It diffuses as people who have learned it on the job move between jobs and firms in the market.

An aircraft, hence, is not only a very complex product. It is multidimensional in the sense that it is composed of (1) the product itself as a physical entity, (2) many years of service, maintenance and upgrading and (3) a "cloud of valuable spillovers" that is difficult to charge for. Advanced firms, such as the aircraft manufacturers, therefore, generate different indirect (spillover) benefits over and above the product itself being purchased. In the short term local employment will be created, but this carries local value only if extra people employed cannot be gainfully employed elsewhere and the effects are only temporary. Sustainable export and employment growth can only be achieved as a result of a sustainable increase in overall productivity and production growth generated by the spillovers.

Effects of lasting value, however, are only gained if local people and firms learn skills and industrial knowledge that can later be gainfully used in other production. Effective such learning requires local receiver competence (Eliasson 1990a), local entrepreneurial ability and a well-endowed competence bloc. The *first* learning item has to do with the level of education and experience of the workforce and the type of production in which they are occupied compared to the new knowledge being spilled from the project.

The *second* entrepreneurial ability is the same and (in addition) requires the existence of a complete competence bloc (see Eliasson and Eliasson 1996; 2008b) to select winning project ideas and to carry them to industrial scale production, notably venture capital competence. The critical policy issue is how to organize a positive sum game. The large benefits to both parties do not arrive if the receiving party does not gear up its competencies to receive and exploit the spillovers. Passive participation yields less.

I will illustrate this feasible win–win case for the three large partners in the Industry Group IG JAS that have also been the large receivers of Gripen spillovers; Saab, Volvo Aero Corporation and Ericsson, and also some smaller spin-off firms in related industries. Finally, I will also say a few words on French military aircraft maker Dassault, which has created two large civilian businesses on its military spillovers; the hugely successful Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) system Catia and Falcon business jets. Dassault also claims to have invented the Product Lifecycle Management (PLM) method to calculate lifelong costs and to rationally price the use of services from products with a long life such as aircraft.

As it looks, most successful and observable attempts to commercialize spillovers have taken place through vertical downstream integration within large companies, notably the large participating companies of the IG JAS and through secondary spin offs from the same large companies.

More rarely, underlining the common inadequacy of local competence blocs even in advanced industrial economies, have spillovers taken the form of new and unrelated entrepreneurial start ups. This latter conclusion may partly have to do with the long time it takes for a small winner to enter the market, grow, and eventually develop into a statistically visible large company. At that time, furthermore, it may be almost impossible to identify the origin of the successful business venture since along the way many other complementary contributions have entered the picture. We have not yet seen more than a few such small business success stories outside the world of big business.

Sometimes, as we shall see in Chap. 6 on South Africa, spillovers have been commercialized as a consequence of offset trade agreements in which the supplier helps the public customer to capture and commercialize the spillovers, sharing in the extra values created.

2.6 Boosting Receiver Competence Through Policy

The value of the dual product being delivered to the local economy (including spillovers) depends critically on the competence of the local economy to identify and commercialize the spillovers profitably, i.e., on the local entrepreneurial ability to establish new businesses on the spillovers. The value to society of the military aircraft being sold in the case studies in Table 4 to be presented in Chaps. 4 and 5, therefore, is the product, or the *hardware equipment itself plus the economic value of the spillovers*. The total value of this "dual product" (Joint production) can however be raised by policy aimed at improving the local commercialization capacity. Such policy includes the possibility of a deal between the public customer (the government) in particular and the producer whereby the producer agrees on a price to support the commercialization of spillovers. Looked at this way the local economy around an advanced public product procurement program faces a potential positive sum game that if properly organized will benefit both parties to the deal.[34]

2.6.1 Capturing the Rents from Spillovers: Joint Customership and Industrial Participation Programs as a Joint Policy and Business Opportunity

Spillovers diffuse because of the potential rents they carry. There are incentives for both parties to the transaction to capture these rents, but the difficulties are large because of weak property rights (for the producer) and lacking receiver competence, or incomplete local competence blocs (on the part of the buyer).[35] This very fact, however, also establishes a situation of mutual interest. The situation of mutual interest is further strengthened if a Government is the buyer and a situation of *joint customership* prevails. We then have a case for explicit producer–customer cooperation as a general policy case and the opportunity to create a win–win situation through policy. This opportunity is most characteristic of advanced industrial nations and has to do with the existence there of reasonably complete competence blocs to support the capturing of the peripheral "further out" (in the outer circles of Fig. 1) spillovers. Developing industrial economies (see Chap. 6) require complementary commercialization support. However, even advanced industrial economies, such as Sweden and continental Europe, are often deficient in some competence block features, for instance industrially competent venture capital provision.

Industrial economies may exhibit great performance in picking up spillovers that fall inside the competence range of their large firms, but tend to experience a loss of winners when spillovers fall outside that range. In fact, Ericsson almost missed its mobile telephone opportunity and Astra (now AstraZeneca) almost world's best selling stomach ulcer prescription substance Losec (or Omeprazol in the USA). IBM missed the Xerox opportunity and Microsoft almost missed the Internet train. The larger the captive area, however, the higher the probability that radically new technologies will be identified and commercialized. All Scandinavian economies are therefore more "efficient" in that respect than Sweden alone. The argument in Eliasson (1999) was that a joint Nordic purchase of submarines (The Viking Project) would increase the pickup rate of spillovers in the area as a whole, even though it would be impossible to predict how the successful spillover captures would be distributed over the different economies. Europe at large, for the same reason, would create an even better such industrial policy opportunity, even though it would be difficult/impossible to predict "which country" would capture which spillovers (see further Chap. 7). A reasonable assumption is that the more entrepreneurial the local regional/national economy the more efficient in identifying and commercializing spillovers it will be. But geographical distance to the spillover source will work in the opposite direction and the local domicile of the successful spillovers commercialized need not be the location chosen for establishing production. In fact, and following up on the argument above, competition among the countries to capture the spillovers industrially would raise the positive economic effects in the pick up area as a whole because a broad spectrum of spillovers will breed cumulatively on one another.

The cooperation case is focused on the inner circles in Fig. 1. Here, the producing company contributes management competence and receives profitable cooperation within an industrial participation program in return. The business opportunity is that there is a profit to be earned from making the spillovers valuable for the local or receiving economy. To do that the producer/seller has to support local receiver competence as a profitable business in itself. For a developing economy well-designed offset trade arrangements are a method to create such a mutually beneficial win–win situation. For this to be successful policy offset trade agreements have to be oriented toward capturing technology, acquiring industrial competence and developing related and new production. Hence, part of the innovative pricing strategy on the part of the producer includes *the art of presenting a convincing case for the long-term industrial benefits of the deal*.[36] Bundling the aircraft sale with an offset program designed to capture the spillovers locally is our example from South Africa in Chap. 6. Encouraging the establishment of local venture capital firms to induce foreign and local investors to establish on the basis of the spillover flow is another example. In one sense, such an “agreement” means establishing a commercially based industrial park (Eliasson 2000a).

2.6.2 Summarizing on Joint Production and Joint Customership as a Policy Opportunity

It is in the interest of the public customer to see the spillovers commercialized. But while the public customer will be satisfied with only seeing the spillovers picked up, the private customers will only be interested and willing to “pay extra” if they can earn a private rent from the spillovers. In the case of advanced public purchasing the role of the policy maker, therefore, is to see to it that the local receiver competence is satisfactory, i.e., that the competence bloc is vertically complete and horizontally varied. The policy maker, however, can do very little to actively contribute to the competencies of the bloc. In the modern high-tax welfare economies the main task rather will have to be to avoid the policies that prevent the creative market forces from developing those competences. The US venture capital industry, for instance, is made up of a large population of industrially competent and privately wealthy (from industry entrepreneurship) individuals. If government prevents individuals from becoming wealthy through industrial entrepreneurship and instead taxes away their wealth and uses the taxes to fund its own venture capital industry, which is common in Continental Europe, it washes the money clean of the critical associated industrial competence. The business risks increase as do the risks for business failure. We have a case of policy failure (Eliasson 2000a).

Hence, to make full use of spillovers from advanced firms the local economy faces the general policy problem of supporting the *local receiver competence* to identify and commercialize winning technologies. This most likely involves the ideological trauma of backing away from excessive egalitarian policy ambitions. At the same time it is in the interest of the advanced firm to establish in a local economy well endowed with industrial receiver competence, since that receiver competence raises the total value of its product (including spillovers) to the local economy. However, only in the case of public procurement is the weak property rights problem (to its spillovers) satisfactorily solved since the government/customer is then directly interested in seeing the economic value of its spillovers raised. A broad industrial base, an educated and entrepreneurial labor force and a complete and varied competence bloc are supportive of that ambition. For industrially less advanced and developing countries the difficulties of taking advantage on their own of the opportunities created often become overwhelming. It should therefore *be mutually advantageous for the advanced firm gearing up for large-scale production and distribution and the receiving country to engage in a mutually advantageous industrial participation program aimed at both boosting local receiver competence* (of spillovers) and offering profitable business cooperation contracts to develop new businesses (c.f. item 5 in Table 10, See page 226). Such considerations offer a rational economic argument for offset trade arrangements, but only for contracts that trade long-term industrial development for profitable business deals. The JAS 39 Gripen (Saab) sale to South Africa created opportunities of this kind (see Chap. 6). Spillovers are positive characteristics of an advanced product. They carry extra value for the buyer and the local economy that depends on the local receiver competence to create businesses on them.

I have now presented (1) a brief executive summary of the entire book and the Saab aircraft industry spillover story (Chap. 1) and (2) a condensed nontechnical version of the book (this chapter).

The rest of the book will document the theoretical underpinning of the analysis (Chap. 3), the (Chaps. 4 and 5) case presentations in concrete detail for Sweden (an industrially developed economy) and for South Africa in Chap. 6 (an industrially less-developed economy). In Chap. 7, the European perspective is briefly discussed. In Chap. 8 the method of calculating social and private returns to investments in spillover-intensive public procurement is presented verbally, and technically in the supplements.

The book concludes (in Chap. 9) with a discussion of public procurement as industrial policy.

2.7 Notes

1. Similar financing arrangements characterize other very long-term civilian development projects, for instance between biotechnology and pharmaceutical firms that may last for a decade and more. Payments are made at agreed-upon milestones, contracts are renegotiated, bonuses paid if obligations have been honored and the customer pharmaceutical firm has a predetermined option to take over the new technology/patent, also at preset intervals.
2. This practice was particularly elaborate during the development of the Swedish JAS 39 Gripen multipurpose combat aircraft that was initiated in 1980.
3. Or rather a “comparative advantage,” since Burenstam-Linder (1961) conducted his analysis in terms of traditional static international trade theory.

4. Thus, for instance, the Swedish weekly magazine *Fokus* (No. 16, 2007) had a cover article on the Swedish JAS Gripen military project that was generally negative. There was no mention whatsoever of the scientifically well-established positive industrial spillovers that are larger than the development budget of the aircraft. Was the journalist unaware of this? If so very few Swedes will know. Or did he not want to mention it? See instead the article in Swedish *Veckans Affärer*, April 17, 2008 where the editorial notes with surprise that those positive spillovers are indeed large.
5. In 1999, British Aerospace and Marconi Electronic Systems merged into what is currently BAE Systems.
6. This externality of the equilibrium is what makes both the old neoclassical and new growth models static. The mathematics used in these models is the same as that of Newtonian celestial mechanics that leaves little scope for human influence on both the universe and the economy (Eliasson 2009).
7. But conceived and designed in the early 1980s. On the new procurement method, see Technical Supplement S1.
8. Because of the high domestic content of military equipment demanded at French public procurement the products are likely to suffer from the same problem. Not even the USA is large enough to be able to maximize product performance over the life cycle on the basis of its own subcontracting industry alone.
9. This is all in terms of axiomatic design (Suh 1990) language. Functional requirements stand for a vector of product characteristics, and DP (Design Parameters) for the minimum of design parameters needed to achieve FR through the production and technology matrix {A}.
10. I will return to this real options pricing of functional flexibility in Chap. 5.
11. Compare with Table 8 (on page 139) on integrated production.
12. Commitments to produce part of the good or system delivered locally may be profitable for the producer, but the production is normally inefficient, it ceases with the final deliveries and leaves little future social value for the public customer.
13. See, e.g., Bill to Parliament *Prop.1979/1980:117, p. 23ff*. Also see Eliasson (1995:155f) and Technical Supplement S1.
14. There is a related problem associated with public venture financing. When the private wealth earned from industrial ventures is taken away and redistributed through public funding institutions (which is a typical policy in Continental Europe and Scandinavia) the money has been washed clean of the industrial competence associated with the original industrial creator of the same private wealth.
15. For instance, in Swedish Vinnova and its heralded notion of a triple helix policy within which government, universities, and industry are urged to work intimately together. Not until recently have notions related to the commercializing of technology been plastered onto the triple helix jargon.
16. Instead of outsourcing. On this see Lewis and Sappington 1991 and Desai et al (2002).
17. Investor AB is the investment holding company of the “Wallenberg group” of firms the portfolio of which includes large and/or majority holdings in among

other firms ABB, AstraZeneca, Atlas Copco, Electrolux, Ericsson, Gambro, Saab and SKF, but since 2007 no longer Scania. See also Day et al. (1993, "Introduction" p. xiii ff).

18. For Saabs Automatiska Räkne Automat.
19. Volvo acquired *Nohab Flygmotor* (founded 1930) in 1941. After a couple of name changes it is, since 1994, called *Volvo Aero Corp*.
20. I specifically introduced the term "the knowledge-based economy" in my study for the OECD (Eliasson 1987b) to distance myself from the ongoing "information economy" discussion and to emphasize that (tacit) knowledge diffuses through the movement of people in careers, through the labor market and through sales and acquisitions of bits and pieces of companies in the markets for strategic acquisitions. My argument was that such diffusion of human embodied knowledge was economically more important than the communication of coded information (Eliasson 1991c).
21. It is more broadly defined than receiver competence (Eliasson 1986, 1990a, b) and absorptive capacity (Cohen and Levinthal 1990) that covers the entire range of technologies needed to identify, select and transfer technology supplies into profitable industrial production. See next section on competence bloc theory.
22. This is the definition of an efficient market (Fama 1970; Fama 1976). If all that can be known (commonly denoted Ω) changes (to a new Ω*) an efficient market immediately establishes a new equilibrium where agents know everything that can be known and prices fully reflect that knowledge Ω*. The critical problem however is to clarify all that can be known, which is not possible in the EOE (see Eliasson 2009).
23. See Eliasson 1990a, 1991b, 2005a; Eliasson and Eliasson 2005b, 2009 and below.
24. As argued by Day (1986) this latter interdependence of demand and supply poses difficult methodological problems in economic theory.
25. The comparative advantage for a nation of an advanced local customer base was recognized already by Burenstam-Linder (1961).
26. Again, to anticipate the industrial policy discussion to come, there will always be a general policy argument for supporting the development of local commercialization/receiver competence to capture spillovers from public and private procurement. It is more difficult to argue generally for more advanced public purchasing since it means arguing for a larger public sector and it is by no means obvious that the public purchaser is more competent as a customer than the corresponding private one. Only if the market is not responding to a private demand, or if the product is a pure public good will there be a rational economic argument for a representative public customer to step in, for instance in defense procurement. We leave this difficult issue at that here.
27. This technical definition of the innovator and the distinction between an innovator and an entrepreneur has its origin in von Mises (1949). On this I prefer to think in terms of innovations as being generated by a technology system (Carlsson 1995) or a technology production function (Griliches 1979, 1984, 1986). Normal language use makes it awkward to talk about a new aircraft

as an invention. Innovation is a more appropriate term, that also covers the concept of an invention. So I don't need both terms.

28. That cannot occur by definition in the mainstream economic model, except in the form of costless random losses in an economic lottery.
29. It should be added that most of continental Europe suffers from the same problem, (Eliasson 1997b, 2003 and 2005a; Chap. 4). Its new innovative high tech firms therefore have become a target for the more competent US commercializing industry that understands how to profit from investments in new technology (ISA 2003).
30. The standard neoclassical model "solves" that dilemma by assuming that all knowledge or accumulated and measurable information needed is available. Then even the optimal outcome can in principle be calculated using analytical methods. See further Eliasson (2009).
31. Dasgupta and Stiglitz (1981) are an example of the awkward assumptions needed to construct a static equilibrium model with entry and exit.
32. Which builds its endogenous growth on the competitive interaction of the investment categories in Table 3. See further Sect. 3.3.
33. Read commercially tested (in the market) technology.
34. On incentive contracts in the case of JAS 39 B Gripen development see Sect. 8.4.
35. The notion of weak property rights is discussed in a similar context in Eliasson and Wihlborg (2003).
36. *Innovative pricing* (IP) is the art of identifying a base on which to price a product with weak property rights, for instance different kinds of digital services or (our case) spillovers that have to yield a return to make the whole product (aircraft and spillovers) profitable for the producer (see further Eliasson 1995: Chap. 15). Innovative pricing is practiced in situations with difficult to define multidimensional products, many dimensions of which not only being unknown to, or unavailable for most customers but also constantly changing. IP then amounts to defining the base (the dimensions of the product) to charge for. Jonason (2001) uses the theory of the experimentally organized economy (EOE, see e.g., Eliasson 1991b, 2009) to price products the quantities of which cannot be defined because of the many quality dimensions, a phenomenon recognized as normal already by Hayek (1937). Hart et al. (2001) addresses the related problem of pricing multidimensional products with difficult-to-specify quality features for which complete contracts cannot be drawn up. A private contractor under competitive pressure (in their case a private operator of a prison) that is forced to cut costs will have an incentive to shirk on noncontractable quality.

Chapter 3
Spillovers and Innovative Technology Supply: A Literature Survey

Mainstream economics treats spillovers as a positive "externality," a term introduced by Alfred Marshall (1890) to account for the extra value creation (or the opposite, negative externalities) that could not be explained within the theoretical framework of the standard (and static) economic (Walrasian) model. Marshall, being at the time the authority on the Walrasian model, was concerned about this deficiency of the received model of economics that was increasingly becoming the standard intake in graduate economics teaching among western universities. He wanted to internalize ("explain") the spillovers, but without abandoning the standard model altogether and exposing himself to the wrath of his colleagues.

The Walrasian model did not allow for economies of scale. This was not an acceptable state of affairs argued Marshall. Economies of scale were everywhere observable in the real world. To solve that mathematical dilemma of the Walrasian model Marshall introduced the concept of an *industrial district,* a cluster of firms within which industrial actors could benefit from each other's presence in the district. This was the first presentation of what has later come to be called "networking externalities" and that became the very foundation of what Romer (1986) called "new growth theory."

Even though a great improvement, Marshall's criticism of the standard mathematical model of economics that economists had been trained to analyze and teach was not popular among his colleagues. He was much criticized, among others by the doctrinarian Sraffa (1926). Marshall, however, endured, wrote the first treatise on industrial economics, "Industry and Trade" (1919), and became the first, according to Joseph Schumpeter (1954) to attempt to integrate economics and business administration thinking.

Marshall was however much too early for a conservative profession. It took almost 100 years, two deep oil crises and the Internet phenomenon of the late 1990s to take "systems effects" or "networking externalities," or for that reason "New Growth" theory onto the agenda of economics research.

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3.1 The Existence and Magnitudes of Spillovers: A Brief Background on Economic Theory

Nothing much occurred during Marshall's life time and until the profession had begun, in the wake of the oil crises of the 1970s to be worried about what was happening to their economies and about competition from the alternative schools of Schumpeterian economics, and perhaps also from other competing disciplines.[1] In 1986, Paul Romer published an article claiming to have endogenized economic growth and such network externalities, that really was a fairly simple mathematical macro version of Marshall's verbal attempt to endogenize the externality within an *industrial district* defined at the micro/firm level. New growth theory had, however, been in the air for years, and a number of similar models rapidly appeared in the academic market, in chronological order; Prescott and Boyd (1987), Lucas (1988), Romer again (1990), Aghion and Howitt (1992, 1998), Pakes and Ericson (1998), and so on.[2]

3.1.1 Austrian/Schumpeterian Micro- to Macrodynamics and the Long-Term Sustainability of Spillovers and Growth

Joseph Schumpeter (1911) had introduced the innovator and the entrepreneur in economic theory. Also these phenomena turned out incompatible with the standard economic model and with the views of the economics profession. While Marshall was too towering a contemporary academic to ignore, Schumpeter was not. Again it took some 70 years and the oil crises and stagflation years of the 1970s to take the entrepreneur and Joseph Schumpeter onto the economics scene.

A positive spillover can be identified in a number of ways. Productivity growth in a firm or an industry can be faster than warranted by investments in equipment and/or R&D. If that faster growth can be related econometrically to some outside factor such as new technologies coming out of a technical university and/or technological advance in related firms, the positive externality can be explained. Six approaches to the estimation of a spillover multiplier can therefore be derived. This *first* (econometric) method for measuring spillovers has the advantage of allowing for generalizations to macro. The disadvantage is that a rich and high quality database is needed.

A *second,* and related approach is cost–benefit calculations that compare private and social rates of return to investment. The theoretical foundation is the same.

Both these approaches are neoclassical and static in the sense that they assume the existence of an external equilibrium that can be determined and that all resources in the economy, including knowledge, have been efficiently allocated at the given prices and fully employed. Hence, prices reflect that efficient allocation one to one and vice versa. This duality property of the standard economic model in equilibrium has been extensively used in economic analysis and measurement.[3]

These assumptions are, of course, utterly unrealistic, and all econometric results depend on them or the "degree of efficiency" of that allocation as reflected in recorded prices. Above all, if the local economy is grossly deficient in commercialization competence, econometrically determined spillovers or social/private rates of return differences may be very small. A survey of empirical literature based on those two methods will follow below.

One can also (*third*) ask firms related to the spillover sources as subcontractors or in other ways to quantify how they have been affected by the R&D spending on, for instance, the JAS 39 Gripen project, and use econometric methods to estimate the social value creation. Fölster (1993) used this method (see further below and in Technical Supplement S2).

The *fourth* approach is more ad hoc and based on case studies. Some of the case studies may add up to such a large minimum value of the spillovers that it is sufficient to motivate the entire project. However, case studies of the successful spillover projects alone do not account for crowding-out effects and what would have happened alternatively in the absence of positive spillovers. Ideally the third method can be extended to econometric analysis on data from a large number of firms, some of the data having been obtained through questionnaires about the nature of the products of the firm. All above methods, therefore, are partial and suffer from not accounting for all dynamic adjustments (positive and negative) in the economy to a positive injection of new technology in the form of spillovers. Only gross effects are accounted for and the net effect may be smaller because less efficient, but still positive production establishments may have been shutdown. The macro effect of spillovers should be therefore counted as net of such indirect effects. In principle, and in the long run, *only productivity increases emanating from the reallocation of fully employed resources from low to high productivity production should count, and their sustainability be investigated.*

There is (*fifth*) another long-term effect that may be even more important. Some spillovers may not be discovered, or take a long time to become visible. The outcome depends on the commercialization competence in the economy (the completeness of the competence bloc. See Sect. 2.4). The US economy is believed to be more entrepreneurial than continental European economies with its larger pickup area and its superior capacity to commercialize spillovers. To some extent, the effects of that entrepreneurial capacity may have been picked up in the econometric studies, but not the very long-term effects. To capture them and all the indirect effects (*sixth*) requires a full-scale micro-based macromodel of the entire economy that not only captures all relevant dynamic micro- to macrointeractions, but also explicitly accounts for the commercialization of spillovers. This micro- to macrosimulation-modeling approach comes close to the principles of the Marshallian industrial district. Since the networking externalities will be explicitly accounted for, dynamic microsimulation of macro outcomes has the additional advantage of not requiring the existence of the artificial exogenous equilibrium of standard economic models. It is not necessary to assume that a very best (optimum) allocation of resources exists, and is known or can be calculated. The micro- to macromodel can be formulated to dynamically integrate the business cycle with the long run trends, the ambition of Schumpeter (1939), and the economy can be allowed to operate far below its capacities, as it normally does all the time. And even if the upper capacity levels are not known, this ignorance should be allowed to influence the quantitative results. The drawback of this method is its dependence on a very high quality micro- to macrodatabase. To simplify, I have combined and condensed the six approaches into three principally different estimation methods.

A. The *case study* method combining (3) and (4) above. Very often cost–benefit studies are of this case study kind.
B. The *econometric* method (1) that depends on data availability may incorporate bits and pieces of the fifth (5) approach.
C. The *dynamic micro- to macromodeling* method (6) that systematically integrates case studies and/or survey data on firms (3 and 4) into a full-scale econometrically determined macromodel within which opportunity costs are endogenized. This is probably the only way to distingtuish – as I will do – between the supply of technically determined spillovers and the rate of identification and commercialization of that spillover flow, a distinction that comes right out of the competence bloc analysis of Sect. 2.4 (More on this below and in Ballot et al. 2006).

In calculating the spillover multiplier in Chap. 8 and in Technical Supplement S2 I will use both the case study method and the econometric method (using estimates on North American data) to bracket my multiplier estimates, but all the time keeping the interpretation and analysis in terms of the more general micro- to macromodel framework.

There are principal differences between the three methods A, B, and C and the underlying priors embodied in the calculation models, which all determine how microdata aggregate up to macro. The first method A is of the partial ceteris paribus type based on assumptions that are therefore not fully consistent. The second econometric method B is framed within a consistent static equilibrium neoclassical framework but therefore also straight jacketed within the very strong and not very relevant priors of that model. The third method C relies on few odd priors but has so far not been fully econometrically estimated. As a theoretical framework calibrated on a unique micro- to macrodatabase the micro- to macromodel has however been a useful theoretical guide when interpreting the results from the other two calculation models, of which they are both special cases. A discussion of what exactly that means follows in Sects. 3.3.2. and 3.3.3.

3.1.2 Long-Term Sustainable Productivity Growth is a Matter of Resource Reallocation, Not of Raising Employment

There is, however, a principal problem to account for in any spillover analysis. We want to have the macroeconomic spillover effects (social value creation) reflect a reallocation of resources to more productive employments out of less productive employments, and not out of unemployment. Advanced public procurement as a means of solving unemployment problems is not a meaningful proposition. Spillovers affect the macroeconomy differently depending on whether resources are fully employed or not. Neoclassical econometric modelers often “solve” this problem by *assuming* the economy to be fully employed to begin with and forcing the data into that straightjacket. While the econometric results will be biased if derived from data in a not fully employed economy, the alternative is to correct for the consequences of unemployed resources explicitly in the analsysis.

Fölster (1993) used a survey method to estimate spillovers around the JAS 39 Gripen development by Saab and an econometric method to estimate the negative crowding-out effects (the opportunity cost) to come up with a net effect measure. He found that the current discounted value of created spillovers around the JAS 39 Gripen project (what I have called the spillover multiplier) was 1.15 times the present value of the R&D investment. Hence, from the point of view of Swedish society the cost for developing the Gripen combat aircraft was zero, or rather negative. As we will see below and in the technical supplements, using econometric estimates on social and private return differences on North American data, Fölster’s (1993) estimate of the JAS Gripen spillover values created must be considered to be on the *very* low side.

Most of the spillover studies use neoclassical models as measuring instruments and treat spillovers as causing increases in process productivities and increases in profits due to cost reductions by comparing two full employment situations, one with and the other without spillovers. Even though both are incorrect specifications of what is going on (spillovers mostly improve products) and lack an awareness of the important commercializing process, this is natural since only successfully commercialized spillovers appear in the data used. From a policy point of view, however, the absence of an explicit commercialization process in the model means that it does not say anything about *how* spillovers are captured, and therefore easily leads to erroneous policy inference. (Lack of commercialization competence may in fact have eliminated the positive output effects altogether, however large the R&D expenditure and the technology spillovers).

Finally, none of the econometric studies, so far, has captured the long-term dynamics of spillover creation. Microdata for sufficiently long periods are not, or rarely available, and if they were, data would be polluted with thousands of unrelated changes in the environment making it in practice impossible to identify particular spillover effects econometrically.

The most sophisticated method that I will discuss below and in the technical supplements therefore is to assess the local commercialization competence through a competence bloc analysis and to simulate the micro- to macroeconomics through a full fledged firm-based macromodel.

3.2 Intangible Spillovers and Economic Growth

Intangible spillovers are difficult to define since they only become visible as they are recognized and made use of. The pickup rate depends on the local receiver competence or absorptive capacity (Eliasson 1986:47f, 1990a; Cohen and Levinthal 1990).

3.2.1 Technology Creation and Productivity Growth

A large econometric literature has demonstrated the existence of the cloud of spillovers around advanced firms, most of the literature originating in the US and being presented under the heading of "technological spillovers" or "general purpose technologies" (for an early survey see Eliasson 1997a).

The main empirical story is that productivity in firms and industries increases with increases in investments in R&D, reducing costs and increasing profits. R&D intensity is usually defined as the proxy for being technologically advanced. But increases in productivity, although not as large, may also be registered in related firms. Being related is also defined by prior classification of statistical data on firms. Spillovers, however, often reach beyond those related firms, which means that their effects may not be captured in the econometric studies.

Technologies also spill over great geographical distances. As already mentioned Bernstein and Mohnen (1994) found that the Japanese firms were better than the "closer" US firms in exploiting international technology spillovers originating in advanced US firms. Klenow and Rodriguez-Clare (2004) in fact claim, on the basis of a survey of econometric research that the wealth of industrial nations largely depends on spillovers their firms have individually spilled for all to be shared, a result indirectly supported by the results of Fors (1997, 1998) on technology transfers within multinational companies.

Technological spillovers are an externality, signifying that they cannot be explained within the standard economic model. The existence of positive externalities or spillovers or unaccounted for infrastructure capital means that output is being observed that cannot be linked to a corresponding registered resource input. This, for the same reason means that private and social rates of return to capital will differ because some of the capital inputs in production have not been properly accounted for. This is a common problem in economic accounting, notably when it comes to accounting for the presence of knowledge capital. During the early part of the post-WorldWar II period economists discussed the technical residual or the so-called technology factor or total factor productivity (TFP) growth that "explained" a growing part of total manufacturing growth and by the early 1970s almost all growth, only to suddenly disappear during the 1970s (Denison and Edward 1961, 1967, 1979; Carlsson 1989a, b). Solow's (1957, 1959) production analysis marks the beginning of this discussion. Erik Lundberg's (1961) so-called Horndal effect added a degree of mystery to the observations that Arrow (1962b) attempted to clear up by his "learning-by-doing" model.

3.2.2 The Mysterious Technology Residual

Unexplained technology generation was the standard explanation until Jorgenson and Griliches (1967) managed to more or less eliminate the technical residual or total factor productivity (TFP) growth by correcting measured volumes of factor inputs in production as recorded in the national accounts. The Jorgenson and Griliches (1967) method comes close to our problem of measuring the value of spillovers. Their method, which is still controversial, is to use duality theory (under the assumption of static equilibrium) to impute the value of unaccounted for inputs from a hypothetical market value of the products.[4] For instance, when Jorgenson and Fraumeni (1992) applied the same method to the US education industry they found and concluded that US educational output accounted for far more of US production growth than previously estimated in other studies.[5] "New Growth Theory" claimed to have sorted all that out and thus to have both endogenized and explained economic growth.[6]

Similar results have been obtained from cost–benefit-based spillover studies indicating social rates of return on R&D investments far above the corresponding private returns, being in Canada as high as ten times (or more) the private return (Bernstein and Yan 1995). When Jones and Williams (1998) summarized the econometric research on social rates of return on R&D investment they found that they on average exceeded private returns more than two times, at least four times and probably more. This corresponds to an underinvestment in R&D in US industry that is very large, they argue, and the optimal R&D investment level is at least two to four times larger than the current level. Hall et al (2010) are more cautious, but their survey covers also publicly financed R&D with considerably lower social rates of return.

A critical factor behind understanding the underinvestment proposition is what one believes about the returns to R&D investment (increasing or decreasing) which in turn depends on what a priori assumptions in that respect that have been imposed on the econometric models (see further Technical Supplement S2). Already Nadiri (1993), and contrary to the common opinion of economists at the time, found little evidence of decreasing returns to increased R&D investment, a conclusion that very much signaled the later superior economic performance of the US economy after 1995.[7] Both Nadiri and Jones and Williams thus concluded that R&D in Western firms generates great spillovers and that the large difference between social and private returns indicates significant underinvestment in R&D among these firms. The implication of this, Nadiri concluded, is that a nation that allows the opportunities to capitalize on that knowledge base in industry slip by will be on a losing track.

Nadiri (1993) even inferred that it would take large increases in R&D spending from the current levels before decreasing returns would set in and social returns come down to private returns. In principle then, if the social rate of return is twice as high as the private rate of return you can infer, under conventional neoclassical assumptions, that the value of capital input in the production of private and social values has been about twice the measured private input. The "cloud of spillovers" is worth about as much as the registered difference. The problem to be sorted out is if returns can be assumed to be decreasing or increasing (see further Technical Supplement S2). Other problems relate to the nature of markets. For instance, the Saab venture to build a civilian commuter aircraft in the 1980s, based on technologies developed in military aircraft production, had to cope with a political market for civilian aircraft with Government subsidized producers such as Bombardier in Canada, Embraer in Brazil and Alenia in Italy. There was no way for Saab to reach sustainable private profitability on its own on that very large industrial project, even though Saab 340 was for some years the best-selling commuter aircraft in the world.

The Saab civilian project was, however, still an advanced industrial project and both a receiver of spillovers (from the military aircraft side) and a generator of its own of spillovers to other industries. Since private Saab R&D investment in the civilian aircraft generated its own cloud of spillovers, that cloud disappeared with the shutdown of the civilian aircraft project in 1999. Suppose, for instance, that the private return to that venture was 5%, and the market (equilibrium) rate of interest 10%, while the social return was 20%. Then the unobserved capital input upon which the social rate of return above the private rate of return has been estimated can be derived indirectly and should be about as large as the total R&D investment in the project. Significant increases in R&D spending in the civilian aircraft project would not depress the social returns much, while Saab's private owners might suffer increased losses compared to instead having invested their money in financial assets. If so, fine for society, at least in the short term. The value to society created through spillovers is larger than the money privately invested. The Saab civilian aircraft project has then functioned essentially as a private technical university, financed unintentionally by the Saab owners. This private technical university will however only be capable of sustaining its activities as long as the private owners find their private returns acceptable to keep investing their private money in it.

3.3 The Macroeconomic Effects of Spillovers

The macroeconomic effects of spillovers are difficult to estimate. Spillovers affect production structure. We therefore have to take individual firms' price and quantity reactions to that structural change into account and the consequent reallocation of resources. No econometric model I am aware of does that. We should also account carefully for the time dimension of the effects (dynamics). Very few studies have even attempted to do that.

If the economy at large is fully employed, the employment effects of spillovers are of no interest. Even if the economy would suffer from unemployment it would be wrong for a number of reasons to be at all concerned about the effects of spillovers on employment. Employment is the concern of macropolicy and labor market policy. If unemployment persists there is something wrong with the other policies and with the organization of the labor market, problems that should be attended to first, and separately from policy decisions to invest in large public development projects. Our concern should be long-term full employment growth in output and real wages. And in principle we are concerned with the macrogrowth effects of a reallocation of resources caused by spillovers in an economy that is fully employed except for the transition unemployment that arises when people move between jobs.

3.3.1 Salter Curve Analysis

What can spillovers do to support sustained faster growth in potential productivity and output? How will the consequent reallocation of resources (competence, labor, and other capital) be achieved from inferior to more productive establishments? Unavoidably some firms will suffer in the process and perhaps shutdown. The immediate effect may even be negative since the negative shutdown of capacity usually comes faster than the long-term positive growth effects. So creative destruction may come before growth to use Schumpeter's (1942) famous parable. Some unemployment would in fact be both needed and helpful to facilitate that reallocation of resources. Let me illustrate with reference to Schumpeter's notion of creative destruction as it can be represented in Table 3 (on page 49). I begin by introducing the concept of a Salter (1960) curve picturing a distribution of performance characteristics over a population of firms. This introduction also illustrates how endogenous growth occurs in the simulation model in the next section.

Figure 3a, b shows the distribution of actual and potential productivities and wage costs per employer in Swedish manufacturing industry in 1982 and 1997 according to the Planning Survey of the Federation of Swedish Industries (see *Moses Database:* IUI 1992). The shaded area pictures unused capacity. As can be seen there is not only significant unused capacity across the firm population, but also large differences in actual and potential productivities. A reallocation of labor from the least to the most productive entities, therefore, at least in principle should raise productivity significantly at the industry level. Similar Salter distributions of profitability in Figure 3c can be put together from the Planning Survey.

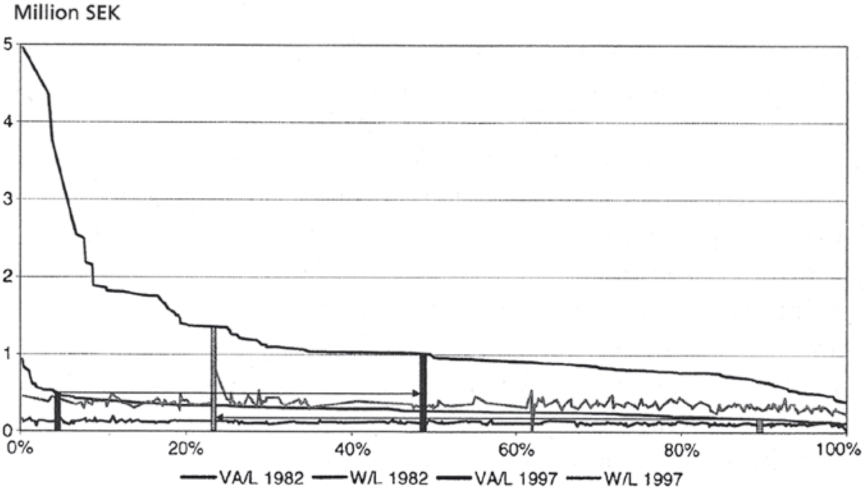

Fig. 3a Salter curves. Distributions of labor productivities in current prices (VA/L) and wage costs per employee (W/L) in Swedish manufacturing 1982 and 1997.

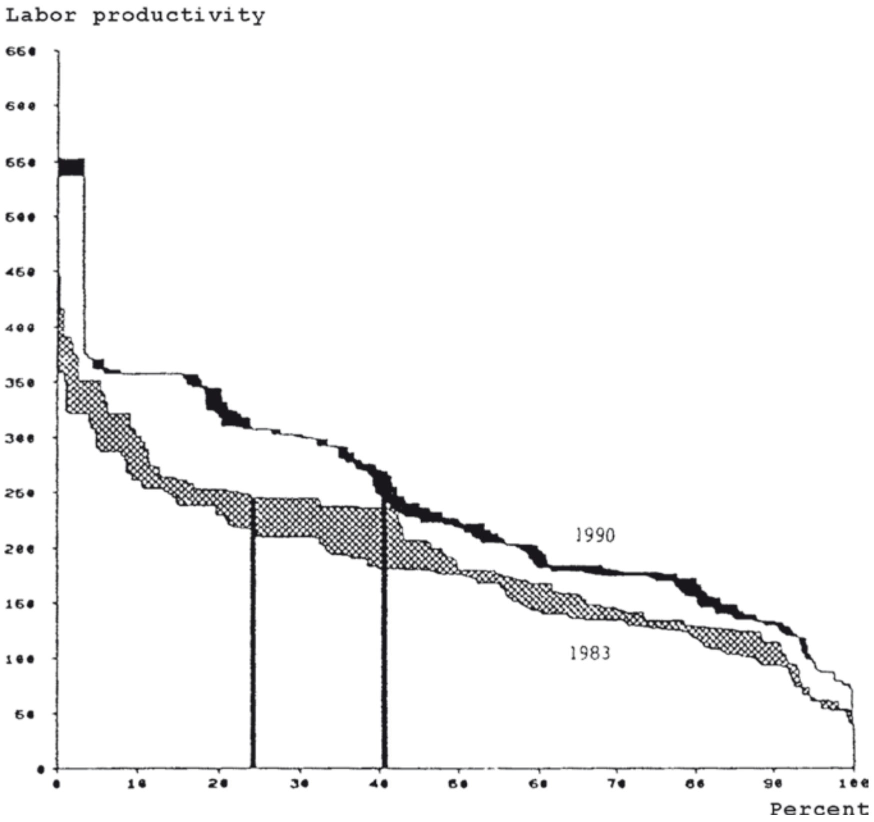

Fig. 3b (continued) Salter curves. Labor productivity distributions in Swedish manufacturing 1983 and 1990. Shaded/black areas denote unused labor capacity in firms. See further Eliasson 1996a:39.

Over time, improvements in macroproductivity are achieved through a combination of economic incentives and competition. Firms at the lower end of the productivity distributions know that firms to their left have developed superior products and production methods. They therefore know that this is possible and have incentives to improve their own productivity and profitability, not least to prevent competitors to their left from overcoming them.

If they are not successful, competitors will force the inferior firms to improve by outbidding them in the markets for resources and/or through lowering their prices, thereby threatening the very existence of the inferior firms.

Take the firm pictured as a black column in Fig. 3a. It is challenged from above (from the left) by more productive and more profitable firms and has to act to improve its performance in order not to be overrun. However, the superior firms to the left, and for the same reason, are also challenged from the right by inferior firms attempting to leapfrog them through innovations.

The situation is the same for all firms along the curve. And new firms lie in wait behind the scenes ready to *enter* when the market situation looks right to them.

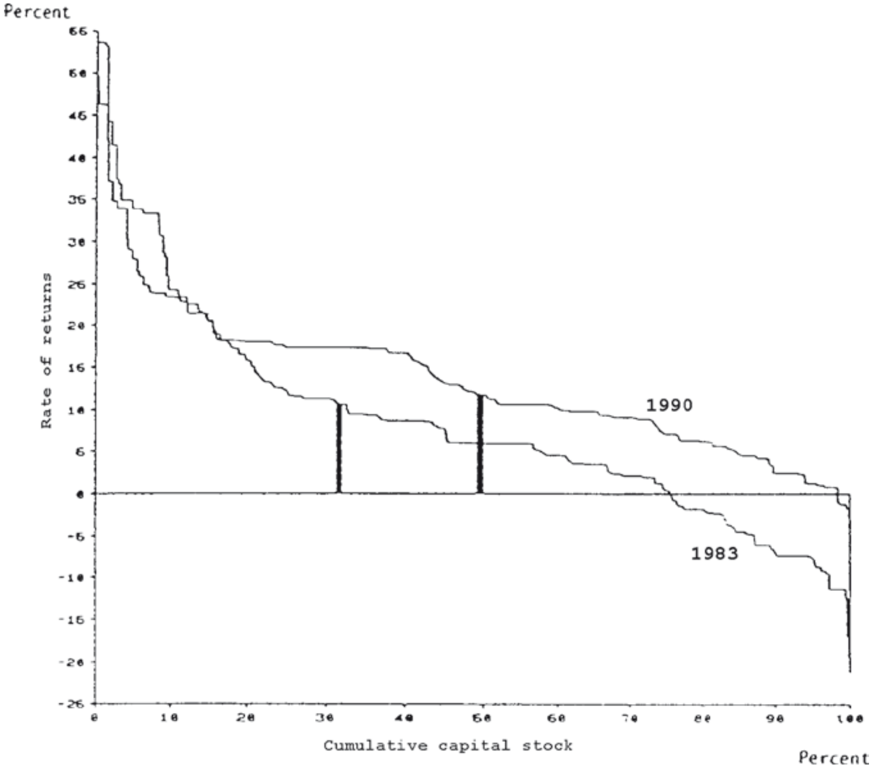

Fig. 3c (continued) Salter curves. Distributions of nominal rates of return on total capital in Swedish manufacturing 1983 and 1990.

There is no way for any firm in the market (along the Salter curve) *to relax*. In an open market characterized by free entry they all have to act constantly, innovatively and long before they know for sure in order not to be rolled over by competitors. If they fail in their assessment of the market they may be forced to exit. As a consequence, all firms improve their performance and their rankings constantly change. Superior firms climb upward by improving their performance and losers slide down the curve to the right, and out if they are unsuccessful in countering competition. A new structure of the economy will be continuously evolving through this constantly ongoing reallocation of resources. As a consequence the Salter curves shift upward and outward and macroeconomic growth occurs. This is also the way endogenous economic growth occurs in the Swedish micro- to macromodel through the Schumpeterian type creative destruction process of Table 3 on page 49 (Eliasson 1991a). *Spillovers function* (in this model) *as free firm entry that keeps the market under constant competitive pressure*. If firm entry and exit can be explained without using an external (exogenous) factor some of the dynamics of economic growth has been endogenized.

Spillovers from advanced firms can be thought of as initiating a Schumpeterian creative destruction process. The mechanism is the same whether they are successfully commercialized within a large firm or through new firm entry. In the latter case, however, success depends on the existence of competent commercializing agents in the market (see competence bloc theory in Sect. 2.4). The Salter curve representation of a Schumpeterian creative destruction process in Table 3 (on page 49) captures both. Let me repeat. A new firm enters, or a new product is launched in the market (item 1, Table 3, See page 49) and challenges the incumbents, or an incumbent launches a new product and reorganizes its business (item 2) and challenges the entire market. All other firms in the market (items 2 and 3) have to reorganize and/or rationalize to cope with the new competition. Those who fail will eventually have to shut down and exit (item 4). As a consequence, the productivity performance of all remaining firms has improved over the previous population of firms and the entire industry has grown. Table 3 (on page 49) therefore explains the endogenous growth mechanism of the Swedish micro- to macromodel in which competition through new entry and/or innovating incumbents moves the entire economy through experimental selection (next section).

3.3.2 Dynamic Simulation

Even a small firm that launches an innovative new product can profoundly shake up a market and significantly change both its production structure and prices. To capture this complexity quantitatively and over time (dynamics) requires a full-scale model of the entire economy specified at the micro (firm) and market levels. The model also has to be capable of capturing the dynamic interaction of prices and quantities and of determining them simultaneously in the market. This is a tall order. Few, if any, such models exist and none of them have yet been fully econometrically estimated as many of the conventional neoclassical models. Simulation models are nevertheless superior representations of the dynamics of the underlying industrial reality and a few of them have been carefully calibrated. Their parameters can however be manipulated to make the model track historic outputs, prices, and microstructures of a business cycle and over the long run. Programs for computerized calibration have been designed (Taymaz 1991a, b).

The Swedish micro- to macromodel employs an endogenous growth generator of the Schumpeterian creative destruction type in Table 3 (on page 49). Such simulation models are particularly useful when it comes to taking crowding-out effects realistically into account since the *opportunity costs are endogenously determined*. In the Swedish micro- to macromodel the exit function is endogenous as is the loss of growth in incumbent firms that suffer from competition from the new entrants.

As in all other endogenous growth models, growth in the Swedish micro- to macromodel is limited from above by an exogenous input factor (an externality). In the early versions of the model an investment pool/frontier of best practice technology expressed in terms of labor and capital productivity of production equipment could be accessed by individual firms through endogenous investment decisions that determined how close to what was maximum possible best practice performance the economy could come (Eliasson 1979). Best practice technologies in the different markets of the model were projected from historic performance and determined through interviews (Carlsson and Olavi 1978). Later the same best practice production technology was also introduced into the economy through endogenous new firm entry (Hanson 1986, 1989; Taymaz 1991a;[8] Eliasson et al. 2005). The best practice technology frontier was endogenized through the genetic learning mechanisms by Ballot and Taymaz (1998).[9] Among the new endogenous growth models that come closest to this specification can be mentioned Klenow and Rodriguez-Clare (2004). Their general model features a global production frontier that is moved forward by the R&D investments of all economies in the past. In this model, access to the frontier technology is determined by the investment in R&D and human capital in the respective economies, which are all growing on individual steady state paths. In the Swedish micro- to macromodel investments in incumbent firms, new firm entry and exit, all endogenously determined, also determine how far below the maximum possible macroeconomic growth trajectory the economy grows.

The interaction of prices and quantities in the markets of the micro- to macromodel is explicitly determined and prices and quantities are simultaneously set through an ongoing stock and flow mechanism that never settles on an equilibrium path. The model has been calibrated against Swedish macro- and microdata and therefore can be said to be capable of realistically simulating the macroeconomic effects of spillovers on the Swedish economy (see Eliasson 1977, 1991b and *Moses DataBase* 1992).

One particular problem of growth analysis is how to deal with *initial conditions*. In reality the resources of the economy are never fully employed. The growth machinery of the economy thrives on such slack making the outcome dependent on the initial conditions. The static neoclassical or new growth models are designed for a fully employed economy. Since they aim for generality the nuisance of unused resources has to be cleared away in empirical analysis, either by some ad hoc correction of data or by simply assuming that resources are fully employed. Then analysis can start from the initial state of a fully employed economy. The growth and productivity effects of an exogenous injection of spillovers then originate in a reallocation of fully employed resources. If the economy operates well below full employment the spillovers will also have a "Keynesian demand pull" effect on the economy. This is a principal problem of some importance, since the employment effects often appear in the arguments for public purchasing, and the employment effects carry no meaning in a fully employed economy.

The Swedish micro- to macromodel integrates the business cycle and long-term trend generation, and hence also the employment and resource reallocation effects of spillovers. The results will then explicitly become initial state dependent and it becomes *necessary to measure the initial state carefully.*[10] A simulation experiment can then be setup at a given initial year and the results will depend on the actual initial state as measured that year. Alternatively, generality of the neoclassical type can be achieved by running and calibrating the model through a series of experiments onto an initial state of approximately full employment, and start the spillover experiment from there.

Suppose now, using the Salter curves in Fig. 3a that the economy is more or less fully employed. The shaded areas in Fig. 3b would then be thin and consist mostly of normal, voluntary transactions unemployment. As can be seen from the diagram there is a very large spread in productivity between the best and the worst performers. Suppose spillovers from aircraft development and manufacturing come in from the left, close to the top, i.e., at some four times the average productivity level of the industry. If these technically defined spillovers are successfully commercialized they will subject the entire industry to competition and force the worst performers to contract or shutdown operations. Labor will be allocated to the better performers. Productivity will increase by four times if average performers only are forced to leave the market and by more than ten times if the worst performers are forced to leave, which would be the likely outcome. Productivity in the entire industry will increase.

Suppose now again that (1) a subcontractor to Saab receives an order to develop and produce a new high-speed machine tool that involves significant innovation, learning, and retooling and that raises the productivity level of Saab, (2) that the new high-speed machine tool is launched in the market, and finally (3) that other firms learn about the new machine tool and introduce it in their workshops (see Case Modig in Sect. 5.5). Let us consider the possibility that this happens in many places because of a large public purchasing project, but restrict our analysis to these three firms.

The Swedish micro- to macromodel has been used on and off to study the *macroeconomic consequences of* such more or less endogenous *technical change in individual firms*. In fact, it was the first empirical application to which it was set up, and the general picture that emerges is that the long-term growth effects of new "exogenous" technology introductions, for instance through spillovers, are positive, but that their magnitude depends on the capacity of the economy to receive and commercialize them. The commercialization process can be more or less crudely modeled, ranging from a simple profitability test/filter in the market as the model was originally formulated to a rather elaborate pre market commercial evaluation of supplied technologies by industrially competent entrepreneurs and venture capitalists (Eliasson 1979, 1981; Ballot et al. 2006). If new technology is introduced through new entry/firm turnover with an endogenous exit feature, as in Eliasson and Taymaz (2000), and Eliasson et al. (2005), this result becomes even more pronounced. An important part of the receiver competence of the economy lies in its capacity to accommodate new technology introductions without inflationary pressure, i.e., to possess an efficient exit or death function. Preventing the exit of inferior firms to avoid temporary unemployment is extremely costly for society. Such policies block the positive effects of spillovers. This became even more apparent when the micro- to macromodel was used to simulate the macroeconomic consequences of the Swedish industrial subsidy program that was enacted in the wake of the oil crises of the 1970s to keep unemployment from rising, and to save the dying Swedish shipyard industry. Macroeconomic growth was more or less eliminated for a decade and unemployment temporarily postponed, to shoot up in 1991 when the Government could no longer afford its generous unemployment subsidies. Alternative policies with the same public budget consequences were simulated on the model and the optimal long-term policy design appeared to be to lower payroll taxes and wait for the market to sort out the best new allocations of resources. The *worst policy design* was to give the money to the worst producers to temporarily save employment,[11] i.e., the actual policies carried out. The time profile of the macroeconomic effects of the optimal policy program was however the one mentioned above, first a sudden shake out and a decrease in output, followed by a slow recovery, eventually to result in a larger long-term output far above the dismal reality (Carlsson et al. 1981; Carlsson 1983a, b).

Also the influence on the macroeconomy of large and rapid technology advance of individual firms have been simulated and interesting effects emerge when the economy is not properly organized to accommodate structural change (Eliasson 1979; Carlsson 1987). A sudden injection of superior technology competes inferior firms in the lower right end of the Salter curves in Fig. 3 out of business. There is a temporary drop in growth in the macroeconomy, but as the "superior firms" grow into dominant ones growth is resumed. However, if the new superior firms are not challenged by competition from new entering firms the now dominant firms eventually cease keeping up with further improvements in best practice technology and the positive macroeconomic effects dwindle away and may even turn negative because competition gradually decreases with the loss of firms. Competition through new entry changes that picture. The once superior firms now have to improve to stay competitive and alive. A balance between entry and exit, the turnover of firms, has to be sustained to achieve maximum sustainable long-term growth of the economy, and if the model economy is equipped with a competence bloc type selection filter (see Sect. 2.4) the long-term optimal growth rate increases because of an improved selection of projects (Ballot et al. 2006; Eliasson et al. 2005).

3.3.3 Commercialization

The above discussion of simulation analysis was designed, as is common in econometric modeling, with no explicit account for the resources used up in the commercialization process. An unfiltered flow of new technologies was simply launched in the market. If found commercially inferior, the new technology flopped. If cost performance turned out inferior, the entire firm shut down. What is new compared to standard neoclassical econometric models is that economic filtering through competition in final product markets has been explicitly modeled. The micromarket-based dynamics that generates improved macro economic performance can be both understood and quantified. Firms with bad solutions compared to their competitors eventually fail. Introducing the commercialization process explicitly (the competence bloc), and the industrially competent venture capitalist in particular, however, changes the outcome significantly through an improved commercial filtering by experienced actors, and returns to R&D investment are significantly raised.

Quantifying what commercialization competence means for macroeconomic growth is however difficult because of lack of empirical knowledge on how the commercialization process is organized. We are now talking about sequences of choices in the markets coordinating actors of the competence bloc, beginning with the entrepreneur in Table 2B (on page 43) and running through the existing range of industrially more or less competent venture capitalists. Exit market actors (private equity markets) take over where venture capitalists leave off winners they have identified and "certified" for the industrially less competent exit or private equity market. Industrialists finally take the winners on to industrial scale production and distribution.

Even though difficult to quantify empirically, the sequencing of decisions can be empirically studied and data on firms are available. This is where simulation method offers great advantages of realistic modeling over standard econometric techniques (see Eliasson 2007:89ff). The competence background of commercializing actors can be explicitly modeled. On the venture capitalists and the way they work I have access to a unique interview material that highlights the difference between US and European venture capitalist practices (Eliasson 1997b, 2003, 2005a: Chap.4). A crude version of the competence bloc theory presented in Sect. 2.4, focusing on the role of the venture capitalist has therefore been integrated with the Swedish micro- to macromodel (Ballot et al. 2006). While the sequencing of decisions of the competence bloc has been fairly well-established empirically, the magnitudes involved in the learning process and the knowledge capital characteristics will have to be hypothetical, as will be the strength of property rights and the nature of financial risks.

Learning in the micro- to macromodel, furthermore, can never be of the traditional statistical learning, rational expectations or efficient market type based on the existence of an external equilibrium and assumed zero transactions costs (Lindh 1993:89ff). Learning among the venture capitalists in the model application is rather in the form of remembering successful choices being made as positive experiences for future choices, a type of learning that can be demonstrated to raise the probability of making better future choices under normal market situations,[12] i.e., a form of accumulation of industrial experience capital.

This part of the analysis is important since it concerns the magnitudes of value creation in the periphery of the cloud of spillovers or the outer circles in Fig. 3, i.e., beyond the spillovers captured in the econometric studies referred to above.

Ballot et al. (2006) use the Swedish micro- to macromodel to simulate the introduction of a "primitive" commercialization process, i.e., venture capitalists that learn from industrial experience and therefore become more competent in separating winners from losers before market introduction, or rather, not losing winners. Over a 50-year time span manufacturing macro output is up by 15% because of the introduction of this learning, everything else the same. More to the point, however, is that productivity is up by 30% on the horizon and the "best practice" technology level that improves with learning by almost 45%, the latter signaling a sustained future increase in output growth or at least the maintenance of the improvement achieved.

These simulation experiments are indicative of how we should look at peripheral spillovers. An economy lacking a broad-based commercialization industry (for instance, in an industrially less developed economy) would not be capable of realizing the long-term increase in output of 15% "on its own." The way I have presented this commercialization industry in the competence bloc Sect. 2.4 suggests that only the US economy is satisfactorily endowed with that capacity. The current development of the Swedish economy means less than 15%, and the gestation period for peripheral spillovers is very long. The maintenance of diversity of structures however requires that peripheral spillovers be captured.

3.4 Notes

1. The standard economic growth model (see further below) featured growth as driven by an exogenous technology factor, i.e., as an externality.
2. While Romer (1986) had condensed Marshall's broad-based thinking on a strict, but narrow mathematical format and without acknowledging the very early work of Marshall, Jones (1995) made Romer's model a special case in his very nicely structured mathematical model of R&D based economic growth.
3. By chosing a model that has an external equilibrium and by assuming that the economy is in static equilibrium and applying duality theory Mellander and Ysander (1990) could study productivity and efficiency in the public and the banking sector without having access to output data.
4. The method has been criticized for being tautological, but the problem is rather the strong assumptions to establish the existence of a known external equilibrium that one has to make. C.f. Mellander and Ysander (1990) who measure productivity in service production without statistical data on output, using more or less the same method.
5. Jones' (1995) excellent survey of new growth theory ambitions explains how new growth theory relates to standard neoclassical theory, and he is not supporting the claims that it is all that new and revolutionary even though he is very parsimonious in his references to the Jorgenson workshop, which had long before done much of the job now relabeled new growth theory. Whatever, properly endogenizing spillovers goes far beyond "new growth theory." Above all, the story has to be taken down to the microlevel where decisions are taken and then generalized to macro. This is also what this study is all about.
6. First man out was Romer (1986). At close inspection, however, growth in the "New Growth models" is also carried by an exogenous equilibrium trend, and hence do not embody more endogeneity than the standard neoclassical growth models, e.g., those used by the Jorgenson workshop (see further below). Jones (1995) nicely integrates the various (R&D based) growth models, making each, including Romer (1986, 1990) a special case of his general model.
7. Later, Mun and Nadiri (2002) observed that IT externalities in US private industry over the period 1984–2000 were stronger than other externalities, and explained considerable parts of TFP growth. This was notably so in service industries, that are characterized by significant inter industry transactions. One should add here that the introduction of distributed production across manufacturing industry should mean an increase in the same characteristics (Eliasson 1996b).

8. The MM model in fact featured exogenous entry and endogenous death (exit) of firms already in its 1976 version (see Eliasson 1978:52ff) and generated the expected macroeconomic outcomes. In an academic seminar on the model the overwhelming conclusion, however, was that the macroeconomics of firm entry and death was of little interest, so the firm entry model was temporarily shutdown to be replaced later by the endogenous entry functions referred to above.
9. See also Eliasson et al. (2005).
10. This is also the major part of the database demand of the Swedish micro- to macromodel. See *Moses Database* 1992.
11. It should be mentioned that the entire Swedish civilian shipyard industry, at the time the second largest in the world, excluding small pleasure craft, has now been shutdown. An instance of methodological interest worth mentioning is that the subsidies were well dimensioned to keep shipyard firms alive and employment there intact. Only a small reduction in individual firm subsidies, however, and the shipyards in the model began to shed labor or exit. As an illustration of this reallocation dynamics should be mentioned that the subsidies deprived Volvos growing plants in the region of welders. Volvo's going wage rate was however significantly lower than that enjoyed by ship yard welders, who were now locked up at the yards destroying steel. Value added at the shipyards were negative for several years.
12. Normal market circumstances mean that the model operates within a "bounded equilibrium area" where price feed back signals are fairly reliable predictors of future prices. See further the discussion in Eliasson (1983, 1984), and in Eliasson et al. (2005). In the latter study, an increasingly faster resource reallocation process eventually destabilizes economic structures and makes price signals increasingly unreliable predictors of future prices, to the detriment of long-term economic growth.

Chapter 4
Capturing the Direct and the Serendipitous Spillovers: The Case of Sweden's Military Aircraft Industry

Competence bloc theory categorizes factors that make economies more or less efficient in identifying, selecting, and commercializing the innovative industrial technologies that move economic growth. Competence bloc theory therefore is central for understanding the role of spillovers in the macroeconomy. The economics of commercializing is about minimizing the costs of two types of business mistakes.

First, losers may be kept for too long on the budget. This, in the end, becomes a business mistake. The by far most costly business mistake, however, and *second*, is to lose a winner. The large winners often appear in the outer circle of Fig. 1 (on page 35) and are the most difficult to identify. But it is almost impossible to observe such losses. Nobody in the firm is made responsible for making up an account of profits that do not materialize. It is, however, sometimes possible to observe the near loss of real winners, as for instance Astra's stomach ulcer substance Losec (or Omeprazol in the USA), and for some time the world's most sold prescription drug, Ericsson's mobile telephony (a story to be told in Sect. 4.4 below), and that Microsoft almost missed the Internet. The following two chapters give a brief account of the economic significance of the industrial spillover cloud around Swedish aircraft industry and Saab over their histories, beginning when Svenska Aeroplan AB (Saab) was founded in 1937 as a separate company, jointly owned by Bofors and a subsidiary of Electrolux, to build military aircraft for Swedish defense.

4.1 A Brief History of Saab

Growing hostilities between Germany, on the one hand, and France and England, on the other, were the reason *Svenska Aeroplan AB* (Saab) was once founded in 1937 to produce aeroplanes for the defense of Sweden.

In 1940, Saab had developed a light bomber Saab 17. Three hundred twenty-two of them were manufactured in four versions. A large bomber (Saab 18) was ready in 1942. Altogether 245 Saab 18 were produced. Finally, 1943 saw the fighter bomber aircraft Saab 21A with its propeller mounted in the rear ready for service. Three hundred one Saab 21A were manufactured for the Swedish Air Force. The Saab 21A

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was also outfitted with the first ejection seat ever designed to shoot the pilot above the propeller in case of emergency. This aircraft was converted to jet propulsion in 1947. Sixty-four jet-propelled Saab 21R fighter bomber aircraft were built.

When the end of WWII could be seen toward the mid-1940s Saab management had begun to prepare for the end of the military aircraft market. Attempts to convert to civilian production began. Seven US B17 Flying Fortress bombers had made emergency landings in Sweden during the war. The US Government allowed Sweden to keep them and to convert them into passenger aircraft for AB Aerotransport (ABA). Saab made the conversions in the late 1940s. Saab Safir 91 was a trainer aircraft that was ready as a prototype in 1945. In 1963, when production was terminated, 323 Safirs had been built.

The passenger aircraft "Scandia 90" was designed to take 24–32 passengers,[1] i.e., about the same capacity as the later Saab 340. The first Scandia aircraft was delivered in 1950. Among other airlines, Scandia was flown by SAS. Production was discontinued in 1954, and transferred to Dutch Fokker after 18 aircraft had been built and 10 of them sold to Brazil. With the cold war heating up the Swedish government wanted Saab to focus on the production of the J 29 fighter aircraft ("The Flying Barrel") and there was not sufficient capacity for a parallel civilian aircraft program. Because of the continuing cold war Saab, therefore, remained a predominantly military aircraft producer until the 1980s. But Saab made several attempts to enter civilian markets on the basis of its military technology.

During the early 1960s Saab developed its military trainer aircraft 105, which was also an attempt to enter the market for business jets. The first prototype flew in 1963. One hundred and fifty aircraft were sold to the Swedish air force and 40 to the Austrian air force, but none was sold as a business jet (Philips et al. 1994a). Some of the Saab 105 were later used by the Swedish Air force as liaison aircraft. The general picture until the late 1970s, however, was that once a military project got under way interest in civilian ventures cooled.

Toward the end of the 1940s, when the demand for military aircraft temporarily disappeared after the now expected defeat of Germany, Saab began to develop an automobile. The principal economic rationale for entering the automobile market was to exploit the engineering ingenuity and competence of Saab to design and build complex engineering products, and the low Swedish wages, to access civilian markets. The first two-stroke engine Saab 92 was launched in 1946. Saab Automobile turned out to be the only civilian activity that survived the sudden resurgence of military rearmament.

Saab had initiated new plans for a civilian passenger aircraft already in the beginning of the 1970s. In 1974 and 1975 a study group within Saab presented a design of an aircraft ("Mulan") with four engines and a capacity of 15 passengers.

Not until the early 1980s, however, was the first serious civilian aircraft project started with the development of the regional aircraft Saab 340. The earlier attempts to go civilian in the aircraft markets had been aborted by the urgency of upgrading the military defense.

The cold war had made the strengthening of Swedish air defenses acute, above all to ward off an invasion, or to prevent harassment from the Soviet Union. The upgrading of Swedish military aircraft technology that followed was instrumental in fueling the rapid development of Saab into one of the world's most advanced producers of military aircraft. This was possible because of Sweden's advanced industrial base, to a significant extent developed during the war rearmament, the existence of a very competent public customer, the government military procurement agency Försvarets Materielverk (FMV) and the political willingness to provide resources for Sweden's defense. Even though not discussed in those words at the time it was possible for a small industrial economy to develop one of the world's most sophisticated military aircraft systems without draining the economy of resources for other industrial development because of the very large spillovers generated by the project. In addition to that, and with implications for the analysis of Saab in South Africa in Chap. 6, Saab's technological prowess as a developer and producer of military aircraft depended in a large measure on access to US technology, notably advanced electronics. The first US Polaris missiles that were deployed in 1960 had a limited range. To reach Moscow they had to be launched from positions very close to Norway and in fairly shallow waters. The US submarines were therefore vulnerable. In return for building a very strong airforce capable of preventing Soviet anti-submarine aircraft from crossing Swedish airspace the USA made advanced military technology available to Sweden, technology that made it possible for Saab to develop a sophisticated aircraft system very fast (*Militärteknisk Tidskrift,* 2005:6–11). For some time, Sweden then had the fourth largest military air force in the world.

The cold war rearmament and the outbreak of the Korean war had demanded the entire manufacturing capacity of Saab. The Saab 29 "Flying Barrel" jet fighter was introduced in 1948. Six hundred sixty-one were built. The Saab 29 was followed by the supersonic Saab 32 Lansen in 1952, by Saab 35 Draken in 1955 and by Saab 37 Viggen in 1967. 1988 saw the maiden flight of the first "fourth generation" combat aircraft ever with "instability properties," the JAS 39 Gripen, that entered service in 1997.

Until 1984 when the Saab 340 was introduced, almost the entire aircraft development and manufacturing capacity of Saab had been allocated to military aircraft. With Saab 340, however, Saab rapidly advanced into the civilian market for regional aircraft, and parallel to the development and manufacturing of JAS 39 Gripen.

Throughout these years Saab has entertained constant ambitions to create businesses and an economic return on its technological spillovers, the diversifying ambitions sometimes giving more a picture of fragmentation than of a coherent business strategy. In fact, spillovers around Saab are found in all four circles in Fig. 1 (on page 35), and I will go through many of them in the form of brief case stories, beginning with the core products in the inner circle and then moving gradually to the outer circles.

One methodological problem, however, makes it necessary to split the case studies into two chapters. To measure the spillover multiplier of the JAS 39 Gripen development investment we have to separate the Gripen spillovers and their industrial effects from those of earlier aircraft generations. Military aircraft development and production had been a continuing business during the entire postwar period and military technology had fuelled both future military and civilian development. This makes it difficult to isolate the spillovers from the JAS 39 Gripen project from a history of earlier military spillovers.[2] The third generation fighter aircraft Saab 37 Viggen development, for instance, was completed in 1967 and all aircraft had been delivered by 1990. Spillovers from the Viggen project can therefore to a large extent be studied ex post and their origin traced. The JAS 39 Gripen aircraft development (next Chap. 5) is more difficult. Procurement conditions were different and tougher. Gripen has a much larger content of imported subsystems than previous Swedish-developed fighter generations[3] and significant parts of the spillover flows and conversions into civilian business are still to be seen. I will try, nevertheless, to identify and isolate the Gripen spillovers in the next chapter.

There is, however, one overriding organizational industrial competence that I have called distributed and "*integrated production*" (Eliasson 1996b) that is generic to engineering industry, that was first developed in military aircraft industry and currently is becoming a critical engineering technology associated with concepts such as modularization, outsourcing and distributed production, and the ongoing globalization of production of the world economy. In the increasingly modularized global production system the technology of the most advanced engineering firms is often referred to as the development of "concepts and integration" rather than manufacturing, development being located to the advanced economy, where the systems architecture of the product and of the production system are being designed. Since much of the physical manufacturing has been outsourced, the final systems integration and assembly of all the subsystems and components then has to be brought back again to the advanced economy. While distributed and integrated production only began to diffuse through engineering industry with the advent of the microprocessor (invented by Intel in 1971), the third generation military aircraft Viggen development program predated the microprocessor by half a decade. The first Viggens delivered in 1971, however, featured the very early, advanced, and extensive use of central digital computing based on integrated circuits. When the last Viggens were delivered in the late 1980s the microprocessor and distributed computing that defined state-of-the-art computing had also been implemented in the aircraft. Not until the integration of computing and communications technology in the 1990s (the fifth generation of computing technology), however, did distributed production really catch on. By this time, however, Saab had been using this "new" engineering technology for more than a decade. This now generic engineering technology is nevertheless more related to the JAS 39 Gripen development program which from the beginning was integrated within an early networked defense system, and notably the ongoing (2008/2009) upgrading to the Next Generation Gripen which is far more intensive in its use of distributed computing and communications than earlier Saab military aircraft.

As I see, it the industrial art of distributed and integrated production on a global scale is what has saved, and will save the engineering industry in the high wage industrial economies, the back bone of their industrial wealth and growth since the advent of the industrial revolution. I will, therefore, pay extra attention to Saab as a pioneer developer and user of integrated production in the next chapter.

It should also be observed already here that the capacity to develop a complete military aircraft platform (see below) or a large commercial airplane and the associated systems is an extremely scarce industrial competence. Not more than six countries can do it today (2008) and they are the permanent members of the UN Security Council and Sweden.[4] If you extend the range to small passenger aircraft you could add Brazil (Embraer), Canada (Bombardier), and Italy (Alenia) to this distinguished group. It is no wonder that a number of aspiring industrial economies see aircraft industry as a vehicle to reach that goal, and that the wealthy industrial economies see their military aircraft industry as the means to maintain their industrial supremacy. This competence (with Saab in Sweden) therefore spills goodwill value to the entire Swedish engineering industry. The development of a complete aircraft industry, including (see below) also a civilian aircraft industry, hence, has been a positive brand for the entire Swedish engineering industry.

4.2 The Saab Group Strategically Reorganizing for a Different Future

A large part of technology spillovers generated within Saab has been, and will be commercialized within the Saab group and within related businesses. This has its advantages and disadvantages. Therefore a few words about the Saab company and its ongoing organizational transition are needed. The organizational change is part of a strategy to raise the capacity of Saab to earn a profit on its own spillovers.

The collapse of the Soviet Union has forced change on military equipment producers around the world. This has especially affected weapons designed for large-scale warfare between nations. It has been believed that sophisticated aircraft designed for direct hostile engagement between nations is out, and especially so because of the large costs associated with the development of a new generation of combat aircraft, so large that the most recent and ongoing procurement of the Joint Strike Fighter (JSF) in the USA, which Lockheed Martin won in competition with Boeing, is believed to be the last such competition that the USA can afford.

These considerations and political cravings for a significant peace dividend to parcel out politically may however be premature for two reasons. *First*, no advanced nation can allow control of its airspace to slip. In a geographically large country like Sweden, or for that matter Norway, which has to be prepared to prevent, or fend off aggression and harassment at its oil platforms in the North Sea and further north, very high performance military aircraft with a sufficient range and speed are needed.[5]

The *second* reason is that very sophisticated military aircraft systems and systems for counter terrorism and civil security in large measure share the same technologies (see further Sect. 5.8.3). The costs of developing a new generation of military aircraft should therefore be weighed against the gain in civilian technology that will have to be developed anyhow, or imported from abroad. And since the social value of spillovers around military aircraft is very large, neglecting this “technology dividend” in the larger social calculation will produce biased results. So it may be premature to rush into the political conclusion that the development of combat aircraft is a phenomenon of the past. The question is which nation, or group of nations that can afford it (see further Chap. 7 on the European perspective).

The change demanded, furthermore, is not only technological. Saab also has to cope with three fundamental changes in its market environment, and market change may be even more difficult and risky to handle than technological change;

1. Compared to the previous business situation with one public customer, the Swedish Government, with a long-term perspective on military procurement and development, Saab now faces many new customers, several private, with more immediate demands that are also less inclined to cover sophisticated R&D-intensive new product development.
2. While the previous defense policy was based on uniquely Swedish (and secret) defense solutions, Saab now has to deliver interoperable solutions, for instance flexible equipment and solutions that function in an international context, together with similar solutions of other countries.
3. Today, the previously dominant task of protecting national borders is only part of the Swedish military policy. Saab defense products, therefore, will increasingly have to cope with new, more complex, and unpredictable global threats and be capable of being part of international peace-keeping operations.

These new tasks define a new market environment for Saab as a military aircraft producer which is forcing the business units within the Saab Group to reorient and to reorganize for a different market life. Saab, hence, is a technology-intensive company in transition, but over the foreseeable future its business will be based on the Gripen aircraft and Gripen technology generation and the ambition is to remain in the *complete military aircraft systems market*. Focus has, however, been reset on (1) military products and systems but also, and in the long term on (2) *civil security* as a new civilian business leg. Companies with needed complementary technologies have been acquired and nonmilitary/noncore businesses sold off. This defines a third (3) business task to be attended to by *Saab Ventures,* established in 2000 both to capture as much economic value as possible on the existing portfolio of noncore technologies and future spillover technologies and to "spin in" complementary technologies that are needed to support Saab core technology development. Celsius was acquired in 2000, South African Grintek in 2005, and Ericsson Microwave Systems[6] in 2006 to complement the military core business. A number of unrelated businesses have been sold off in recent years (see below).

Finally, (4) Saab has entered the upper end of the potentially large market for engineering consultancy through its fully owned but independently managed *Combitech AB* consultancy arm. Through Combitech AB Saab can capture some of the rents from its spillovers through selling military aircraft engineering expertise in civilian markets. Combitech AB is also a vehicle for keeping specialized military engineering capacity employed with civilian jobs within the Saab group (see Case 23).

4.2.1 A Business Organization in Constant Transition

Currently (October 2009) Saab is composed of 15 business units grouped under three business segments: *Aeronautics* (mostly Gripen), *Defense and Security Solutions* (DSS, including surveillance systems (Erieye, and since 2008 Civil Security) and *Systems and Products*, each one accounting for about one-third of total group sales of some 23 billion SEK 2007. Aeronautics is dominated by Gripen military businesses but also includes Unmanned Aerial Vehicles (UAVs) and civilian operations associated with the Saab partners Airbus and Boeing, for which Saab develops and manufactures subsystems, notably based on light weight structural components.

From January 1, 2010 these three business segments will be reorganized into the five *business areas*:

1. *Aeronautics*, dominated by Gripen and Unmanned Aerial Systems, including civil aircraft systems and components covering 31% of sales in 2008.
2. *Dynamics,* including weapons, missiles, remotely operated vehicles, and signature management systems or today's business units Saab Bofors Dynamics and Underwater Systems (18%).
3. *Electronic Defense Systems,* including defense electronics and avionics, early warning and control sensors, radar systems, and electronic warfare systems (19%).
4. *Security and Defense Solutions,* including surveillance systems, civil security, training, and telecom technology in South Africa (22%).
5. *Support and Services,* for military and civilian products, logistics, etc. (14%).

The new security and defense business area (including the previous Saab Security unit) has moved up in priority in the new organization. It draws on several common technological platforms within Saab (to support for instance anti terrorist weaponry) mostly within the command, control and communications area, including sensors and systems integration. It is considered strategic and ready to be geared up for future expansion. It will, and has to draw on other Saab business units for sophisticated technology.

As before *Saab Ventures* operates from the corporate level and *Combitech AB* is a separate joint stock company with a separate Board, albeit fully owned by Saab AB.

Saab is probably best known for its advanced military aircraft development and aircraft certainly is Saab's largest business. However, high technology deliveries to army and naval forces and weapons together are almost as large. Civil security and other commercial products make up almost 20% of Saab group sales. Altogether almost 70% of sales went abroad in 2008.

4.2.2 Military Aircraft Technology is the Platform for Future Industrial Development of Saab

As before, military aircraft platform, weapons, and networking technology development not only will define the frontier technology for all five business areas. To develop a new military aircraft a large number of technologies have to be developed or modified and integrated. The Gripen business project will therefore continue to function as a broad-based technology driver and technical university, both for Saab itself and for the rest of Swedish industry, using already today the technologies of future engineering industry. This also means that it is difficult to group the business units of Saab along clear market or production technology lines. The Saab organization chart therefore is not only correspondingly complex but will continue to be in constant transition.

The reorientation of Saab and the need to focus has also meant an increased need to add new complementary technologies to its core businesses, both for the military product development and for the strategic expansion into new civil security markets. In addition, Saab faces a need to earn, and to raise its return on the steady flow of technology spillovers that is generated as an "accidental" byproduct by its core operations. The policy is to incorporate and sell more new technology than before and for maximum price, rather than trying to operate new activities in new markets within the Saab group. *Saab Ventures* was established in 2000 to attend to these two tasks. Also in the new organization, Saab Ventures will operate from the corporate level across all five business areas. Saab Ventures will not only monitor the now rapidly evolving markets for strategic acquisitions to acquire complementary technology, but also supply these markets with new and innovative Saab technology that has fallen outside Saab's core businesses. The difficult management problem of nursing new businesses for the market is for one thing to identify winners, but also to prepare radically different and odd technological spillovers for full-scale industrial production and distribution. The crtitical business task then is to decide when the maximum price can be captured and remove the venture from under the parent's management umbrella. This is no easy task that Saab Ventures has been strategically placed to manage, but looking at Saab as a concept and solutions systems developer it is a competence that it has to develop profitably.

4.3 The Cloud of Spillovers

The story now to be told begins with a brief account of the economic significance of the industrial spillover cloud around Swedish Saab over its history. I move gradually outward through the circles of Fig. 1 (on page 35), beginning with the core products in the inner circle, the military aircraft. Table 4 (on page 51) lists the specific technologies that I will go through using the same classification. When reading this and the next chapter it is important to bear in mind that the diffusion of technology rarely occurs in the form of transfers of well-defined and patentable technology packages. The main diffusion channel is people with knowledge and experience who move on through internal careers in firms or over the labor market (or rather the market for competence) to new, but related tasks.

4.3.1 Core Technologies (Aircraft and Engines)

4.3.1.1 The Aircraft/The Core Product

A military aircraft is a complicated product with a very long life that requires an extremely complex and distributed production organization (Table 5 on page 51).

An aircraft integrates advanced mechanical technology with electronics, sensor technology, hydraulics, new materials, communications systems, etc. (Table 6 on page 51). In military aircraft, weapons systems have to be integrated with the aircraft, communications systems modified, and encryption technologies installed, etc.

The final product, furthermore, the aircraft, has to be robust, fail safe, and capable of operating in extreme environments.

In general, an industrial project of the size needed to develop an entirely new combat aircraft system drives technology over a very broad range because of the large number of technical problems that have to be solved along the way.

The design of the third generation Saab 37 Viggen combat aircraft to which this chapter is largely devoted began in 1961, the first prototype was flown in 1967, the first production aircraft was delivered in 1971, and the last in 1990. The last Viggen aircraft was taken out of service in 2006.

The early Viggen aircraft was the first to have its functional properties heavily geared on modern digital computing. When the Viggen design phase began in 1961 the fourth computer generation, the microprocessor was not yet invented (by Intel in 1971). A central computer based on integrated circuits (the third computer generation) was used through all the modifications of the Viggen, the last one being made at the end of the 1990s. The Viggen design had been dedicated to invasion defense, and, hence, was not as flexible in aerial combat as the JAS 39 Gripen design. (It is illustrative to observe already here that the Gripen incorporated a broad range of new functions that were unthinkable when the Viggen platform was designed. The Gripen was also designed to make export sales to countries demanding different functionalities possible. By now, the microprocessor that defined state-of-the-art computing had arrived, and with it the potential to enhance the flexibility of combat aircraft functionality went far beyond the limits set by the physical configuration of the Viggen aircraft. It was therefore not considered cost efficient to attempt to improve upon the Viggen platform, so around 1980 the design phase of an entirely new military aircraft began (next chapter)).

The long life of the aircraft means that to enjoy its services as a user, updating of functionalities, maintenance and repair services have to be delivered over its life cycle, and the entire product might even have to be completely updated and modernized now and then. In fact, the electronics has normally been replaced one or two times, sometimes three times during the almost half century life span of a modern combat aircraft. Today updating of the electronics and its software is more frequent and occurs continuously. The architecture of the intelligence functions of the JAS 39 Gripen aircraft that makes this possible (notably its modular design) is also one reason for the higher spillover intensity of the fourth generation aircraft, compared to the previous generation. With the rapid turnover of electronics technologies also large civilian aircraft of today have to be designed to accommodate such change of its intelligence functions. The early definition of the product, hence, must include both the features that lower maintenance and repair costs and facilitate upgrading and modernization, and some kind of understanding of the properties of the aircraft desired 50 years hence. Flexibility in basic structural and systems design thus becomes an important product characteristic, and the JAS 39 Gripen (next chapter) represents the ultimate art in designing a large, complex mechanical product system. This in fact represents an important systems design and architectural competence for the systems integrating firm. It is obvious that the “art” of being successful in such “future product design” is an important spillover characteristic that benefits the rest of the systems integrating engineering industry, and not through the receipt of well-defined and patentable technology packages but through the constantly ongoing diffusion of people with such competences over internal and external labor markets.

The design and integration of many different technologies and subsystems with different economic life spans are often referred to as “clock speed design”. The new technologies arrive with different cycles (clock speed). This is typical of aircraft industry where materials and structures with long cycles are integrated with electronics and software with short cycles. The art of integrating systems with a capacity to handle this diversity during perhaps half a century that can also integrate new technology to achieve new functionalities is a great competitive advantage in an industry developing and manufacturing complex and expensive systems products.

Easy adaptability means product longevity, and product longevity means low lifetime costs for the user. This also means that the ability to manage product upgrades becomes critical for product lifetime costs. This partly explains why the user of very complex products often outsources the management of the product system over its life cycle to the producer. The producer understands the product better than the user. This began with aircraft and aircraft engine manufacturing but is becoming common with other expensive and complex products such as heavy trucks and telecom systems that are designed to be integrated with other systems and bundled with networks of services.

The case presentations to follow in this chapter will be ex post in the sense that commercialized spillovers have been identified and their history and origin traced. Besides some historical observations, most spillover cases in this chapter therefore relate to Saab’s Viggen “third generation” supersonic aircraft that used digital systems and computers extensively to achieve functionality that was first delivered to the Swedish Air Force in 1971. The Gripen spillover story will follow in the next chapter.

4.3.1.2 Case 1: Civilian Aircraft

The most obvious direct spillovers around Saab (in the first circle of core technology) are the large civilian (regional) aircraft project of Saab and the aircraft engine production of Volvo Aero (item 1 in Table 4, See page 51).

Civilian aircraft projects have been attempted earlier in the life of Saab (that was founded in 1937), but tended to be shelved when a new generation of military aircraft had to be developed fast. The first serious civilian project was initiated in 1974. In the late 1970s Saab identified around 30 passengers as the optimal size for a small civilian passenger aircraft to be used for short distances. Saab was therefore fortunate to have had the right business idea when the US air travel market was deregulated in 1978. Saab had a fully engineered regional turbo prop aircraft (Saab 340) for 34 passengers ready for delivery already in 1984. Saab 340, therefore, soon became the world's most sold regional aircraft in its size range. A larger and quieter turboprop regional airplane for 50 passengers (Saab 2000) was developed and ready for delivery in 1994. Both the civilian aircraft and the military JAS 39 Gripen projects were started at the same time, but this time the civilian project was also realized because the Swedish Government demanded a civilian production project to complement the JAS 39 Gripen project. *To accommodate both these large industrial programs simultaneously without choking on thousands of detailed engineering tasks a new product development and manufacturing organization was needed, including a modularized systems design and extensive outsourcing of both development and manufacturing compared to earlier generations of military aircraft.* As it happened this was exactly the right learning experience to prepare for the development of engineering industry technology and organization to come.

The market for civilian aircraft is, however, almost as political as the market for military aircraft and many countries, notably Brazil, Canada, France, Germany, and Italy have subsidized their aircraft manufacturers heavily to establish – such has been the ambition – a local technological spillover source to support domestic industrial development. With a market distorted by heavy subsidies the commercial screening of the new technologies became deficient (Eliasson 1995, 1996b). Without a government willing to pay handsomely for the spillovers the market for regional aircraft went dead for private and not subsidized Swedish producers. Saab shut down its regional aircraft venture in 1999. Saab's civilian aircraft arm has refocused and Saab is now an established developer and supplier of advanced subsystems to the two large aircraft companies Airbus and Boeing. In this reoriented business Saab has been successful in reemploying resources from the shut down regional aircraft venture (secondary spillovers again. More on this in the next chapter).

Saab's venture into the civilian aircraft market was the largest industrial venture in Sweden ever. It was too large for Saab to go it alone. Saab therefore teamed up with US Fairchild already in 1979. In retrospect, the choice of a turbo prop engine rather than a jet engine may look entirely wrong, but at the time, after a decade of oil crises and skyrocketing oil prices the turbo prop engine compared well with the current generations of gas guzzling jets, and definitely so for the small regional jets that were becoming competitive in the deregulated US air travel markets. The "wrong choice of engine" was one reason given for shutting down the civilian aircraft venture in 1999. However, this might have been no reason for Saab to shutdown its civilian aircraft activity had it had an opportunity to sell its turbo prop planes for a profit to finance the further development of a new regional jet. Saab was certainly a competent developer of jet aircraft. Also, there was no way to correct for that choice, since the Saab 340 and 2000 aircraft bodies were optimized for turbo prop engines. A change to jet engine propulsion would have required, for instance, that the wings be swept backward, instead of the straight wings of the 340 and 2000 bodies. Such remodeling of old aircraft platforms was not economical.

The Saab 340 and 2000 models had used innovative new techniques from the Gripen project for the aircraft structure, the fuselage, for instance aluminum parts that were bonded together rather than riveted together. These new techniques using light materials are now not only spilling over into Saab's current subsystems contract work for Boeing and Airbus, but have also fed back into the light weight designs and production of JAS 39 Gripen (next chapter).

4.3.1.3 Case 2: Aircraft Engines and Commercial Gas Turbines: Core Technologies

Volvo Aero Corporation or VAC (item 2 in Table 4, See page 51) is a winner within the inner circle of core aircraft technology in Fig. 1 (on page 35). The history of Volvo Aero Corporation (VAC, or for short Vovo Aero, earlier Volvo Flygmotor) is as old as the Swedish Air Force.[7] It was founded in 1930 to build combustion engines (and from 1949 jet engines) on license for Swedish military aircraft. Volvo Aero increasingly modified the engine design and added own technology to fit the special requirements of the different generations of military aircraft developed by Saab.

To begin with Sweden had two competing developers and manufacturers of complex aircraft engines. In 1941 Volvo Flygmotor was commissioned to develop a 24-cylinder air-cooled piston engine, a project that was soon abandoned in favor of jet engines. So Volvo Flygmotor was asked in 1944 to develop a jet engine. At the same time STAL (an ASEA, now ABB, subsidiary) was commissioned to design a similar engine called the Dovern.[8] While the Volvo Flygmotor project had been stopped, work on the Dovern continued. Even though it had been fully tested and was flying, work on the Dovern was also discontinued in the early 1950s and the test benches were used for the modification of the British-designed de Havilland Ghost engine for the Saab 29 "Flying Barrel." For some reason[9] this modification job was awarded to Volvo Flygmotor and the success of that engine project probably would not have been possible without the previous experience from the STAL Dovern project.

Already, in the early postwar period VAC's management began to worry about the low civilian share of production (in 1970 only 10%). Volvo Aero management envisioned a future of empty factories if they did not do something, and began to systematically develop a civilian activity. This reorientation has been quite successful and VAC development and production of advanced components for the three large civilian aircraft engine manufacturers (GE, Pratt & Whitney, and Rolls Royce) in combination with Volvo Aero's commercial aftermarket business currently exceeds 90% of sales. Among European manufacturers of aircraft engines and engine subsystems VAC has been a pioneer in converting itself into a civilian producer. The reason for success (see Eliasson 1995: Chap. 10) is the successful capitalization of military competencies in combination with focusing on a few selected specializations. The civilian reorientation has also benefited from the marketing knowledge and experience residing within the larger Volvo Group.

Volvo Aero developed early relations with all three large aero engine manufacturers of the time (General Electric (GE), Pratt & Whitney (P&W), and Rolls Royce (RR)). The RM6 engine for Saab 35 Draken was a modified version of the RR Avon engine that was manufactured on license from Rolls Royce and was the beginning of a civilian relation with Rolls Royce in the 1950s. The Saab 37 Viggen RM8 was based on the P&W JT8 engine and established a relation with P&W in the 1960s.[10] The Gripen RM 12 engine is based on the GE F404 engine.

Currently Volvo Aero Corporation is focusing on three specialty technology areas to enhance its international competitiveness; lightweight constructions, manufacturing process technology and product support. These are general engineering technology areas of today that warrant special attention. Since they relate to the JAS 39 Gripen project rather than earlier generations of aircraft, they will be presented in the next chapter.

Volvo Aero Corporation recently (2008) announced two new major civilian contracts, one with P&W and one with RR (DI, July 15 and 16, 2008) to which I will return below. One contract was to develop subsystems for the P&W Geared Turbofan engine program that will also involve engine development for the Mitsubishi Regional Jet (MRJ, see BW, August 13, 2007) and for Bombardier aircraft engines. The Geared Turbofan engine is unique in promising to achieve double digit reductions in fuel burn, environmental emissions, engine noise, and operating costs. This is the largest single commercial engine contract ever for Volvo Aero Corporation amounting to SEK 50 billion over 40 years. Volvo Aero's engagement will involve the light weight structures for the intermediate case, the turbine exhaust case and the low pressure turbine shaft (cf. engine break down in Fig. 5B, See page 147).

The second contract was between Volvo Aero Corporation and RR and involved risk and revenue sharing in the development of the Trent XWB engine to be mounted on the Airbus A 350 aircraft. VAC will develop and manufacture the intermediate compressor case. VAC estimates the value of the contract to be 40 billion SEK over 40 years. The competitive securing of this contract was altogether based on VACs superior light weight technologies.

In both the P&W and the RR contracts VAC will participate as a risk sharing partner and also be responsible for its share of after market support. The GE engine in the Next Generation Gripen rolled out in April 2008, furthermore, has laid the foundation for a continued civilian relation to General Electric.

Aerospace is rapidly becoming a new growth area for Volvo Aero Corporation, however, so far dominated by public purchasing of equipment for use in space exploration. Within the space market VAC has developed the construction of engine turbines and nozzles for liquid rocket engines as a specialty. This specialty involves the new electron-beam welding of crack-free welds in cobalt material (Widfeldt and Fryklund 2005:84ff). Together with SNECMA Volvo Aero (as part of an EU program) was awarded in 1984 the contract to develop the nozzles, and the turbines that drive the hydrogen and oxygen pumps in the Vulcan engine for Ariane 5 and has been involved since then in the European Ariane program.

The VAC involvement in space rocket engine development was originally based on its military aircraft engine production. Both military, space, and civilian aircraft and rocket engine development now combine synergistically to make VAC an advanced player in its markets.

While the leading aircraft engine manufacturers focus on the combustor and the high pressure turbine as their core technologies (cf. Fig. 5A, See page 147), that are critical for the engine's fuel economy, noise and environmental performance, Volvo Aero Corporation has developed lightweight structures, manufacturing process technology and lifelong product support as their core specialties. These are competence areas currently much in demand internationally that have broad applicability outside aircraft and space industry.

While military aircraft R&D amounts to almost 50% of VAC's total R&D investment, it is a critical contributor to civilian technological proficiency. Similarly 20% of total VAC R&D goes into space-related projects, the turnover of which is only 2–3% of total VAC sales. There are large synergies between space and military and civilian technology development which makes VAC management worry about a decline in public military and space procurement. The decision in July 2009 of the Swedish Government to continue participating in the European Ariane 5 space rocket project and the European Space Agency (ESA) program was therefore welcome (DI July 16. 2009).

Participation in global, notably European military engine and space programs has been one way of compensating for declining Swedish military procurement. The intimate cooperation between a competent domestic user and both Saab and Volvo Aero Corporation is however difficult to compensate for internationally.

Volvo Aero Corporation, furthermore, is still developing and producing gas turbines for a variety of civilian applications, for instance auxiliary power plants to hospitals. Energy-efficient gas turbines are expected to capture new markets, for instance home heating and automobiles. VAC has spun off six firms, three of them being started by former VAC employees. The six firms currently employ more than 1,000 people in Sweden. Three of the firms, VOAC (owned by US Parker Hannifin since 1996), Trestad Svets (acquired by Siemens), and an automobile heater activity (acquired by German Eberspächer in 1996) will be presented in more detail as secondary spillovers under general engineering below.[11]

Above all, however, the early military engine experience of Volvo Aero Corporation has been the stepping board for advanced engine subsystems development and production for the three large aircraft engine producers in the world, and for ventures into the engine services, maintenance, and upgrading markets (see below).

4.3.2 Related Technologies

4.3.2.1 Case 3: The Early Innovation Market Around Saab

Saab has systematically attempted to capitalize on its own spillovers. A very early Swedish computer industry, first developed within Saab, became a separate division and was incorporated as a separate company (Datasaab) in the 1960s. It had some 3,000 employees when it was acquired by Ericsson in 1981. The Swedish computer industry, however, disappeared in the late 1980s with Ericsson's large Business Information Systems failure.[12] With that, a budding Swedish computer industry also disappeared.

The civilian aircraft project could only be realized on the basis of technology and experience from Saab's earlier military production. Some aircraft technology links exist, but not to the same extent, to the automobile manufacturing that Saab began already in 1946. One innovative spillover from Saab was the early concern with automotive safety in both Saab Automobile and Volvo Car. The efficient cockpit design of the military aircraft was in part transferred to the Saab automobile and the need to press together the legs and arms of the pilot when catapulted out of a crashing aircraft[13] led to the development of a primitive airbag based on Saab sensor technology that was later, in part, transferred to the Swedish automobile safety firm Autoliv (see further Sect. 5.6).

During the years from 1969 to 1996 Saab and the heavy truck manufacturer Scania were merged into one company Saab Scania with Swedish Investor as the main owner. Even though this arrangement was more financial than industrial and technological, a frequent exchange of experience between development and production took place where the two business areas could benefit from each other. For example, Scania took advantage of the knowledge and experience of the aircraft division to design trucks with reduced drag. Scania claims that this corresponds to 10 years of engine design when it comes to reducing fuel consumption. After many ups and downs Saab Automobile was sold to US GM in two stages in 1990 and 1999, and Saab Automobile is suffering from the current (December 2009) distress of US General Motors. When my text is being finalized discussions are going on about whether to sell Saab Automobile, or shut it down.

Saab Aerostructures, as mentioned, has been successfully building up a presence as a specialized systems supplier to the large civilian aircraft manufacturers, and Saab has recently decided to use its military technology as the base for a move into the rapidly expanding civilian security market (see further Sect. 5.8.3). One difficult management problem, however, has been to identify and nurse radically different technologies spilled from the military aircraft business to profitable industrial production and distribution within the parent's management umbrella, eventually to be sold off.

While military aircraft are sold to the government through its technically very competent procurement arm (The FMV), civilian aircraft subsystems and the products from the many firms earlier organized under the Saab Combitech umbrella are designed for and sold in civilian markets that demand a different kind of commercial attention.

Saab was intimately involved in the launch of the first Swedish communications satellite Tele-X during the 1980s. This kick-started Saab's use of light weight composites and the development of new antennae technology, the latter being a parallel development with Gripen antennae technology that was later transferred to Ericsson mobile antennae development (see *Transfer,* No. 4, 2003 and below). These and other space-related activities were combined with Saab Space that was sold to Swiss Ruag Holding in 2008 for 335 million SEK.

In 1999, Saab and Celsius (since 2000 within Saab) acquired the transponder activity within the Swedish Space Corporation (Rymdbolaget). The acquired activity was merged with the existing transponder activity within Saab and a new company *Saab Transpondertech* was formed. Its GPS-based technology is used to monitor marine traffic and has been the base for a successful expansion into the marine security market (*Transfer,* No. 4, 2003). The product of Transpondertech is based on a patent by Håkan Lans which combines GPS-based satellite navigation, air radio technology, and time division multiple access (TDMA) wireless communications technology, the latter being the same technology as that used for a long time in Ericsson mobile telephony (see further Sect. 4.4 below).

4.3.2.2 Case 4: Secondary-Related Industrial Spillovers from the Development and Modification of Aircraft Engines

Aircraft engine development and modification have generated many secondary spillovers several of which have diffused into general engineering production, some of them becoming automotive companies, others being acquired by foreign companies and one being temporarily successful, but later shut down. Six firms spun off from VAC currently employ some 1,000 people in Sweden. They are VOAC that develops and produces hydraulic engines or pumps (now US-owned); a company producing automotive heaters (now German-owned Ebersprecher Nordic), diesel engine component firm Finnveden Powertrain; Toltec which was started by a group of engineers that left VAC and that has become one of the world's largest suppliers of specialty tools for the tire industry; and Trestad Svets AB. To this group once belonged Volvo Aero Engine Services (VAES) that was for some time very successful but then suffered the fate of improved maintenance technology as new generations of aircraft engines that needed much less maintenance than before were introduced (see Sect. 5.7.2 on "maintenance-free" engines). VAES was shutdown in 2007. There is also the important general manufacturing knowledge designing and manufacturing complex light weight structures using welding simulation and high-speed machining technology that is directly related to the JAS 39 Gripen project, that I will return to in the next chapter.

Engine Services

As with aircraft, also aircraft engines are complex machines with a very long service life. This means that service, maintenance, and modernization costs figure importantly in the economics of aircraft engines. Over the expected service life of 25 or more years of the jet engine for a large passenger aircraft the total cost can be divided into three equally large parts for (1) engine purchase, (2) spare parts, and (3) maintenance, repair, and servicing, respectively.[14] *Volvo Aero Engine Services* (VAES) therefore was a direct spillover from the licensed manufacturing of a modified version of the Pratt & Whitney civilian JT8D engine for the military jet fighter Viggen (see further Eliasson 1995:93ff). JT8D was one of the most used civilian jet engines. It was mounted on all DC9s (and all MD 80s) and Boeing 727s. Modifying and manufacturing a military version of this jet engine on license meant that VAC "learned the engine" and hence became both an efficient modifier (first for Swedish military applications) and maintenance operator, serving also civilian jet engines.[15]

At the end of 1992, furthermore, VAC (then still Volvo Flygmotor) had become a partner in the US AGES group. AGES was one of the world's largest trading companies in aircraft/engine components and in engine leasing and maintenance. In 1996, Volvo Aero raised its stake in AGES to a majority holding. In 1999 the company was granted exclusive rights for the sale and distribution of both new and used spares/parts for Boeing's passenger aircraft. In 2001, Volvo Aero owned 95% of the company and changed its name to Volvo Aero Services (VAS). The company is now one of the world's leading providers of services in the aircraft industry (Widfeldt and Fryklund 2005:138). The parallel rapid development of increasingly robust and "maintenance-free" (see below) engines associated with the JAS Gripen development has however undermined the market for VAES. What was soon left was only the too unsophisticated and not very profitable servicing of engines. VAES was therefore shutdown in 2007.

4.3.3 Engineering General

Aircraft and aircraft engine development have generated several secondary spillovers that have come to be used in general engineering production that is quite unrelated to aircraft and aircraft engine production.

4.3.3.1 Case 5: Secondary Spillovers: Hydraulic Engines

Hydraulic pumps

Hydraulic pumps[16] is a secondary spillover from aircraft engine development that became a winner. This story is a good illustration of the nature of entrepreneurship. The Saab 37 Viggen jet fighter needed a stronger fuel pump than the one used on the civilian P&W JT8 engine, and VAC engineers found a design developed by US Sundstrand which had found no use for its invention. A license was acquired in 1969 and VAC engineers began modifying the hydraulic pump for the Viggen. Somehow, they did not succeed and Volvo Aero faced the problem of how to recover the money invested in the license and the redesign. Even though the hydraulic pump was too weak for the military jet engine its capacity was more than sufficient for heavy construction machinery (Widfeldt and Fryklund 2005:76ff). Volvo was first to grasp the significance of this and soon developed a global lead in the use of hydraulics in construction equipment. A separate company (Volvo Hydraulic) was started in 1983 and merged in 1992 with the Atlas Copco subsidiary Monsun Tison into VOAC Hydraulics that employed about 900 people in 1994 (Eliasson 1995:98f). The company was acquired in 1996 by US Parker Hannifin.

Automotive Heaters

The knowhow of Volvo Aero Corporation from aircraft engines and combustion technology was well-protected by patents that could readily be generalized to engine heaters for cars, boats, and other equipment. VAC (then Volvo Flygmotor) started manufacturing these heaters already in 1978, and sold its Ardic business to German Eberspräscher in 1996 (Widfeldt and Fryklund 2005:79ff). Eberspescher Nordic currently employs some 70 people in Sweden.

Diesel Engines

Already during the 1940s Volvo Aero began manufacturing diesel engines for Volvo trucks. One reason was to obtain an even production flow over the business and military procurement cycles, another to earn profits on its competence and its machine equipment. The experience from quality control and achieving engine reliability, learned from aircraft engine manufacturing, could now be transferred to the rest of the Volvo group. In fact, this transfer initiated an entirely new quality control and knowledge transfer program within the Volvo group. The diesel activity became a separate division within Volvo Aero Corporation that was sold to automotive component manufacturer *Finnveden* in 2000, which still employs some 250 people in the old factory.

In 2000, Volvo Aero Corporation brought all staff that was engaged in maintenance, property management, and the management of service equipment and measurement instruments, etc., and that was not critically linked to core production together into a separate company. This company could now work both for the entire Volvo group and for outside customers. This company was later sold to *Coor Service Management* in Trollhättan and currently employs some 230 people. In fact, Coor Service Management recently captured a large 500 M SEK service contract (over 5 years) from Saab (DI September 11, 2008).

Turbo Chargers and Other Civilian Spillovers

Turbo chargers are used to increase the power of a combustion engine without increasing its weight. Volvo Aero's specialist knowledge in hydrodynamics, in compressors and in turbines and as a precision manufacturer came in usefully when it began already in 1960 (as Volvo Flygmotor) to manufacture steering systems for Volvo cars and later of turbo chargers for large trucks. Volvo and Scania Vabis were the largest European users of such turbo chargers for their trucks (Widfeldt and Fryklund 2005:76). It is probably no coincidence that Saab Automobile, for a long time a subsidiary of Saab Scania, was the pioneer of turbo engines in automobiles.

4.3.3.2 Case 6: Integrated Production, Lifelong Product Support and Maintenance-Free Products

Distributed and integrated production, lifelong product support, and the design and development of "maintenance-free" products are the paramount spillover technology that originated in aircraft industry. Its significance for engineering industry in general is highlighted by the integration, first of computing and mechanical technologies and then of the computing and communications (C&C) technologies from the mid-1990s. Today we talk about the integration of electronics and mechanical technologies with software, witness the fact that a large and growing part, far above 50%, of work in the R&D departments of advanced engineering firms is devoted to software engineering. The Internet revolution was born with the integration of computing and communications technologies around the mid-1990s, and it is still moving the globalization of production. Virtual design is another off shoot of the same technology that began in the aircraft industry and is diffusing to the rest of industry. This production organization technology is particularly important when it comes to complex systems products that integrate advanced component systems, the development of which has to be distributed globally over specialist subcontractors. This universal engineering technology is mainly associated with the platform of the fourth generation of combat aircraft that puts the fourth and fifth generation of computing to extensive use (Microprocessor and C&C technologies). This is even more so when it comes to the complex networked defense systems that include the development of sophisticated weaponry, real-time battle field surveillance and management (see further Sect. 5.2). The same is true for the development of products needing much less service than earlier (Sect. 5.7). Easy and less frequent servicing and needing less specialized and skilled workers, was a demand on the JAS 39 Gripen by its customer, FMV. I will therefore return to these two general engineering technologies in the next chapter.

4.3.4 Industry General and Serendipitous Discovery

The outer circle of Fig. 1 (on page 35) is reserved for general industrial spillovers that do not relate to any of the markets of those firms that have spilled the technologies. The receiver competence to pick up such technologies therefore cannot be expected to be available within the established industry, and the loss of winners will easily go unnoticed. Serendipitous discovery talent is required for the identification of odd winning technologies and such entrepreneurial talent is more likely to be available in the external markets for commercializing agents, or with foreign investors, than in-house, in the specialist manufacturing firm where the technology might have originated.

The industrial development programs or ventures to be described below all depend on the early use and integration of sophisticated electronics with mechanical technologies that were pioneered in military aircraft industry. Electronics is known throughout its development history to be particularly spillover intensive (Greenstein and Spiller 1996; Lichtenberg 1993; Mun and Nadiri 2002). Many of the early electronics spillovers that fell outside the aircraft industry proper, hence, were not naturally picked up by Sweden's mechanically inclined engineering firms, even though the Swedish government's computer and electronics committee (*Data och Elektronikkommitten, DEK* 1980) reported that Swedish engineering industry had been very early, compared to other advanced industrial economies, in integrating electronics in their mechanical products.

The following account of successful and failed ventures to capture spillovers from the aircraft industry dominated by electronics content therefore belong to both the pre- and post-JAS 39 Gripen periods. They all should be told, however, in one context and are best understood if told in this chapter. This poses a small didactic problem for me, since the idea of dividing the text into the two Chaps. 4 and 5 has been to isolate the influence of the JAS 39 Gripen development program on the macroeconomy from the influences of the earlier military aircraft development programs. I hope the text will speak for itself when I now lump a large part of the electronics spillover story together in this chapter. The critical spillovers that have moved the macroeconomy in the last decades or so, including the digitalization and rapid break through of Ericsson's mobile telephony owe their origin to the JAS 39 Gripen aircraft systems development.

Sweden and Ericsson were lucky to have both the fixed line telecom and switching technology and the military radio technology under the same corporate hat, even though it took a long time for Ericsson management to understand that the combination, mobile telephony, was a winner (see Sect. 4.4 below). Ericsson was also fortunate to have developed both a military and a civilian digital radio link on the basis of its military radio technology, the civilian link drawing directly on the microwave and antennae technologies developed within the JAS 39 Gripen and space projects by Ericsson Radio Systems and Ericsson Microwave Systems.

The need for a telecom monitoring and control system was more obvious, and when Ericsson's military electronics technology facility in Mölndal had developed such a system for the Saab 37 Viggen jet fighter the group of engineers involved in that task was reorganized to develop a similar system for Ericsson's fixed line telecom networks (see Sect. 4.5).

The need for internal information and communications systems in large business organizations has always been obvious, but not how to design them. When the dream of the "universal information system" reemerged in the information technology business community in the early 1980s, and parallel, as it happened, but independently of the JAS 39 Gripen development program a couple of dozen firms in the international computer, telecom and office information systems market swung into action on the basis of an information misconception. They all failed to the tune of billions of dollars (Eliasson 1996a). Ericsson's business Information Systems (EIS) venture was part of that failure flow (see Sect. 4.7) and it pulled a promising Saab computer business (Datasaab) with it when it failed (see Sect. 4.6).

4.3.5 *Creating a Critical Mass Aircraft Industry Competence Bloc Rich in Spillovers (Case 7)*

The presence of a major industrial player in a local area is likely to influence its industrial environment. Saab has also been the source of new technologies that have initiated the establishment of new businesses not only in Linköping, but across

Sweden. It influenced the orientation of the new technical university established in Linköping in 1969. Through its increasing demands for graduate engineers in computer science (see *Sectra* case in Sect. 4.8) the Linköping technical university was far ahead of all other academic institutions in Sweden to establish a computer science department.[17] Saab has also acted as a competent customer to existing and new specialized subcontractors in the Linköping area and initiated the development of an aircraft industry competence bloc that has reached critical mass, become an attractor for new sophisticated businesses and grown into a prolific spillover generator in all categories of Fig. 1 on page 35 (see Sect. 2.4).

The supply of new technologies in the aircraft competence bloc around Linköping has therefore become an attractive factor behind new firm formation in the area not necessarily based on Saab-generated technologies. Thus, for instance, Saab Missiles in Linköping (after 2000 Saab Bofors Dynamics, SBD) developed guided weapons. The presence of SBD in Linköping has meant that the city also has become a competence center for the integration of computer development, microwave technology, and signal/image processing and recognition. The Swedish defense research company FOI has established its competence center in this technology area in Linköping. Saab Aerosystems and SBD have together developed the integrated control and navigation system for the Gripen weapons (missiles). This development project has spun off several businesses, among them Saab Transponder Tech that has integrated Gripen missile guidance technology with the Lans patented GP&C technology in a civilian anticollision system for marine use and to avoid collisions between civilian aircraft. Autoliv Electronics in Linköping, furthermore, develops anticollision systems for automobiles. (For other spinoffs from guided missile technology see above in Sect. 4.3.2). Environmental externalities from military aircraft industry such as these can be expected to be more local than the well-defined technologies I have identified and described and go beyond what can be captured in econometric spillover studies.

Because of its much larger electronics and software content these more diffuse environmental effects are likely to have increased with the transition from the Viggen to the fourth generation Gripen aircraft and the emergence of distributed and integrated production.

4.4 Digital Mobile Telephony: A Swedish World Success with a Military Origin[18] (Case 8)

The reorganization of Ericsson into one of the world's leading mobile telephone systems companies is one of the most successful internal reorganizations of a large Swedish company ever. Not only was Ericsson close to missing the enormous business opportunity that mobile telephony represented. Ericsson's organization also had to forget about its past technologies. Few would, however, expect that Ericsson owes its success to a long history of military electronics development. It is an embarrassing story that Ericsson top management for years tried to suppress the internal development of radio telephony to free resources for its failed entry into the business information systems market (Eliasson 1995: Chaps. 12 and 13, 1996a:194ff. Also see Sect. 4. 7). Ericsson Radio Systems AB (ERA), a subsidiary of Ericsson, was almost 100% devoted to military electronics. In fact, without a large military activity in radio communications dating back to the WWII years, Ericsson would not today have been an autonomous player in mobile telephony. The failed venture into the business information systems market (EIS) is interesting from an academic point of view. Although practically and commercially wrong it was a perfectly logical conceptualization of what static economic theory suggested management needed to be informed about that guided Ericsson top management, together with top management in more than 40 computer and telecom companies in the world into huge business failures (Eliasson 1996a:Chap. 5, 2005b, 2009). The failed information systems venture of Ericsson also had a military technology base even though this link is a bit far-fetched. More serious, however, is that Ericsson's business information systems failure pulled a budding Swedish computer industry with it (Datasaab) with a well-defined origin in Saab military electronics (see further below Sect. 4.6).

The story of Ericsson's mobile digital telephony success is truly serendipitous and based on three positive circumstances; (1) a curious and innovative customer with plenty of money, the Swedish Telecommunications Agency, that tried for years to get a reluctant Ericsson top management interested in mobile telephony, (2) the existence of a digital, modularized switching technology within Ericsson (the AXE system) and (3) the lucky fact that Ericsson military electronics had developed several technologies that were needed for a rapid advance into mobile telephony. In fact, Ericsson was almost alone among the many telecom companies in the world to have both fixed line telecom systems competence and (military) radio experience in-house.[19] If one of the three legs had been missing, perhaps only one of the part technologies, Ericsson would not be the dominant player in, and perhaps not even an autonomous player in the highly competitive mobile telecom systems market of today.

Strategic decision making based on analytical methods ("analytical strategizing") is commonly taught at business schools. Such decision methods are, however, highly failure prone in what I have called an Experimentally Organized (market) Economy (EOE) in Chap. 2. The EOE exhibits features that carry strong implications for the nonanalytic organization and management of a firm. Above all, *in the EOE it is more important for top management to be attentive to the correction of the business mistakes that are constantly committed than to attempt to do it right from the beginning* (Eliasson 1990a, 1996a:Chap. 6, 2005b). A top management that is neither curious nor attentive to changing market potentials is a common attribute of failing firms in such an experimental setting. The Ericsson venture into the business information systems market was perfectly logical, a transparent case free of disturbing details and based on the misconception of the universal information system capable of uncovering a stable objective truth, well suited for a journal article, but it failed miserably in confrontation with the real market. Competence bloc theory (in Table 2B, See page 43) brings the competent and active customer and two innovations (the AXE system and new military electronics technology) together with the internal commercialization competence and resources of a large firm that clicked in, once the top management of Ericsson understood that it had a winner in-house. This occurred with the change of CEO. The entrepreneurial competence entered in the form of the stubborn manager of Svenska Radio AB (SRA, later Ericsson Radio Systems, a subsidiary) that resisted top management pressure to terminate development work on radio telephony using a secret slush account provided from a military budget.

When Ericsson top management finally realized they had a winner, money was no problem (items 4 and 5 in Table 2B, See page 43) and industrial competence (item 6) to scale up was already available internally. The Ericsson marketing people, however, being more accustomed to deal with a few government customers than with fickle, fashion conscious and unpredictable individuals, turned out not to be experienced players in the consumer electronics markets. Ericsson therefore merged its cell phone business with Sony's into a separate company, *Sony Ericsson* in 2001, which, even though currently (2009) in trouble, has recently been the third or fourth largest player in the world (*Dagens Industri*, February 21, 2001:18f; SvD, October 22, 2008).[20]

Ericsson mobile telephony is so interesting for the subject matter of this document that the story to be properly told requires some background.

4.4.1 The Origin of Nordic Mobile Telephony: How the Advanced Public Customer Initiates a New Swedish Industry

Nordic mobile telephony has a complicated origin. There are three distinct contributions of innovative technology/competence and curious customers prepared to take initiatives. If one of them had been missing, neither Sweden nor Finland would currently represent the core of the world's mobile telephone industry. The *first* critical condition was[21] the existence of a curious, competent, and entrepreneurial telecom authority (at that time a public authority in Sweden), the public customer that initiated experiments with mobile telephony already in the 1940s. The *second* was the existence of an advanced fixed-lines-based telephone industry (Ericsson) that had developed (again together with the customer within a jointly owned company *Ellemtel*) an advanced digital switching system, the AXE system that had already captured a large part of the world's fixed-line telecom systems market. The *third* digital leg was the existence of a number of critical military technologies (notably 4 out of 14 technologies, see Table 7 and Eliasson 1995:102 ff) that were in place at the decisive moment when the global market, notably the US market, was deregulated and became ready for mobile telephony, and rapidly could be activated for civilian use. Ericsson's digital mobile telephony experienced an extreme, by modern Swedish standards, business success during the early 1990s. This third military electronics factor also explains the attention paid to mobile telephony in this book. It should however also be noted that without the early experiments and investments in mobile radio telephony that were initiated by the Swedish telecommunications authority in cooperation with the industry during the 1940s and 1950s, and especially the Nordic cooperation among the customers toward the end of the 1960s, there would probably be no advanced mobile telephony either in Sweden or in Finland today.[22]

Table 7 The critical components of a digital, mobile telephone system

1. Specially designed integrated circuits (so-called ASIC that make extreme miniaturization possible)
2. Circuit designs
3. Software systems
4. Digital signal analysis
5. Modulation
6. Vocoder technology (Voice coding and decoding)
7. Switching technology
8. Roaming
9. Hand-off technology
10. Synchronized frequency jumping
11. Antenna technology
12. Data communication technology (protocool standards, etc.)
13. Error correction
14. Encryption

Sweden did not have a FCC (Federal Communications Commission) type regulatory authority of the US kind. The FCC probably delayed the development of mobile telephony in the USA when it waited until 1983 to release specifications of the first license to operate a mobile telephone system. This gave Europe, and the Nordic countries in particular, a window of opportunity that they exploited, and a lead in analog mobile telephony.[23] Sweden, in particular had an understanding, innovative and driving customer in its Telecom authority (Televerket) that offered, not only direct cooperation, but also initiated a Nordic cooperation when it came to developing and introducing a Nordic Standard (NMT, Nordic Mobile Telephone network).

This story runs like this: A manual mobile telephony system MTD was designed and introduced in Sweden during the early 1970s. Due to its design the capacity of the MTD was limited to a small number of subscribers and the system therefore became expensive to operate. During the 1970s the future automatic mobile telecom system was discussed and developed through a cooperative arrangement between Ericsson's Svenska Radio Aktiebolaget (SRA), on the one hand, and the Nordic telecom authorities on the other. This system was ready for introduction in 1980 and 1981. It was entirely analog and was operated at the 450-MHz band. This development was civilian and without any links to the military, but it was based on specifications from a very competent, curious and interested procurement agency, the customer, the Swedish Televerket.

4.4.2 The Emergence of Digital Mobile Telephony as a Swedish World Success

Soon after NMT had been introduced in the Nordic countries in the late 1970s the US authorities woke up. Specifications from the FCC in 1983 for the licensing and operation of a US mobile phone system AMPS (Advanced Mobile Phone System) differed from the Swedish NMT system in two ways. FCC

1. Specified a higher frequency range, namely 900 MHz and
2. Demanded a different signaling system, FSK (Frequency Shift Keying)

The big problem was the higher frequency. Ericsson, however, just happened to have developed for its military radio a new *tactical radio link* that operated close to the US frequency specification (760–960 MHz). This military technology therefore became a bridge that allowed Ericsson's civilian analog telephone business to be rapidly introduced in the US market.

The higher frequency used in military radio communications also turned out to have an advantage in civilian mobile telephony under the TDMA technology on which GSM and Ericsson's mobile business is (was) based (see below), since signals could be compacted more densely.

Sweden has been a technological leader in the development of data communication links for the military. It began already in the 1960s with the Saab jet fighter Viggen. With the fourth generation combat aircraft Gripen digital technology and digital data communications were necessary to make communication between all the microprocessors of an "unstable aircraft" (Gripen) possible. The microprocessors were available in the market when development work on the JAS 39 Gripen began. The task now was to engineer

- The data communication between the microprocessors within the aircraft, and
- Communications between aircraft

This task involved heavy software development. Ericsson and Saab did it together. This development work on data communications was taking place at the same time as Ericsson was readying itself for the US mobile telecom market in the early 1980s.

Analog mobile radio communications now rapidly advanced into digital technology, an advance that was decisive for the rapid development of Ericsson's mobile telephony. Digital radio telephony had a military origin among most of Ericsson's competitors (in Motorola, to begin with Ericsson's worst competitor, both on the military and the civilian sides). Historically Ericsson had been responsible for the development of fixed land-based radio communications, while AGA, the large international Swedish gas company that was attempting to diversify into high technology ventures, among them radio, was responsible for military radio technology in the air. The problem in both cases was to achieve maximum robustness vis a vis deliberate enemy disturbance. Therefore they had developed the frequency hopping technique for the first time in the world around 1980. The purpose of frequency hopping was to confuse, through frequent frequency shifting, active radio disturbance by the enemy. Reliable radio communications between different units (land vehicles, airplanes and central command units, etc.) often decides the outcome in mobile battle by small decentralized units, the actions of which have to be coordinated.[24]

The frequency hopping technique could be directly used in the GSM-system to raise the quality of voice communication. Even though AGA (and later Bofors and Celsius) developed an advanced technique to correct for frequency drift in radio communications at fast speeds that could be used both with analog communications (early) and digital communications (later), they lacked the complementary technology infrastructure that the Ericsson group possessed. In addition, high speed was not a problem with civilian mobile telephony.

Frequency hopping is used in the radio systems of both the Swedish Army and the Air Force. The mobile telecom systems do not have to be designed to deal with deliberate hostile disturbances, but frequency hopping means higher robustness when it comes to accidental disturbances and therefore has become an increasingly used voice quality enhancing technology in mobile telephony.

It should also be mentioned in this context that the radio system for the Swedish Army that ERA (Ericsson Radio Systems AB, since 2006 within the Saab group) developed at the beginning of the 1980s was the first (in Sweden) genuine digital radio system. When digitization of Ericsson's mobile telephony system began during the 1980s, military radio technology within Ericsson had already been digitized and the people from the military radio development moved over to the civilian radio activity within Ericsson. Ericsson's move into mobile telephony, hence, had its beginning in military radio communication.

4.4.3 The Critical Technology Elements of the Early Digital Mobile Telephone System

The development of a cellular mobile telephone system requires specialized competencies within at least 14 technology areas and systems, listed in Table 7. At the time at least four of them had a clear military origin. The specialist competences are one thing, the art of integrating them into a functioning system another. Systems integration is an additional competence where military aircraft industry has long excelled (see Sect. 5.3).

Mobile telephony requires a systems integration competence, and not only a number of individual specialist competences. All component systems have to be integrated and made functional as one single system. This is an art rather than a specialty that can only be developed within the right industrial culture where many specialist teams have developed the art of working together with a view to a common whole.[25] Saab was the early developer and user of that competence and in the beginning Ericsson recruited engineers with that experience from Saab (Gustafsson and Lindvall 1978). It has gradually become a specialty of some of the Swedish manufacturing firms and the competences in integrated production developed in those firms have diffused to other industries as people embodying those competences have moved between jobs (see Case 3 in Sect. 4.3.2 above). I am not only talking about the competence to organize distributed and integrated production, but also, and not less important, about the capacity of subcontractor firms to understand the role they play in the larger complex they participate in, and adjust their behavior accordingly. This is also why we have compared the Swedish aircraft industry, and notably Saab, with a unique and very advanced technical university that not only represents top of the line specialties in a number of technical areas, but also, and distinguishing itself favorably from the academic universities, the art of integrating those technologies in the design of a very complex product that functions and even can be sold in international markets.

The development of mobile telephony was, and is dependent on a small group of talented engineers who had been placed to head strategic teams within Ericsson. Their task was to work together with an eye to the functioning of the system as a whole (systems integration).

Cellular mobile telephony is based on the partition of the geography into cells within which communication between a stationary station and a mobile station can be maintained through relatively weak radio transmitters. The system of base stations constantly stays in contact with all turned on mobile terminals within the cell. When a terminal (for instance, in a car) leaves the cell, the system searches to find the terminal in a new cell. This technology of searching is called *roaming* (item 8 in Table 7).

Both the earlier analog and the current digital mobile telephony with a cellular organization and low-effect (weak) communication within the cell were originally developed and patented by Bell during the 1940s. Since the remaining specialized technologies needed to establish a cellular mobile system were lacking nobody saw any use of the Bell patent. The technology was forgotten to emerge again during the 1970s when the development of a mobile telephony system was being discussed in both the Nordic countries and in the USA.

Hand-off technology (item 9 in Table 7) is critical within mobile telephony. When the quality of an ongoing telephone conversation has been reduced too much the telephone conversation has to be automatically moved on to a new base station. Hand-off technology does that. To choose a better base station the system has to continuously measure both the signal level of ongoing telephone conversations and the signal level of adjacent base stations. When the signal level of the ongoing conversation sinks below that of another station the system immediately moves the conversation to the new station without any audible disruption.

There is also the possibility that a better quality can be obtained through a change of frequency which can only be achieved in digital mobile systems through a synchronized *frequency jump* (item 10). The conversation can then be switched during an ongoing conversation, again without an audible disruption. With this technology it is not necessary to stay on a "bad frequency," which is a problem in bad radio environments, for instance in the center of cities.

Besides the roaming, hand-off and synchronized frequency-jumping technologies there are 11 more listed in Table 7.

Specialized and *miniaturized integrated circuits* (item 1, so-called ASIC) allowed Ericsson engineers to get the physical size of both land-based equipment and terminals down. Special *circuit design* (item 2) and *program code* (item 3) were needed.

Modulation (item 5) technologies were roughly the same in military and civilian radio communications. In both applications, it was important to filter out the message from the noise. Since advanced radio telephony began to be developed for the military the direction of contributions was from the military to later civilian applications.

Encryption (item 14), which is almost impossible in analog radio communication pushed the early introduction of digital radio communications for military use (see *Sectra* on digital technology and digital encryption in Sect. 4.8). The need for rapid digital *signal analysis* (item 4) and *error correction* (item 13) constituted strong early incentives to digitize military communications. The rapid development of process capacity of computers soon made digital technology totally superior to analog communication. This was apparent already in the 1970s (Eliasson 1980: 253ff, 1981).

The mid-1990s saw the revolutionary introduction of the *Internet age*. In 1994 Mosaic Corporation (called *Netscape* from 1995) introduced the first graphic browser. As computer capacity increased and computing process costs decreased, civilian applications based on military technology to handle complex systems soon entered the market, for instance within Internet communications, secure payment systems, etc. In retrospect, those links are obvious. The interesting thing is that when I wrote the earlier book on this theme (Eliasson 1995) there appeared to exist no understanding at that time of the potential future economic significance of the Internet neither in the business community or in the professional media following the developments.[26] The Internet is perhaps the single most important military-related spillover creation when it comes to macroeconomic consequences. Even though a single ingenious innovation (a browser that was simple to use) started it all off in 1994, this was only possible because of a sequence of earlier instances of military (mostly) and civilian public procurement.

Error correction is particularly interesting. The introduction of digital technology was held back by a slow development of the use of *digital signal analysis* for *error correction*. Without error correction the loss of signals is too large. Speech is very redundant. Analog noise can therefore be corrected for, if not otherwise by the question: "What did you say?"

A loss of bits above 10% is however difficult to correct for in digital telephony. This digital error correction was originally developed for military use, for instance satellite photography and to correct for radar echoes. Cosmic noise is however easy to correct for compared to variation in the radiation fields on earth, where mountains and buildings block communications in an erratic, nonstochastic way. Signals then often reach the minimum level where they cannot be heard. This is called *fading*. A number of difficult mathematical techniques to correct for fading to achieve an even signal quality has been developed. Error correction techniques have also been developed rapidly in pace with the development of computer technology and the emergence of fast computers with large capacities. While this technique has a military origin, today both the military and the civilian application areas are large and rapidly growing, not least when it comes to graphic communications and image recognition. In fact, the development of guided weapons by Sabb Bofors Dynamics for the Gripen has created a separate competence bloc in signal analysis, microwave communication and the design of very compact and robust systems that has generated a flow of sophisticated civilian spillovers.[27]

An interesting illustration of military to civilian production spillovers from the end of the cold war is the lay off in California of thousands of IT engineers from military industry. These engineers moved into Hollywood, and have been instrumental in revolutionizing the movie industry (animation) and to the automotive industry where they have helped the car manufacturers to develop advanced virtual design technology.

The military use of high frequencies came in usefully again in the mid-1980s when Ericsson was about to enter the Japanese mobile telephony market. Here Erieye technology (see below) came in usefully with individually (electrically) directed antennae (Eliasson 1995:108). The Japanese used high frequencies. The advantage with high frequencies is that signals can be compacted more densely. Ericsson therefore developed the complete digital mobile telephony system based on TDMA (Time Division Multiple Access) technology on which GSM was based for both the Japanese and the European markets already at the beginning of the 1990s. Ericsson had by that time already modified its system for the US market and therefore was able to offer a complete TDMA product also there. Hence, Ericsson was the only firm in the world at that time that could offer complete digital mobile systems ready to use for the three large markets: the USA, Europe, and Japan.

4.4.4 Advanced Consumer Electronics

Ericsson belongs to the exclusive but rapidly growing group of firms in which almost all production consists of product development and different forms of service production such as marketing, servicing, and modernization and sometimes running of the systems. In addition, as much as 90% of product development consists of software development. The strategy of Ericsson has increasingly been to outsource physical manufacturing and focus on systems design, development and integration, maintenance, technical servicing, modernization, and (increasingly) on operating the mobile telecom systems installed, outsourcing almost all physical manufacturing in between. Thus, for instance, Ericsson recently landed its largest order ever, when its Global Services division contracted to operate US Sprint Next's mobile telecom network (DI, July 10, 2009) Apparently the integrated systems competence once developed in the military product development together with Saab[28] has made it possible to focus on such profitable segments of the value chain.

Early on Ericsson also produced mobile terminals, embodying very sophisticated consumer electronics, where miniaturization, physical robustness and easy handling were important features.

While the first mobile terminals were large and bulky boxes that required significant manual craftsmanship to manufacture (4 h to assemble in 1982), Ericsson in 1994 had introduced technology for the mass manufacturing of five million GSM terminals a year, or more digital terminals than both Motorola and Nokia, requiring only 12 min of manual work per terminal. Ericsson top management expected that his manufacturing process technology would make the company competitive even at the high Swedish wage levels. With this edge in digital technology Ericsson management was convinced (in 1995) that it would soon be the largest manufacturer of mobile terminals in the world.

It did not help. Terminal manufacturing never became a profitable business within Ericsson even though Ericsson at least in the beginning had that extra edge in manufacturing efficiency and also was able to integrate its systems and terminal designs to achieve better quality of voice and data transmissions. The high speed and efficient production line was not sufficiently flexible to accommodate fickle and fashion conscious customers. The latter was not Ericsson's thing. In 2001, Ericsson merged its terminal business with Sony's into a separate company, *Sony Ericsson*. Sony contributed customer and marketing knowledge, Ericsson technology.

4.4.5 One Technology Wave After Another: Nobody Is Safe

In the last 20 years or so telephone technology has moved at breakneck speeds, and each technology generation changes into another every few years. The analog NMT system was based on Frequency Division Multiple Access (FDMA) technology. One carrier radio frequency was needed for each phone call. This analog technique was very capacity demanding. Once mobile telephony had grown into a volume business the need for more efficient solutions became acute. Military radio technology based on TDMA technology within Ericsson, notably the digital troop radio, together with the other military technologies listed above became the foundation for the rapid development of Ericsson's digital TDMA technology during the 1980s. Under TDMA one radio wave is modulated digitally with a number of channels (calls) partitioned in time. GSM had eight such channels.

The military TDMA was a complete digital system (even the calls were transmitted digitally) that was developed into the civilian *Global System for Mobile service* (GSM) which became the European digital mobile telephone standard. The once military synchronized frequency-jumping technology now became critical for the quality of voice transmissions and to make it possible for senders and receivers to stay in touch. The frequency jumps were synchronized when the signal became too weak. This frequency jumping was monitored through a digital signal that was constantly switched on.

Ericsson got its own civilian TDMA system accepted by the FCC in the USA in the 1980s. It was there called DAMPS. DAMPS is not a version of GSM. Instead of eight calls per carrier radio frequency, as in GSM, DAMPS can only handle three. By way of an advanced vocoder technology these three channels have been squeezed into 30 KHz, which is much less than the 200 required by GSM. The smaller frequency range, however, lowers the voice quality in the US system. But these specifications have been deliberately chosen. With its system Ericsson, according to its management, was the top of the line world developer and producer of telecom systems. For a while, it appeared as if the US telephone equipment producers were prepared to accept TDMA as the mobile standard. Suddenly, however, in the early 1990s a number of telephone operators became interested in an alternative system: Code Division Multiple Access (CDMA), also a military radio technology that was developed in the USA. Under CDMA each call carries one address (a code). All calls are then carried on a digitally modulated radio wave, and the calls are sorted out at the receiving end. CDMA was developed by QualComm and was used in the Vietnam War already during the 1970s. CDMA had been partly adopted by Motorola and AT&T, but by the early 1990s it had still not been possible to make the CDMA system operational in civilian contexts. One problem with CDMA was that its capacity was heavily taxed by the administration needed to distribute signals in batches as well as to collect and integrate them again at the receiver end. Computers were not up to that at the time. Even though promises were extended that it would soon become operational it took far too long to see any civilian application that worked.

CDMA may be a more advanced technology than TDMA but the US mobile telephone market was impatient. The telephone operators had paid large sums for the frequency slots that FCC auctioned off during 1994 and 1995. They could not afford to wait for the US companies (QualComm, Motorola, and AT&T, or rather, since 1996, Lucent Technologies, AT&Ts technology arm, which merged with France's Alcatel into Alcatel-Lucent in 2006) to get their CDMA systems to the market. It was not enough for the operators to be offered better systems in the future, the systems had to be much better to make it profitable for the operators to wait, and the technology providers could still not guarantee that their better systems would neither be delivered on time nor work, which they did not. So Ericsson, with a functioning TDMA system in the market, won the first round. But technical change was continuing, and much of it now within the civilian telephony, an increasing part of the competition originating in the US computer industry. Currently (2009) CDMA appears to be a fading technology (see below).

Around the mid-1990s the US president was concerned about the lagging US companies and announced an initiative, the Personal Communications System (PCS), which was part of his earlier so-called information highway initiative (Eliasson 1995:112). The idea was to integrate mobile telephony with the existing fixed line telephone systems to make it possible for several competing networks to function simultaneously and to raise technological competition in the field.

This initiative was, however, both political and late. The same development was already on the way spontaneously in the market and Ericsson's *Minilink* (with a military radio origin, see Sect. 5.2) became an effective facilitator for the private competing mobile telephone systems operators to interconnect with the fixed line systems.

By the mid-1990s technological change was already heading toward *broadband digital mobile telecommunications* (BTDMA). That technology was expected to be needed for the wireless transfer of the large data volumes that (inter alia) multimedia would require. Multimedia was then expected soon to become an integral part of the mobile Internet.

This development in turn required a corresponding upgrading of switching technology, Ericsson's core technology. The standard circuit coupled AXE switches (circuit switches) when connected ties up the entire system and cannot be used for broadband transfer under a PCS system. So an entirely new packet-switching technology was being developed for mobile telephony. The Asynchrous Transfer Mode (ATM) technology wraps up telephone and data calls in packets. This switching technology had already been in use for a considerable time in the computer industry in so-called Local Area Networks (LANs). And Ericsson's past in combined mechanical and electronic telecom technologies no longer carried any advantage in this new market, probably the opposite.

The telecom crisis of 2000/2001 was triggered by the extreme auction of 3G licenses that initiated a wave of optimism in the equipment industry (Ericsson, Nokia, Motorola, Nortel, etc.), a bubble that collapsed when the operators got cold feet about the prices paid and the demand now realistically expected. The entire industry on both sides of the Atlantic went through a shake out and thousands of people had to go from the large equipment makers (Eliasson 2002a:149ff). In the wake of that crisis, telecom equipment makers such as Ericsson, Lucent, Motorola, Nortel, and Philips emerged much reduced in size, but the market had sorted out Ericsson and Nokia as the promising players in the mobile telecom systems market.

Ericsson's reorganization toward product development at the one end, and the installation, servicing and (sometimes) operating of the mobile systems, on the other hand, meant that software programming now made up the bulk of development work, perhaps more than 90%. Even though Saab has been a pioneer developer of software engineering (see next chapter) this was not necessarily a Swedish competitive advantage.

Even though Ericsson's market is enormous and Ericsson the dominant player with 29% market share (SvD, September 30, 2008) the swift technological winds expose Ericsson to dangerous competitive challenges from two ends. As mobile and fixed line telephony converge the *Internet protocol* (ip) that merges voice, data, and multimedia increases in importance and raises competition from router developers such as *Cisco*.[29] To counter that challenge, Ericsson acquired a share in US Juniper in 1997, only to be forced to sell it in stages during the telecom crisis that struck in 2000 and 2001, realizing a huge capital gain (see further Technical Supplement S2).

Computer makers and related communications firms (Cisco, Intel, and Google in particular, and even Nokia) from the USA are edging into the mobile telecom systems markets pushing in different directions. Computer industry and data communications technologies offer a challenge. Small computers, using the Linux operating system are becoming mobile communicators (SvD, October 5, 2009) and Cisco's routers represent dangerous competition. Ericsson has initiated a joint project with Intel in which Intel's new platform for very small computers is to be integrated with Ericsson's modems that give the computer a constant broadband connection via the mobile networks. The trend around 2008 appeared to be toward very small computers (so-called netbooks) that are constantly connected to the Internet and that are often undistinguishable from the very advanced mobiles (SvD, November 3, 2008). The other challenge, surprisingly, did not come from the old established players, but from the new Chinese upstart Huawei, that does not at all offer old technology at a low price. Already in 2004 Huawei had set up office in Kista, the mobile telecom valley of Sweden in Stockholm, to spy on Ericsson (*Ny Teknik*, Del 2, No. 21, March 19, 2004) as did Chinese ZTE (founded in 1985) that established a research center in Kista in 2008 (*Ny Teknik*, September 17, 2008, SvD, September 30, 2008). Change in Ericsson's markets has therefore been fast and there is no way for the company to relax (*The Economist*, September 26, 2009, Special Report:10f).

To cope with the new situation and to focus Ericsson has shedded defense electronics (to Saab in 2006), the office switches (not long ago the technology core of Ericsson's bold venture EIS into business information systems, in 2008). On technical platforms for mobile telephony, Ericsson has merged with Swiss ST to make their platform technology more generic and available to other systems developers. The shifting of focus toward Symbian and Windows mobile platforms means that the recently acquired Uiq platform technology is put aside (DI, June 25, 2008). Instead Ericsson has been on a buying spree to complement missing technologies, so far for 60 billion SEK. Marconi, and its fiber optics technology that will combine with the minilink technology, was acquired for 17 billion SEK in October 2005, Redback in December 2006 for its broadband routers (for 13 billion), and Tandberg in February 2007 for its ip-tv compacting technology (for 10 billion).[30]

Ericsson is now an almost 100% mobile-based telephone systems company. To prepare for future technology and market developments Ericsson has reorganized itself into three business areas; Networks (the largest with 63% of sales in 2007), Professional Services (the promising growth engine with 23% of sales), and Multimedia, the most recent business area with 8% of sales.

Most competitors have now given up on Ericsson's core business, mobile high performance telephone systems. Nokia and Siemens merged their underperforming mobile systems businesses into Nokia Siemens Networks in 2007. Alcatel-Lucent, currently the world leader in fixed line and broadband telecom systems has not given up on mobile telephony. It is however locked into the US CDMA standard that is losing market share and WiMax, which Ericsson does not believe in, and lags far behind in GSM technology and notably in Ericsson's specialty Long-Term Evolution (LTE) or "Super-3G" technology[31] (BW, April 8, 2002; SvD September 3, 2008; DI, May 23 and September 6, 2008). Ericsson recently (DI, September 16, 2009) captured an LTE order from Metro PCS, the fifth largest mobile telecom operator in the USA. But both Nokia Siemens Networks and Alcatel-Lucent have been rapidly losing market shares and money in the last few years, and Nokia Siemens Networks at times have appeared ready to back out, at least of Ericsson's core business (DI, September 2, 2008).

The business situation is however far from simple. Ericsson is expecting a surge in mobile services that demand large data transmission capacity such as multimedia, games and search services. The question is whether Ericsson will enjoy that increase in demand indirectly from the telephone operators service businesses such as Apple's IPhone, Youtube, etc. that hire transmission services from the operators at low prices, or directly from the operators, that still have rather thin profit margins. Even though Ericsson has been the largest and technologically leading mobile systems developer in the world its share owners have since 1980 not enjoyed more value growth than a passive investor who has followed the index. Intense competition is quoted as the reason. But the company has no choice but to go on investing heavily in R&D (DI, Nov. 28, 2008). So far, however, Ericsson's main technology choices seem to have been the right ones even though it has left a string of mistaken acquisitions along the way. And Sony Ericsson is currently (2009) suffering.

Ericsson is developing its next generation network brain called IP Multimedia Systems (IMS) for multimedia applications that will make it simpler for the operators to offer sophisticated services.

Ericsson is also involved in developing its Gigabit Passive Optical Network (GPON) system for AT&T to be used for data transmission to firms and homes over high capacity optical fiber, a technology that was acquired with the purchase of Entrisphere in the USA in 2007.

4.4.6 A Number of Civilian Opportunities and Challenges

Solid-state technology, integrated circuits, and the miniaturization of electronic equipment that can withstand bad weather, extreme temperatures and physical shocks, as before have their origin in military electronics. Producers of military products that were intense in their use of those electronic technologies therefore had an advantage when civilian applications were developed. As civilian mobile telephony developed, the civilian producers developed their own technology capabilities. Today civilian technology often spills back to the military side. There are now many more players in the market and the flows go in both directions. Above all, the integration of standard subsystems and components from the shelf in large integrated product systems has reduced the obsolescence problem since each subcontractor keeps upgrading its specialist subsystems and components maintaining their interface standards.

Some producers with a (now) dominant civilian production (such as Volvo Aero Corporation) still consider the large R&D content of its now small military production critical for maintaining its civilian competitive edge. Ericsson, however, sold out almost all of its military electronics activity (in 2006), most of it to Saab, and is confident that it will stay competitive without it.

More than a decade ago mobile telephony was predicted to take over completely, even though much of the traffic would still be carried by both land-based (fixed line) and radio systems. This prediction has come more or less true and today almost the entire business of Ericsson is mobile based. The telecom equipment manufacturers that were slow in getting into mobile systems and going digital are still suffering or out of business. Motorola was slow in getting out of analog mobile telephony and has not recovered. French Alcatel and American Lucent (previously the technology arm of AT&T) merged in 2006 to become competitive and are still struggling to get their act together. And the joint venture between Siemens and Nokia to beat Ericsson in mobile systems appeared to be moving toward a breakup in late 2008 (DI, September 2, 2008).

4.4.7 Summing Up

Technology development has however continued at breakneck speeds and made unexpected turns. Mobile broadband is already here making mobile Internet a reality.

Mobile payment systems and banking is available. Mobile entertainment and games seem to be winners among the young, using up large data transmission capacity because of its large demands on higher and higher resolution graphics.

Computer makers are entering the digital mobile market from their end, mobile telephone equipment makers such as Ericsson and Nokia are developing their terminals into computers and mobile systems makers are expanding their systems for high-speed transmission of large volumes of data besides video and voice. Also mobile terminals are increasingly used to surf on the Internet, make payments and communicate by e-mail. The military orientation toward a networked defense constitutes a parallel development of similar technologies, but it is now more difficult than before to tell which is the strongest driving force, military or civilian technology. It is obvious, however, that the civilian and military projects will be mutually reinforcing in developing new technology and in keeping costs down on both sides (Axelson et al. 2004).

Aircraft production and distributed production technology are increasingly taking in virtual technology that requires enormous data communication capacity and (in military applications in particular) secure communications, which raise capacity demands even further.

The emergence of modern digital mobile telephony, therefore, has been a story about entrepreneurship in at the time a complicated and in large parts unknown composite technology where a number of specialized technologies and systems have had to be integrated, a composite technology area within which the different specialized technologies still, after almost 20 years, advance at a breakneck speed, and so fast that no established producer can feel safe. This means, for instance, that the entry into this market has been impossible without the backing of a large company with large financial resources. It has also meant, and will mean in the future, that the telephone operators may suddenly decide to shift to a new and more advanced system leaving existing equipment and systems developers without customers.

The critical factors behind Ericsson's success so far are mostly the ability to chose, and the competence to develop and combine the right technology mix, but also the fact that critical technologies already existed and that Ericsson management at the time (but dangerously late) saw the opportunity to enter the market, and the US market in particular, fast and ahead of their competitors. This was especially the case for the digital technology embodied in the *tactical radio link* and the digital *MiniLink* that Ericsson had developed in its microwave business in Mölndal during the 1980s for civilian markets on its military technology (see Sect. 5.2). Without that the rapid development of Ericsson's digital mobile telephony during the 1990s would not have been possible, and the window of opportunity opened up was no more than a few months.

This means that while Ericsson's telephone business in general, and notably its mobile telephone business, owes a lot to military radio systems development within Ericsson since the 1970s, the critical moment occurred when digital technology catapulted Ericsson into the new market based on the new digital data communications technology developed for the new military communications system of which JAS 39 Gripen was the central part. Therefore Ericsson's mobile telephone business, also including its part in Sony Ericsson belongs to the commercialized spillover flow of the JAS 39 Gripen systems development. To estimate the magnitude of spillover values created, I will have to say something on what Ericsson and some other firms would have done with the resources now engaged in the mobile business had they failed in entering digital mobile telephony. This question is appropriate since several large competitors have failed, or are struggling to come back. The question is a difficult one that will have to be based on a number of more or less reasonable assumptions that I will clarify in the Technical Supplement S2.

Swedish mobile telephony, furthermore, would not have developed naturally and favorably from the traditional fixed lines telephone technology within Ericsson. Telecom equipment makers without radio technology in their portfolio did not fare well in the market and neither did companies with only radio technology such as Motorola, which in addition was dangerously slow to go digital. The existence of military radio technology within the Ericsson group of companies, and digital radio technology in particular during the 1980s, on the other hand, was decisive for the success of mobile telephony and the speed with which it could be introduced. The merger of computers and digital telephony is, however, still as serious a challenge to the entire mobile telephone market as it was when my 1995 book was published. Apple has successfully entered the sophisticated end of the terminal business with its iPhone and is challenging both Sony Ericsson and Nokia, and Ericsson is constantly raising the capacity of its mobile networks to accommodate the increasing data flows that come with mobile Internet browsing, graphics communications, and mobile multimedia. So the competition between digital mobile and computer technologies from the US West Coast and increasingly sophisticated mobile networks and terminals is still being sorted out.

It should finally be recalled that the development of mobile telephony was to a significant extent the result of a clandestine activity within Ericsson financed through a military slush account and moved by the ingenuity and stubbornness of a single person (Åke Lundqvist, at the time head of SRA, later ERA). It was not the outcome of a planned corporate strategy. Quite the opposite. During the critical early 1980s Ericsson's top management was stubbornly opposed to mobile telephony and focusing on the failed attempt of EIS to enter the business information systems market, a venture that also pulled down the budding Saab computer business with it (see Sect. 4.7). So, generally speaking, without an advanced military radio activity within Ericsson at the time, Ericsson today would not be the dominant player that it is in mobile telecom systems, perhaps not an autonomous player at all.

4.5 Secondary Spillovers: Ericsson HP Telecom and Telecom Monitoring and Control Systems (Industry General, Case 9)

Ericsson HP Telecommunications (EHPT) illustrates the positive industrial spillover benefits embodied in a mobile group of people that has learned to solve a particular type of difficult technical problem. A modern aircraft, and notably a fast, high performance jet fighter needs an onboard monitoring and control system for all its avionics that “sounds an alarm” when something malfunctions, and preferably also automatically corrects the situation by turning on a backup system. Digital technology made such control systems feasible. The first versions of Saab’s Viggen were electronically analog, but the later fighter version was one of the first third generation combat aircraft which combined extensive use of digital electronics with mechanical technology. For that version of Viggen Ericsson Microwave Systems in Gothenburg/ Mölndal (already at the end of the 1960s) developed a centralized digital control system. (JAS 39 Gripen is a fully digitized fourth generation fighter aircraft based on distributed computing. Even internationally the Gripen system was equipped with an early and pioneering digital control system that Ericsson had designed and this would not have been possible without the prior upgrading of the Viggen electronics.)

Also Telecom networks need similar control systems to reorient traffic when one link crashes. Ericsson understood that there was a demand for such a control system to monitor their large land-based AXE switches and systems. They also understood that the experience from solving organizational programming problems for the Viggen control system would be useful here. Hence, the engineers from the military software development project were assigned to this civilian project. Toward the end of the 1970s the Automated Operations Maintenance (AOM) 101 system was ready to be installed in the AXE fixed line switches for Saudi Arabia and Australia. The AOM system was proprietary to Ericsson’s own telecom system and used proprietary software. The system was therefore further developed in 1990 into an open UNIX-based architecture called Telecommunications Management and Operations Support (TMOS). Again the experience from both the military system and from AOM 101 constituted the foundation for the new system. The open UNIX-based TMOS control system was introduced in 1990.

The civilian AOM 101 and TMOS systems did not use the same software as the military system. The military solutions were too specialized. But engineers from the military development team had learnt to solve the organizational programming problems when designing the control system for the fighter version of Viggen. They were familiar with digital signal analysis and could readily transfer their experience to the civilian program.

The control systems AOM and TMOS were operating in real time and performed, in order of complexity, three main tasks:

1. Fault management
2. Performance management
3. Configuration management

It is difficult to define the interface between the three steps/tasks. Fault management is concerned with correcting partial errors. Performance management involves measuring and controlling the service quality of the entire system. TMOS, for instance, was the system that monitored signal strength of individual calls in Ericsson’s mobile system. If a cable breaks in the land-based telecom system TMOS automatically redirects traffic.

Configuration management, finally, is about optimizing the long-term changes in the organization of the telecom system.

Real-time digital monitoring and control has a potentially very large application area, not least in the development of civil security technology and crisis management. The electrical grid is one example and the economic value of being able to overcome electricity supply break downs such as the North East US failure in 1965[32] and the more recent blackout in New York is enormous. More generally, the task is to keep complex systems up and running even when some critical links collapse, for instance to mobilize fire brigades and ambulances over large distances even when communications have failed. It is obvious that problems of this kind were first encountered, and had to be solved, in the context of large-scale military operations, but they are becoming a challenge in the civilian life of the increasingly complex Western industrialized economies. The Celsius group, since 2000 within Ericsson, has long been working on such real-time based crisis management systems, including real-time based command systems, also these based originally on military technology.

But the telecom control systems needed advanced computing technology that Ericsson did not have. Hence, a cooperation with HP was established and *Ericsson HP Telecommunications* (EHPT) was founded in 1993. Ericsson HP was however 100% oriented toward mobile and land-based telecom systems, old and new. One argument against broadening the business application range was that it is difficult, requires specialist application competence for each field, that Ericsson's business agenda was already sufficiently fragmented and that earlier failed attempts advised against it.

At that time, the telecom market was considered more than sufficient to support future growth of Ericsson Hewlett Packard's products. There was no limit to the need for such control systems in mobile and land-based telecom systems alone, even though an even larger demand existed outside telecom. Ericsson HP Telecom therefore decided to stay within their own business area. The company employed 1,200 people in 2001. In 2001 Ericsson acquired HP's 40% share in EHPT and the company has since then been internalized within Ericsson. Again, this is an example of second generation spillovers from a military development program that dates back to the end of the 1960s.

4.6 The Emergence and Disappearance of a Swedish Computer Industry[33] (Industry General, Case 10)

Saab engineers could always use more computing capacity to solve their design problems than was available. They were thus very early users of computers and advanced customers of the early computing industry. To solve their computing problems they, in fact, developed their own computers and in particular in conjunction with developing similar computers for their products/aircraft. They designed a vacuum tube-based computer SARA in the 1950s to support the design of the Saab 32 Lansen and 35 Draken. For aircraft missiles to be carried by the Viggen jet fighter Saab engineers designed a fully transistorized control computer already during the second half of the 1950s. This control computer was redesigned for civilian use in 1960 as *Sank* or D2. Hence, Saab was first in Europe with a fully transistorized computer, and about a year after the launching of RCA's, Remington Rand's, and IBM's transistorized computers in the USA. This computer convinced Saab management that the decisions of the pilot on the next generation combat aircraft Viggen should be supported by a central digital computer.[34] Saab had a minicomputer ready in 1962 which became the basis for *Datasaab*, the computer division within Saab that soon had some 3,000 employees and was later spun off as a separate company. Technologically, hence, Sweden and Saab were occupying a joint leadership position in the global market for transistorized computers in 1959/1960 together with seven US manufacturers.

Datasaab was acquired by Ericsson in 1980 and 1981 as part of Ericsson's failed venture into Business Information Systems (next section). The budding Swedish computer industry died with that venture (more on this in Eliasson 1998b).

In a way Saab should, however, be lucky to have left the computer business in time. The entire computer industry went down when IBM launched its 360 system in the mid-1960s based on integrated circuits, killed its own, and not even 5-year-old generation of transistor based computers in passing, and then went on to global prominence. Competition returned through the establishment of a number of minicomputer firms, most of them in the USA, and Digital (or DEC) soon rose to become the second largest computer business in the world. With the launching (by IBM) of the standardized PC in 1981[35] based on microprocessor technology, however, a struggling minicomputer industry (Digital,[36] Prime, Wang, Nixdorf, Norsk Data, Olivetti, Tandberg, etc.) more or less disappeared from the market.

4.7 The Business Information Systems Venture of Ericsson (EIS, Case 11)

Economic development builds on business experiments. Many, perhaps most experiments fail, and the costs of failure should be regarded as a normal cost for economic development. It is therefore important for society not only to organize complete competence blocs (see Sect. 2.4) to make project selection efficient and to minimize the loss of winning business experiments, but also for society to be organized such that its inhabitants are capable of coping with the social consequences of unavoidable business mistakes. The story of industrial spillovers around Swedish aircraft industry, to be complete, therefore has to include the spectacular failure of Ericsson Information Systems (EIS).

Quite often business failure depends on some critical complementary technology not being available, on an exaggerated appraisal of the importance of own technology, or on the difficulties of integrating the various technologies and the market knowledge needed to get the entire business act together. Common to all such ventures is that all difficulties cannot be foreseen. Experimentation is always necessary and in an experimentally organized economy you don't know until you have tried.

Sometimes the logic of a proposed business venture is so convincing that it carries everybody but a few along, even though it was in practice entirely wrong. This was the case with EIS.

Hard engineering work made Ericsson the winner with its fixed line circuit telecom switch AXE which embodied an ingenious failsafe doubled computer device based on a modular design that made the system both very reliable and easy to upgrade. As a consequence, Ericsson had a large internal cash flow to invest in the 1980s. Ericsson opted for developing an integrated office and business information system around its digital office switch Eripax for data communications. All Ericsson resources were needed for, and concentrated on this business information systems venture. Odd internal ideas about mobile telephony therefore were discouraged or even forced out. The fact that Ericsson drew an enormous winning ticket in mobile telephony was therefore accidental and not the result of a deliberate strategy. EIS, on the other hand was.

Parallel to the EIS venture Celsius Industries, notably its Celsius Tech division (since 2000 within Saab) initiated its own venture *Celsius Information Systems* (CIS) seemingly occupying almost the same market niche.[37]

CIS had a clear military origin. The strategic idea was to transfer the competence of Celsius in military information technology to the civilian market. On the surface the project therefore looked similar to the EIS venture. The basic competence input in CIS, however, was in computing and communications technologies and software programming with applications in real-time command and management systems, competences that could naturally be extended to air traffic control, rescue operations, the police, fire protection, and the taxi business. One could therefore say that Celsius was developing very concrete solutions to well-defined control problems while Ericsson was on to a much more abstract management problem; how to be informed (centrally) about what is going on internally in a large company. CIS was introduced on the Stockholm Stock Exchange in 1996 under the name *Enator* (Eliasson 1996a:197f). Enator merged with Finnish Tieto in 2000 under the name TietoEnator and changed the name to Tieto in 2008.

EIS had no direct foundation in military technology, except that it had been increasingly based on complementary acquisitions of external technologies/firms, notably from Saab, most of which had a military origin. All that went down with EIS, most of which was sold to Nokia 1988.

The pure strategy of EIS was to develop an office and business information system around Ericsson's office switch MD110 and the digital switch Eripax for data communications. As I have already mentioned, this strategy was in no way unique. At that time a number of telecom firms entered the same international market on the same idea and at least six of them on the basis of their office switch (Northern Telecom, Siemens, Mitel, Rolm, AT&T, and American Bell). Word processing and copying technology were vehicles for the same ambition in an even larger number of firms (Xerox, Exxon, Canon, Ricoh, 3M, Lanier). Computing was the technology platform of 12 companies venturing into the same business information systems market. Among these companies were, in chronological order of entry, IBM, Burroughs, DEC, Univac, Olivetti, Honeywell Bull, Prime, HP, and Philips. No company possessed both telecom and computing technology internally and they were frantically attempting to acquire or develop the missing technology through acquisitions (Eliasson 1996a:243ff). Ericsson soon discovered the need for complementary computer competence and acquired Datasaab and Facit in 1980 and 1981, and with them almost the entire hardware part of Sweden's computer industry and parts of Swedish software industry.

Ericsson had begun experimenting with digital technology already during the 1960s in its military electronics business, but no advanced computer competence existed within the company. None of the above companies understood in time that digital office switches were not by far in the neighborhood of possessing the data communications and fast transmission capacities that were required. The first local area networks (LANs) that did that were developed by Xerox during the 1970s (the Ethernet), but it took most of the 1980s before this technology was available for business information systems applications.

As the internal digital switch was found to be inadequate for the purpose, and more critical complementary competencies had to be acquired even for a simple office information system the now deregulated telecom market in the USA (during the first years of the 1980s) was swamped with entrepreneurs that created a formidable explosion in innovations in the US computer and communications markets. Computer firms entered the telecom market and vice versa. Not only had Ericsson failed to solve the increasing number of technical problems it faced. Soon the company was lagging technologically in a large number of critical areas which it had acquired through large complementary investments. The PC was one example. What looked perfectly logical became a nightmare. In 1988, EIS sold its failing PC activity and the commercially successful Alphascope (also a military-related Saab innovation) to Nokia. Nokia messed up further and sold it on to British ICL in 1991. ICL was not up to it either and was acquired by Fujitsu, the largest computer maker in Japan which was very mainframe oriented and wanted a foot in the PC market. Fujitsu acquired ICL to learn the PC market. It purchased a Swedish technology that can be traced all the way back, by way of Ericsson, to Saab's early venture into computing to support its own development of combat aircraft during the 1950s and 1960s.

It can be said that Saab's early computer knowledge in Datasaab that was acquired by Ericsson was a necessary condition for Ericsson's EIS venture. Computer technology of the kind Ericsson needed was so to speak available in the local Swedish market. In addition to the difficulty of identifying what kind of information product was needed for the management of a large company and its offices, Ericsson was not capable of integrating its own core competences (telecommunications) with the additional number of technologies, including computing, that a complete information systems product needed and that had to be acquired externally (the systems integration competence). It may also have been the case that the early successes of Datasaab, and the Alphascope in particular (it had become an international success) made Ericsson management overconfident. Ericsson underestimated the pace of development within information technology in the USA. When Ericsson had acquired most of the Swedish firms in the computer market (hardware and software) and finally realized the enormity of the task it had taken on, it shut down the venture and with it the budding Swedish computer industry.

Common to EIS and practically all international competition had been a shallow knowledge of what the business information product they were developing was supposed to be used for (Eliasson 1996a). The adventurous companies also lacked both the internal knowledge needed and the necessary complementary hardware.

4.8 Medical Technology Spillovers (Sectra): A Creative Entrepreneurial Environment (Case 12)

Already in the 1950s Saab needed computers to design the Draken aircraft. It developed its own computer SARA ("Saabs Automatiska Räkne Apparat") and soon understood that computers would define future industrial development. To that end Saab convinced educational authorities to establish the first department of computer science in Sweden at the new Linköping Institute of Technology (founded in 1969). Saab's continued work on developing its own computers and the supply of graduate engineers specialized in computer science became the foundation of *Datasaab* (see Sect.4.6 above). At the same time Saab was experimenting with medical applications for its computer technology, so the Linköping Institute of Technology opened up a separate medical technology department.[38] The founder of *Sectra* (1978) came from that department at Linköping University. Sectra was founded on a device for SECure TRAnsmissions (SECTRA) of voice over the regular telephone network on contract for Swedish military defense. Sectra is still the leader in encryption technology for the Swedish defense. Since the mid-1990s Sectra delivers its Tiger mobile telephone encryption system to several European countries. As late as 2005 FMV asked Sectra to develop a new crypto module for data communication in different telephone networks that was robust and resistant to both humidity and shocks.

In the mid-1980s, however, another person from the department of computer science at the Institute of Technology in Linköping joined Sectra with a vision of digital radiology and imaging. Combining the medical knowledge with its electronic computer platform Sectra was on track into its currently largest business, digital medical imaging based on mammography. Computer-based image processing has been one specialty developed around Saab (Notably Saab Missiles, or since the merger with Bofors Missiles in 2000, Saab Bofors Dynamics) and the Linköping Technical Institute. Computer-enhanced detection has made it possible for Sectra to use very low-intensity X-ray radiation. Sectra's knowledge in communications security has come in perfectly when it comes to making the transmission of very large data volumes needed for communicating medical images secure. Currently Sectra is surfing on a strong digitalization wave and digital mammography and image analysis in health-care services is planned to be its largest business area. Sectra has ambitions to introduce its microdose system on the very large US health-care market but regulators there take their time to give their OK (DI, August 18, 2008 and September 15, 2009).

Saab has continued to spill medical technology applications that have come out of a large number of military technologies. Among them should be mentioned:

- Saab, Linköping University and FOI are studying improved diagnostic techniques for heart disease by simulating blood flows in and around the heart. The project experiments with mathematical simulation models similar to those Saab used to simulate airflows around an aircraft. High resolution magnetic camera technology is combined with computer simulation modeling to understand such blood flows and raise measurement precision (*Transfer,* No. 4, 2003).
- A team within Saab Tech is working with digital register systems. Saab Bofors Dynamics has developed a telewar simulator. The capacity to manage very large flows of data will be critical both for the development of unmanned aerial vehicles (UAVs) and for the performance of the networked defense systems of the future. A critical part of such systems is a timeless memory structure that can cope with very large data flows, high dataflow speeds and continuously streaming data. Such technologies have many civilian applications and a company within the Saab group was founded (*HS Memory AB)* to deliver such civilian applications (*Transfer,* No. 4, 2003), but has later been shut down.
- The development of a new G-suit for fighter pilots also resulted in an elastic sock made of a smart (piezoelectric) material which can be used to help people with circulatory problems such as edema. This innovation came out of a patented method to control skin pressure developed for the G-suit that was small enough not to prevent the movements of arms in the cockpit. Some materials of polymer type can be activated by an electric current. It changes its form and functions as an artificial muscle. *SMM Medical* was founded on this innovation (*Transfer,* No. 4, 2003).
- Saab's specialty to keep track of a complex of details has come in usefully for a new contract with FMV to organize a field hospital for the Swedish Battle Group. Saab does not manufacture anything but organizes the system, makes it function.
- Rfid chips with memory developed and used within Saab has found a number of applications in hospital care.
- Saab is also developing sensors to be mounted on, or attached to soldiers in battle dress to monitor their state of health.
- For some time Saab took over the manufacturing of the radiation knife for Elekta from Motala Verkstad that was not capable of doing the job. For Saab's fragmented production agenda this was however too small a job, so Saab trained Motala Verkstad for the task and the manufacturing task went back to them. Again, this illustrates Saab's role as a technical university.

4.9 Notes

1. See Olsson (1987:26).
2. It should also be mentioned here that the Gripen spillover estimates in the next chapter for practical reasons exclude spillovers from the development of

Gripen-related weapons systems. Weapons development within Saab Bofors Dynamics, notably on guided missiles, is currently the subject of a separate inquiry.

3. This has in fact turned out to be a benefit for Gripen's future and for export sales, since it slows the obscolesence rate of the aircraft considerably compared to competing aircraft. See further Technical Supplement S1.
4. They are France, Russia, the UK, the USA, and Sweden and perhaps China.
5. This objective is very clearly stated in the Norwegian *Avropet til Rammeavtalen* between the Norwegian Defense and Treasury Departments, signed Nov. 29, 2005, Pkt 2.1.
6. Now Saab Microwave Systems. While Ericsson has been unloading almost all military radio technology and focusing on its mobile telephone systems, Saab sold off its space business in 2008 to focus on activities with a common technology platform with its military aircraft business.
7. See further *Flygmotor, 1930–2005, Volvo Aero*, Värnamo: Air Historic Research.
8. A project headed by Curt Nicolin, later CEO of ASEA and chairman of ABB, and of the *Industrial Institute for Economic and Social Research (IUI)* for many years.
9. See *Mekanisten* 1, 2008:16–18. The Dovern military jet engine still exists in modified versions, among other things as backup electrical generators for ships, hospitals, etc. Siemens acquired the business 2003 from ABB and is currently (SvD April 18, 2008) experiencing a booming demand for its turbines for steam-generated electrical power based on solar energy.
10. The civilian version of this engine (JT8D-200) is mounted on the back of all DC 9s. Learning to manufacture that engine was the beginning of Volvo Aero Engine Services (VAES) that for some time was a profitable business within VAC (see below).
11. The other three are *Coor Service Management* that Volvo Aero spun off as a separate company in 2000, *Finnveden Power Train* that took over VAC's diesel activity in 2000 and *Toltec Trestad*, one of the world's largest suppliers of specialty tools for the tire industry.
12. See Eliasson (2009) and Eliasson (1995: Chaps. 12 and 13), and Sect. 4.7 below.
13. The first ejection seat in the world was developed by Saab already in the 1940s for the Saab J21 with a propeller engine mounted in the rear of the aircraft, pushing it forward. The ejection seat was necessary to catapult the pilot above the propeller.
14. The numbers are for the civilian version of the Viggen RM 8 engine, or the P&W JT8D-200 engine mounted on the back of all DC9s (Eliasson 1995:93f).
15. See Widfeldt and Fryklund (2005:79ff) and Eliasson (1995:94ff).
16. The same as a hydraulic machine. Its function decides whether it is called a pump or an engine.
17. On this Agrawal and Cockburn (2002) note that the establishment of a large, local R&D-intensive firm – what they call an "anchor tenant" – enhances local

industrial productivity by making local university research more likely to be absorbed by local industry. To this should be added the positive innovative influence of the advanced firm on the university, and a newly established university in particular, and on the entire local industrial climate.

18. This section on mobile telephony should logically be placed in the next chapter being more related to spillovers associated with the development of a Swedish centralized information and command system (STRIL 90), a forerunner of what has more recently been called a *networked defense system*, that began in the 1980s and to which the JAS 39 Gripen aircraft development belongs, than to earlier military aircraft projects (see further Sect. 5.2). However, from the point of view of systematic presentation it belongs here, to be followed by the Ericsson HP (EHPT) joint venture which is a clear Viggen spillover, and the Minilink, which is a commercialization for civilian mobile telephony of the military data communications technology associated with the Gripen project.
19. See Ericsson's annual report for 1983. Nokia was perhaps also an exception. Nokia's business, however, is primarily in mobile terminals where Ericsson did not score a success. Nokia, in turn, still (2009) has to show its industrial prowess in mobile telephone systems (see further footnote 22 and below).
20. Sony Ericsson is owned by Ericsson and Sony (one half each). It has a small CHQ in London. Its center for mobile terminal development is in Lund, Sweden. It employs 12,000 people, but is currently (2009) going through a crisis period, concentrating and shedding about 2000 people.
21. See Hulten and Möllerud (1993, 1995).
22. In Finland the DX digital switch was instrumental. The government owned electronics company *Televa* had developed radio telephone systems for the Finnish army. Nokia acquired Televa in 1981. See Bruun and Wallen (1999:49ff) and Stenbock (2001:86ff).
23. See Meurling and Jeans (1994).
24. This the French learned the hard way when German tanks coordinated by radio communications and crossing through neutral Belgium succeeded in invading the country in a few days. General Heinz Guerdian, the innovative promoter of the German *panzerwaffe*, however, had been forced for a long time to convince the traditional German generals of the merits of this new war technology (Barnett 1989: Chap. 19). It did not take long, however, for the Allies to come up with effective counter technologies.
25. It has to be remarked in passing that this is a nonanalytical competence the development of which presents specialized academic research and teaching environments with a disadvantage that cannot be overcome without changing the organization, the culture and end objectives of academe.
26. The same was the case with the US White House Report on *National Critical Future Technologies* published in March 1995 by the Office of Science and Technology, Executive Office of the President, to be discussed further in Sect. 5.1.
27. See further Sect. 5.9.3 and Technical Supplement S2. Spillovers from weapons development have not been included in the Gripen spillover multiplier estimate even though they have been presented as cases.

28. Saab engineers with systems experience have long been in demand in other industries, including Ericsson, where they have fetched higher salaries (Gustafsson and Lindvall 1978).
29. Cisco, however, argues that Ericsson and Cisco rather complement each other. Cisco, for instance does not intend to enter the base station market (DI, Oct. 24, 2008).
30. Other acquisitions are Spanish Netspira (software) in June 2005); Norwegian Axxessit (connecting platforms) in June 2005, Swedish Netwise in June 2006, the latter to be better at connecting telephony and data transmission, US Entrisphere for fiber access in February 2007, Swedish Mobeon for Ip-based message services in March 2007, German LHWS (software for payment systems for three billion) in June 2007, Swedish Drutt Corp (mobile services platforms) in June 2007 and Spanish HyC for ip-tv consulting services in December 2007. The acquisitions of Marconi, Redback, and Entrisphere have been made to make Ericsson competitive in Alcatel-Lucent's specialty adsl and fiber broadband equipment (DI, May 23, 2008). Altogether this adds up to 60 billion to compare with sales of defense electronics and office switches for 4.4 billion (SvD, September 23, 2008).

    However also Nokia has been on a buying spree to add capacity to its ambition to develop terminals that are constantly accessed to Interent services (SvD, Oct. 3, 2009) and Cisco is offering to buy Norwegian Tandberg's HD video activity as part of its ambition to enter the high quality end of video conferencing (DI, October 2, 2009).
31. That speeds up downloading of data far beyond Turbo-3G.
32. See Sharefkin's (1983:300f) analysis of the controllability of complex dynamical systems, and energy systems in particular.
33. This section is presented in more detail in Eliasson (1998b).
34. *Datasaabs historia*, 1994, Linköping:Tema D2, 1994:6ff.
35. Using Microsoft as the supplier of the operating system. The first PC was introduced in 1977 by Apple.
36. Digital was acquired by Compaq 1998 that became the world's largest PC maker. The new company merged in 2002 with HP.
37. CIS was founded when the Telub, Dotcom, and Enator activities within the Celsius group were merged. CIS became a subsidiary under Celsius AB in 1995.
38. In fact, the Linköping Technical University or Institute of Technology that it is also called, at the time were alone in offering the three academic specializations: computer science, medical technology, and industrial economics.

Chapter 5
Looking into the Future on JAS Gripen Spillovers

While the previous chapter has been devoted to tracing the origin of spillovers that have already been identified, I now take on the more difficult task of looking ahead. I will identify spillover cases originating in the JAS 39 Gripen multirole fighter aircraft development. While some JAS 39 Gripen spillover cases can be clearly identified and defined, others mix in with pre-Gripen aircraft technology development. Ericsson's digital mobile telephony, for instance, is an intermediate case. It originated in Ericsson's military radio technology, but has benefitted from the general development toward a networked defense from the early 1980s of which JAS 39 Gripen was the core capability.[1] Many JAS 39 Gripen spillovers, furthermore, still have a long way to go to materialize in the form of "statistically visible" cases.

The JAS 39 Gripen aircraft is in many ways special. Its flexible physical design structure, extensive reliance for functionality on distributed digital electronics and extremely low-cost maintenance, or even "maintenance-free" design will guarantee a longer life than that of the Saab Viggen combat aircraft and, above all, have made modifications for export sales possible. This chapter still, however, will have to include a touch of speculative analysis.

There will also be a section of clear ex post character, namely the Swedish JAS 39 Gripen spillovers that failed to be commercialized, or were picked up by foreign subcontractors.

The life of the Swedish fourth generation multirole combat aircraft system JAS 39 Gripen is expected to cover more than half a century. Design of the aircraft platform began in 1980, the first prototype was flown in 1988, the first production aircraft was delivered in 1993 and redesigned and modernized versions of the aircraft are expected to still be in service by 2035, perhaps even by 2045. The versions then flying will look quite similar to the first aircraft delivered in the 1990s, but they are entirely different aircraft when it comes to performance. Many of the aircraft in the Swedish air force flying in the 2030s will have left the Saab production line already but be thoroughly reequipped and modernized one or more times over. New embedded electronics and software make the difference. The Viggen software was updated every 18 months on average. The Gripen software is updated much more frequently, or continuously. Hence, the *Next Generation* Gripen first presented in April 2008 more or less looks the same[2] as earlier versions, but has a stronger

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engine, can carry a larger weapons load, has a 40% longer range, better avionics and above all the advanced electronics that makes all this possible.

Military aircraft systems development of today also illustrates the extreme complexity of the different subsystems to be integrated. For modern fighter jets dog fights are an outmoded type of combat. Modern weapons can be fired from long distances, long before the pilot can see the target. Targets are identified and its coordinates determined through separate surveillance and communications systems and the information transmitted to the weapons system of the aircraft. The pilot locks the weapon on the target and fires, and then disappears before the attack has been discovered and the weapon keeps track of the moving target until it hits. Obviously the integration of weapons carrier (the aircraft), the weapon (perhaps a missile), the targeting and the guidance system becomes a very complicated task, especially when carrier, weapon, and targets may all be moving at supersonic speeds. JAS 39 Gripen in fact was defined from the beginning to become the backbone of an early "networked defense system" that allowed for real-time communication both between the aircraft and a land-based command central and between aircraft (see further below). A very large number of different technologies have to be integrated to create such a system and many of them can be modified for civilian applications. Saab Missiles (now Saab Bofors Dynamics) has in fact been a prolific generator of spillovers.

The integration of the weapons system with the aircraft system and external information and communications systems in real time by necessity becomes highly specialized, but sometimes (as in the JAS 39 Gripen case) the aircraft can switch between mission tasks in mid air (the swing-role capacity, a unique Gripen feature for many years), for instance from attack of a land-based target, to defense from attacks by enemy aircraft and to surveillance, provided the necessary weaponry and equipment had been mounted on the aircraft before it took off. This functional flexibility in flight is all the result of modern electronics technology and an ingeniously flexible design of the physical platform. It is interesting to note again that the weapons system developer/integrator of the JAS 39 Gripen (Saab Missiles, today Saab Bofors Dynamics) has spun off a number of civilian technologies (See further above under Sect. 5.3).

As will be further elaborated below the upgrading of the fourth generation aircraft JAS 39 Gripen from its initial and generally designed hardware platform, the development of which began in 1980, is largely a matter of redesigning the electronic software embodied in the aircraft, as is the flexibility just mentioned that allows the aircraft to switch between fighter tasks, attack and surveillance in flight. Such flexibility in product design for customized uses over the life cycle is increasingly demanded of complex products in industry, from automobiles to telephone systems. The ingenuity of the early platform design explains much of this flexibility, but it also depends critically on high capacity and robust computers, special safety-critical software (see Sect. 5.4) and data communication devices. In this sense aircraft industry uses already today the production technologies of future engineering industry. This is one additional and rational reason for the concern of advanced industrial nations about having an in-house aircraft industry.[3] It functions as a technical university that delivers technology, education, and training services free of charge to other firms in related industries and of a kind closer to production and use than the more academically inclined technical universities are capable of providing (Eliasson 1996b). It is difficult and takes a very long time to develop such an industry. Only the five permanent member countries on the UN Security Council plus Sweden have the capacity to develop and build a complete military combat aircraft system. Five more countries should be added if we include also small civilian passenger aircraft.[4] This competence to develop a complete aircraft (with Saab in Sweden), including (see below) a civilian regional aircraft, also spills goodwill value to the entire Swedish engineering industry and should allow its firms to add a quality brand margin when pricing its products.

5.1 Spillover Areas: A Brief Survey

In a report in 1995 from The *Office of Science & Technology Policy* from the White House entitled *National Critical Technologies Report,* a list of "technologies of the future" was presented. From the point of view of this study, two observations of the report are particularly interesting. *First*, of the 27 future technology areas listed, 17 are used in or developed for the design and production of military aircraft. *Second*, and somewhat puzzling, there is no mention of the integration of computer and communications technologies, and the Internet as a future critical technology area and a mover of economic growth. This was more or less the year when the Internet revolution took off quite abruptly. The years just before and just after 1995 the discussions of technology forecasters and economists rather focused on robotics and factory automation (Carlsson 1995) and the so-called productivity paradox formulated by the American economist and "Nobel prize" winner Robert Solow. How come we have seen so little economic progress in the statistics despite the enormous investments in computer and communications equipment of the past decade (Solow 1987, Berndt and Malone 1995)?

Fortunately for the real economic world, aircraft industry, and the military aircraft industry in particular, had understood the critical industrial potential of C&C technologies early and begun to implement them. Since 1995 digital computing and communications technologies have radically changed the industrial landscape of the global economy and the early pioneer in introducing digital technology has been the military aircraft industry.

In the second half of the 1970s the Swedish Government's so-called computer and electronics committee (*Data och Elektronik Kommitten, DEK*) observed that the revolutionary nature of electronics was digitization technology, that Swedish engineering industry was ahead of the rest of the industrial world in incorporating digital devices in mechanical products and that the early use of those technologies in Swedish aircraft industry gave the Swedish engineering industry at large a competitive edge (DEK 1980; Eliasson 1980). Saab and Swedish military aircraft industry may even have served as a vehicle to bring advanced US technology to Sweden throughout the cold-war period; and this transfer of technology to Sweden through the military industry may explain the exceptional growth performance of Swedish engineering industry during the same period, a growth that was further supported by the internal reallocation of financial resources within the Wallenberg group of firms to engineering firms, also during the same period. This would then also explain the observation of the DEK Government Committee mentioned above.

These were summary observations from the previous chapter.

The fourth generation combat aircraft JAS 39 Gripen development, the concern of this chapter, pioneered a number of product features that have later been incorporated in new generations of aircraft. It was also far more intensive in its use of digital technology, and therefore much more spillover intensive than earlier combat aircraft generations. In fact, Gripen was designed to be the backbone of an early version of a networked defense system. This also means differences in the nature of spillovers.

In the previous chapter, focus was on a number of well-defined spillover cases from Swedish military aircraft development and production. These cases could be presented in great detail because they were dated far back in time, well defined, observed, and their origin well documented.

The JAS 39 Gripen story includes a number of such well-defined cases that are each interesting on their own merits, including the success story of Ericsson digital mobile telephony that partly belongs to this chapter even though it was presented in the previous chapter. The JAS 39 Gripen development, due to its systems complexity and extreme integration of electronics with other industrial technologies, however, also features the evolution of several generic industrial technologies and new product markets that will, if successfully assimilated in Swedish industrial practice, have a decisive influence on its future development, notably the future of Swedish engineering industry. The main reason for the enhanced intensity of generic spillovers is the larger computing and communications technology content of development work. So even though it is difficult, or close to impossible, because the data needed is missing, to identify and establish the very large and very long-term influences econometrically of generic technology diffusion, it is probably safe to conclude that the Swedish aircraft industry has been, and will continue to serve Swedish engineering industry as a very advanced technical university and, as such, be part of the general industrial infrastructure.

The main technology areas where aircraft industry has provided technological services to manufacturing industry at large is the development of *systems integration competences*, or the integration of the many technologies needed to develop particular product functionalities, a competence where academic institutions are by their organization inferior. The main beneficiary of such systems competencies from military aircraft industry has been engineering industry that has witnessed a revolutionary integration of digital electronics and mechanical technology through software since the 1970s, and notably an industry specialization toward large and complex product systems where Swedish industry has excelled.

I am talking of both design, engineering and manufacturing support from digital information technology and the integration of digital devices in new and increasingly complex products. The latter took a great leap forward with the invention (by Intel) of the microprocessor in 1971. The microprocessor was immediately adopted in the later modifications of the Saab 37 Viggen and put to extensive use in the JAS 39 Gripen aircraft.

Complex high performance products with a long life such as aircraft also pioneered the use, and integration of (see Table 6 on page 51):

- New materials
- Hydraulic devices
- Sensors and measurement devices
- Digital connections by fiber optics
- Computers to integrate and coordinate functions

It is not possible to trace the origin of all individual applications, but we know that Saab military aircraft was a pioneer user and developer and it is possible to trace some civilian applications (to be reported on) back to their military origin.

The development cost of advanced systems products of today has a *software programming* content well above 50%, in many cases 90% and above. In response to that a large and partly separate software engineering industry has developed and become a critical technology for engineering industry at large (Sect. 5.3 and 5.4).

Aircraft industry has also been a pioneer in distributing production over specialized subcontractors. The reason has been the high cost of subsystems and the strict demands on performance which overcame transport costs early. Being an early practitioner, the aircraft industry therefore took advantage of the reduction in global transport costs over the last three or four decades, and above all the dramatic improvements in product functionalities that came with the integration of computing and communications (C&C) technologies that ushered in the Internet age from the mid-1990s.

New C&C technologies made it possible to distribute and integrate production over geographical distances and markets of specialist subcontractors. *Distributed and integrated production* has therefore become a defined industrial technology that deserves special attention. Globalization is the popular catch word.

With the global distribution and integration of production come specialist competencies in

- Modularization (part of what today is called systems architecture)
- Exact definition of modular interfaces
- High-quality measurement
- Customization of products
- Precision manufacturing
- Reliable delivery times
- Quality control
- Traceability

The further development of complex products into systems that deliver services rather than hardware has already opened up a new market agenda, and especially for products with a long life. Product Life Management (PLM) methods originated in aircraft industry.

Advanced sensor technology figures importantly in the control of complex systems products such as aircraft. To reduce maintenance costs of aircraft and aircraft engines, sensors are increasingly used to monitor the health of the different functions that make up the whole.

Embedded systems or subsystems modules within which a number of electronic and mechanical functions have been integrated can be made smaller, lighter, and more robust and allow for easy replacement.

In aircraft flying at supersonic speeds and relying more on instruments than actual vision, the *man–machine interfaces* become critical for pilot performance and hence for aircraft performance. Saab and Ericsson have developed a unique integrated digitized instrumentation for the JAS 39 Gripen the presentation of which can be flexibly changed to suit the particular tasks of the combat situation. This technology has been partly transferred to the Saab automobile.

Modern weapons technology for military aircraft is using digital image analysis and pattern recognition extensively to guide weapons to targets far beyond human vision, a technology that has found its way into several civilian applications.

A related area of great importance to engineering industry is the capacity of C&C technology to visualize product designs and functionalities using virtual methods to achieve flexible product designs, and perhaps even more importantly the construction of "maintenance-free" products. Maintenance-free aircraft was, in fact, a property forced upon the JAS 39 Gripen designers by the customer FMV and this technology has gradually diffused to engineering industry at large. The change from calendar-based servicing of aircraft and aircraft engines to measured and monitored servicing has radically reduced maintenance costs and idle time of the equipment.

Virtual design is another technology with large future potential productivity effects. It makes it possible to deal with complexity in design and development work, and also to work with subcontractors over large geographical distances. It makes it possible to foresee the wear and tear on products and to attend to maintenance problems already at the early design phases. The technology already exists in large parts but data communications capacity in real time is still a limiting factor. On the military side the use of virtual design is often prevented because of secrecy problems. Encryption will never be completely safe. Since the potential is so large, however, aircraft industry cannot afford to abstain from using this technology. Military aircraft industry therefore will probably be a leader when it comes to developing encryption technology for uses where large data communication capacity is needed. It is interesting to observe that the Linköping company Sectra (see Case 12) has two product specializations; secure data and voice communications for the military over regular telephone networks and digital medical imaging and communication. We should, in fact, observe already here that secure communications is exactly the technology that is limiting the rate of introduction of e-trade and e-business, i.e., of the possibilities of safe business transactions and payments in particular. "Information security is the enabler for electronic markets" (McKnight and Bailey 1998:19).

An additional generic and future engineering technology spawned by Gripen development is the use of lightweight construction. It was demanded of the JAS 39

Gripen designers that the aircraft be light and fuel efficient and be able to fly longer and faster. Such lightweight structures were needed both for the aircraft fuselage and the engine. Here, the use of composites came in importantly.

Thus, more recent energy and environmental concerns have opened up new agendas for innovative industrial development where the JAS 39 Gripen project has pioneered the use of *new materials and lightweight structures* and new stress calculation methods in engineering products (see further Sect. 5.5).

We are talking about a broad range of industrial systems technologies that may turn out to be the savior of engineering industry, the back bone of the rich, high-wage industrial economies since the industrial revolution. This technology is so important that it deserves a separate section.

As systems are developed and their integration takes precedence over physical manufacturing, digital computing, and communications (C&C) technologies are becoming even more important. As Saab develops toward a "systems house" that focuses on concepts and development rather than on manufacturing, new opportunities open up for partners to pick up advanced subcontracting jobs.

The transition away from specific physical weapons platforms to integrated networked defense systems based on increasingly complex computing and communications technologies is already changing both the nature of military hardware development and of civilian spillovers. The JAS 39 Gripen, in fact, was designed as the backbone of the first, even though at the time primitive, networked defense system. I therefore begin with that.

5.2 The Erieye Surveillance System, Electrically Directed Antennae and the Minilink: The Development of an Early Networked Defense System Moving Ericsson Mobile Telephony On (Case 13)

Networked or Network-Centric Warfare (NCW) and real-time-based defense systems are topical issues in current military discussions. An aircraft platform carries little military capacity in itself. The weapons make the difference, and if weapons can be effectively integrated within the aircraft capabilities increase radically. Similarly, real-time surveillance capabilities, target identification, guided weapons, and effective coordination of aircraft and other land-based or naval vehicles are together rapidly changing the nature of modern physical warfare. Superiority in virtual and electronic warfare may even in the long run eliminate the need for traditional physical combat and civilian destruction. The evolving networked defense technology will also allow us to revisit Ericsson's mobile telephone success, which has continued to be carried by technologies related to the networked dimension of the defense systems vision of which Gripen was the backbone from the beginning.

The Erieye surveillance system, electrically directed antennae, and digital data links, all with a military origin related to the JAS 39 Gripen system, combined to move Ericsson's mobile telephony through the 1990s.

5.2.1 Erieye Surveillance Technology

In the early 1980s, and complementary to the development of the JAS 39 Gripen system, the Swedish military procurement agency (FMV) asked Ericsson to develop an airborne radar system for Swedish defense. Ericsson delivered the first prototype of Erieye in 1985, an effective, inexpensive, and in some ways more advanced version of the US airborne air surveillance system Awacs.[5] When mounted on a Saab 340 Erieye became a cost-efficient and effective surveillance system for the Swedish defense. A clever electrically directed antenna technology developed for Ericsson's space research program was modified for the Erieye that made it possible to follow several moving objects through "multiple direction" of the antenna. When high frequencies were used it was particularly important to be able to aim the antennae exactly. The quality of the transmission improved and the capacity increased. Both military radio communications and increasingly civilian radio communications benefited.[6]

Erieye was first planned to be operated through a land-based information command central, but there was an early international interest and Brazil, that acquired the system, wanted its central command on board. The radar system was therefore mounted on a larger Embraer jet. Since then the system has been purchased by Mexico, Greece, and Pakistan. Thailand acquired 12 Gripen and the Erieye in 2007 (*Militaer Teknikk,* 4–5/2007).

The STRIL 90 central command and military management system was developed together with the JAS 39 Gripen as its core force. The system is a forerunner of the networked defense technology based on real-time communications between land, sea, and air-based moving units. A high capacity, secure, robust (jamming free), and reliable data communications link was needed for that, a technology that Swedish military developed and used very early.

Erieye is intense in its use of data communications and Erieye and weapons technology have to be integrated. Individual aircraft can communicate with Erieye to get the coordinates for targets to attack. Even though advanced for its time the STRIL 90 system is, however, still too rigid to be called a network-based military command system. Communication is still mostly run by way of a land-based command central. Even though data links were developed very early (in 1985) for communication between the aircraft in the air and between individual aircraft and the land-based command central (see further Sect. 5.2.4 above) free and flexible communication between individuals or vehicles in battle is still difficult within the current network structure.

Military digital radio technology, however, came to be used early in civilian telephony and the development of complex central military command systems such as STRIL 90 pioneered the development of radio communications technology in the early 1990s. During that time, the merge of computing and communications (C&C) technologies took giant steps forward opening the doors for the Internet age. A number of civilian systems were soon launched in the market; for instance, Internet-based information access and payment systems, credit card control systems, the complicated logistics networks associated with distributed production, etc. that all required large data communications capacity. These civilian systems of today may at times be as advanced and complex as the military systems and some current civilian telecommunications technologies even lead the corresponding military developments. The need to develop robust, shock proof, and reliable systems is, however, still unique to aircraft industry, and military aircraft in particular, but is increasingly demanded of civilian systems applications. As both military and civilian electronics industry increasingly purchase the same, standard components "from the shelf" the two industries are also supporting each other. Thus, for instance, the increasing cost share devoted to electronics and information and communications systems development in future developments of the JAS 39 Gripen aircraft on the original physical platform will also raise the spillover intensity of R&D investment in the Gripen aircraft. Using "off-the-shelf" standard components has another important benefit in that it reduces the rate of obsolescence of the entire system. Custom-designed components are expensive to develop, manufacture, store, and update. Standard components or systems used widely and with well-defined standard interfaces, on the other hand, are constantly upgraded and produced. The French policy of forcing products subjected to public procurement to use French-made components and subsystems therefore contributes to a more rapid rate of obsolescence of the entire product.

5.2.2 Antennae

Antenna technology early became a world specialty of *Ericsson Microwave Systems* that considered its microwave antenna technology the best in the world. The antenna of the JAS 39 Gripen radar was developed by Ericsson Radio Systems together with the Scottish firm Ferranti and included both a turning platform and electronics for digital signal analysis. This antenna technology could be further developed both for Ericsson's space activity, the Erieye and for the MiniLink. The electrically directed (omnidirectional) antenna or aerials for Erieye could then be further developed to be used in Ericsson's mobile base stations that were increasingly connected through MiniLinks. People from the Erieye group moved over to the civilian mobile business. As Ericsson experienced a rapid growth in its mobile business, it began to draw on its mobile radio people to support the expansion, first in Stockholm and then in Mölndal.

5.2.3 The MiniLink

Ericsson had accumulated a considerable knowledge in radio communications, most of it with a military orientation. Work was located both in Stockholm and in Gothenburg/Mölndal. During the 1970s, the Swedish defense asked Ericsson to develop a tactical digital radio link. This work took place in a secret facility in Stockholm. During the 1970s, Ericsson in Mölndal experienced a recession in order inflows and was looking for civilian applications for its extensive knowledge in military radio communications, radar, microwave, and antenna technologies and signal analysis. This is the way the civilian *MiniLink* came about, but the project had to be protected from Ericsson top management that was at the time preoccupied with concentrating all available resources to the failed business information systems project, EIS (See below). A skunk work was organized to cover up the activity. But marketing the product was slow and the product first had "to search hard for a market," as one interviewed person expressed it. After a while, however, an unexpected military demand presented itself and the market grew rapidly.

Even though the tactical radio link and the MiniLink were originally intended for analog radio traffic (mostly voice) they could be modified for digital radio communications.

The Minilink represented a new concept. With its electrically directed antenna brought in from Erieye and extensive miniaturization, a lower cost structure than for similar military systems could be achieved. A new CEO who did not come from the fixed line telecommunications activity understood the new business situation better than the earlier one. A breakthrough came when the telecom industry was deregulated in the 1980s and new operators were allowed into the market. Or it was rather the case that new C&C technology contributed to the breakdown of telecom regulation. The MiniLink suddenly became the useful device that allowed the new operators a convenient and inexpensive way to link up with existing networks.

A critical circumstance behind the rapid success of the MiniLink was an order from German Mannesmann that had decided to enter the mobile telecommunications business. Deutsche Telecom, sensing competition, had offered an impossibly costly deal to Mannesmann to connect with its fixed line system, a link that in addition would not be available until one and a half year later, when Mannesmann's license to operate had expired. Mannesmann management understood that a radio link would solve their problem and contacted Ericsson. This kick-started the civilian use of the MiniLink. Civilian demand from mobile operators for the MiniLink expanded dramatically and outgrew military demand during the 1990s.

Even though Ericsson top management was still skeptical about mobile telephony, the radio people at Ericsson Radio Systems (ERA) persisted. They saw that something was going on in the USA. The CEO of ERA, Åke Lundqvist who had vigorously protected and supported the clandestine venture into radio telephony went to the USA and found maverick entrepreneur Craig McCaw who was pioneering mobile telephony in the USA. McCaw adopted the Ericsson technology. McCaw soon expanded into one of the largest mobile telephone operators in the USA and was acquired by AT&T in 1994. AT&T had set its focus on integrating the Internet and mobile telephony with its complete USA network for long-distance communications (BW, March 7, 1994:30f).

So, even though mobile telephony systems and terminal developers and manufacturers may today be capable of continuing successfully on their own, the origin of mobile success is to be found in military radio technology and later in military data communications within increasingly networked battle systems. It will therefore be interesting to study how Ericsson, which sold off most of its military radio activity to Saab in 2006, will manage mobile telephone development into the future.

5.2.4 A Networked Defense Enhances Spillover Intensity

The JAS 39 Gripen was defined from the beginning to be the backbone of a broader and integrated defense system in which the platform and its weapons capacity of course was central, but the combined effect of which was radically enhanced by operations decisions integrated within the world's perhaps first, even though at the time primitive, "network-based" surveillance, information, and combat management system. But the groundwork for this at the time ambitious development project had been laid much earlier, and the Gripen system could not possibly have been engineered into the successful systems design that it became without its previous history of experimental development and learning.

The Saab Draken was the first combat aircraft in the world to be data-linked during the early 1960s to a land-based command central. A complementary "broadband" data link was developed already during the first half of the 1960s that made the communication of radar pictures to land-based command centrals possible.

In 1982, the Saab 37 Viggen was equipped with a data link that connected aircraft to a land-based command central both ways in real time and Sweden was again first, in 1985, to introduce data communication between the aircraft. As one interviewed person expressed it, "In this technology we have been at least 15 years ahead of the Americans."

In conjunction with this, new military tactics and battle methods, a "military art," were developed that fully employed the new information capacities that the integrated and real-time-based aircraft system made possible. All that had, in fact, been foreseen by the military procurer FMV and worked into the Gripen specificatons in 1982.

As I have already observed, several econometric studies indicate that the more of electronics and software in product development the more intensive spillover flows. This is quite well illustrated by Ericssons's spectacular transformation from a land-based traditional telecom equipment producer to the world's leading mobile telecom systems developer of today. It began with Ericsson's development of military radio technology well before Gripen, but was carried through the 1980s and 1990s by Gripen systems-related digital microwave links and antennae technology.

5.3 Distributed and Integrated Production as a Generic Engineering Organizational Technology: The Art of Systems Integration (Case 14)

Complete product systems design and development are a rare industrial competence in which Swedish industry appears to have developed an excellent record (aircraft, telephone systems, heavy trucks, engines, automobiles, etc.). These complete systems design competences and the capacity of holistic understanding are, to a considerable extent, a necessary ability of, and experience for engineers to develop sophisticated subsystems for even larger and complete systems products. It is a competence, or rather an art that can only be acquired through participating in such production and through systematic learning on the job. This ability to integrate many different technologies also underlines one unique competence advantage that the advanced firm has over the regular technical universities. It also emphasizes the ultimate competitive advantage the already industrial nations have over developing industrial economies. Learning can take place on the job and in the market.

With the development of systems products designs comes the art of modularization and distribution of both development and manufacturing over markets of subcontractors. Aircraft industry faced the need to outsource advanced development and production early. Too many technologies and too many components had to be integrated in too many different ways to make it possible for one firm to develop and produce everything needed for an entire aircraft. Above all, one firm could never be the best on more than a few of the many subsystems and component technologies that make up an entire aircraft or aircraft engine. So the art was to focus on the core systems of the product. Hence, the technique of modularizing the design and outsource entire complexes of components of the aircraft to subcontractors was pioneered in military aircraft industry. Subsystems and components represented large value so it was cost efficient earlier than in other industries to outsource to the most efficient producer, rather than to develop the components internally. Integrated production (Fredriksson 1994; Eliasson 1996b) is the art of integrating all these activities efficiently in the design and manufacturing processes. The more advanced the product, however, the less likely those specialized subcontractors can be found in the local neighborhood. A global technology of organizing integrated production developed early as did various standards to facilitate the design and manufacturing processes. Still, most of what we see in the form of distributed production was neither feasible nor economical before the sudden leap forward in industrial technology that came with the integration of computing and communications (C&C) technologies around the mid-1990s. The Internet age was created. Obviously, the competence to participate in such a globally integrated production system requires long organizational learning and experience accumulation.[7] Such learning can only be efficiently organized through active participation in a dynamically competitive subcontracting system (item 3 in Table 1, See page 39).

5.3.1 *The Nature of Complex Products*

Two critical parts of a globally competitive engineering firm of today are (1) advanced product design and marketing competence and (2) ability to organize *integrated production* over global markets. One way of dealing with complexity in product development and manufacturing is to decompose the product into a number of subsystems and components (modules), all with exactly defined interfaces, the development and manufacturing of some of which are outsourced to subcontractors, and then bring all subsystems together for final "assembly." The art of designing and making all component systems fit in the end is often referred to as *systems integration* and to do it well the design has to be guided by a competently conceived *systems architecture* of the whole. Systems integration (see case immediately below) requires that each subsystem be designed with an understanding of its role in the whole product. *Integrated production has therefore developed as a sophisticated way of distributing some of the production over markets of specialized subcontractors without losing control of the development and manufacturing of the entire product and the final quality control.* In fact, the extremely elaborate quality control associated with all stages of distributed and integrated production of aircraft has gradually diffused through engineering industry at large and is one of the reasons why we now rarely hear about "monday cars" in automobile industry. We rather hear about bad quality brands, or automobile makers that have not learned the art of quality control. There is little of such experience-based hands-on competence to learn in the classrooms of technical or commercial universities. The knowhow is a matter of organizing specialized teams of engineers such that each responsible team integrates its subsystem smoothly into the entire product system (the aircraft). This requires an implicit understanding of the whole of each participating team. In US aircraft industry, one often refers to a *design team*[8] of some 1,000 academically educated engineers (In Sweden a smaller number). A design team defines the minimum range of competences needed to move the development of an aircraft up to a prototype. Within the design team there are about 100 specialist areas, the number depending on the definitions, and what kind of aircraft that is being designed. For the military and civilian activities of Saab there were once a common denominator of 80% of those specialties.[9] A critical part of the competence of this design team is embodied in its organization and ways of work. Hence, it is impossible to recruit a whole team in the market. It takes decades to develop such a team. Once broken up, it may be impossible to reconstitute. A too fast turnover of the competent members of the team, furthermore, tends to break up the internal self-organizing capacity that defines a large part of the competence of the team.[10] This experience-based knowhow diffuses as people move between jobs and firms in the market. An aircraft, hence, is not only a very complex product. It is multidimensional in the sense that it is composed of (1) the product itself as a physical entity, (2) many years of service, maintenance, and upgrading, and (3) a "cloud of valuable spillovers" that unfortunately, for the producer, is close to impossible to charge for. Advanced firms, such as the aircraft manufacturers, therefore, generate different indirect (spillover) benefits over and above the product itself being purchased. In the short term local employment will be created, but this carries local value only if the extra people employed cannot be gainfully employed elsewhere and the effects are only temporary. Sustainable production and export growth can only be achieved as a result of a sustainable increase in overall productivity generated by the spillovers.

I will illustrate the role of distributed and integrated production in Saab aircraft and VAC engine development and manufacturing and identify how military technology has diffused into advanced civilian manufacturing.

5.3.2 Integrated Production

The overriding organizational competence that I have called "*integrated production*" (Fredriksson 1994; Eliasson 1996b) and that is generic to engineering industry, was first developed in aircraft industry and is currently becoming the critical engineering technology associated with concepts such as modularization, outsourcing, and distributed production and that is increasingly carrying the globalization of production in the world economy.

Integrated production or systems integration makes it possible for very advanced firms to focus on what they are good at; for instance, product development and global marketing and later systems installation, operations, maintenance, servicing, and upgrading, sometimes outsourcing all or most of physical manufacturing. The reason is that a large global firm cannot excel in developing and manufacturing everything. Complexity sets limits to how many different competence areas that can be accommodated within one hierarchy. When the production of large parts of the systems product has been distributed over the market of specialized subcontractors the critical competence is to integrate the various subsystems back into a product without losing control of costs and quality. As mentioned, this organizational competence is fairly new and mistakes abound.[11] This modern organization of production is however here to stay and firms are learning. The firm has to focus on what it is best at. At the same time the outsourcing of large and complex subsystems jobs creates many opportunities for the development of a local specialized subcontracting industry, provided the local business environment is geared up to support that. There is also another macroeconomic benefit of this distributed production technology. It breaks up local monopolies and subjects firms, and not least labor, to increased global competition and holds back inflation. This is one reason globalization has been a bad word in some political circles in the industrialized world.

Integrated production has been made possible through the integration of electronics and mechanical technologies making software engineering a critical engineering technology. Integrated production makes it possible to achieve a holistic view of both the product and of the production process (item 1, Table 8) and allows, as well, for a geographical distribution of both product development and manufacturing. "Concepts and integration" are terms increasingly used to describe the development of an advanced global engineering firm of today. Simulation techniques (for instance, computational prototyping), furthermore, make "optimization" of complex designs (items 5 and 6) possible. Maintenance and repair problems can also be solved ahead of time (items 3 and 7) and costly ex post product modifications and corrections avoided (item 9). On the whole, C&C technology has made more efficient as well as flexible coordination in space, over geographical distance and over time possible. The economic benefits of this increased coordination capacity and flexibility are the largest for very complex and costly products that are produced under very complex circumstances, notably aircraft. Hence, the organizational technology of integrated production was first developed in aircraft industry and is now diffusing to other advanced parts of engineering industry. Integrated production is increasingly

Table 8 Integrated production allows the following advantages over regular production

1. A *holistic* view of production processes is achieved based on functional modules, exactly defined interfaces, precise measurement and extreme quality control. Competently organized design teams make delegation of work combined with central control of product performance characteristics
2. Development and manufacturing can be distributed geographically and outsourced over many subcontractors
3. The holistic view minimizes expensive mistakes (design errors, bulky devises, and badly organized manufacturing flows)
4. Product development and manufacturing processes can be integrated
5. Among many possible ways of organizing production, it becomes possible to choose one of the best
6. Simulation techniques (*computational prototyping*) makes efficient product solutions possible from the beginning. Large cost reductions can be achieved
7. Maintenance and modernization problems can be anticipated and solved already at the design stage
8. The manufacturing process can be organized for one-piece production, short production runs, as well as volume production.
9. Quality control becomes more efficient and can be reduced. Costly after production adjustments can be avoided

Source: (Eliasson 1995:48ff)

becoming a critical competence element that determines the ability of firms to participate in the global production networks increasingly built on modularization and outsourcing.

5.3.3 Systems Effects in Integrated Production

Modern computer and communications (C&C) technology allows the distribution of production over markets of specialized subcontractors and again the reintegration and assembly into a complete product. Through specialization in the development and manufacturing of components and subsystems economies of scale can be achieved in component production as well as in the final integration. The total systems productivity improvement is however dependent on achieving the right (optimal) organization of the entire (global) production system. This is not easy and many bold attempts have failed. The wrong parts have been outsourced or the entire systems integration has been badly organized. The critical lesson learned by many outsourcing companies is that the sum of all individual improvements may cancel altogether, and even turn negative, if you put them together in the wrong way. This is only an application of Adam Smith's (1776) principle of work specialization. The way large systems productivity effects can be achieved with the support of modern C&C technology is illustrated in Table 9.

There are five principally different stages of improvement to consider. In the pre-C&C production organization, information flows were normally coupled with

Table 9 Systems effect categories at different levels of aggregation

1. Speed up info flows over given structures (rationalization)
2. Speed up physical flows over given structures (rationalization)
3. Reorganize info flows
4. Reorganize physical flows
5. Do all simultaneously (integrated production)

Source: Eliasson (1998). Information Efficiency, Production Organization and Systems Productivity – quantifying the effects of EDI investments; in Macdonald, Madden, Salama (eds.), Telecommunications and Socio-Economic Development. Amsterdam: North-Holland, 1998

physical production flows. Sometimes, information flows were slow and tied up production. If information flows could be speeded up over the given physical production structure (item 1 in Table 9) productivity gains could be registered. The productivity effects were however usually small. A classical example referred to was that CAD systems were often used as electronic drawing boards, and that the users never learned what else such systems could do. If physical production flows could be speeded up (without changing the information flows) productivity improvements could also be registered (item 2). There is a large engineering literature on the optimal organization of a workshop.

C&C technology, however, opened up new ways of decoupling information flows from physical flows and improving one, holding the other constant (items 3 and 4).[12] Finally, the real opportunity came when all could be done simultaneously. And this is what defines the productivity potential of well-organized global production. The heralded benefit of CAD/CAM systems such as Catia (see Chap. 7) is to be supportive in achieving that.

With globally organized production organizations where information and physical flows are decoupled comes the additional benefit of *flexibility*. Product specifications can be reorganized in real time and even though this may reduce physical productivity as traditionally measured, the flexibility adds value to the product and that value should be added to the productivity measure, and will influence profitability. *This establishes integrated production as a separate and critical engineering organizational technology.*

5.3.4 Systems Integration: An Illustration

Figure 4 illustrates how Gripen military aircraft development and assembly integrates at least ten different subsystems/functions. We have (1) the aeronautical engineering of the physical aircraft structure and (2) the on-board computer system. We have noted already that on-board electronics is what gives the fourth generation of combat aircraft its extreme flexibility when it comes to engineering different functionalities. Also in the later post-1992 period, further development, compared to the original development of the Gripen aircraft, the electronics part of total cost has been raised from about one-third to at least two-thirds.

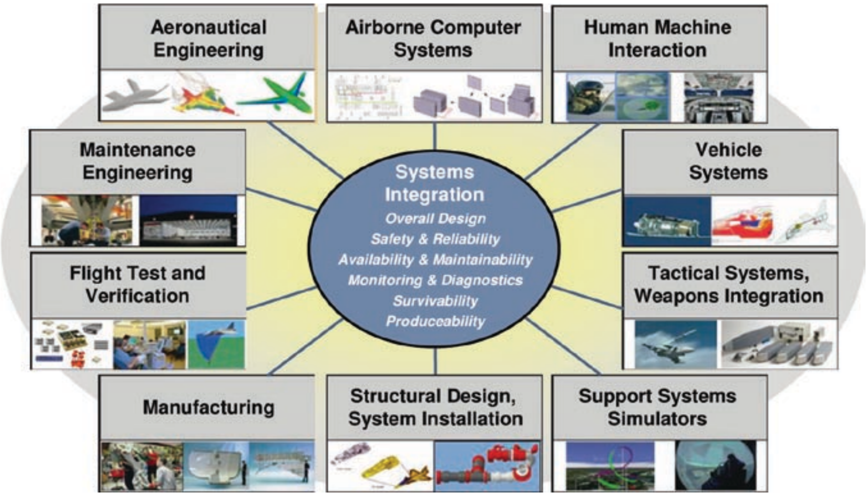


Fig. 4 Systems Integration – the Case of JAS 39 Gripen

The handling of the aircraft in the air, furthermore, combines the functions of (1) and (2) with (3) human–machine interaction (information) systems. JAS 39 Gripen is extremely easy to fly, which means that the pilot can focus on his military tasks. This ease of handling is partly a matter of how the cockpit instrumentation and controls have been organized, but also, and more importantly, of how the control hierarchy of the entire aircraft has been designed and how much control can be delegated to the computers in different situations. This defines the principal user design. Before the aircraft is ready for operational service, however, all (4) internal systems within the aircraft have to be made internally compatible, (5) be tested and verified, (6) structures developed and installed, and (7) a whole series of aircraft manufactured.

All the above (8) has to be integrated with a critical eye to lifelong maintenance, and (9) the need for, and availability of supporting systems, including all information necessary for the networked defense. Coordination of target identification on an attack mission with information sources and (10) weapons system and delivery is a separate art in itself that has a wider application area for the police, disaster preparedness, rescue operations, and fire defense. Here, the art is to be capable of simultaneous online visualization of complex situations that require immediate decisions. Simulation is the technique increasingly used to achieve (and to practice) such holistic overview.

5.4 Safety-Critical Software Engineering (Case 15)

JAS 39 Gripen development was unusually fast and the principal design was rapidly carried through its engineering design phases to manufacturing without many of the costly prior tests on full-scale mock ups and prototype versions of the aircraft that had been the standard practice for earlier generations of aircraft. One explanation for the rapid passage through the sequences of development, of course, was that there were few or no prototypes built. The test aircraft today is normally the first series aircraft that leaves the production line. Another explanation is to be found in the intensive use of computer-simulated design technology more or less enforced by the tough demands on performance, costs, and development time of the customer. JAS 39 Gripen represented an early use of Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) and virtual prototyping and simulation in both the structural design, the manufacturing and in its avionics, and in the special safety-critical software design environment of aircraft development. It also belongs to the picture that the dominant cost item in modern engineering product development and manufacturing of sophisticated products is software engineering.

The initial development of the Saab JAS 39 Gripen platform was about one-third (of costs) software development. Later developments of the JAS 39 Gripen aircraft for exports and for the Next Generation Gripen version are two-thirds electronics and software development. Modern engineering products with significant systems content all depend critically on advanced software engineering, so we are talking about a generic manufacturing technology, notably an engineering industry technology.

One specialty of Saab aircraft development is what goes under the name of *safety-critical software.* The name says what it is all about, namely the development of integrated software systems that are to the extent possible fail safe with built in checks, controls and redundancies. Many applications of safety-critical software development are imposed by public regulators. This is obvious when it comes to aircraft control systems, but such regulation also rules railroad safety systems, nuclear power plants, telecom systems, etc., and, of course, also automobiles.

It is expensive (labor intensive) to develop safety-critical software bottom up from source code. Hence, such software programming is often outsourced, for instance to India, but this makes it difficult to develop customized product features. Customized product development with secured total systems safety and quality requires a special competence of the systems integrator; skilled and efficient designers of the systems architecture, e.g., modularization with well-defined interfaces. Swedish software programmers/engineers may have difficulties competing with low costs against software engineers in India who are both good and inexpensive. The art of integrating complex systems concepts/architectures, on the other hand, with the development of software programming that is integrated with the hardware and the electronics and mechanical solutions is to a large extent an experience-based competence that advanced Swedish engineering industry excels in because of the pioneering work done in military aircraft industry. It is mainly learned and improved through experience building on the job, and it is difficult to achieve if the teams responsible for designing the aircraft have to cooperate over large geographical distances.

A complementary method is to buy already developed and tested specialized operating systems and/or software modules. But again, this makes it difficult to develop customized performance features for the product. Saab has some 300 software engineers constantly at work on Gripen, half of them on a consultancy basis.

A new software engineering method that Saab has put to use in JAS 39 Gripen is called Model-Based Systems (or Software) Engineering or so-called auto code generation, a technology that allows the software engineers to model their systems at a higher level of abstraction than before without having to build their systems on standard "lego" modules of software.

The so-called Unified Modeling Language generates software with the desired functional specifications (FR in Sect. 2.2) from archives of algorithms that are made to conform to (approximate) Gripen reality. The software used to generate new software rapidly comes up with suggested structures of software that can be validated. This artificial intelligence system saves many rounds of software development by hand. Tests are first performed through computer simulation and then in reality.

The first Swedish application was the flight control system on the Gripen. Saab was a pioneer in using methods of this kind in the world to the extent that its engineers were in great demand by, for instance, Ericsson that paid higher wages to make them move (Gustafsson and Lindvall 1978). The demand for a low-cost aircraft imposed on Gripen development forced Saab to develop this technology further.

Saab product development and manufacturing are special in the sense that engineers have to work with *hybrid systems* that integrate a very large number of electronic, mechanical, sensor, hydraulic, etc. functions to achieve a complicated high performance functionality.

An earlier advantage in military aircraft development has been the long lead times and the consequent possibilities to modify functionalities during the development process. The new automated software engineering methods as they are being refined and made more sophisticated are, of course, faster than earlier "manual methods." In the new and faster product design environment of Saab the earlier experience of Saab in complicated software integration comes in handy, and as a consequence Saab engineers will be even more demanded in the external markets.

5.5 Manufacturing Lightweight Technology (Case 16)

From the beginning of the procurement process, the customer FMV required that the JAS 39 Gripen engineers designed an aircraft with a radically reduced weight, compared to its predecessor the Viggen, to increase range and potential weapons load and to make landing on, and take off from, regular roads possible. Significant parts of that requirement were passed on to the engine modifiers and designers. The importance of achieving a lightweight fuel efficient design was perhaps even more emphasized for the Next Generation (NG) Gripen that was officially presented in April 2008.

5.5.1 Lightweight Aircraft Structures: Saab and Gripen

To accomplish the lightweight design of JAS 39 Gripen demanded by the Government customer the Saab design team adopted a holistic approach to optimize the choices made. This approach involved an evaluation of the weight reductions to be achieved through

1. The use of new and light materials, for instance carbon fiber composites.
2. The design of special framework constructions (lattices) that allowed lighter panels to be used.
3. The development of special machining techniques, for instance the high-speed machining tool of Modig (see Case immediately below) that made it possible to cut the weight of metal structures without weakening its load-carrying capacity.
4. The use of electric control systems on the aircraft (for instance fly-by-wire) instead of hydraulic or mechanical.
5. The development of simulation technology to optimize the localization of new lightweight structures.
6. To optimize the use of the complementary weight saving that came with other new design features of the Gripen aircraft.

The wing of the Gripen was built in carbon fiber composites together with British Aerospace. Twenty to twenty-five percent of the weight of the airframe was to be made of carbon fiber composite components giving together a weight reduction of some 25%.

Thanks to the new miniaturized electronics, composite materials, and software development, it was possible to reduce the volume significantly and consequently also the weight. Compared to its predecessor Viggen, Gripen is roughly half the volume and weighs half as much, but it still has the same or superior performance in all respects, and notably in systems functionality. Its range is much longer, and it carries the same weapons load.

To achieve the aerodynamic “instability” properties of the JAS 39 Gripen aircraft it was necessary to use an electrically directed fly-by-wire control system, rather than the earlier and much too slow mechanical and hydraulic systems. The fly-by-wire system required much less space and was much lighter and therefore also contributed to the desired lightweight features of the aircraft. Electrical (fly-by-wire) controls and the densely compacted electronic circuits designed by Saab reduced weight further. One could say that the design of compact, lightweight, and robust systems products is a special competence of modern military aircraft and weapons industry.

The fly-by-wire control system introduced on the JAS 39 Gripen was not only necessary to achieve the speed of controls and maneuverability (immediate functional flexibility) necessary on a statically unstable aircraft. Weight was significantly reduced (as were space requirements) when the mechanical and hydraulic transmission of signals was replaced by electrical wire. Considerable flexibility for future functional modifications of the aircraft also came with the fly-by-wire control system. One example is the in-flight swing-role capacity, the integrated cockpit displays and the “joy stick” to make maneuvering of the aircraft easier and free time and attention for the combat role of the pilot. The swing-role capacity was achieved by combining the design of the avionics with sophisticated software and the fly-by-wire control system. Safety was achieved by having two or more parallel systems and constant electronic monitoring of functions.

The lightweight construction technologies pioneered on the JAS 39 Gripen aircraft have come in handy on the civilian side. Saab is currently manufacturing the Tactical Management System for the new European lightweight helicopter NH 90 for Eurocopter (*Ny Teknik*, No. 4, Jan 26, 2005). Saab's military lightweight technology was also transferred, to the extent it was economical, to the parallel development of Saab's civilian passenger aircraft, the 340 and 2000 models. On the choice of material, civil aircraft is sensitive to costs, while performance is the prime concern of military aircraft. The military aircraft pioneered the early use of expensive carbon fiber and composites. Their higher costs, however, are to a considerable extent a matter of the small volumes of their production. The new environmental and fuel economy concerns of today and the rush for lightweight structures in many industries mean that volumes are now going up and that Saab's experience from lightweight construction both from the JAS 39 Gripen and its civilian aircraft development has become the foundation of its systems contracting work for both Boeing and Airbus.

5.5.1.1 Case: Modig Machine Tools in Virserum

A high-speed metal machining technology was first developed as Saab Gripen engineers cooperated with a machine tool manufacturer in a remote district in Sweden (*Modig Machine Tool* in Virserum). Modig had a long history as a developer and manufacturer of machine tools. It was founded in 1948. The quality of the Modig machine tools had already taken the company to both the North and South American markets and to Australia.[13]

In 1985, Modig had started experimenting with a high-speed machine tool to raise process productivity. But the method did not work because temperature increased rapidly as the speed of machining increased. Both the tool and the metal being cut melted. By accident, however, the high-quality Modig machine tools had caught the attention of Saab, which now asked Modig if it could develop an intrusion machine for long aluminum profiles. It did.

Saab engineers, however, also understood the problem with high-speed machining that had halted Modig's experiments. They understood that as the speed was increased further temperature would go down since the heat would then be removed with the waste material created. The first test center in the world for high-speed machining was established in 1987 at the Modig Virserum location where experiments were performed together with Saab and the Linköping Technical Institute. Saab understood that this machine tool could manufacture (lightweight) components that had not been possible to manufacture before and acquired its first Modig high-speed machine tool in 1989. Processing precision could now be raised which made it possible to process metal components for Gripen with very thin walls for structures that were very light but could still carry the needed loads.

Saab was also very generous to Modig and allowed Modig's customers to visit and inspect the machine in use in its Linköping facilities. Saab's support raised the quality reputation of Modig and very soon the Modig high-speed machines were used by most air craft manufacturers in the world, including Boeing. Modig has even become a quality supplier of tool development for Boeing.

Before "September 11" Modig had 130 employees. After September 11 it received no order for 16 months and went bankrupt. The managing director and owner Percy Modig, however repurchased the bankrupt company, which is now again a global supplier of high-speed machine tools, albeit no longer the only one. The number of employees is much smaller, but Modig uses a large number of its former employees as subcontractors. Modig has developed a method to distribute development work geographically in a fashion that was unthinkable before the mid-1990s when the Internet began to become a practical industrial tool. During my interview visit, the Modig and Boeing people had an Internet-based video conference with online live presentation of CAD designs to discuss the progress of work on, and technical details of a machine tool Modig was designing for Boeing.

5.5.2 Lightweight Engine Designs: Volvo Aero Corporation

The design and manufacturing of lightweight structures also became important in the modifications of the JAS 39 Gripen engine. That technology is now being increasingly demanded in a world of increasing oil prices and concerns about environmental pollution and carbon dioxide emissions, putting a premium on fuel efficiency. Volvo Aero Corporation has therefore invested heavily in the manufacturing of lightweight designs to meet those requirements, investments that are now paying off in the civilian aircraft engine programs where Volvo Aero Corporation tends to be entrusted with the design and manufacturing of "heavy" subsystems in the engine.

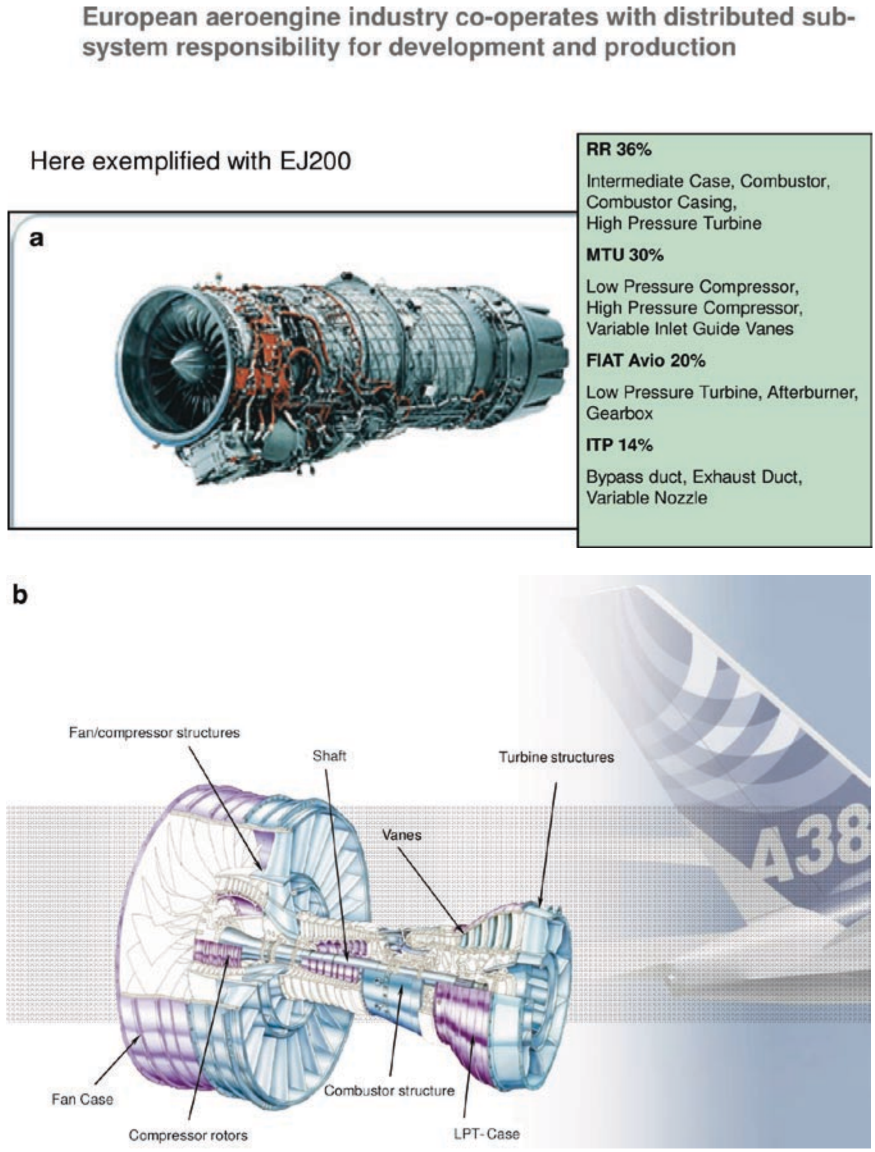
Figure 5A demonstrates the complexity of a large civilian aircraft engine. Figure 5B indicates the components (of a particular engine) on which VAC has specialized.

The Gripen engine developed from the GE F 404 – two of which are mounted on the Boeing (McDonnell Douglas) F18 Hornet – has 30% fewer parts than the more-than-twice-as-heavy Viggen engine and is using metal matrix composite materials extensively. It weighs less than half of the Viggen engine but is almost as powerful. The increased fuel efficiency achieved means that much less fuel needs to be loaded on for the same missions.

Volvo Aero's three specializations are:

1. Manufacturing process techniques
2. Lightweight structures
3. Production support in a lifelong perspective (40-year partnerships, or more)

(1) and (2) together exploits the modern laser welding and joining (bonding) techniques combined with simulation that Volvo Aero developed for the modification and manufacturing of the RM12 GE engine for JAS 39 Gripen. The mastering of that technique has played a decisive role for the recent capturing of the very large civilian contracts with RR and Pratt & Whitney mentioned above right.



European aeroengine industry co-operates with distributed sub-system responsibility for development and production

Here exemplified with EJ200

RR 36%

Intermediate Case, Combustor, Combustor Casing, High Pressure Turbine

MTU 30%

Low Pressure Compressor, High Pressure Compressor, Variable Inlet Guide Vanes

FIAT Avio 20%

Low Pressure Turbine, Afterburner, Gearbox

ITP 14%

Bypass duct, Exhaust Duct, Variable Nozzle

Fig. 5 Aircraft engines. (**a**) Distributed subsystems responsibility of European manufacturers. (**b**) The Specialization of Volvo Aero

It may look as if the engines and the aircraft body are two separable concerns when it comes to design and production, and two specialized producers are always involved. Large aircraft engines, however, have two systems dimensions when it comes to achieving the desired performance characteristics of the entire aircraft. *First*, the engine type and the design of the aircraft fuselage depend on one another and there is an optimal relation. The jet, turbo prop, and propeller engines require different aircraft designs. *Second*, the performance of a large aircraft engine, in turn, relies as much on its internal design as does the entire aircraft, and draws almost as much on a complex of specialized subcontractors.

The three producers of large aircraft engines have focused on some core technologies that determine fuel consumption, noise and pollution levels, maintenance costs, etc. and outsourced much of the rest. There is today a small number of accredited engine subsystems developers and manufacturers, Volvo Aero being one, that have developed their own systems capabilities and specialties, but that also have the competence to optimize subsystems performance within the context of the entire aircraft system.

As it appears both for Saab and for Volvo Aero this capacity at holistic understanding, and experience from the manufacturing of complete aircraft and engines have mattered significantly for their competence to "optimize" (integrate) increasingly complex and demanding subsystems development and manufacturing and to capture jobs from their large customers (Boeing/Airbus and GE/Pratt & Whitney/RR, respectively).

The long life of an aircraft engine means that a significant part of its life cost has to do with the cost of servicing, maintaining, and upgrading it. Life cycle cost, therefore, is also an important product characteristic. Because of this, the product definition has gradually shifted from buying and owning the engine toward the airlines renting the services of the engine, the manufacturer retaining the ownership of the engine, or at least supplying the aftermarket of the engine. Since pricing practice has developed such that the manufacturer gets better margins on the after market than on the engine itself, the large engine manufacturers have tended to internalize a large part of that service.

5.5.3 Welding Simulation

Welding simulation technology to obtain crack-free joints on critical parts of the engine structures has become a common method in the manufacturing of complex lightweight structures such as subsystems for military and space engines, and increasingly so for large civilian engines where lightweight structures are being rapidly introduced. The manufacturing of lightweight designs of large engine structures is one of VAC's specialties. This production is intensive in its use of welding and the complexity of the structures has required development of welding simulation methods, a technology that Volvo Aero Corporation has developed in cooperation with the local Technical University of Trollhättan and as partners in the EU Vital project. VAC is using that welding technology, instead of single casting, under its lightweight design concept to manufacture rear turbine structures. It welds smaller castings, forges pieces and components from sheet metal using a computer-optimized welding technique that was developed in cooperation with the Luleå University of Technology. VAC considers itself one of the pioneers in the world using welding simulation in advanced manufacturing design that makes reductions in weight of 10% possible compared to single casting. The origin of this technology is the lightweight design of the JAS 39 Gripen engine. The extreme heat resistance requirements of rocket engines for the space program has forced a further development of the welding technology into electron beam techniques to produce crack-free welds in cobalt. The expectation is that this technique will soon be introduced in civilian engine technology.

The cooperation with the EU Vital project and technical universities, notably the Production Technology Center (PTC) at the local Technical University of Trollhättan has also facilitated the commercialization of this welding technology. Volvo Aero puts the value of that technology at SEK 100 million (2008). The long-term ambition of that cooperation program also is to develop structures using a new lightweight concept based on new composites to reduce engine noise and carbon dioxide emissions from aircraft.

5.5.3.1 Case: Applied Composites AB (ACAB)

Applied Composites AB (ACAB), then named Nobel Plast, was the only Swedish subcontractor outside the IG JAS partners that took on a complete subsystems development job at the first round of purchasing in 1982, the RAdarDOMe (radome) on the nose of the Gripen aircraft that protects the radar antenna.

ACAB was, however, already well established in that business. It had been founded in Ljungby already in 1957 as Trelleborg Plast to manufacture radomes for the J 32 Lansen. After a series of reorganizations and repackaging through mergers and acquisitions, and a few years when it was owned by Saab, the company moved to Linköping in 2004 and was acquired by Volvo Aero Corporation in 2007. Volvo Aero Corporation was interested in the experience of ACAB with composite materials and their usefulness in lightweight engine construction for future civilian markets. The origin of this knowledge of composite materials is military subcontracting jobs, mainly radomes and the manufacture of “disposable” barrels for Bofors guns.

A radom covers a mobile antenna at the nose of an aircraft or a missile. A radom placed at the front of a supersonic combat aircraft is subjected to both high temperatures and strong wear and needs protection (Thylen 1969). It also has to be capable of weathering a hit by a flash of lightning. The Gripen radom, furthermore, is not only protecting the radar system physically. The art has been to develop a plastic material that only lets radar waves through on very narrow and particular frequencies. Since the enemy does not know those frequencies the Gripen pilot can see, but not be seen, a stealth feature. The plastic material is also composed in such a way that it absorbs a minimum of energy from the microwaves to enhance radar visibility.

ACABs volume product (60% of sales) is barrels for the launching of missiles from Bofors guns (now within BAE Systems). Those particular composites can stand reasonably high temperatures and have been attractive for the development of lightweight structures in large aircraft engine systems, such as the fan and cooling systems. To achieve that was one of the requirements of the Gripen engine.

The civilian share of ACAB sales is currently 17% and consists of a number of small volume composite products; for instance, tubing for Gambro dialysis machines and transparent and lightweight stretchers for patients undergoing X-ray and mammography analysis. ACAB also makes the front axis for competition motorbikes that have to be both very robust and light.

The potential civilian applications of reinforced composite plastics materials are, however, many. Already Westerlund (1992) presented a number of uses for this strong, temperature resistant and robust material in flagpoles, the front of fast trains (X-2000), bubble pools, military stealth ships (a Kockum specialty), suspension and rear axes in automobiles etc., much of which was already then, or has later become industrial reality. The factor that currently holds back the use of composite materials is high costs, but that problem will go away as volume production increases, and ACAB has the competence to go upscale in volume manufacturing. The future use of ACAB lightweight composites in Volvo Aero's growing markets for civilian aircraft engine systems is, therefore, expected to raise its civilian share.

5.6 Automobile Safety Systems as a Swedish Export Product

A single military aircraft represents a considerable investment for society and the human capital investment in a combat pilot represents a not negligible economic value even in comparison to the value of the aircraft for which s/he is responsible. Pilot safety therefore was an early concern at Saab. A military aircraft was designed with two safety considerations in mind. The aircraft should be easy and safe to fly and be designed, and to the extent reasonable, incorporate devices to save the pilot in case of an accident. The first ejection seat ever was developed for, and installed in the Saab J21 fighter aircraft already in the 1940s. The J 21 was pushed by a propeller mounted at the rear of the aircraft. The ejection seat was launched by a gunpowder-powered "cannon" The cannon was needed to catapult the pilot above the propeller in case of an accident. Even so, of the 661 Saab 29 "Flying Barrels" fighter jets manufactured between 1951 and 1956, 190 crashed and 99 pilots were killed. Such numbers are totally unacceptable today.

Already in 1951 a special section at Saab was made responsible for safety designs on the military aircraft. The two-seater version of the supersonic Saab 35 Draken demanded more effective solutions. As the first combat aircraft in the world, toward the end of the 1960s, the Draken was equipped with both a rocket-launched and a cannon-launched ejection seat. To prevent the pilot from getting stuck in the cockpit when ejected, an air cushion was installed to push his arms close to his body at ejection.

Already in the late 1950s, Saab safety engineers understood and applied the principle of the three-point safety belt and that the pilot should be straightened up and pulled hard into his chair in case of an accident. Gunpowder-activated retractor belts were installed on the Draken combat aircraft at the end of the 1950s that straightened up the pilot and fasted him securely in his chair. The pilot and his parachute furthermore were fastened to his chair with a three-point belt.

Cockpit design and instrumentation is another important aspect of both aircraft maneuverability and safety.

Saab's development of simulation methods to optimize structural designs, and especially the balancing of thin and light but strong lattice structures and the thickness of the hull came in handy for Saab's parallel development and manufacturing of automobiles. When Saab (together with Linköping University) acquired a Cray supercomputer for its aircraft design work the aircraft engineers also helped the automobile people during the 1980s to design, for its time, very safe automobile structures that absorbed the impact of automobile accidents through collapsing in a "structured" way. As the first automobile in the world, Saab could offer side-impact protection in 1972.

The Saab aircraft and automobile engineers also experimented with transferring the Gripen fly-by-wire steering system and head-up instrument display to the Saab 9000 automobile model. This transfer, however, turned out to be too expensive. The sensors, on the other hand, that were used to release a primitive airbag to hold in the legs of the pilot when, in case of accident, the catapult seat was ejected, eventually found their way to the Swedish automobile safety firm Autoliv. Autoliv currently operates two development and research centers, one being located in Saab's Linköping. When Autoliv acquired Nokia's automotive electronics activity in Motala it became rational to concentrate to, and expand in Linköping because it was much easier to recruit qualified personnel there.

ABS brakes were defined in the Gripen specifications already around 1980 and were installed in the landing gear when the first deliveries took place 1988. Also before that, the last 37 Viggen aircraft manufactured had ABS brakes.

Because of this, Saab Automobile and Volvo Car not only became pioneers in automotive safety. As early and competent customers for safety solutions in cars, Saab and Volvo also influenced the establishment of a specialized automotive subcontractor industry in Sweden, its most prominent member being Autoliv.

5.6.1 Case 17: The Swedish Automotive Safety Industry and Autoliv

The close contact between military aircraft development and automobile manufacturing in Sweden, both within Volvo and Saab meant that safety considerations became an early concern in Swedish automotive industry and among its subcontractors. As Saab engineers moved between aircraft and automotive workplaces over internal and external labor markets they brought safety awareness with them (item 1 in Table 1, See page 39). (With time, however, influences began to move in both directions. The airbag, for instance, that is mounted in the rear cabin on the two-seater version of the Gripen is there to prevent glass fragments from the cockpit roof from hurting the pilot if ejected, and is an airbag based on the same principles as the one Autoliv developed for the Saab 900 automobile). In general, however, a flow of technical safety solutions developed within military aircraft diffused to the Swedish automobile industry and its subcontractors.

Autoliv was founded 1956 on a new two-point safety belt technology made in a polyester material with a high energy-absorptive capacity.[14] This belt almost immediately became the standard in Sweden, and in 1958 Volvo was first in the world to offer this two-point belt as standard on all PV 444 cars. At the same time, Volvo had initiated the development of a three-point safety belt (Nilsson 2003:28). Nils Bohlin, who had worked with ejection seats and safety systems at Saab aircraft during the 1950s was recruited by Volvo as a safety expert. He is said to have "invented" the three-point belt that was installed on all Volvo cars in 1972. As mentioned, safety belts had, however, always been installed on combat aircraft and aircraft safety systems developers understood the three-point principle early, and that the pilot had to be both straightened up and be fastened tightly to the seat to be protected when ejected from the aircraft. The retractor belt for the Saab 37 Viggen was developed in the beginning of the 1960s. Already during the 1950s, Saab 32 Lansen had a gunpowder-activated retractor belt from the USA. The retractor belt did not arrive at the automobile industry until the early 1990s.

In 1967, Autoliv had developed a new three-point belt with a retractor that adjusted the length of the belt automatically to fit the position, the size and the body shape of the driver of, or the passenger in the car. *Svensk Tryckpressgjutning* in Vimmerby that had been founded by a Saab trained mechanic (Sven Hjelte) was asked by Autoliv to fix the retractor belt which tended to jam. The solution had to do with the precision with which the parts were cast. Hjelte's firm solved this problem and is still a subcontractor for Autoliv. The competitor Gränges Weda acquired Autoliv in 1975 and when Electrolux acquired the entire Grängesberg company in 1989, Autoliv became a subsidiary of Electrolux. Svensk Tryckpressgjutning also became a subcontractor to STIL that manufactured retractors for Volvo. Electrolux had acquired STIL in 1984 and all these activities were gathered under the Autoliv cap. Autoliv, however, was not a natural strategic part of Electrolux. Even so, the Electrolux management had long-term ambitions for the company and enacted a number of complementary acquisitions. In 1994 Autoliv was introduced on the Stockholm Stock Exchange and the firm continued to grow through acquisitions. In 1997, Autoliv merged with US Morton Asp under the original Swedish name Autoliv. Morton contributed with an improved airbag technology and Autoliv Inc. was introduced on the New York Stock exchange. Today Autoliv is the global leader in automotive safety with one-third of the world market of its products and 34,000 employees in 2009. However, only 5% of manufacturing takes place in Sweden, 80% of the owners are American. The company headquarter is however still located in Stockholm.

The history of automotive safety has left several traces that lead back to the Swedish military aircraft industry. The traces are of three kinds. We have (1) the introduction of safer automobile structures and of (2) other complementary safety devices such as safety belts and air bags.

The most important contribution however is (3) the systematic attention to safety that was developed in the engineering of military aircraft at Saab that diffused to the Swedish automotive firms Volvo and Saab Automobile because of their close relations with Saab Military Aircraft. The automobile producers in turn, acting as customers, imposed the same concerns on the growing automobile safety subcontracting industry. Specialist automotive safety firms were established and Autoliv soon became the most prominent one. That transfer of safety thinking and safety technology was largely a matter of people with competence moving between jobs. We know that engineers with experience from safety work at Saab went to automobile industry where they could apply their experience about how the products should be designed to be safer. Saab Autmobile "borrowed" engineers from Saab's safety group on a routine basis.

Sensors for airbags are developed by Autoliv and Svensk Tryckpressgjutning is one of the subcontractors. The airbag is very demanding on the quality of the energetic material (the "gunpowder") and of the small sensors that blow up the airbag reliably and in no time.[15] This pyrotechnical technology was developed early in conjunction with the missile development at Bofors in Karlskoga. Bofors Bepab was established as a separate company and acquired in 1995 by a group of engineers at the company. Bofors Explosives (as the company was later called) developed this pyrotechnical technology further for Autoliv. This activity is now integrated with the Karlskoga based part of the French, Finnish, and Swedish-owned company Eurenco that develops both civilian applications for Autoliv and military applications for the missiles of Saab Bofors Dynamics.

Bofors also developed a mechanical sensor for a side-impact protection device for cars together with Autoliv (Fransson 1996:365). Combitech AB, a Saab consulting subsidiary (see Case 23), has integrated the safety-critical systems on the Volvo S80 model.

A specialized competence bloc in signal analysis, image recognition, and microwave communication has evolved around the weapons development of Saab and Saab Bofors Dynamics in Linköping. Sense and avoid technology at sea and between aircraft to avoid collision is a Saab specialty that has been derived from the Gripen systems project. It is no coincidence that Autoliv has located its automotive electronics research (at Autoliv Electronics) in Linköping. Collision alert and avoidance systems are developed there on the basis of military technology. Autoliv develops heat-sensitive cameras together with Flir Systems (originally a military technology that was developed within Swedish AGA). This automotive alert system has already been installed on the new BMW 7 series.

5.7 Maximizing Functional Flexibility and Minimum Life Cycle Maintenance and Service Costs (Case 18)

The development and production of complex products with a very long life such as aircraft and aircraft engines are always based on a distributed and integrated production organization. Three desired characteristics are associated with the development, production, and sale of such products; (1) flexibility in design such that upgrading is facilitated, (2) lifetime product support, and (3) the option to buy, rent or buy the services of the equipment. The latter means that the producer owns the equipment, services it, and charges per hour of use. The mode of sale influences the design of the equipment. The first two characteristics are typical of military aircraft design and especially so at the procurement of the JAS 39 Gripen. The third option is more typical of civilian aircraft and engines, but really is an extension of the previous two, since the military customer has been intimately involved in the design of the product.

5.7.1 Product Design and Functional Flexibility

Achieving future functional flexibility and low maintenance and service costs requires a holistic view and a user (customer) friendly approach at the very early design stages, i.e., a holistic view of all subsystems and critical components that will play a role in determining the functionality of the complete product in use and make sure that subsystems can be reengineered at later stages of the life of the product. Such foresight will always have to be based on cooperation among a large number of design teams and the managers of the teams. Simulation has become an increasingly important technique to achieve those functionalities. How to organize that interplay is an art in itself, and particularly so when very complex products are developed. All this taken together goes under the term *systems architecture*, which is the core competence of a systems integrator.

The success of the JAS 39 Gripen aircraft design both in terms of flexibility and functionalities and in terms of lifetime cost effectiveness can to a large extent be explained by the close cooperation between the customer, the Swedish Government Procurement Agency (FMV), the Swedish Air Force (the user) and Saab. From the beginning, the customer demanded that the aircraft should be easy to maneuver to allow the pilot more time and attention for his main combat tasks so that in-flight shifts between the three roles of fighter, attack, and surveillance be possible, and that life cycle costs should be low both in terms of maintenance and upgrading. Hence, simple and low-cost solutions in construction, implementation, use, and maintenance were necessary. To achieve that, a modularized design that could be upgraded in batches was devised. Modern digital information technology not only made the flexible functionality of the aircraft in service possible but also made it possible to simulate every subsystem with a view to the whole and therefore compose an "optimal" total JAS 39 Gripen system. Lifetime cost minimization was supported by an incentive contract.

5.7.2 Maintenance-Free Products

Operational costs have gone up faster with every new generation of fighter aircraft than have actual development and manufacturing costs. Maintenance and servicing have been a significant and increasing part of total lifetime costs of the aircraft. Reductions in the needs to maintain and service the aircraft, or any product, therefore offer large potential cost savings and these effects begin at the expensive and complicated systems end with aircraft and aircraft engines. The key to success is to be found in the early product design and engineering stages. JAS 39 Gripen was a pioneer product in this respect because of the strict standards on both reliability of service, on costs and on availability imposed by the military customer FMV. The Swedish conscript defense and the road bases of the Swedish Air Force, hence, were critical factors behind the development of an aircraft with simple operational design, low maintenance needs and rapid turn around, and hence, low life cycle costs. The very high availability of the Gripen aircraft has dramatically reduced the number of aircraft needed for a given service capacity in the air, and costs.

The higher import content of the Gripen aircraft (See Technical Supplement S1) compared to earlier Swedish military aircraft procurement, and to current practice abroad is interesting. It may look as if the practice to demand a high domestic content should be negative for Swedish industry, and perhaps so in the short run. But it also means that the Gripen development process has pioneered the introduction of a distributed production technology that now, two decades later, is becoming the main technology of engineering industry. It means that the component systems that have gone into the Gripen aircraft have been filtered in globally competitive markets. State of the art technology is therefore embodied also in the details of the aircraft. Above all, however, and here the Gripen aircraft compares favorably with military aircraft developed in economies where the political government has demanded a high local content such as France, it reduces the rate of obsolescence of the entire aircraft system. Components and subsystems supplied by globally competitive subcontractors are defined by standard interfaces and are constantly upgraded technologically and improved. They can be resupplied over the lifetime of the aircraft in the market, while the aircraft built around taylor designed components and subsystems cannot easily be upgraded and will have to rely on costly storage or remanufacturing of old spare parts. Obsolescence of the entire aircraft is faster.

Earlier procedures had been to service the product at preset intervals whether needed or not, meaning both more service than needed and more down time. Modern aircraft and aircraft engines use what is called *current maintained diagnostics* based on sensors and electronics, a technology that allows the user to determine precisely where and when service is needed. In addition, service needs can be reduced by designing the aircraft or the aircraft engine such that fewer components are needed. One instance of this is to modularize the design such that subsystems modules are used. Rather than needing specialist personnel to repair malfunctioning parts, which is normally impossible in the field, the entire module can be replaced and without the need for specialist and highly skilled personnel. Another benefit from designing the entire aircraft around modules is that a large number of the modules are standard and available in the world market.[16] One reason for the low maintenance cost of the Gripen is its design as a multirole fighter aircraft from the start. Hence, the Swedish Air Force only has to operate and service one version of the aircraft, instead of three (fighter, attack, and reconnaissance). This, in turn, could only be achieved through the intimate cooperation between the customer FMV and Saab in the design process, and at times the use of incentive contracts (see Sect. 8.4), which also meant that expensive redesign could be avoided. The Swedish Air Force also claims that with the Gripen aircraft the "battle against increasing operational costs" has been won (*Militaer Teknikk,* 4–5/2006:2).

The flexible design of the Gripen aircraft and its almost "maintenance-free" construction therefore was a challenge for the engineers. The in-flight swing-role capacity and the fact that the aircraft should be capable of landing and starting from regular roads and be serviced by unskilled labor in the field constitute a technical capability that has many civilian applications, notably when it comes to complex systems products and the integration of mechanical devices, electronics and software engineering. This maintenance technology has already diffused to other industries, for instance automobiles.

The flexibility features of the Gripen aircraft have also been illustrated with the conversion of the aircraft for export to South Africa in 1995 and with the Next Generation of the Gripen presented in April 2008.

5.7.3 Real Options Pricing of Flexibility

Flexibility can be achieved at a cost, and those costs can be computed and compared with the value of the extra flexibility in product functionalities achieved. Real options pricing is a fairly new field in the pricing of future options of increased functional flexibility that derives more or less directly from the theory of financial options (Trigeorgis 1998), a calculation technique that obviously has many business applications, and notably so when it comes to the pricing of abstract qualities associated with expensive multidimensional systems products with a long life, such as aircraft. I have already discussed the notion of innovative pricing. Building future flexibility into the design of a product normally commands an extra cost so you may think in terms of offering today, and charging for an option to change the functionalities of the product in the future. I am not only talking about a formula to use mechanically. I am talking about a way of structuring what we know about future needs and about achieving that flexibility, and assessing the risks involved for customer and developer to reach an agreement on how much flexibility in functional design is worth aiming for.

5.7.4 Lifetime Product Support

To sell a product with an expected life of up to half a century, the producer has to demonstrate technical and financial sustainability of the same duration. Spare parts, technical support, and engineering knowledge to facilitate upgrading have to be credibly guaranteed for the entire period of use, and credibility is very much dependent on the private profitability of the producer. This is no easy demand on the producer. *For a military aircraft producer, it in practice requires that the government* *of its home country has bought the aircraft in sufficient numbers and declared that it is prepared to operate the aircraft over its expected service life.*

Product lifetime support is normally the responsibility of the producer and the cost for maintaining that support has to be calculated and factored into the price of the product. Obsolescence often makes it difficult/impossible to have spare parts available. For products being used for half a century or more, there is no good solution except regular rebuilding of the product (the "aircraft") and (as mentioned) the extensive use of "off-the-shelf" components and subsystems. This problem is not unique to aircraft even though its length of life makes the problem extreme. A luxury car brand manufacturer has to honor product lifetime support to be able to charge the price of a brand name. Developers and manufacturers of complex computer and telecom systems will be expected to supply a smooth transition from one version to another of its system. One way of dealing with this problem has again been to develop products with a modular architecture. As long as the product architecture is the same, spare parts become spare modules that can be used on all versions of the product.

5.7.5 Product Life Management

The responsibility for lifelong product support is an ownership problem. The customer who plans to operate the product over its expected lifetime will want not only to maximize flexibility in product design but also to minimize lifetime operating costs. The producer who sells the equipment may not be as concerned about those two things. To achieve the desired lifetime functionalities the customer, and notably the military customer, gets intimately involved in the product design. Renting the equipment or charging for its use (buying the services of the equipment, "charging for power by the hour") simplifies this decision for the customer and it is becoming increasingly common in civilian markets; for instance, civilian aircraft and aircraft engines, trucks, and automobiles (rentals). It then becomes a cost-minimizing problem for the producer to decide on the durability of the equipment, when to change parts or the entire product and/or when to modernize it. The product will be designed accordingly, and it is to be expected that the technical designs will differ depending on who will own the equipment.

How to achieve all this is a practical engineering task, even though the art of integrated production (See Table 8) has added a degree of analytical method to it.

5.8 Additional Product and Technology Areas the Origin of Which Can Be Traced to JAS 39 Gripen

A number of additional technology and product areas with a future market potential have their origin in military aircraft industry. Four of them will be mentioned explicitly here; space technology, virtual and secure on line design, civil security and unmanned aircraft (UAVs). These three areas are expected by many to define a great industrial future and they all draw directly on the most modern aircraft technology, i.e., on the JAS 39 Gripen system. For the time being that industrial future may be far off. Something, however, has to be said about the potential.

5.8.1 Space Research and Exploration (Case 19)

Military aircraft development and space exploration are closely related, and both Saab and Volvo Aero have had significant development work going on in the area. For Ericsson, space and military communications technology associated with the Gripen system combined to contribute to its mobile telecom effort (see Sect. 4.4 above). When Saab Ericsson Space acquired Fokker Space in 2000, it became the largest subcontractor in Europe to the space industry. Saab has specialized on antennae and computer systems and Fokker contributed solar panels and robot controlled instruments (DI, Nov. 29, 2000).

Swedish space companies have demonstrated a competitive advantage in building inexpensive satellites. Saab Ericsson Space was the leading developer and manufacturer in the Odin 430 million SEK space project of the Swedish Government space company (*Rymdbolaget*, DI, Feb. 7, 2001).[17] Even so, Saab has had difficulties achieving the internal synergies between its core aircraft design and space product development that are necessary for satisfactory profitability. Saab therefore sold its space business in 2008 to Swiss Ruag Holding for 335 million SEK. "There are better opportunities for synergies within Ruag" says CEO Åke Svensson (DI, July 16, 2008:9). One reason for this divestment is Saab's already very fragmented product portfolio. The space activity for Saab can therefore be seen as a spillover from its military aircraft operation that has been nursed and then sold off.

The situation for Volvo Aero is different. Space rocket engine development contributes directly to its military and civilian aircraft engine systems development. The main contributions fall within new materials and welding technology to achieve systems components, today notably lightweight structures with a capacity to withstand high temperatures. High temperature robustness is important for fuel economy which is becoming increasingly demanded in civilian aircraft engine design.

5.8.2 Virtual and Secure Online Design: Encryption/Security (Case 20)

The geographical distribution of product development and manufacturing (distributed and integrated production) requires high transmission capacity and secure data communications, and increasingly so when it comes to virtual representations of visual drawings and maps. Security is especially demanding in military aircraft and engine development. The same technology, however, has a host of civilian applications.

It is possible today to develop and, to some extent, test the prototype design of an aircraft in the computer to make the first aircraft is the production run also the first test aircraft to be flown. The first Gripen subjected to test flights was a conventional drawing board product. The first production aircraft were, however, CAD products. The first civilian aircraft Saab 2000 in 1992 was a digital mock up. In the late 1980s, Dassault Systems and IBM secured a contract with Boeing to "build" the first digitally designed aircraft (the Boeing 777) using Catia. Catia is a CAD/CAM software system, a spillover from French military aircraft industry (see Chap. 7). By the mid-1990s Dassault Systems and its Catia dominated the use of CAD/CAM systems in the auto and aerospace industries (BW, March 2, 1998). We have reasons to expect the virtual design technology potential for industry at large to be great.

Most safe telecom connections have been developed for military applications (Cf. Sectra case). One belief is that encryption technology and security technology, furthermore, will be the ultimate enabler for electronic banking, payments, and trade (McKnight and Bailey 1998:19).

In the aftermath of the cold war in the 1990s, thousands of electronic engineers laid off from the California aircraft and military electronics industries went to Hollywood and have since then created a revolution there in the animation and entertainment industries. Others went to automotive industry to form the backbone of a revolution in automotive virtual design. Virtual real-time game technology has been developed for military training and strategic analysis. Saab Training has been successful in marketing its systems in that field internationally. It looks as if the virtual game industry and the possibility of real-time game simulation will, in turn, spill a new wave of technologies to other civilian industries and back again into military industry.

5.8.3 Civil Security (Case 21)

In the early post-cold war era, it was soon realized that the military task might no longer be to protect national borders from armies but the interior of a nation from particularly dangerous groups of individuals. Protection of airports, nuclear power plants, and sensitive spots in the electric power grid from terrorist strikes are examples. This is a very different and probably more difficult task than monitoring the outer national borders. It has become a new challenge in the post-cold war era. Not least important is *the need to protect without violating the integrity of individuals in, and the democratic principles of Western nations*, indeed a challenge that the technologically advanced Western democracies simply have to win.

The civilian security markets are potentially enormous and to a significant extent based on military systems technology, and particularly so when it comes to computing and communications. From the beginning of the new millennium service-oriented software-based systems architecture and network-based thinking dominate development. The civilian security technology may not be as sophisticated as the military technology, but without a base in military technology there won't be a civilian security technology development. Losing the military technology competence, therefore, is synonymous with giving up on a business opportunity in the sophisticated end of the civil security market. And the civil security markets, even though not yet well defined and extremely diverse, are enormous.

In the post-"September 11" era, protection from terrorism has become a civil security issue of some magnitude. Most of the military surveillance and information technologies, notably those related to the so-called networked defense have direct applications to the whole range of catastrophe preparedness issues, rescue operations, etc. The capacity to monitor a complex rescue operation in real time, such as the Estonia disaster of 1994 in the Baltic, is simply impossible without modern military resources. The EU has also defined a huge R&D program for space and security research where defense from terror against civilian aircraft plays a key role (*Ny Teknik*, May 9, 2005). Most producers of military equipment also have a foot in the security business. Saab Avitronics develops and manufactures the electronic jammer that Gripen has instead of stealth protection. It also develops and markets the civil aircraft missile protection system CAMPS. This equipment can be installed on passenger aircraft. It automatically reacts to attacking UV-missiles and dispenses pyrophoric decoys that divert the incoming missile. In fact, South African industry has a long experience from terror protection and Saab's industrial involvement there therefore may become mutually beneficial in this area for both countries (See further Chap. 6). Saab Avitronics, for instance, has captured a one billion SEK order from the German Air Force for its radar alert system to be installed on the Tornado aircraft (SvD, Aug. 16, 2005).

To prepare for an established future in the civil security markets Saab pulled together activities from different business areas in 2008 to form a separate civil security business unit. To emphasize the future priority of this market civil security has been made a central part of the new Security and Defense Solutions business area that will become operational from January 1, 2010 and will account for some 20% of Saab sales. The fact is that a large number of sophisticated small technology businesses have been established and Swedish aircraft and space technology will support expansion in this market, but they are also interesting acquisition objects for foreign investors.

5.8.4 Unmanned Aircraft and Future Air Transport (Case 22)

Unmanned aircraft (UAVs) is already a military reality, and a very effective reality at that. In the long term, however, many people see a civilian market for pilotless aircraft that will be based on military technology developed ahead of time. So, all aircraft developers of importance have a foot in this field.

Midcas is a joint project between a number of European nations and aircraft producers, among them Saab. The longer-term ambition of Midcas is to define what is needed to fly UAVs in controlled airspace. In the near term, the development of sense and avoid, or collision avoidance systems, is on the agenda.[18] These technologies will have a wide application area also in current manned air traffic and in automotive accident prevention. Even if unmanned aircraft in the civilian aircraft market may be far off, development in this area is certain to steadily improve the safety of the manned civilian air traffic.

Saab is developing *Neuron,* a military UAV demonstrator together with French Dassault and some other European aircraft manufacturers. Such European collaboration projects are important for both Saab and Swedish defense and security authorities that learn to work together in the slowly merging European industrial environment.

A significant part of the problem to be solved for UAV traffic to become a reality has to do with developing and agreeing upon international standards for UAV traffic in controlled airspace. And even though completely unmanned civilian air traffic is beyond the current horizons many of the security devices already developed or in advanced stages of development can be implemented on manned aircraft, for instance to reduce the number of pilots required on long-distance flights.

5.9 The Development of a Specialist Consulting and Subcontracting Industry: Competence Bloc Formation

The JAS 39 Gripen generation of military aircraft differed from its predecessors in acquiring many more components and subsystems in the market “off the shelf,” than was the case with its predecessors. This has increased the intimacy between military and civilian producers compared to before, each side benefiting from the other. For orders to be placed in the same national markets as the developer and user of the aircraft, however, a wide range of specialist subcontractors also have to exist locally. This is less likely to be the case the smaller the economy. This “commoditization”of the military aircraft industry therefore also opens up a new perspective on the role of the national customer/procurer that I will discuss in Chaps. 7 and 9.

A more acute concern of this study, however, is the local development and existence of such a specialist subcontractor industry. Its spontaneous development is a matter of local entrepreneurship. Its existence constitutes a national competitive advantage and therefore is a national concern. If successful, entire industrial competence blocs may develop. And the original ambition of the procurement process for JAS 39 Gripen was to support spontaneous industrial formation and development.

5.9.1 Advanced Subcontractors as a National Competitive Advantage

Not long ago, most components and subsystems of military aircraft were developed and manufactured internally, even advanced subsystems. This was the case, for instance, with landing gear and rescue systems for the Swedish military aircraft up to and including the Viggen. One reason that is still to some extent valid for this seemingly inefficient and costly practice was that tailor design of subsystems and components was necessary to achieve the extreme performance characteristics demanded of the military aircraft as a whole. Another and more acute reason was the absence of specialized producers of such products and markets for specialized subcontractors. Such markets have developed in pace with the evolution of distributed and integrated production. Saab was also the pioneer both when it came to developing a safety technology for its aircraft and in out-contracting the manufacturing of particular equipment for its rescue systems such as the ejection seats. Advanced and expensive products such as military aircraft also use very expensive components and subsystems so the economic base for outsourcing arrived earlier in aircraft industry than in other manufacturing industries, and this was especially so if there existed a complementary civilian aircraft industry.

The evolution of global markets for specialized and very advanced subcontractors that are a must for modern manufacturing industry, therefore, could be first studied in and around aircraft industry. To some extent the capturing of the opportunities to develop an advanced subcontracting industry depended on the generosity of the customer in allowing for a margin of experimental technology development. This was a nice feature of earlier Swedish military procurement. Generosity, however, has its limits in business life. Tough competition also sharpens the innovation process and forces economical selection of new technologies.

The development of global markets for specialist subcontractors has improved the technology transfer links both ways between military and civilian aircraft industry to the benefit of both. Access to specialist subcontractor markets also makes it possible for a firm to complement its internal competence with technologies it does not possess rather than trying to develop them on its own. There is also the possibility of overcoming the *organizational forgetting* syndrome for which aircraft industry tested positively in Benkard (1999), namely that recent production is more important for learning and current production efficiency than more distant production. Expressed differently, learning on the job is important for firm efficiency,[19] but old learning embodied in the staff of people may raise the costs of using the most recent technologies. Forgetting matters. Benkard (1999) studied this at the transition of accumulated experience between different civilian aircraft models, but the same problems will probably be more difficult to overcome when it comes to commercializing military technology in civilian markets.

Kelley and Cook (1998) have studied the special relations that Pentagon imposes on prime defense contractors that "obligates them to "volunteer" information on their business practices as a "condition of their special relationship with the government." They find that defense contractors have learnt more quickly about IT applications than firms outside the defense contractor network, and that this learning about advanced industrial practices in military production has spilled to the civilian operations of the networked companies as well. Kelley and Cook (1998) observe that "this unusual regulatory regime" has promoted a kind of cooperation among the networked companies that has been difficult to organize in other industries in the USA. They refer to the similar effects of collaboration among automobile and machinery manufacturers in the German Baden-Württemberg region which has occurred spontaneously in the market.

5.9.2 Engineering Consulting Bridges the Gap Between Technology Creation and Technology Adoption

To identify, select, finance, and take commercially interesting and odd technologies (winning spillovers) to industrial-scale production and distribution, a sophisticated local commercialization industry is needed (see competence bloc theory in Sect. 2.4). A similar bridge made up of a diversified and sophisticated engineering consulting industry is needed to bridge the gap between odd technologies (once identified as commercially interesting) and industrial implementation in a receiving firm. This engineering consulting industry has mushroomed with the rapid increase in recent years in technological sophistication across industries and above all with the distribution and globalization of production. Distribution of production means that technological links have to be created between autonomous producers in the market and that often large deficiencies in competence requirements have to be patched up. This is all a natural extension of Adam Smith's principle of decentralization, of the associated requirements of learning and finally of the creation and diffusion of knowledge. Large high-tech firms such as Saab, Volvo, and Ericsson draw heavily in their daily business on external consulting services in this market for distributed (tacit) knowledge. Consultants are brought in for long and brief periods when their knowledge is lacking internally and when only temporarily needed.[20] This consulting market therefore enhances the efficiency of the entire industry. The firm that hires these external specialists, furthermore, needs to master the complementary art of managing and coordinating its complex network of specialists.

Diversity in this market is enormous and complete secrecy impossible to maintain. To be able to participate and take, the participant also has to give. Even though Saab itself uses such specialist consultants extensively there is an even greater market demand for the specialist knowledge that resides within the Saab organization, and that can be commercialized.

5.9.2.1 Case 23: Engineering Consultancy (Combitech AB)

Saab Scania Combitech was founded in 1983 and assigned the task of developing separate businesses based on the military aircraft technology spillovers. A flora of companies was founded under the umbrella organization that Combitech represented (See Eliasson 1995:81). Technologies were spun off from the Saab "technology cloud" at a rapid rate and incorporated. Strategic complementary acquisitions were made and new business combinations formed. Many of these firms were sold off in the market. In general, however, it was found difficult to charge reasonable prices for these high-technology firms. It was difficult for the Saab technology organization to market and identify matching high-paying customers for technologies, the commercial side of which was often entirely outside Saab's own experience. Even more important was the fact that developed markets for trade in such strategic high-technology assets were and still are lacking. This is in practice also the case in the USA. As a consequence, it was also a less than profitable business for Saab to outsource the task to match technology supply with interested customers. The rare customer found almost always appropriated the profit, except when it made a mistake or when the market was overheated, as it was during the IT bubble in 1999/2001. In 1997, Saab therefore decided to shutdown its Combitech umbrella organization and most of its ingredient companies were sold off at a rapid rate and not at extraordinarily high prices. Among the remaining firms was the consulting firm Combitech Systems[21] that was merged with Aerotech Telub (that had come to Saab with the Celsius acquisition in 2000) in 2006 into the consulting firm *Combitech AB*. Combitech AB currently (spring 2009) employs some 800 people, practically all of them professional engineering consultants. The businesses of Combitech are divided between two divisions, one working almost exclusively with security solutions for public customers, notably defense, the other with private industry. Thirty percent of turnover is from internal Saab consulting and about as much is directed at private industry. The main competence assets of Combitech draw on Saab's (and Celsius's) internal competence accumulation and engineering experience. The military origin is dominant and from the Gripen system in particular. A group of Combitech people worked on the Gripen control and guidance system before Combitech was formed.

Embodied real-time systems is one Combitech specialty and this competence is currently being integrated with mechanical systems competence which is one of the heavy competence areas of the Gripen project (See above). Since Gripen is an extremely sophisticated high-technology product, having worked on a Gripen project or in relation to Gripen is a valuable reference for Combitech consultants when addressing the civilian market.

Systems integration and *safety-ciritcal software* are related competence areas that originate in Gripen and carry many potential civilian applications. The Combitech engineering consultants have great use for this experience in medical technology, automotive, and telecom industry consulting in particular. *Model-based work practices*, for instance, have been developed for simulated automated engineering production at Atlas Copco Tools, for instance, to establish traceability when it comes to the quality of the tightening of bolts. Safety-critical software has been used on a consulting job on Volvo S80 where a large number of internal computer-controlled systems from different suppliers (climate control, the telematic system, ABS brakes, engine control, safety systems, etc.) were to be made compatible and integrated. All these technology areas were developed within Saab long ago for the Gripen project.

5.9.3 Industrial Competence Bloc Formation in Linköping (Case 24)

When a vertically complete and horizontally varied competence bloc has reached critical mass it becomes a combined attractor for advanced industrial location in, and a spillover source, in short a sustainable endogenous growth generator (see Sect. 2.4). As a consequence not only an aircraft industry competence bloc has developed around Linköping but also a highly sophisticated competence bloc in signal analysis, image recognition, microwave communication and the design of compact and robust mechanical systems, notably around the weapons and guided missiles development of Saab Bofors Dynamics (now within the new Dynamics business area. See Sect. 4.2.1). A special technology area development that has benefitted from the integration of sensors and electronics technologies with mechanical products in aircraft development has been the diversified formation of medical technology firms in the Linköping area and an associated development of chemically based medical firms in the not so distant Karlskoga region where energetic materials such as gunpowder and dynamite have been produced for cannons and (now) guided missiles since the times of Alfred Nobel.

A cluster of high-tech innovative start ups has been developed around Saab over the years. Some of them, for some time, were organized under the Saab Combitech umbrella company. Some of them developed military technology (like Saab Missiles), but many of them civilian technology. Some of them are currently part of the previous Saab–Celsius cooperation (since 2000, a 100% Saab operation).

The difficult management problem, however, has been to identify and carry radically different and odd technological spillovers to full-scale industrial production and distribution under the parent's management umbrella. *Saab Ventures* was, therefore, founded in 2000 to manage the selling of noncore technologies spilled by Saab.

The list of noncore technology spilled from Saab is impressive (See further *Transfer*, No. 2, 2003). Saab Missiles (now *Saab Bofors Dynamics*) converted some of its military radar technology to an instrument to measure the level of oil in tankers and to compute remaining volume. *Saab Marine Electronics* was established on that technology. It became a winner that earned Saab good profit. In 2003, it was sold to US Emerson for 800 million SEK, and Emerson has never regretted the price it paid. *Saab Traffic Systems*, another Saab Missiles spillover located in Jönköping was sold to Austrian Kapsch Traffic in 2000 for some 100 million SEK. Kapsch recently captured an order from South Africa to install one of the largest traffic toll systems in the world around Johannesburg and Pretoria to finance the improvements of the motorways needed to prepare for the global soccer competition there in 2010 (DN, Sept. 29, 2009).

Track AB was spun off as a separate "entertainment" company in 2005. Trackab uses image recognition technology and tracking algorithms for missiles developed by Saab Missiles to "target" individual soccer players in the field through an array of cameras such that TV viewers can follow individual players during a game.

C3 Technologies is a – according to Saab – promising company that has developed three-dimensional air surveillance (photographic) pictures. It was spun off as a separate company in 2008.

For its 2000 regional aircraft, Saab developed a system for electronic noise reduction. The method was to reduce noise from the propellers and the turbo prop engines in the cabin by computer generated antinoise. This technology is the base for the Saab company *A2 Accoustics*.

There are also several medical technology spin offs to report. Already in the 1970s, the Bofors metallurgical laboratory (now within Saab) began cooperating with

Dr. Per-Ingvar Brånemark to develop bone-compatible dental implants in titanium. The critical military contribution that made that feasible was extremely precise metal machining technology used in the production of guns and its ammunition. After a long series of delays that were associated with a slow customer acceptance of the new dental technology (the dentists) and difficulties of financing the project (even though Bofors had founded it originally) a new company (Nobel Biocare) based on the *Brånemark method* was founded and later introduced on the Swedish stock market in 1994 (Fridh 2002). The company has later been acquired cheaply by Swiss BB Medtechs (see Eliasson and Eliasson 2005a: note 181).

There are other more recent military medical spin offs; for instance, *Sangiustech* based on a technology to centrifugate blood that was sold to Gambro in 2000.

A patented method by Saab to pressurize the skin, originally meant for the development of a G-suit for military pilots was later used to develop an elastic sock for helping people with circulatory problems, e.g. oedema. The company *SMM Medical* was founded on that technology and has later been spun off.

The mathematical methods used by Saab to simulate airflows around combat aircraft have been used to simulate the flow of blood around the heart. Together with the Linköping University Hospital, magnetic camera techniques and computer simulation have been combined to achieve a better understanding of blood circulation flows under different conditions and to improve the precision in measuring those flows.

Sectra is another IT and medical technology company that was established in Linköping because of the very early computer and digitally inclined academic environment of the Institute of Technology, an academic inclination that owed its existence to early support, demand and encouragement from the users of computing technology within Saab (See Case 12 above).

All business units within Saab in fact have a history of spillover intensity, spillovers that Saab has attempted to capture and earn a profit on using different management methods. Saab Missiles (now Saab Bofors Dynamics) has been particularly prolific in that respect and I will detail some cases below. The overall picture of Saab, however, is that of a technology-intensive business organization with a tremendous creative capacity that has to both focus and to find better ways to capitalize economically on its rich flow of spillovers.

5.9.4 The Subcontracting Contract

The standard military procurement contract in the past was *cost plus pricing*, and separately negotiated charges for modifications. From the 1970s, electronics had entered manufacturing industry in a serious way and profoundly changed the aircraft industry. Technological change became overwhelming and cost overruns for modifications large. This had become a concern with the JAS 39 Gripen procurement negotiators, and the concerns even included the possibility of the purchase going abroad. So even though the expected future technological change was expected to become even larger than before, the concerned industrial partners approached the Government customer in the late 1970s and offered to take on a fixed price contract (See the *Gripen Chronicle* 2005). This made it important for the supplier firms to come up with a flexible platform design that allowed easy future modifications of the aircraft.

IG JAS consortium formed to manage the industrial side of the procurement (see Technical Supplement S1), therefore, was different from earlier procurement of combat aircraft. IG JAS was committed to delivering a complete aircraft with certain well-defined functionalities/properties and at a fixed price, or a *design to cost* contract that was far tougher than earlier and more loosely negotiated cost plus contracts. The IG JAS consortium thus had to take on a significant technical risk and therefore also attempted to pass the risks on to their subcontractors.

5.9.5 Risk Sharing Among Contractors

Saab was the coordinating contractor and therefore took on a considerably greater risk than the other participants/ partners. As a consequence, it became necessary to shift some of the risks on to the subcontractors, very much as the big civilian aircraft and aircraft engine producers also do today when they engage Saab and Volvo Aero in the development and manufacturing of subsystems. IG JAS alone carried the risk of delivering the complete aircraft on time with the agreed-upon properties.

The consequence of this tougher procurement process was that Saab could find very few Swedish firms that were willing to engage in the large risk sharing required of them to be allowed to be involved in the development of advanced aircraft subsystems. In the end, therefore, almost all Swedish subdeliveries consisted of components, and most subsystems contracts went abroad. Only one Swedish subcontractor (Nobel Plast, now ACAB, see case presentation in Sect. 5.5) outside the IG JAS partner group took on a complete and very advanced subsystems contract, the radom nose cone of the Gripen aircraft that housed the radar antenna within a plastic nose, a material that could be designed "to receive signals, but not leak signals."

Saab's argument when negotiating subsystems contracts was: This is your opportunity to become a global competitor/ subcontractor in your field. That opportunity is valuable to you, so you should cover a significant part of the financing and the risks yourself. IG JAS is only paying the global market price charged by already established volume producers. Swedish potential subcontractors were not used to this, and did not come forward (for more details on this see Technical Supplement S1).

For several reasons it was considered impractical for the IG JAS partners to organize a central purchasing operation. The main reason was that components and subsystems for Saab, VAC engines, and Ericsson electronics were so different and required such specialized knowledge on the part of the purchasing agents that potential synergies would be small, the power to negotiate price concessions of limited importance and a joint organization more a bureaucratic nuisance than an improvement. The systems subcontractor then negotiated correspondingly tough risk-sharing contracts with their subcontractors.

Each aircraft, for instance, has to be equipped with a black box that registers what happens to the aircraft in flight and can be recovered in case of accident to figure out the reason. For the Gripen aircraft the specifications were that the black box should stand a water depth of at least 100 m. SLI Avionic Systems (a Lear company) got the contract, but did not deliver up to the specifications. The Saab purchase director did not accept the product and demanded that the product be redesigned. The Saab delivery therefore probably became a loss contract for SLI Avionic, but when it had fixed the black box up to Saab specifications they managed to have the US Air Force install the new black box on all its F 16 combat aircraft. So in the end this became a profitable deal for SLI Avionic Systems.

5.10 What Did Not Happen

An aircraft consists of a number of complex systems and functions; fuselage, wings, engines, guidance and control systems, landing gear electronics (avionics), internal control systems, air conditioning and cooling systems, rescue systems, and Auxiliary Power Unit (APU) systems. In the old days the entire aircraft was normally manufactured in the same factory. Not any longer. Each such subsystem on a modern aircraft is a complex and advanced product, partly embodying extremely advanced technology. The engine is the best example. Most of these subsystems have become the platform for the development of specialized subcontractors that operate internationally.

The tough conditions enforced at the Gripen procurement (compared to the Viggen purchase) meant that Swedish subcontractors became too expensive. One reason for the old Saab contractors being expensive was that contrary to many of their international competitors they were not specialized on the kind of products now demanded. They were also not willing to take the opportunity and the risks of becoming a specialized global systems supplier through sharing development costs with the IG JAS Consortium. To get Swedish subcontractors Saab had to go down to the component level.

5.10.1 Spillover Opportunities Missed (Case 25)

In several Swedish firms some competence from previous subsystems contracts with Saab existed. Still the contracts went abroad. The best examples are (1) the landing gear, (2) the rescue system (for military aircraft), and (3) the air conditioning and cooling system. These are good examples because the Swedish firms had been subcontractors for earlier Swedish military aircraft. At the time of procurement for the Gripen, however, there were three or four specialized international subcontractors for each of these systems.

5.10.1.1 Example 1: Landing Gear

The landing gear of the Viggen and earlier Saab aircraft had been designed by Saab engineers but manufactured by Motala Verkstad in Motala, Sweden. This time the designers of landing gear in Saab had retired or left the company. Motala Verkstad only had manufacturing knowledge. The Gripen contracting conditions left no economic leeway for the reestablishment of an internal team within Saab to design the landing gear for Motala Verkstad, not even considering the new civilian aircraft that was then in the development phase. Saab was involved in too many engineering tasks even to consider this one. With the new civilian aircraft in the making there was also a considerable future domestic market for a Swedish subcontractor of an advanced subsystem for aircraft. Motala Verkstad, however, was not interested in taking on this business. The real threat of seeing the contract going abroad, however, stirred the political opinion both at the local and the national level.

Saab still considered the possibility of outsourcing design and development of the landing gear to a foreign firm and let the four potential manufacturing subcontractors, including Motala Verkstad, compete for the job. This alternative was, however, not economical compared to buying an existing landing gear in the market and have it modified. So the purchase of the Gripen landing gear went to UK AP Precision. This firm had just weathered a crisis and was prepared to deliver at a very low price.

The purchase of landing gear for the civilian Saab 340 was managed by Saab's early partner in the civilian venture, US Fairchild Industries on Long Island. Quite independently of the Gripen contract, the contract for the 340 also went to AP Precision. Again, this cooperation continued and the landing gear for Saab 2000 as well went to AP Precision.

5.10.1.2 Example 2: Rescue System

Saab pioneered the use of ejection or catapult seats in their military aircraft. The J 21 from the 1940s (see Sect. 5.6. and Technical Supplement S1) used a pushing propeller mounted behind the pilot. In case of accident it was necessary to catapult the pilot far above the propeller. Saab engineers therefore constructed an ejection seat, one for each generation of combat aircraft up to and including the Viggen. Despite its initiative, competence, and technical lead Saab did not develop this business further. During Gripen procurement a competition was organized and the Saab engineers were invited to bid for the contract in competition with foreign specialist suppliers. The contract went to Martin Baker in the UK that was a volume supplier of rescue equipment for aircraft.

Rescue systems require special modifications for each aircraft and are expensive to develop. To be successful as a specialist supplier, an international reputation as quality supplier has to be established and this requires large marketing investments. The alternative to develop aircraft rescue systems as a specialist business within Saab, therefore, was never an issue, even though Saab had the required technical expertise. The interesting question rather is why no outside Swedish entrepreneur rose to the opportunity to establish a separate business in rescue systems. The consolation, however, is that Saab's pioneering of rescue systems technology for military aircraft, because of its close links to the automobile industry appears to have diffused to Swedish automobile industry (Saab Automobile and Volvo Car) that in turn became pioneers in automotive safety.

5.10.1.3 Example 3: Environment Control System

Cooling, ventilation, air conditioning, heating, and air pressure control of the aircraft are handled through a separate system. There are differences between military aircraft where the cooling of electronics and instruments is important and civilian aircraft where the comfort of passengers matters more.

Cooling and air conditioning consists of a number of component systems of which the cooling machine is one. These component systems have to be integrated with other functions of the aircraft and the efficiency of the system requires a significant input of technical calculation. The installation, in turn, requires extensive tubing.

Most components are purchased in the market but the overall design is particular for each type of aircraft. There are several subcontractors in the market but the most important ones are Garret (for the Viggen), British Aero Space (for the Gripen), and Hamilton Standard (for Saab 340).

The aircraft developer is normally responsible for the technical calculations and the tubing which are unique for the aircraft. Altogether advanced systems and systems integration knowledge is needed to do this right, not least to save weight. Individual components on the other hand have always been purchased in the market. Contrary to the case with landing gear and rescue systems, which consist of standard systems modified for the particular aircraft, the cooling and air conditioning systems are designed to be integrated with the design of the aircraft and installed as part of the building of the aircraft. This market is not yet ready for separate specialist integrators. It was never an issue for Saab as an aircraft developer and manufacturer to enter the relatively low tech market for cooling and air conditioning equipment, since at the time of Gripen procurement such equipment was readily available in the market. For Saab to enter that same market as a designer and installer of complete and integrated systems has never been an organizationally and economically feasible alternative.

5.10.1.4 Example 4: The Auxiliary Power Unit

When on the ground, large civilian passenger aircraft in particular have to keep a number of internal systems up and running. In the air these systems are driven by the engines. Such systems are electricity supply, air conditioning, hydraulics, etc. On the ground these systems are kept running by a small gas turbine that is supplied by external vendors. The most important external suppliers are Garret (USA), Sundstrand (USA), P&W (USA), and MicroTurbo (France).

Saab has always purchased these systems externally. This is a matter of specialist and fairly low tech competence that has not naturally existed in, or been developed within, Saab. The contract for Gripen went to French MicroTurbo. The interesting observation from a Swedish point of view was that despite the local opportunities associated with the combined Gripen and civilian aircraft programs no potential Swedish entrepreneurs rose to the opportunity. MicroTurbo, however, was not up to its technical commitments and a new APU had to be developed by US Sundstrand. New and more advanced design technology for communication over long distances between the integrator and the subcontractor now had to be introduced to prevent serious delays of the entire aircraft.

5.10.2 The Large Part of Gripen Spillovers Has Been Captured by the Large Partners in the IG JAS Industry Group

Summing up on this theme, I make the following observations. The previous subcontractors to the Swedish (military) aircraft industry have been unable to manage the transition from simple contract manufacturing to subsystems development and production increasingly associated with the upper end of the value chains in distributed production. This should be considered a problem for Swedish industry at large. I have not studied the purchasing of components in the markets for contract manufacturing. The situation here is more similar to those in automobile subcontracting where competition is notoriously intense, and high-wage Swedish producers without superior products disadvantaged. Entering those markets apparently was not viewed as a business opportunity by small Swedish producers.

Even though most independent potential systems producers backed out, the IG JAS partners rose to the opportunity and developed technologies and products that spilled further into civilian production and markets. So, one cannot say that the advanced systems subcontractors for Swedish aircraft industry have disappeared. Both in electronics and in aircraft engines the advanced competence remains in Sweden and has been developed further. When seen from a very long-term industrial perspective, however, this may not be what matters most importantly. The important observation to make is that only the large and established firms were prepared to take on the considerable technical and commercial risks involved even though even more technical competence might have existed among the small- and medium-sized firms. Was this so because of risk aversion among the small- and medium-sized firms, or because of lack of industrially competent venture financing.

The situation is entirely different when it comes to the simple contract manufacturing industry that manufactures on specification and only competes with costs. Swedish subcontractors took on such jobs. But this carries little significance for the Swedish economy in the long run. Some of the deliveries discussed above, furthermore, have been out-contracted to South Africa as part of the Saab South African sale of 26 Gripen aircraft. That production is definitely more welfare enhancing for South Africa than it would ever have been for Sweden.

5.11 Notes

1. For presentational reasons, however, the spectacular Ericsson mobile telephony success story was told in the previous chapter.
2. The visible difference is the landing gear, which has been moved into the wings to make room for a larger fuel tank.
3. See, for instance, Hartley (1994).
4. They are in alphabetical order China, France, Russia, Sweden, the UK, and the USA. If we include small civilian aircraft, Brazil, Canada, Germany, Italy, and Japan should be added.
5. The US Awacs airborne surveillance system is extremely expensive to operate.
6. Also see *Transfer,* No. 4, 2003 on Saab Ericsson Space.
7. There is no surprise that the idea of "a learning curve" first appeared in aircraft production even though in a very simplistic form compared to what we are now talking about. See Wright 1936.
8. See Drezner et al. (1992) and Eliasson (1995:52f)
9. Saab shutdown its civilian aircraft activity (Saab 340 and 2000) in 1999. The situation is somewhat different now when Saab is engaged in developing and manufacturing complex subsystems for Boeing and Airbus. But the complete product systems design competence comes in readily because subsystems designs still require a holistic capacity. The Internet, furthermore, has made it easier to achieve the necessary coordination between teams over geographical distances. Cf. Modig Machine Tool (Case 16) that works intimately with Boeing from a remote small town in southern Sweden.
10. This probably also explains Stafford and Stobernach's (1989) observation that the more experienced and educated the workers and the more complex the product, the longer they hold their jobs. This contrasts with the faster turnover of workers that hold low skill and well-defined jobs. They have access to a larger market but can also easily be replaced in the market. Also cf. the concept of *the firm as a competent team* in Eliasson (1990a).
11. There has been a strong drive to outsource the manufacturing of simple components to low-wage economies such as China. Outsourcing and globalization have, therefore, almost become bad words. However, even holding together a simple value chain over many subcontractors in many countries, and especially in the industrially less-developed countries, have proven to be a difficult management problem. The common problem has not been delivery delays, but misspecified products, especially for customized products, and quality has suffered. To correct for that ex post has often eliminated the gain from the low wages and made firms return the manufacturing of even simple components to high-wage Sweden. Both to compute the productivity benefits of well-organized, distributed, and integrated production and to calculate the costs of disturbed flows in the production and distribution network has proven difficult using old-fashioned sequential calculation methods (Eliasson 2005c).

12. This is still a great concern in economic theory. Prices (prices carry information) are analyzed under the assumption of constant structures, and vice versa, production theory assumes constant prices.
13. The German and French markets, however, had been closed in practice, apparently, the Modig management believed, by a prevailing nationalistic business mentality there. German and French customers, it is true, courted Modig and learned what the company could offer, but orders always went to a domestic producer.
14. For its history, see Nilsson (2003).
15. The sensors of today are however based entirely on electronics.
16. Hence, about one-third of Gripen is American, one-third European, and only one-third Swedish (*Militaer Teknikk*, 4–5/2006:4)
17. *Saab Tech Electronics* manufactured structural components and *Saab Ericsson Space* developed the computing, guidance, and control system and assembled and tested the entire satellite.
18. This work is based on the anticollision or sense and avoidance systems that had been developed for, and installed on the JAS 39 Gripen. Saab, in fact, had advanced plans to test its sense and avoidance system in an UAV over Linköping in 2008 (See *Ny Teknik*, Sept. 3, 2007:23 and 2008:36).
19. The notion of a learning curve was first developed in military aircraft industry (Wright 1936).
20. There is an interesting parallel. It was long argued that the establishment of engineering schools and universities has been a vehicle for moving the Industrial Revolution. How come then that England, where the industrial revolution started had no such technological universities. On this Hill (1965) observes that in the emerging industrial areas in England, a prosperous and growing engineering consulting industry could be found that specialized in converting the new science principles into industrial practice. These consulting firms were, however, too small to be "statistically observed" by the economic historians. It is also worth noting in the special context of this book that the first technical university in the world, Ecole Polytechnique, established in 1794 in Paris, was founded to teach military engineers build roads and bridges to beat the English in war.
21. Until 1996, Combitech Software that was created from Saab Instruments in Jönköping in 1992 in response to a growing demand for software in Saab's products.

Chapter 6
Saab in South Africa: Technology Transfer to an Industrializing Economy[*]

Spillovers are a positive characteristic of an advanced product. They carry extra value to the buyer and the local economy over and above the product itself. Their value, however, depends on the local receiver or commercialization competence to create a business on them. This local receiver competence is embodied in what we have called local competence blocs. The quality of the competence blocs as industrial "business promoters" varies from economy to economy. Since the receiver competence of a company is strongly related to its own R&D spending we would expect the industrial economies to be far superior in their ability to benefit from spillovers to the industrially developing economies and that the smaller the economy the larger the share of benefits drawn from global spillovers. The South African purchase of 26 JAS 39 Gripen military aircraft, therefore, offers an opportunity to compare the industrial spillover effects between an industrially developing economy and that of Sweden.

The South African purchase was intermediated in 1995 by a joint industrial company created between Swedish Saab and British Aerospace.[1] Even though the JAS 39 Gripen had been developed and largely manufactured in Sweden the purchase was accompanied by a number of industrial cooperation programs designed, as part of the purchase contract, to support the local South African capacity to benefit from the spillovers and the presence of Swedish industrial firms. The strategic aim of most of the agreements was to support local industrial development under a long time horizon, not the creation of temporary employment. In that sense the Saab sale of Gripen to South Africa can be seen as part of an industrialization support program competing with other forms of industrial development programs.

I have found the main contributions of the Saab/BAE Systems sale to South Africa to be:

1. Saab/BAE Systems contributed industrial management competence in return for profitable industrial cooperation. The transfer of *management knowledge* is the perhaps most important contribution to South Africa, even though,

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[*] This chapter is based on two interview visits to South Africa in 2008 and has benefited very much from the perspective of two previous interview visits to South Africa in 2000.

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for some reasons, offset credits were not granted for such knowledge transfers (More on this below).

2. Saab/BAE Systems has been a competent purchaser of sophisticated components in South Africa, thus operating as very *competent customers* and stimulating the development of a *competent local subcontractor industry.*
3. Saab/BAE Systems and associated firms have *helped local firms reach foreign commercial markets*.
4. Important in the long run is the establishment of specialized subcontractor arrangements for subsystems and components for the JAS 39 Gripen assembly in Sweden. Several South African subcontractors have gradually learned the manufacturing precision and quality control requirements. They have also learned that delivery commitments have to be honored by suppliers to become part of a modern logistics system and to participate in today's globally distributed production.
5. To be counted as a successful generator of future exports the public customer has to insist on commercially sound contracts and avoid distributing favorable subcontracts to politically allied businesses.
6. The South African military aircraft deal has contributed to the development of a growing pool of *skilled and experienced workers*. The rate of growth of the entire South African economy is, however, limited by the size of the advanced industry from which workers can learn modern industrial methods and practices, and growth in this advanced part of industry is in turn limited by the availability of educated and experienced labor. This catch can only be resolved through increases in *foreign direct investment (FDI)*. And foreign investment will only be in steady supply if politicians make it their prime objective to create and maintain a viable and predictable entrepreneurial climate with low political risks.

All this has been (and will be) necessary for South African industry to return to modern industrial practices lost during three decades of isolation.

Well formulated offset trade contracts should therefore benefit both parties, especially offset trade agreements that focus on the support of both local receiver or commercialization competence and on the development of worker skills. We are then talking about incentive contracts formulated such that economically valuable spillovers are both generated and captured locally.

So if political uncertainty can be kept low and the situation maintained that makes foreign direct investment reasonably profitable, industrial wealth in South Africa will grow along with the supply of labor skills.

The Saab/BAE Systems consortium has thus functioned *as a technical university* that delivers research, experience, and training services to other firms in related industries and of a kind close to operations that a more theoretically inclined technical university is incapable of developing and providing. This latter practical knowledge transfer is important for the already developed industrial economies. However, as Keller (2001) observes, it may be far more important for the less-developed economies. But for the less-developed economies to benefit from the global pool of spillovers they have both to attract advanced spillover-rich industrial activities through FDI and to organize themselves such that these FDIs are translated into sustainable local enterprises. For this to happen, the developing economy has to offer something in return. For an industrially developed economy, technology transfer and support in its local introduction is what matters in the long term. The advanced international company, on the other hand, is known to use its international reach to (1) source technology and to (2) overcome barriers to trade to access markets (Eliasson 1991a; Kokko 1992; Lichtenberg and de la Potterie 1996). The attractive long-term argument for both parties therefore has to be to go beyond market access and to find ways of sharing the greater values created when the advanced firm supports the local introduction of advanced industrial technologies that come with the public procurement.[2] To ask the multinational firm to extend subcontracting orders to inefficient local firms or to create temporary local employment means inviting the international firm to pay more attention to its own market access than to support host country long term industrialization goals.

6.1 The South African Opportunity

Military aircraft has often been quoted as the classical example of products the production of which generates large technological spillovers. The aircraft manufacturer is also the best illustration of an advanced firm that functions as a technical university in the local economy. As a consequence aircraft industry has been much sought after in both highly developed and in industrially developing economies as technological boosters of industrial performance. In the rich industrial countries the policy argument has been to maintain industrial superiority, notably in engineering industry. For developing industrial economies such as Brazil and South Africa the purpose has been to make it serve as an industrial catalyst for the development of industries that do not yet exist.

Part of the early marketing challenge of the Saab/British Aerospace consortium therefore was to present a credible long-term story of the economic value of the entire JAS 39 Gripen purchase to the South African Government, including the value to South Africa of the cloud of spillovers. As I have elaborated in the previous chapters these spillovers carry weak property rights and are difficult or impossible to charge for separately. Part of the entrepreneurial skills of the group, and (critical for business success), therefore, was to find an innovative method of bundling the spillovers with the product (the aircraft) to be able to charge for the spillovers (Innovative Pricing). The bundling therefore involved commitments on the part of Saab and BAE Systems to make the technology transfers, or the spillovers economically valuable to South Africa. This task becomes easier when we have a case of both joint production and of joint customership, as is the case with advanced public procurement. Under such circumstances, as I have demonstrated in Chap. 2, a win–win situation that benefits both parties in the deal can be created through cooperation between a competent customer and the supplier. It requires competence on the part of both supplier and customer to organize win–win business situations.

Perhaps most important for the customer is to abstain from directing subcontracts to politically friendly businesses.

Three economies are particularly interesting for my analysis; those of Israel, Sweden and South Africa. For different reasons these countries have developed their own military aircraft capability, and to a large extent on their own.

Israel was forced to learn and to develop their own military aircraft after the 6-day War in 1967 when Charles de Gaulle turned off French military exports to Israel. Public budget restrictions and other circumstances have forced Israel to close down its own full-scale military aircraft program. Imported US venture capital competence has, however, been instrumental in converting local military aircraft technology into competitive civilian businesses. Israel's success in picking up spillovers from its aircraft industry, therefore, has unique qualities and depends on different factors than in Sweden. This is notably so when it comes to making their competence blocs complete by a deliberate policy to import venture capital competence, hence stimulating new start ups in radically new industries. Still, the recipe appears to have been to introduce the firms and their technology on Nasdaq for further industrial development in the US.[3] The technology dependent Israeli economy has thus become very dependent, not only on global technology markets, but also on the US financial market, a situation that clearly hurt already during the IT crisis years around 2000 and 2001 (BW, June 18, 2001).

Sweden was already a fairly advanced industrial economy when Saab was founded in 1937. It had a broad-based competence to receive spillovers within the technological reign of its existing engineering firms. The previous chapters have documented in detail how spillovers from Saab military aircraft development and production generated significant new industrial production. Swedish industry has also been capable of developing six generations of complete jet fighter systems, one bomber (B 17) and two generations of civilian regional aircraft, the latter a very large industrial venture that however failed commercially.

As I observed in Chap. 3, the early and rapid advance of the military aircraft industry during the 1950s and 1960s in Sweden also depended on access to top of the line US technology, notably electronics technology that transferred the capacity to build, and maintain the fourth[4] largest air force in the world to control its airspace across the entire Scandinavian peninsula. (It may even be so that the exceptionally rapid development of Swedish engineering industry throughout the entire post-WWII period depended in part on Saab serving as a vehicle for the transfer of very advanced US industrial technology to Sweden.)

South Africa has had a similar experience to that of Israel of closed off access to foreign military technology. Both countries were forced to develop their own capabilities. (For some time Israel and South Africa also cooperated when it came to developing arms technology). South Africa, and notably after the two UN embargos in 1963 and 1977 had neither the advanced manufacturing industry of Sweden capable of receiving and commercializing top of the line technology from the US, nor access to US venture capital markets as Israel did.[5] The isolation of South African industry during several decades from developments in global markets for products, technology, and industrial specialization, therefore, defines a serious problem of reindustrialization after the lifting of the embargos in 1994. The Saab/BAE Systems industrialization deal also has been important in supporting a reasonably rapid return of South African industry to the global industrial community. This transformation tells an interesting story of the difficulties involved in recapturing ground in a global economy advancing technologically at an accelerating pace after the new Internet connected "technological revolution" had gotten under way by the mid-1990s.

This chapter, therefore, is concerned with the industrial capacity of the South African economy to capture spillovers from the purchase and parts production of the fourth generation Swedish jet fighter JAS 39 Gripen. A full-scale inquiry of the Swedish kind already presented in the previous chapters has not been possible for South Africa. The approach will be to use as much as possible of the Swedish experience. To that end we need to compare the nature of the South African sales and production agreement from a technological spillover point of view with the corresponding military aircraft program in Sweden, that has in fact given rise to documented spillovers, and to compare the receiver competence of South African industry with that of Swedish industry. (The potential of Swedish *Investor* and the *Volvo Group* to boost South African receiver competence through participating in this program will be part of this South African economic analysis.)

A particularly difficult problem is the dual nature of South African industry, being divided into one specialized and technically quite advanced part, oriented toward defense, and one, from an employment point of view, very large but industrially much less developed craft industry sector. Even the image of the advanced part of South African industry is tarnished by the African industrial inferiority syndrome ("the wood carving syndrome"). Another side of the same coin, however, is a technically advanced industry that lacks international production and marketing experience because of its 30 years of isolation from the world's industrial community after the UN embargos were imposed in 1963 and 1977 and until they were effectively terminated in April 1994. This embargo also meant that South African producers had become accustomed to protection from international competition for many years.

The empirical inquiry of this chapter was initiated already in 1999 and began with two interview visits in 2000 to South African firms related to the Saab sale, but for various reasons the study was not completed then. When the study was now reopened I have, however, had the opportunity of almost 10 years of hindsight and early interview protocols from 2000 to compare with.

To remember as we go on is that:

1. Contrary to traditional military sales of hardware and little more (said to be typical of the US business orientation) or deals based on useful political contacts (said to characterize, for instance, Euro Fighter and French marketing), the Saab deal is a commercial hardware sale with embodied spillovers and an industrial support program.
2. The political South African agreement emphasized technology transfer and new industrial formation more than immediate job creation.

3. The entire deal therefore was in part an industrial policy program with complementary offset arrangements to help boost local receiver competence. Since such programs are common in the context of large public purchases, not only in developing economies, the efficiency of such programs as industrial policy will be discussed in Chap. 9.

6.2 The Downsizing of the South African Arms Industry

The de Klerk government began the downsizing of South African defense between 1989 and April 1994. In 1994 the UN embargo was lifted. Even though it had been forced for decades to live a life in isolation from the rest of the industrialized world, being locked into old or odd technologies and the wrong structures, the large South African arms industry still represented an industrial asset. To allow it to collapse or disintegrate, leaving its resources to find useful employments on its own might have worked in an advanced and entrepreneurial industrial economy with plenty of other advanced industries and functioning labor markets like the US, but hardly in the more regulated European economies and not in a developing economy such as that of South Africa with no commercial infrastructure capable of picking up released resources. Here Armscor pursued the only reasonable policy option.

6.2.1 Armscor

The state-owned Armaments Development and Production Corporation (Armscor) had been set up in 1968. As the UN embargo became effective and it became increasingly difficult to procure complete weapons systems in international markets Armscor developed into a large weapons manufacturer to a large extent through acquisitions, for instance Atlas Aircraft in 1969. With time the UN embargo forced Armscor to resort to a number of uneconomic production practices. By 1989 Armscor had developed into the 15th largest company in South Africa in terms of employment and the 34th largest arms company in the world and the largest in a developing economy.

With the demilitarization of South Africa, beginning already in 1989, after South Africa had lost its air superiority in Southern Angola, and being a largely home-based supplier of arms, it suddenly became critical for Armscor's survival to transform its production facilities for commercial markets. But Armscor was prohibited by law from doing this. Most of its production and research facilities, employing some 15,000 people had been separated under the umbrella of the state-owned industrial company *Denel* in 1992. Armscor now focused on its responsibility for procurement for South African Defense (Batchelor and Wilett 1998: Chap. 5).

6.2.2 Denel

Armscor now also gave up its previous preferential purchasing in favor of the domestic arms industry, and therefore soon met with objections from Denel. It broadened its procurement to foreign suppliers, which had become easier even though the UN embargo had not yet been lifted, and began to offer its procurement expertise as a service to other public organizations and to the defense forces in other African states (Batchelor and Wilett 1998:87f). The ambition now was not only to acquire quality, but also to capture the industrial competences there were for South Africa to be found in its private and public defense industry. This strategic view of South African defense industry as an asset, and employing the bulk of South African educated and skilled labor, also an asset, defined an early orientation of South African procurement efforts toward securing industrially interesting long-term growth promoting offset arrangements with foreign military producers (Batchelor and Wilett 1998:85). South Africa's purchase of 26 JAS 39 Gripen combat aircraft and associated offset deals in 1999 should be viewed in this context.

A dramatic downsizing of the South African arms industry followed. Denel shed 1,600 persons 1992/1993, but almost only administrative and unskilled staff, keeping the more expensive professionals and management personnel that were considered critical for its civilian ambitions. The number of operations ("business areas") were cut from 21 to 6 industrial groups in 1993: systems, manufacturing, aerospace, informatics, properties, and engineering. The downsizing and turnaround, however, were both costly and slow. In August 2005, Denel had to announce a new turnaround plan including a request for government recapitalization of R 5.2 Billion, but by April 2008 there was still much left to be done (*African Armed Forces,* April 2008).

The strategy had been to decompose the company into a number of smaller companies each of which should look for foreign partners. Among them should be mentioned *Denel Aviation* (Denel owns 100%), *Denel Dynamics* (100%) developing missiles, guided weapons and UAVs including some businesses with local equity partnerships (e.g., ATE), *Denel Munitions* with a 51% stake of Rhein Metall, *Carl Zeiss Optronics* (Denel owns 30%) and *Turbomeca Africa* with Turbomeca France (Safrane) owning 51% (*African Armed Forces*, April 2008).

6.2.3 Saab Denel Aerostructures

As part of its South African business strategy and to collect offset credits Saab had already acquired 25% in the electronics conglomerate *Grintek*[6] and Aerospace Management and Systems (AMS) in 2006 (DI, Jan. 31, 2006). Saab now looked at three companies "offered" from the Denel complex and opted for Denel Aerostructures. Saab proposed that a new entity be established that was composed of certain businesses, personnel and assets taken out of Denel Aviation. After due diligence Saab found, and demanded that the number of employees must first be significantly reduced. The company was overstaffed, its infrastructure run down, and large losses that Saab did not want to cover remained from a bungled and poorly carried out job for Airbus. Saab and Denel signed a letter of intent in 2006 (*Militaer Teknikk*, 2–3/2006). In early 2007, Saab and Denel formed the jointly owned *Saab Denel Aerostructures Corporation* with Saab taking on a 20% ownership share and a 100% management responsibility. Denel Saab Aerostructures mirrors Saab Aerostructures in Sweden which allows for a rational future division of labor. Even though there are still problems with delivery times and profitability Saab Denel Aerostructures develops and manufactures sophisticated components to the Gripen.

6.3 The Nature of the Product and of Spillovers[7]

An aircraft is a complicated product with a very long life that requires an extremely complex and distributed organization to manufacture.

The product itself integrates advanced mechanical technology, electronics, sensors and new materials with software. In this sense aircraft industry, we have observed, already today uses the technologies of future engineering industry. This is one rational reason also for advanced industrial nations to be concerned about having an in house complete aircraft development capability. *It functions as a technical university* that delivers research, experience, and top of the line training services to other firms in related industries and of a kind close to operations and markets that a more theoretically inclined technical university is incapable of developing and delivering. This is important for the already developed industrial economies. However, as Keller (2001) observes, it is far more important for the less developed economies.

The long life of the aircraft means that to enjoy its services as a user, maintenance and repair services have to be delivered over its life cycle and the product may have to be updated and modernized now and then. In fact, the electronics of a modern military aircraft is normally replaced many times during its 50-year life span. The definition of a sophisticated such product includes features that lower maintenance and repair costs and a built in flexibility in the early platform design that facilitates upgrading and modernization. As the electronics and software content of complex engineering products needed to integrate its many systems functions grows in importance the spillover flows that originate in its development and production also increase.

But this is not enough. Compared to a university, an industrial firm delivers technology embodied in products that both function (are operational) and have been more or less tested in a market for usefulness and/or commercial viability. This means that an aircraft that has gone through both a functional and a market test spills industrial knowledge that has a greater value for civilian production than spillovers that are only partial and technical. This again means that technological spillovers are a misnomer. The spillovers documented econometrically around R&D intensive US firms are industrial, i.e., both technological and commercial.[8] The commercial dimension of industrial knowledge represents great economic value.

Three critical parts of a globally competitive engineering firm are (1) advanced product design and marketing competence, (2) ability to organize integrated production over global markets and (3) the capacity to develop products that can be flexibly upgraded, and are relatively "maintenance free." Product design, international marketing, and organizational competences are typically developed in industry. Complex integrated production was pioneered in (military) aircraft industry. The Saab JAS 39 Gripen project group pioneered the flexible and maintenance-free designs that constitute its competitive edge, a property that had its origin in the demands from the customer. The Swedish Military Procurement Agency (FMV) demanded that it be possible to service the aircraft for long periods in the field by unskilled labor and far away from equipped service workshops.

An aircraft, hence, is not only a very complex product. It is multidimensional in the sense that it is composed of (1) the product itself as a physical entity, (2) many years of service, maintenance and upgrading and (3) a "cloud of economically valuable spillovers" that are extremely difficult to charge for (weak property rights).

The JAS 39 Gripen sale to South Africa with subcontracted local deliveries and offset trade arrangements should therefore generate different indirect (spillover) benefits for South Africa over and above the product itself being purchased. In the short term local employment may be created, but this carries local value only to the extent that these people cannot be gainfully employed elsewhere. If not, the effect is only temporary. *Sustainable export growth can only be achieved as the result of an increase in overall productivity growth.*

Effects of lasting value, hence, are only gained if local people and firms learn skills and industrial knowledge that can later be gainfully used in other production. Effective such learning, however, requires both local receiver competence and local entrepreneurial ability. The *first* learning item is individual and has to do with the initial level of education and experience of the workforce and its capacity to benefit from the new knowledge being spilled from the project.

The *second* ability is entrepreneurial and relates to the capacity of the economy (and the existence of complete competence blocs. See Sect. 2.4) to select winning project ideas and to carry them on to industrial-scale production and distribution. The large benefits to both parties in this transaction (South Africa and Saab) do not arrive in full if the receiving party (in this case South Africa) does not gear up its competences to receive and exploit the spillovers. If South Africa succeeds in that with the support of Saab value has been created to be shared by both parties.

The product sold to South Africa by Saab/ BAE Systems was the military equipment itself plus the economic value of the spillovers. The total product value will thus depend on the extent to which spillovers are identified and matched and the local ability to nurse a profitable business around them. In addition this local ability can be raised by further cooperation with the foreign supplier. The joint business and policy ambition therefore was (must be) to create as much positive value from the spillovers as possible to share. The critical part of that business is to create a mutual understanding of the nature of that (intangible) value of the product such that the right incentive contract can be negotiated. This I have called innovative pricing in Chap. 2.

6.4 Gripen in South Africa: Facts

Developing the JAS 39 Gripen combat aircraft in Sweden on the basis of half a century of aircraft industry experience is a different thing than to modify the same aircraft for, and to produce parts and subsystems for it in South Africa.

The JAS 39 Gripen combat aircraft is built on a platform with particular and very flexible aerodynamic properties. In that respect it differs radically from previous Swedish combat aircraft generations that were designed for specialized tasks, notably invasion defense against the Soviet Union. The JAS 39 Gripen aircraft furthermore embodies electronics that were not available to previous generations of aircraft and that dominate the flexible and still internationally unique functional characteristics of the Gripen. Its general physical architecture will therefore look more or less the same through many modifications and upgradings of old and new versions of the aircraft, e.g., for South Africa. The physical platform still has 30–40 years of expected life that imposes some limitations on further development, but the rest, including its completely digitized equipment offers large combinatorial possibilities when it comes to tailoring the JAS 39 Gripen aircraft for specialized tasks. Most interesting for a civilian and commercial development program is the fact that the digitized communications and guidance system of the aircraft offers exceptional variety that raises the probability of generating serendipitous civilian industrial spillovers, again compared to the previous and more specialized Viggen aircraft. Foreseen investments in modification of the aircraft for particular purposes are of the same order of magnitude as the original platform development, or larger. Hence, the potential for civilian industry spillovers from modifications on the original platform should be larger than from the original platform because of the new and broader technology base, the larger computing and communications technology content[9] and the greater use of "off-the-shelf" components.

Furthermore, as Saab develops toward what company executives sometimes call a systems house, focused on concepts and development rather than on physical manufacturing, new opportunities will be opened up for those partners that have developed the needed capabilities to pick up advanced and increasingly complex subcontracting jobs. Saab will, in fact, be shown to have been a very competent customer that has supported competence development in the South African subcontracting industry.

6.4.1 The Gripen Purchase: Technical Background

The contract with the South African government includes the following activities.

1. Component production for JAS Gripen worldwide
2. Technology transfer to South Africa
3. Offset trade arrangements oriented toward building local receiver competence

Activity 1 is obvious and I will come back to it. In the long term activity 2 is the most important part of the deal for South Africa, and I will begin there. Activity 3 supports activity 2.

The existing South African arms industry around 1990 was regarded as an asset to be managed cleverly and transformed to the extent possible to civilian production over the period when deliveries to the South African military forces were drastically reduced.

Besides providing South Africa with the airpower it needed, South Africa's purchase of 26 Saab Gripen aircraft should therefore be seen as part of an ambition (a) to maintain, modernize and upgrade critical aircraft industry functions, that would otherwise collapse and disintegrate and (b) to do that in particular areas (generic technologies) deemed important for the future advance of South African engineering industry. This is in keeping with the main theme of this book that aircraft industry already today employs the technologies of future engineering industry, and therefore serves the economy as an advanced technical university.

The technology transfer was technologically defined, but to an increasing extent it has come to include the transfer of complementary and needed industrial management competence. For some reason offset credits were not awarded for the transfer of management knowhow, only for technology transfers. It was probably not well understood neither by South African authorities nor (before the deal) by Saab and its partner BAE Systems that a large part of the technology transfer would have to consist of a transfer of supporting industrial management competence.

To organize subcontractor work in South Africa, Saab and BAE Systems often had to take full management control. Their assessment of the management situation in South African firms was not kind, or as one interviewed executive expressed it: When we arrived in the late 1990s South African firms were "overstaffed, over resourced, had no foreign market contact, had aged and inefficient capital equipment, and were subsidized." All that had to be fixed before the South African firms receiving offset support could begin to edge closer to international markets for civilian production.

Saab teamed up with part of Denel (Denel Aviation) and formed Saab Denel Aerostructures with a 20% ownership and a 100% management responsibility in 2007. Within Denel Aviation a *Design and Development* Centre *(D&DC)* was organized during 2002–2004 to help build modern Western industrial design and production competence. Its services were in principle available to other South African firms. The Skill and Technology Transfer Program (See below) was closely coordinated through this D&DC centre. Concurrent engineering came to

Denel Aviation (later Saab Denel Aerostructures) with the Nato pylon job. The pylons that would make it possible to carry NATO weapons on the Gripen were designed at the D&DC centre. The design and development of a subsystem for Airbus A 400M (The wing fuselage fairing[10] and the top shell) turned out to be an important learning experience for some ten engineers at the centre and their experience has gradually diffused through Saab Denel Aerostructures. The organization of design work improved. Fewer mistakes were made. The problem, however, is that the more educated and experienced the engineers the faster they leave South Africa, for instance to Airbus. Saab Denel Aerostructures manufactures the rear fuselage, the Nato pylon and the main landing gear unit on Gripen. Saab also argues that if it had been involved in organizing D&DC from the beginning as an owner, rather than later having to integrate its own technology with an old Denel structure many problems would never have arisen. One particular problem had to do with the existing management structure that determines how people are treated and directed.

Simera in the Aerospace group of Denel was awarded a contract with Rolls Royce to supply gearboxes for commercial aircraft engines. The informatics and properties groups were fairly successful because the synergies between military and commercial software and information technology were strong.

ATE is partly owned by BAE Systems. It was set up by French engineers that came to Denel with the Mirage 1 deal in the late 1960s. It is a highly sophisticated operation because of the French engineers, but almost all military.

Aerosud was founded in 1990 by engineers who left Denel. It was supported (not owned) by BAE Systems as part of BAE Systems offset commitment. BAE Systems gave Aerosud access to the international market, introduced new manufacturing methods and better methods of management, and helped Aerosud finance new technology acquisitions and growth. Aerosud manufactures light weight galleys on specification from, and for the major civilian aircraft producers. Most production is commercial even though Aerosud takes on some military jobs, for instance for the Eurofighter.

6.4.2 Volvo Aero Corporation in South Africa

Volvo Aero Corporation had the advantage of being part of the large Volvo Group when organizing its businesses in South Africa. At the time of the Saab/BAE Systems South African deal VAC could still benefit from the presence of Volvo Car within the Volvo Group. In fact, VAC has been supportive of the creation of eight new businesses in South Africa, not counting four that have closed down, some of them quite sophisticated businesses related to the automobile and heavy truck industry. One firm was engaged in active exhaust cleaning for trucks using Volvo technology. Other firms were producing very strong materials that could withstand high temperatures, leather interior clothing for automobiles and catalysts for exhaust cleaning using platinum.

VAC could not direct a Volvo subsidiary firm to get engaged in earning South African offset credits, but it could point to, and ask the firm to evaluate business opportunities and support the engagement.

6.4.3 The Organization of Technology Transfers

Even though the technology transfer and the commercialization of South African industry associated with the Saab/BAE Systems sale to South Africa increasingly became a transfer of management competence, the technology transfer associated with the Gripen program was no small thing. This ambition, voiced and pushed for already by Armscor (Batchelor and Wilett 1998), was explicitly detailed in the technology transfer programs agreed upon between Saab–BAE Systems and Armscor. There are also two additional and important aspects of this purchase of military aircraft.

First, and contrary to other competing suppliers of military aircraft, Saab could offer a broad industrial support through the IG JAS industrial group (and to some extent through the associated Swedish Volvo and Investor groups), and this support commitment was explicitly detailed in the technology transfer agreement.

Second, it was out of the question for Saab to deliver such advanced and complex military systems to a developing economy without not only a supporting formal technology transfer program, but also a functioning transfer of a product life cycle use and support program. Saab as a producer of complex military aircraft systems could not afford to tarnish its image as a quality supplier by simply delivering the equipment and hoping that the customer would then learn *how* to use it. In particular, Saab could not afford to have its equipment displayed in an accident prone context. The transfer of knowledge of how to use the equipment efficiently, how to maintain and service it and how to modify it simply had to work. The Swedish defense procurement agency FMV has contributed significant user technology for the development of the different generations of Saab military aircraft. In South Africa, Saab will be a locally competent technology contributing purchaser of components.

There are large deliveries to South Africa of entire aircraft and other Gripen-related systems manufactured in Sweden. The purchase, however, also includes a significant technology transfer to the South African economy at large that may be worth many times more than what Saab got paid for. The value of this transfer to South Africa, however, depends on the local competence (of South African firms, supported by Saab, the firms in the IG JAS group and other firms through offset arrangements) to commercialize the technological spillovers from the Gripen arrangement. The knowledge transfer covered both how to use the aircraft and how to service, maintain and to some extent how to modify and upgrade the aircraft.

This technology transfer program is large by any definition. The transfer in itself is a major task and the manuals detailing the technology transfer are of an order of magnitude that would make any university professor pale in the classroom.

(In fact, my personal observation, having seen what has been involved to accomplish this transfer of knowledge effectively, is that educators in the regular university community should set aside time to learn about this for themselves.)

The transfer of technology began by having South African engineers with sufficient initial technical background work for considerable time in Linköping together with Saab engineers for periods between 6 months up to 2 years. The breakdown of technology elements to be transferred was grouped under 24 main headings. To illustrate the complexity of the transaction I will itemize some by key words. The safe operating and maintenance of the aircraft requires a basic understanding of the technologies integrated in the Gripen system as a whole of both pilots and ground personnel. The transfer begins with (1) "Decision and mission support," devising functions for the pilot handled through the Gripen systems computers based on information from aircraft sensors and continues with (2) "Primary flight data and navigation" (3) "Communications," external voice and data, including all antennae coordination for the aircraft, (4) "Sensor integration" of laser, radar, and infrared detectors, (5) "Human–machine Interface" and the cockpit layout of electronic displays, and helmet mounted displays, (6) "Weapons integration" including weapons integration with aircraft, (7) "Software integration and verification" of all computers of the aircraft, (8) "Function monitoring and testing," (9) "Avionics system," (10) "Airframe technology" and (11) "Manufacturing," (12) "Flight testing," (13) Logistics, and (14) "Flight training" including the training of South African personnel in serving and flying the aircraft, and a number of functions and technologies to make it possible for South African personnel to use, service and manage the aircraft up to the final item (24) "Engine Technology." Each main group covers a number of specialist competence areas, and to implement the transfer 60 South African engineers went to Linköping for periods of 6 months up to 2 years of introduction and training.

Subcontracting to aircraft industry requires significant manufacturing competence and in the long run South Africa has to develop that competence for its civilian and military industry to become a member of the global production community. As part of the South African deal Saab engineers have therefore been stationed at subcontractors for considerable time to instruct, monitor, and manage upgrading programs. In fact, this support has already paid off for some subcontractors (for instance Denel and Grintek) who have received additional subcontracting work from other foreign producers thanks to the skills they have developed (See below).

It is important to observe that we are talking about technology and learning transfer and that South Africa needs this technology transfer both to be able to *use* the JAS 39 Gripen aircraft and to *gain* from the spillovers. And it is important for Saab that the transfer be effective and that the aircraft functions as promised. It is bad for Saab goodwill if accidents occur because of insufficient local competence to service and use the aircraft. In general, if you know how the hardware and the support systems function technically you become both a more advanced user and a more efficient and reliable operator when it comes to service and maintenance. Hence, *one would expect technology transfer programs of the kind organized in the* *context of Saab deliveries to South Africa to be an excellent illustration of how learning and knowledge transfer in general should be organized, for instance in schools, because it is in the interest of Saab to make the transfer of knowledge effective.*

6.4.4 Subcontracting in South Africa

Further development of the JAS 39 Gripen platform requires volume, and volume is needed for a successful future participation of Saab in business development in other markets, for instance in the A380 Airbus project. Further broadening and expansion require outsourcing of noncore production. Hence, there are mutual gains to be captured from the project between Saab, Sweden and South Africa, with possibly larger spillover effects than those that originally benefitted Sweden. Military production today, furthermore is much less military than before. It builds to a larger extent on off-the-shelf standard components and subsystems. This gives the future military product (the aircraft) more broadly defined (closer to civilian) spillover characteristics than earlier.

Outcontracting to South African producers depends on the competence of available South African producers. Deficient local skill supply has been a problem. There are three categories; (1) secret proprietary technology that Saab prefers not to outcontract, (2) component and subsystems production for local JAS 39 Gripen deliveries, and (3) component production for Saab global sales. (The more of offset obligations that can be related to categories (2) and (3), and the less that diffuses into unrelated activities the better for both South Africa and for Saab). Deficient local skill supply, however, has been a problem that has often restricted offset arrangements or outcontracting with a sophisticated technology content.

The use and support of the Gripen aircraft and its functions in South Africa include:

- Operations
- Diagnostics
- Maintenance
- Modification
- Upgrading

As you go down the support categories competence requirements increase. The more advanced the functions the more important this competence also is for using the aircraft efficiently. The better you understand the support functions the more efficiently you can also use the aircraft, and the more capable as a local producer you become in taking on advanced civilian subcontracting jobs.

Denel engineers, for example, have been through a learning course with Saab and BAE Systems in which certain skills were developed that made Denel competitive in taking on a partial upgrading job on Boeing 737s, acquired by South African Airways.

Other subcontracting jobs where a Saab/BAE Systems experience has mattered are:

- Cargo doors for Airbus, fully engineered and checked by Denel
- Accessory gear boxes for Rolls Royce large engines that were outsourced to Simera (Batchelor and Wilett 1998:95)

The more experience gained the more outcontracting jobs will become available, and the more jobs Denel (for instance) can outsource in turn. The critical subcontracting industry will develop. A positive development sequence is established.

6.5 South African Receiver Industry

South Africa is not an industrial beginner. It has partly developed and manufactured own aircraft since the 1970s and helicopters, and its defense industry in general has been technologically quite competent. But for decades the South African industry has not had access to state of the art technology available in global markets. It lacks modern industrial production and commercialization experience and there is a large gap in all respects to the nondefense part of South African industry.

The dual nature of the South African economy, different traditions and the UN embargos between 1963 and 1994, therefore explain important differences between South Africa and Sweden when it comes to the ability of South African firms to capture the spillover rents from the JAS 39 Gripen purchase. It is thus of interest to compare assessments of South African industrial capabilities at the time of the Saab/BAE Systems sale and my early interviews from 2000 with current experience and assessments. Has the Saab Gripen sale contributed to observable improvements in South African industrial capabilities?

Particular observations on the competence of local industry have been made in literature, among others Batchelor and Wilett (1998), Forsberg (1996), in my interviews from 2000 and in the return interviews 2008. Concerns have been raised about:

- Lacking labor skills and the need for detailed job instructions
- Lack of technical manufacturing capabilities (of subcontractors)
- Difficulties of upgrading local production to global industry standards; unreliable time delivery commitments, work discipline, quality control, etc.
- A noncommercial mentality
- The fragmented production structure and the excessive, internal manufacturing of components and parts that were constantly mentioned as a result of the imposed isolation

Still, the latter is not unique. One very large and sophisticated German manufacturing firm has been known for making their own proprietary screws well into the 1980s.

6.5.1 A Dual Economy Isolated from Industrial Neighbors

South Africa is the industrially most developed economy on the industrially least developed continent. This, for one thing means that it is located far away from neighboring advanced economies with which it can engage in mutually beneficial trade in advanced industrial products.

South Africa is a dual economy in the sense that less than one-fifth of the industry is technologically advanced and employs labor that is not less educated than Swedish labor. The other part of the economy, on the other hand, is only slightly ahead of the rest of Africa.

The arms embargos imposed by the UN since 1963 and 1977 gradually moved the advanced part of South African industry further and further away from the international networks of industrial production and trading between the advanced economies with which South African firms had to some extent been engaged before 1977. Since the oil crises of the 1970s the world production and trading system has been through a gigantic transformation that South Africa has not been a natural learning party to, and the C&C revolution in the mid-1990s initiated a globalization of the industrial economies with an even greater long term significance for the organization of world production and for the distribution of wealth in the world (Eliasson 2002a,b). The isolation of South Africa from the industrial world at large, therefore, has been a serious negative experience for the advanced part of the South African industry that has halted its development.

The most important negative consequence is that South African production for a long time was not tuned to western industrial standards and exposed to world competition. Without commercial access to the global production system, modularization of products and outsourcing became unknown organizational technologies, and no specialist subcontractor industry developed around the large South African producers. Firms got used to producing everything themselves in-house under protected market conditions. One consequence has been that South African firms became good at piece production but not at volume production. Modern quality management experience was not regarded as important and little understanding of the importance of time delivery discipline to realize systems productivity gains developed. This means that almost the entire South African production system got stuck in an organizational technology of the past. When suddenly exposed to global competition like the formerly planned economies large parts of the South African production system was based on obsolete production techniques and therefore risked being competed out of business. Many of the proposed remedies for the formerly planned economies therefore also apply to the South African economy, notably the need to team up with western producers with best practice product technology and experience from western markets (Eliasson 1998a). Similarly, the planning mentality adopted during the many years of isolation appears to still be a problem in South Africa. At the time of the first interviews in 2000 authorities kept asking for 11-year plans and too many politicians got involved in projects best managed alone in the market. The right commercial mentality, furthermore was lacking. On the other hand producers with experience from many countries at the time placed South African firms ahead of Eastern European subcontractors. The latter may have had a better educated labor force, but labor there at the time of the interviews (2000) lacked (because of the planning mentality) incentives to do a good job.[11]

My conclusion from the first series of interviews in 2000 therefore was that it would take a long time even for the advanced part of South African defense industry to catch up with ground lost during the embargo without competent and constructive support from Western industrial firms. It is therefore good that this project began already in 2000 and for various reasons was discontinued for 8 years, now restarted again. Several interviews and case studies conducted in 2000 can now serve as bench marks to assess improvements in industrial capacities at the firm level. And my conclusion again is that the return to industrial health still has a long way to go.

6.5.2 Participating in Global Production and Marketing Networks

South Africa has a license industry with little experience of, and competence in own product design and development. South African firms may however perform well when working on specification. The exception has been military industry with its competent and experienced procurement system. It is, however, difficult to convert that experience to modern civilian production. A large investment in design competence and international marketing knowhow has therefore been needed. As in the eastern European firms the only solution to acquiring that is to enter global competition together (or in partnership) with an advanced foreign company.

Thus, for instance, aircraft industry is rapidly moving toward an "off-the-shelf" design culture where only the airframe (the platform) is unique. The product break down then becomes:

1. Platform (airframe)
2. Engines
3. Avionics

Each subsystem, in turn, can be decomposed into elaborate systems modules with well-defined interfaces. It is an art to do that right, and to integrate the systems into a consistent whole. Each module is increasingly becoming standardized, a standardization that is accompanied, in turn, by a standardization of the tools used to manufacture the components. This enforces the modular standards even further. To be accepted as a "certified" subcontractor you have to demonstrate capability in working with these standards and tools, and with the level of precision and the quality controls required. The subcontractor soon becomes a virtual extension of a globally distributed common design team. Technology transfer will occur naturally within such virtual teams, but not outside them. To work with such teams, notably in military production, efficient encryption is often enforced. Since US and

European manufacturers become more and more focused on concepts and systems integration and outsource larger and larger parts of the manufacturing there will be an increasing number of openings for increasingly more sophisticated subcontractor jobs for firms capable of participating.

As with the formerly planned economies many years of isolation from Western markets also mean lack of marketing experience and a focus on manufacturing processes rather than product development. Being isolated from the difficult to predict customers of the rich western economies has developed a neglect of market awareness and competition and reinforced old fashioned thinking in terms of long run production plans. The absence of efficient profit controls and a too fragmented and inefficient production structure have allowed cost inefficiencies to creep in everywhere. Each firm has learned to produce “everything” itself according to its own standards and specifications. In general, South African engineers (notably in the military industry) were therefore good at technical evaluations, but bad at commercial evaluations.

As a consequence of all this no sophisticated specialist subcontractor industry had developed neither by the time of the Saab/ BAE Systems deal nor interview time 2008, and outsourcing was still (2008) a rather unknown concept. This is of course a serious experience disadvantage for an industry that will have to begin “returning to work” as a receiver of outsourced jobs.

6.5.3 Management Competence

The most efficient way to speed up much-needed organizational learning was considered to become actively involved in an advanced global subcontracting arrangement under such contractual circumstances that it was in the interest of both parties to contribute. In other words, citing the Saab/BAE Systems South African deal; Saab/BAE Systems contributes global industrial management experience (part of spillovers) in return for profitable cooperation.

Lack of management attention to details and a deficient transport system make it difficult to organize just-in-time production in South Africa. Modern logistics was (2000), and still (2008) is more or less unknown concepts. This again is the result of the many years of economic isolation. There has been little management attention to what the firms are good at.

A positive way of looking at all this is of course that a great potential for profitable specialization should exist, but the competence to reorganize production accordingly must come from abroad.

Lack of international marketing experience and management competence, such was the argument in 2000, would make it difficult for domestic South African producers to operate in a global market economy during a transition period during which significant structural change and reorganization would take place. South African firms were not used to Western competition and considerable “learning from” Western producers would have to take place before the domestic producers would be able to manage on their own. Such contributions of modern industrial knowledge to potential future competitors would not be offered free of charge except in mutually beneficial arrangements such as the JAS 39 Gripen sale coupled with offset trade. At another level it is difficult to get a commercial evaluation of a project, even though South African industry, notably its military industry, is capable of very advanced technical evaluations. All this has to be changed for South African manufacturers to move up the value chain to be able to capture European outsourcing jobs. Since some military equipment producers had already delivered fairly advanced product design jobs using their own in-house standards it was expected to be difficult to make these engineers, who would have to be pioneers of the needed adjustment, understand that they would have to back down to more simple jobs to learn how to work in an international production network. Experience in 2008 is that this is still a problem.

A South African engineer was, however, said to be able to manage a broader portfolio of skills than his European counterpart, but possessed less specialist competence. This was good for the customized production that ABB at the time of the first series of interviews in 2000 was carrying out. Similarly, the broader activity base of a South African company was said to be good for the development of purchasing competence, a potential that could be taken advantage of.

Another interesting observation in 2000 came from the Swedish design and production (through complete outsourcing) of boxes for antenna equipment of mobile telephone base stations (MIAB). MIAB made the boxes and Ramboll (a Danish company) delivered nice-looking antennae. The experience reported in 2000 was that South African customers had not learned to buy quality boxes that were durable and lasted and cost less when seen over their entire life cycle. South African customers were, however sensitive to design, more sensitive than Swedish customers appeared to be. The base stations were camouflaged as trees. MIAB was at the time part of Saab's offset program.

It has to be noted that there are, despite the problems mentioned, centers of excellence in the nonmilitary industry of South Africa, capable of advanced organizational learning, notably within the foreign subsidiaries of Western firms, and also in the South African defense industry. ABB (employing 1,800 people in South Africa in 2000, 200 of them engineers) operated the second largest plant in the world for the manufacturing of high voltage transformers in South Africa. The plant was highly competitive internationally. ABB South Africa therefore had a first world capacity in many areas at third-world labor rates. To be profitable the plant would have to be much larger in Europe. ABB South Africa could therefore customize products, notably the assembly of high voltage switching gear.

For large industrial fans, ABB operated centers of excellence in South Africa, France, and Sweden (Växjö). After ABBs crisis experience at the turn of the millennium, ABB has however sold off both its power generation business (to French Alstom in 2000), and its industrial ventilation business, to focus on electrical distribution and transformation and customized industrial automation and robotics systems.

6.5.4 Attractive Technologies

The technologically advanced firm in South Africa in 2000 was more or less synonymous to a defense industry firm. Even though lacking commercial and marketing experience, these firms often offered an interesting portfolio of sometimes unique and innovative technologies that could only be efficiently exploited commercially in cooperation with Western firms. Here South Africa had an early edge on Eastern Europe which had been deprived by the Soviets of the opportunity to develop unique industrial competence and consequently had little to offer beyond cheap labor (Eliasson 1998a). In some areas, the South African defense firms even had a technological edge on Western producers.

Avitronics offers an example. Avitronics was an independent South African company owned jointly in 2000 by Swedish Celsius (49%) and South African Grintek (51%).[12] At the time it employed 250 people. When Celsius did due diligence on Avitronics it was found to have been isolated for so long from Western industry that it had developed different technical solutions to the same problem. Avitronic's UV alert system that warned for approaching missiles illustrates. Rather than using the computer to identify dangerous patterns (Avitronics had not had access to top-of-the-line computer technology) they came up with a technology to blind all UV radiation than what came from known man made radio sources.

The due diligence on Avitronics also turned up other new technical product solutions:

- A *radar warning system*, developed on South African technology that is currently sold to Saab to be used in all JAS 39 Gripen aircraft. This product needed microwave knowledge that was developed early in South Africa. Here Avitronics was at least as good as the corresponding Swedish companies.
- A *laser-based alert system*. The above-mentioned UV alert system could also be used for passive approaching missiles. When it comes to guided missiles (such as Swedish Robot 70 developed by Bofors) a laser warning system is used. It can be preset for three different lasers.

These two techniques can handle all known types of incoming missiles. The computer recognizes them. They can be fitted on the Gripen aircraft. The Gripen on board computer can also be equipped with different software, different for different areas, that tells which weapons are used in the different areas.

It is, however one thing to possess a unique technology, and quite another to build a profitable and growing business on it. There was not yet (2000) much to show and the firms that had succeeded had done it in cooperation with foreign producers. Grintek is one case. Grintek was founded in the mid-1960s under the name of Grenell. It developed radio technology and was associated with the British firm Racal. It developed the first radio frequency hopper (in the world) for an army communications radio in 1976. Soon electronic warfare (EW) became a big issue. South African defense had a long war experience and had learned the use of EW. A new division was started within Grintek to develop EW technology.

In 1994, Grintek acquired a small company with specialized competence in EW and merged it into Avitronics. It is now part of Grintek Electronics. Forty-nine percent of Avitronics was acquired by Swedish Celsius, and apparently both parties found this cooperation mutually beneficial. In 2006, Grintek was acquired by Saab. After a technology transfer program Avitronics now manufactures the systems computer for the Gripen aircraft.

Modern weapons systems and their applications furthermore require a lot of supporting computer capacity and software development. The pilot today fires a missile long before he can see the target, guided by a separate information and communications system (for instance Erieye from Sweden or Awacs from the USA. See Sect. 5.2), and the weapons carrier (the aircraft), the missiles and the target and perhaps also the information and communications system may all be traveling at the speed of sound. On the military side this weapons development for Gripen was supported in South Africa in 2000 by three computer companies:

1. Grintek Communications Systems (GCS), owned by Saab since 2006.
2. Advanced Technology and Electronics (ATE, a spin off from Denel, partly owned by BAE Systems)
3. Analysis Management Systems (AMS), partly owned by Saab. Among other things it produces the black boxes.

Besides what I have already mentioned above the interviews in 2000 and 2008 have turned up a number of industry competence areas where South Africa had developed advanced specialized technology, sometimes on par with what you can find in the advanced Western industrial nations, almost all of them being within the military industry.[13] It would, however, be wrong to make commercial predictions on the basis of these “discovered” areas of technological proficiency. Swedish experience tells of many apparent technical opportunities that never made it to a business venture, while commercial success stories shot up in unexpected, sometimes low technology places.

Summarizing so far, we can say that the important industrial knowledge contributions from Sweden to South Africa that have been intermediated through the JAS 39 Gripen purchase are not so much in commercializing particular technologies. They can rather be found within:

1. Management
2. Logistics
3. Quality systems

6.6 New Firm Formation

Offset trading has been one way to take industrial and marketing knowhow to South African industry in return for profitable cooperation. And Saab is priding itself to have, in contrast to US competitors, transferred sophisticated technology, for instance aeronautical integration and loads. There are also plenty of other advanced technologies. Furthermore, the business concept of a mutually profitable partnership is not (for Swedish firms) to sell core technology cheap, but to support the commercialization of advanced South African technology through contributing commercial knowhow in return for profitable cooperation.

With so much own technology, but little local design and global marketing and commercialization experience the conclusion would be that rather than starting new companies on their own, trying to compete with simple products and low production costs, South African entrepreneurs should team up with foreign companies to commercialize their own technology and to develop new products for global markets. This requires cooperation with Western firms with market knowhow. Within the Gripen context there have been many useful partnerships, not only within the Saab group, but within the entire Investor and Volvo groups, with potential developments beyond the JAS 39 Gripen project.

The alternative way to acquire foreign competence and expand aggressively on your own requires a commercial competence base that does not exist locally in South Africa. Even though there might be entrepreneurs in abundance, venture capital and other supporting actors in the competence bloc are lacking. Here, the JAS 39 Gripen project has functioned as a catalyst that has also been capable of moving idle technology in South African firms from piece production to industrial-scale volume production within its area of experience. For this to function, South Africa, however, has to give up its hold on its own technology. The "invented here" syndrome was a problem voiced frequently at the time of my first interviews in 2000.

Most examples are from the subcontracting of components, not large and complex subsystems and South African firms have been able to deliver the quality required of Gripen components.[14] *Kentron* produces an aluminum bolt for Ericsson in South Africa that is delivered to Ericsson in Mölndal.

Among the spin offs from Denel should be mentioned:

Semprel (in Pretoria) develops tracking equipment for vehicles based on GPS. Since theft, criminality, and irresponsible behavior are common in South Africa, GSM positioning technology and enforced routes for large trucking fleets are in demand. Military technology has been useful here.

Aerosystems Solutions (*Aerosud*) is a spin off from Denel that produces not only in flight entertainment systems and light weight interior aircraft designs such as kitchenettes for commercial aircraft but also sophisticated components for Airbus.

6.7 Competence Blocs, Lack of Commercial Attitudes, and Venture Capital Insufficiency

Parts of South African industry, notably the former arms industry are potential suppliers of innovative technology. But there is a long way to go before a winning technology has been identified and carried on to industrial-scale production. Here Saab has functioned as a midwife both in helping Gripen jobs and spillovers to the market and its supporting South African firms through its offset trading agreements. But in the longer run the industrialization process in South Africa requires its own commercialization industry.

The innovative South African firm has a choice between teaming up with foreign investors to exploit own technology and to commercialize it on its own. The latter, however, is bound to be slow and risky. If the firm has a winner the risk of imitation by smarter and faster competitors is large. And the final stage of taking a winner on to industrial scale manufacturing and distribution is always risky and draws the large financial resources. Imitation for competitive exports is also something much more demanding than creating a small-scale firm producing for local markets. I noted at the beginning of this chapter that Israel had chosen to industrialize its military technology through the US commercialization industry (Also see next chapter).

The risk of losing a winner is, however, largest in the outer circle in Fig. 1 (on page 35). Here the demands on competent commercial evaluation of new technology are the largest and the need for complete competence bloc support obvious. Going over these demands, as shown in the competence bloc theory (in Chap. 2), we see that South Africa in general lacks the advanced local customers that are so important to support the development of products for the advanced customers in the West. Here Saab and BAE Systems may have been most useful both in the capturing of competent customers to South African firms and in helping local subcontractors and producers to reach foreign markets. Subcontractors to Gripen have, however, sometimes grown too dependent on a seemingly safe long-term demand and abstained from breaking out and develop complementary markets on their own.

6.7.1 Case 26: TMI Dynamatics

Thivash Moodley, who had worked as an engineer on airframe and aerodynamical designs at the Council for Scientific and Industrial Research (CSIR) had been selected as one of the first to participate in the Gripen-related training program in Linköping, Sweden. Upon return to South Africa he understood that the knowledge he had acquired was entirely lacking in South Africa, but in great demand, so he founded TMI Dynamatics in 2004 to offer modeling and simulation services to the aerospace and defense industries. TMI has specialized on real-time simulation support of aeronautical/mechanical designs and systems integration, on automation of both product development and manufacturing processes and on interactive training in virtual environments. Even though these technologies are quite generic to engineering industry, so far 70% of TMI sales involves Saab work, most of it Gripen related. The rest is CSIR related. So, one concern has been how to break out of this dependence on Saab, a dependence that might otherwise be reinforced when Saab catches more Gripen orders from other countries.

6.8 Labor Quality Supply

The labor supply situation in South Africa is that of a dual economy. There are six million white as well educated as the Swedes, and there is a large black population with very little education. Part of the reason for that is that during apartheid education above some simple labor skills was denied to the black population. Availability of skilled labor is correspondingly limited. Mechanics are available and assembly workers can be trained. Engineers are also available, but they had little experience from modern production organization in 2000 and even though the situation has improved somewhat since then, the size of the educated and skilled labor force is still too small to support a rapid development into a sophisticated industrial economy. If engineers are highly educated and experienced they are also often as expensive to recruit as Swedish engineers. And deficient training and education are a resource-demanding problem to overcome for a developing economy.

Another difficult task is to change the mentality that lingers on from apartheid and the (central) planning attitude that has dominated much of politics. Here South Africa shared (in 2000) a problem with the formerly planned economies of Eastern Europe. Opinions voiced in the year 2000 interviews also repeat themselves in 2008. Few want to take initiatives and take on responsibilities, and respect for delivery commitments is still lacking. Somebody forgets to order a part and production comes to a standstill. Such problems have to be overcome in modern distributed production. They can to some extent be solved by systematic quality controls, but the productivity of volume production in a Western factory is entirely dependent on uninterrupted production flows.

Even though it was frequently emphasized in my interviews that the South African people were naturally entrepreneurial, this applied typically to Indians and whites. The unskilled labor force was said to have acquired a learned passivity, and unskilled people do not naturally take responsibilities. They prefer to shift the responsibility for mistakes to others. It becomes difficult to delegate jobs. It is necessary to be extremely clear when defining standards and assigning work tasks, and to control performance ex post. This means that standard Swedish production management does not function and to correct for that tough management methods are required. These negative characteristics of the South African labor force were said to affect productivity negatively, and the salary costs for skilled workers and professionals furthermore are not far below those in Sweden.

Since strict management has been decisive for work performance, it has been a bit surprising for me to learn that while technology transfers gave offset credits, the transfer of management knowhow did not. Legislation furthermore, is a negative factor. It forces the small entrepreneur to be responsible not only for the employee, but also for his family. Black labor from different tribes, furthermore, sometimes have difficulties working together. Outsourcing decisions have to be accepted by unions which make organizational adjustment to modern production organization difficult. And Black Economic Empowerment requirements often force unnecessarily costly production practices when employers cannot choose freely from the labor supply.

Another problem at the engineering level was, and is the lack of awareness of the need to document processes, the importance of attending to quality, notably "tolerances" and worker safety in the manufacturing processes. On the other hand these are competences that should come automatically with the participation of the Swedish partners. Saab, Volvo Aero, ABB, and BAE Systems took pride in asserting that they had brought in management competence in, and reorganized those South African businesses they had teamed up with or taken over, and set them up "on a sustainable growth path," as one interviewed person expressed it.

Taken together this means that the assembly of a Scania truck from Swedish parts in South Africa was only somewhat less costly than in Sweden in 2000. South African subcontractors of parts, furthermore, had difficulties competing with capital-intensive Swedish production. Steel bars for Scania trucks produced manually in South Africa had to compete with a huge automatic press in Sweden. It was economical in 2000 to ship these heavy steel bars to South Africa.

By 1994, South Africa had developed its own, and considering the circumstances very advanced arms industry based on proprietary standards and technologies that accounted for a very large part of South African manufacturing. When South African manufacturing industry emerged out of the UN embargos in 1994 it had, however, been effectively closed off from interacting with, and learning from the global production community for decades. Firms had not been allowed to source standardized and inexpensive components in global markets and advanced new technology, notably computing and communications (C&C) technology had not been available. This became an especially serious hindrance to South African industrial development during the last decade before the embargo was lifted. Computing and communications technology had then already taken a grand leap forward and been pushing the rapid globalization of production for some time between industrialized and industrially developing economies.

Lifting the embargo also meant exposure to foreign competition. The absence of experience from modern industrial production practices, product technologies, international marketing knowhow and commercial competence in general for decades, however, now required a dramatic upward adjustment of South African industry that did not come about on its own. Survival depended on low wages. In these respects the situation in South Africa was very similar to that in the formerly planned economies (Eliasson 1998a). New technology and modern industrial experience could however to some extent be imported and also came with rapidly increasing foreign investments. Limited supplies of labor skills and experienced engineers were therefore the most serious concern during my first series of interviews in 2000, and still appeared to be in 2008.

Part of the current skill shortage of course has to do with demand outrunning growing supplies and the learning capacity offered by industry. In that sense, skill supplies has limited growth. To overcome this limit, the capacity to educate and train at technical schools and universities has been increased, but *the limiting factor was experience from the use of modern production methods. The advanced production system demands both educated and experienced labor, and experience in building requires exposure to and practice in the right modern work environment that cannot* *grow faster than it is being supplied with trained and experienced labor.* This is the difficult policy catch, and a model of development familiar to economists. Poor production structures, furthermore, mean limited exposure to modern production methods and organization and, hence, a limited local learning capacity for the labor force.

The *only way to break this deadlock within reasonable time is through foreign investment* that introduces the modern production methods, but foreign firms need skilled and experienced labor to begin with. Foreign investors can train their own workers. Foreign investors such as Saab and BAE Systems also brought a large number of engineers to Sweden and England to learn the high tech manufacturing practices associated with the South African Gripen purchase (See above). So the rational policy maker should aim at exploiting the industrial competences residing in the South African arms industry while they still exist. This is also what Armscor has been attempting to achieve (Batchelor and Wilett 1998). The process is, however, slow but has to be sustained to result in significant improvement in the longer term.

It was also argued in one interview that military aircraft production is a too sophisticated environment for the training and learning needed by an industrially developing economy. But in the dual South African industry, the local defense industry is the only one that embodies sufficient sophistication to begin with to receive even fairly simple western technology. And the existence of a sophisticated industry means that advanced skills gradually diffuse through the rest of the economy as workers learn, change jobs, or start new firms.

Saab has contributed to the upgrading of the South African labor force through the sponsoring of local vocational schools. Even though one purpose has been to secure a long term supply of South African workers for its own Gripen support and production programs the Saab industrial school project in Centurion is a far more generic institution than that.

6.8.1 *Case 27: The Saab Industrial School project in South Africa*

Tshwane College is the largest vocationally oriented college in South Africa with altogether some 6,000 students distributed over four campuses. Tshwane South College in Centurion has a student body of some 1,500. It offers education in business administration and engineering and vocational training. The college was founded already in the 1930s. It recruits students from all over Africa and the students are diffused over the entire continent even though most of them stay in South Africa where most job opportunities are found.

Saab has supported a CNC machine learning program in all four colleges and contributed a number of CNC machines that had been taken out of production in Sweden but that were very advanced and expensive by South African standards. This gift even included very modern high-speed machining equipment from

Swedish Modig Machine Tool, the development of which had been supported by Saab (see Case in Sect. 5.5). In addition, Saab offered financial aid to talented students and to make it possible for the colleges to recruit good teachers.

This college investment is not part of the offset deal. Saab considers it an investment in goodwill that paves the way for the development of advanced engineering production by supplying adequately trained labor, not least to Saab's own subcontractors.

Engineers and technical personnel from the down-sized South African military have been recruited by the college. Thus, for instance, an aircraft engineer from the South African Air Force was teaching safety procedures for ground staff. This is an urgent skill to acquire on a continent that accounts for most air accidents in the world.

6.9 Political Uncertainty High

Having been to a not negligible extent a centrally planned economy with pronounced elements of socialist mentality for a long time means that traditional values of Western market economies, notably property rights, are not always well recognized or respected in South African business. In that sense, there were similarities with Eastern Europe at the time of the first round of interviews in 2000 and many of them still persist. In 2008, after massive protests, the South African parliament withdrew a proposition that would have allowed the Government to not only enforce the acquisition of farms at below market prices, but also other property and businesses (SvD, Aug. 31, 2008). This and other suggestions to enforce socialization of private property have conjured up visions of a new Zimbabwe situation and several politicians, marking a distance from the ruling left-oriented ANC are sounding warnings that South African politics is frightening away the necessary foreign investors (SvD, Nov. 20, 2008). With foreign investors cautious and worried about a new Zimbabwe situation, the inflow of financing to South Africa from abroad has suffered.

Policy priority associated with the South African Gripen deal has been long-term sustainable export growth. This is synonymous to negotiating technology transfer arrangements to support long term sustainable growth as part of offset agreements. Employment has not been a priority, although black empowerment to some extent means forcing investors, and their subcontractors to reluctantly employ unskilled and inexperienced labor that they have little use for. Export promotion is a medium-term and easily understood objective. This chapter, however, is about technology transfer to, and the long term development of an industrial economy. The general problem, therefore, is: How to introduce a long term view in practical policy. Long term commitments by investors require a long term credibility of policy makers. This is first of all a problem of predictable, credible, and rational institutions, no corruption and no awarding of generous contracts to friends who have been supportive in political elections, so-called fat cats. Problems of political uncertainty are large throughout the developing world and they exist in South Africa. But even though they have kept surfacing in my interviews, South Africa has been observed to be in a far better shape than all the other African economies and the reason is, it has been emphazised in my interviews, that it is already a more developed and wealthier economy with a fairly large and growing both black and white middle class.

6.10 Conclusions

A modern, globally integrated and market-based industrial economy is moved by economic incentives and competition in combination. Incentives and competition forces are embodied in the institutions of the economy, including a long history of traditions. Such an economy has been demonstrated to be capable of being extremely productive and of supporting long-term growth and the high wages of the industrial world. But the dynamic efficiency of such an economy is based on an ability to adjust flexibly to change and to accept the cultural and social adjustment that comes with industrial change. This is something firms in a market economy have to accept – such are the rules of the game – but people may not like it and react negatively through the political system.

Coming out of a semi-planned economic situation not only means that different rules, and a new mentality have had to be adopted and accepted in South Africa. But also the adjustment process has been extra demanding during the transition period. Eastern Europe has been going through this transition for a couple of decades. It is not yet over and significant diversity of individual outcomes and adversity have been the result. South Africa is still going through a similar experience.

There has been a need to prepare the country for these consequences to avoid political reactions that may block a successful transition to a new economy, and considering everything this process has so far been both smooth and successful, not least thanks to the contributions of foreign direct investors.

Innovative entrepreneurs appear to exist, but the competence to support innovative entrepreneurship for volume marketing and production for export markets is lacking. In addition, industrially competent financing of sophisticated industrial ventures is completely lacking locally. Hence, the local South African capacity to identify winners for exports to international markets does not exist, and the same verdict goes for the final industrialization phase. Within manufacturing there is very little to show of that competence. This is particularly so when it comes to the international marketing competence needed to boost sales to support industrial scale volume production. Teaming up with a foreign investor/large firm appears to be the only viable business opportunity if the portfolio of a firm includes a winner. *But foreign investors that are capable of contributing that competence won't do it for free.* A mutually profitable economic deal has to be organized.

Also here the situation is similar to that in Eastern Europe. This, however, makes the choice (above) easy. Attempting to industrialize your own technology on your own is a competence – demanding and precarious affair, likely to be slow, but also prone to failure. To move fast, teaming up with foreign partners is again the preferred way out. But the foreign partners want a share in the profits they have contributed to creating. Since many South African firms have own technology to offer, such a partnership should still not only be superior for those South African firms, compared to doing it on their own, but also be a profitable venture for both parties. In fact, trying to negotiate a contract on other grounds than a mutual benefit is likely to fail.

Spillovers are a positive characteristic of an advanced product. They carry an extra value for the buyer and the local economy that depends on the local receiver competence to create a business on them. An important part of the marketing task of Saab/BAE Systems therefore has been to create a credible long term story of the economic value to the customer country of the Saab 39 Gripen purchase of South Africa.

So if political uncertainty can be kept low and the situation maintained that makes foreign direct investment reasonably profitable industrial wealth in South Africa will grow in pace with the supply of labor skills.

6.11 Notes

1. In 1999, *British Aerospace* and *Marconi Electronic Systems* merged into what is today called *BAE Systems*.
2. Cf. the different capacities to exploit and earn a return on R&D investment in different industrial and industrializing economies in Nadiri and Kim (1996a, b) and notably their comparison of the differences between the US, Japanese, and Korean industries up to 1990.
3. See Case no. 5-0032, "Note on Private Equity in Israel," *Tuck School of Business at Dartmouth*, Center from Private Equity and Entrepreneurship, Dartmouth college, the *Economist,* Aug. 31, 2006, Traitenberg (1999, 2000) and Vedin (2000).
4. See Bertil Wennerholm (2006), *Fjärde Flygvapnet I Världen?* (The Fourth Airforce in the World?), Stockholm:Försvarshögskolan.
5. Related to this observation are the econometric results of Nadiri and Kim (1996a) that R&D capital and technical change were key contributors to TFP growth in US and Japanese manufacturing between 1974 and 1990, but not in Korean manufacturing.
6. Grintek became a fully owned subsidiary of Saab in 2006.
7. This section, in parts, repeats part of the analysis of previous chapters. I have kept the Section to make this chapter self contained.
8. Read commercially tested (in the market) technology (Eliasson 1996b).
9. Several econometric US studies demonstrate the particularly strong spillover content in IT-intensive product technologies. See, e.g., Greenstein and Spiller (1996), Lichtenberg (1993) and Mun and Nadiri (2002).
10. Part of the production engineering of the fairing was done at D&DC.
11. Cf. Eliasson (2005c) on home sourcing (the opposite to outsourcing) who gives examples of the inflexible and rigid hierarchies of an Hungarian subcontractor

that made Ericsson return the out-contracting of some fairly simple and labor-intensive production to Sweden, despite wage costs that were only a fraction of those in Sweden. The total cost because of bad quality and late deliveries, and outright faulty products that had to be attended to, in the end came very close to those of high wage, but also high quality production in Sweden.

12. Saab acquired Celsius in 2000 and Grintek in 2006.
13. We have: (1) telecom, (2) antenna, (3) microwave, (4) air traffic control, (5) electronic warfare (EW), (6) encryption (7) radio trunking, and (8) on board electrical power supply (not generation, but systems to give electricity supply desired characteristics) technology. In addition, South African industry has developed (9) electrical power load management technology and (10) methods to convert coal into oil.
14. Aircraft repair and services were expected by Denel to be a big deal until it was discovered that the Gripen aircraft needed very little maintenance and servicing.

Chapter 7
The European Policy Perspective

The topics addressed in this document are a concern common to all advanced industrial countries, and in a particular sense to the European Union. The main empirical story has been about technical spillovers around advanced product development, the implications of these spillovers for economic growth and the possibilities of stimulating such spillovers through advanced public procurement of privately demanded public goods. The discussion of the previous chapters has been conducted against the background, documented in econometric literature, of the significant underinvestment in private R&D investment among the industrial countries, and how the engineering industry is to remain effective as the backbone of economic growth and welfare among the old industrial economies. More precisely, the question has been how to help overcome that underinvestment through policy. In the earlier chapters, the JAS 39 Gripen development project has been placed in a macroeconomic Swedish and South African context. The main concern there has been the size of the macroeconomic spillover multiplier in an industrially advanced and an industrially developing economy. In this analysis also the significance of direct exports of the Gripen military aircraft and related products was considered. The study has been partly methodological and partly policy oriented. These results, however, carry a wider interest beyond Sweden and South Africa. So now the time has come to broaden the view, and to take the Swedish story up to the European level.

Spillovers tend to diffuse internationally, and the public purchase of defense products may be internationally organized, for instance at a Nordic or a European level. On this, Klenow and Rodriguez-Clare (2004) conclude that externalities appear to be needed to explain economic growth. International knowledge diffuses rapidly and international knowledge externalities figure importantly in the explanation of growth of individual national economies. And local receiver competence measured by R&D investments appears to explain most of the differences. Therefore, new aspects of public procurement at the European level will be briefly considered in this chapter where the national industrial policy theme is extended to the European level.

While the industrially developing world lacks both the capacity to develop and manufacture a complete combat aircraft system and needs help in commercializing the spillovers from the procurement of sophisticated aircraft for its own defense (see previous chapter on South Africa) some (but only a few) Western European

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economies have both the capacity to develop and manufacture a complete military aircraft system and the ability to commercialize the spillovers. However, the commercializing competence of Europe is not comparable to that of the US economy. To some extent this commercialization capacity has to do with the size of the "capture region" and this is one dimension of the topic of this chapter. Israel, for instance, with a much smaller economy than most European countries, including the Swedish one, in fact constitutes an interesting case of policy innovation. Israel has acquired the unique industrial capacity to develop and manufacture a sophisticated military aircraft, but has had to turn to the US markets for commercialization to effectively capture the economic value of the spillovers. This brings up the new dimension of public procurement at a supra national level. There won't be space here for more than a limited discussion of the wider European and global perspective, but a few highlights will make up a good background for the previous empirical analysis, and the European policy discussion to come.

7.1 The Future Dependence of Western Industrial Economies on their Engineering Industries

The spillovers from military aircraft development have served as an important technical university for the engineering industry at large that for the foreseeable future will remain the industrial back bone of the rich economies of the West. Having served them as the economic welfare generator since the industrial revolution, their engineering industries are currently being subjected to intense and sometimes devastating competition from developing economies such as China, South Korea, and Taiwan. There is no other way to survive for the low-skill manufacturers of tradable goods in the high-wage economies than to convert successfully to human capital and technology-intensive production, but even there countries like China have ambitions to become competitive. In a pointed sense the growth implications of advanced aircraft industry, so far explored, therefore suggest that it may even be a "savior" of the engineering industries and therefore, as well, of the future economic well being of the wealthy industrial economies. There may not be another industry with the same capacity to respond positively to advanced public procurement. And it is still an open question whether the new high technology industries (biotech, IT, nano, etc.), heralded as "the replacement" among the industrial economies, will be capable of filling in where traditional engineering firms shutdown or contract their operations, or lead the way into the New Economy faster than in the developing economies. In one sense, hence, we have discussed the role of this Old Industry in the New Economy. This policy implication will be explored further in the last two chapters.

The wider EU perspective changes these concerns in three ways. *First*, the role and interests of the customer and policy maker are different at the regional, national and European levels, and the policy ambition therefore has to be seen in a new perspective. *Second*, the most important aspect of the EU is the enlargement of the spillover pick up area and the increased difficulties of predicting the national and regional localization of spillovers. *The national policy role will therefore gravitate to that of a* *facilitator or national attractor*. The *third* aspect is that European procurement rules change the game and the role of the customer. While military procurement can still (within the EU) be directed nationally, and civil security procurement is an open question, all other national European procurement has to be subjected to competitive bidding from all European producers on an equal and fair basis. Such are the rules.[1] The problem, however, is that the principles of competitive bidding for minimum cost imposed mechanically do not apply for business situations where (1) quality, rather than volume, constitutes the dominant product characteristic and where (2) customer and supplier cooperate to improve on the product qualities, share risks, and work under a joint financing scheme (see Sect. 1.8).

On the whole, the industrially advanced EU nations are concerned about the future markets for advanced military and similar products, quoting their spillover generating capacity. This study and its predecessor (Eliasson 1995) are positive witnesses on that issue.

Similar studies have been presented in support of the same story, such as Hartley (2006)[2] on the Eurofighter Typhoon project, and even though many of them exhibit a Keynesian employment generation side issue, they convey a sense of importance for the sustainable establishment of a domestic military aircraft industry. Against the background of the enormous escalation of costs for developing entire military aircraft systems, domestic in the sense of European rather than the traditional national context, changes the character of the decision.

Israel's defense industry illustrates the points made in a contrasting way. Israel's precarious defense situation in the midst of more or less hostile neighbor countries, and its sometimes strained political relations with benevolent and normally supporting nations, has forced the country to develop a domestic military industrial potential of enormous proportions when seen in comparison with the size of the Israeli economy. The consequence has been that this small country of some six million inhabitants has grown an impressive high-tech military industry that spills attractive technologies widely. In Israel, as well as in Sweden, the spillover flows range over the intersection of electronics, software, and mechanical technologies that defines the upper end of engineering industry. A sophisticated civilian innovation industry has been established around the Israeli defense industry (Vedin 2000; Traitenberg 1999, 2000). But like all other industrial economies Israel has also had problems with commercializing its high technology spillovers within its own borders. It has, however, succeeded in developing a unique and profitable relationship with the US venture capital industry, in practice selling and capturing the value from its spillover technology in the US market. US venture capitalists have monitored the innovation supply in Israel, identified, selected, and invested in winners and helped them exit, for instance on the Nasdaq (cf. competence bloc Table 2B, See page 43).[3] The reason for this apparently successful outcome is that a rational commercial culture has been allowed to impinge upon this normally policy-infected market. In the right industrial commercial market, the firms of small nations will be appraised by their industrial and commercial abilities and won't be allowed to be intimidated by the firms of the large economy that wield financial and other powers on the procurement side. The question is how commercial rationality will come out in the political wheeling and dealing in the political markets for aircraft in Europe.

7.2 The European Concerns

While the special circumstances of Israel have made its defense-related high-tech industry a success story, the European defense policy community is full of industrial failure and concerns. Will the fragmented European aircraft industry fade away in the wake of the disappearing cold war?

In 2000, the *European Aeronautic, Defence and Space Company* EADS was founded by German Daimler Chrysler Aerospace AG, French Aerospatiale Matra, and Spanish CASA. With that the largest aerospace company in Europe and the second largest in the world had been formed. This organization is unique in being established in consensus between politicians and industry to pool strategically important industrial resources. This is in contrast with Saab's one-time partner British BAE Systems that was mainly founded on private market considerations. Political industrial alliances are, however, not free of problems as witness commercially failed projects such as the Concorde.

A contrasting and more successful example, however, has been the Airbus consortium, now within EADS. The reason is that commercial and industrial considerations have been allowed to grow in importance over national political and technological prestige. Together with US Northrop Grumman EADS, after 6 years of careful preparatory work to win the trust of the Pentagon, managed in 2008 to land the $35 billion order to provide refueling tankers for the US Air Force over US Boeing (FT March 4, 2008). Even though Boeing has contested the order, quoting the Buy American Act, this represents a great and unexpected commercial step ahead for EADS.

Hartley (2006) discusses the national benefits of the joint Eurofighter Typhoon project to the European economies and has identified an "impressive set of examples of the technology benefits" to industry at large that have been spilled already from Typhoon development. Eurofighter Typhoon is Europe's largest military aircraft program. It is a joint project between Germany, Italy, Spain, and the UK and is estimated to have involved some 100,000 personnel in over 400 companies throughout Europe. Hartley (2006) points to two particular long-term benefits from the program, one of which may appear as an inefficiency in the short term. *First*, the project has involved the development of skills and experience to manage international collaborative programs, not least (my observation) to overcome the inefficiencies associated with the national political meddling with the industrial processes. The *second* observation is the transfer of technology between participating nations that the program has occasioned.

After the UK, France features the second largest defense industry in Europe. France has a long tradition of integrating its defense industry with its strategic military ambitions. French aerospace industry was still not internationally competitive in 1950 (Lundmark and Giovachini 2005). After the mid-1990s, the special political control of the French central Government, exercised through its procurement agency DGA, has been loosened up. DGA's powers have been reduced and it has moved to develop more of a partnership with industry (Lundmark 2004), very much as it has been all along in Sweden. Dassault Aviation (DA) has, however, occupied a unique position in the French state-run system by managing to preserve its autonomy and integrity. DA is the only designer of military aircraft in France and together with the Eurofighter group and Saab the only producer of complete fourth generation military aircraft systems in Europe. DA "only cooperates with other companies when it has no other option, but prefers to work on its own" (Lundmark 2004:75).

7.3 Facilitation Rather Than Directed Procurement Becomes Important

Taking in the European dimension raises the issue of nationally directed procurement. The EU still allows that for defense. In other areas, however, and probably in the longer run also in military procurement, this won't be the case. So what will that mean for military aircraft industry in the role of serving industry at large as technical universities and for its potential role as an instrument of industrial policy?

Three observations should be made on this. *First*, military procurement will probably be a long-run EU policy concern, meaning that the EU as a customer will take on the previous double role of national customers and be concerned both about obtaining a high-quality product as procured and about *the social values created in the EU at large*. Success in that respect will depend on the abilities of EU authorities to suppress national maneuvering to gain prestige and particular benefits (such as a high national content) at the expense of product performance and industrial efficiency. In 1996 France, Germany, Britain, and Italy established a common arms procurement agency, the Organization for Common Cooperation in Armaments (OCCAR) to eliminate costly duplication and to award contracts to the most competitive bidders (BW, December 23, 1996). In 2003, EADS captured the fixed price A400M military transport aircraft project from OCCAR. Deliveries of 180 aircraft to seven European Governments were to take place between late 2009 and 2020, but the project is running years late and OCCAR has been considering its contractual right to terminate the project (FT, March 11, 2009).

The EU, *second*, should have a much larger budget for defense procurement than any of the national economies individually and be capable of developing more sophisticated and costly defense platforms than individual EU countries are capable of, comparable to the capacity of the US economy.

Third, and the prime reason for adding this European perspective to the study, is the larger European spillover pick up area. I have already (in Eliasson 1999) made the point for collaborative defense procurement on a Nordic basis. With a larger and more varied industrial capture base the probability of winning spillovers not being lost to the joint economy (the Nordic economy or the EU) will be significantly increased. And the policy concern at the wider Nordic or EU level will have to shift away from the national direction of spillovers to a concern for the area as a whole. The national concern, in turn, will change. The only way (if procurement cannot be nationally directed) to capture winning spillovers will be *to organize the national economy as an entrepreneurial local environment and its institutions to become attractors for, and efficient commercializers of winning spillovers that will support economic growth. This is the same thing as to see to it that relevant competence* *blocs* (see Sect. 2.4) *are as complete and varied as possible.* National and regional competition for spillovers, not through local tax benefits or subsidies, but through the offering of attractive local entrepreneurial environments would not only be a workable local policy, but also a desirable policy competition that the EU should foster in the interest of the entire community.

7.4 Dassault Aviation, France

Sweden is not alone in Europe in being the home of a prolific aircraft industry spillover generator. *Dassault Aviation Group* is the Euro 4.1 billion (2007) French maker of military and civilian aircraft and a successful provider of industrial software. As Saab, Dassault was also an early user of digital electronics and computers to design aircraft and to install electronic devices in its aircraft. For its own use it developed a sophisticated CAD/CAM software.

In 1981, Dassault launched *Dassault Systems* to capitalize on its military knowledge in computer-aided design and manufacturing (CAD/CAM) in civilian markets. With IBM as marketing and sales partner the *Catia* software of Dassault Systems had soon captured a sizable share of the market for mechanical CAD/CAM designs. In the late 1980s Dassault and IBM secured a contract with Boeing to "build" the first digitally designed aircraft (the Boeing 777) using Catia. By the mid-1990s Dassault Systems dominated the use of CAD/CAM systems in the auto and aerospace industries (BW, March 2, 1998). The Catia software was also used to design the Guggenheim museum in Bilbao.

The Catia digital design software aims for complete factory applications and simulates industrial design processes from initial definition to the detailed design of manufacturing and final assembly and maintenance. Dassault Systems currently (2007) works up sales of Euro 1.3 billion, or 30% of Dassault Aviation Group sales.

As with Saab, Dassault military aircraft technology could also be directly transferred to civilian aircraft development and production. Here Dassault has been more successful than Saab in establishing a profitable civilian business in business jets. Sales of its civilian *Falcon* accounted for 57% of Dassault group sales in 2007 or 2.4 billion Euro. Together this means a civilian share of Dassault Aviation group sales of more than 85%. Dassault prides itself with transferring advanced military technology early to its Falcon corporate jets, notably the electronic flight controls of the Mirage 2000 and safety and navigation systems.

7.5 What Should Europe Do?

Advanced military and civilian procurement has been demonstrated to be an effective provider of positive economic externalities. Public procurement, hence, embodies the capacity to serve as a vehicle for industrial policy and a way to get away from the wasteful R&D subsidizing policy agenda. It is, however, important to distinguish between (1) the magnitude and quality of the spillover flow (technology supply),[4] on the one hand, and (2) the identification, capturing, and commercialization of winning spillovers on the other. There will always be fewer locally commercialized than there are innovative spillovers locally generated. Policy direction of procurement to less than the best producers, or to support local employment will lower the quality of the spillover flow. Competitive public purchasing across Europe, on the other hand, will maximize the quality of the spillover flow, but the national distribution of benefits will be difficult to foresee. It will depend on the local industrial competence to capture orders and on the local entrepreneurial/commercialization competence to capture spillovers. To attempt to direct that distributional outcome through policies, for instance through regional quotas or requiring local content will be counterproductive. And to be fully effective industrial policy through public procurement also requires the complementary local capacity to commercialize the spillovers, which is also a domain of policy concern. Commercialization may take place within the company where spillovers have originated or over the market (the competence bloc. See Sect. 2.4). The range of receiver competencies residing within one particular company is practically always too narrow for it to make a business out of more than a few own potential spillover winners. While the company that has created the spillover cloud is interested in capturing the rent for itself, society at large would want to make sure (1) that the spillover flow is as large and rich in content as possible, and (2) that no winners get lost. There is a significant common denominator of interests, since the more of these spillover rents the supplier can capture for itself the higher the private return to its R&D investments and the larger the spillover flow. The best way of realizing that common interest is to make sure that the local economy is in good entrepreneurial shape and that there are many firms competing for new technologies. Since there is little the political community can do here in the form of direct contributions, it should first of all concentrate on the institutions, and above all institutions that prevent local entrepreneurship from developing naturally. Taxes are one such problematic institution, and a bureaucracy with the legal power to contain economic initiatives another. The likelihood that spillovers will be locally captured is, of course, larger for the EU economy as a whole than for any ingredient national economy. While the EU policy makers have few instruments to effectively operate at the local national and regional levels to enhance local capacities to commercialize spillovers it can still effectively rig national competitions for spillovers through supporting the creation of attractive local competence blocs.

In conclusion then, the policy potential of advanced industrial procurement increases at the European level (because of the larger capture area) while the national or regional outcome becomes more difficult to predict.

As a consequence, one would expect national policy authorities to attempt to capture their "fair" share of the procurement as they have already been seen to do in other instances, for instance the Airbus business. The more they succeed in skewing the procurements politically the less efficient the procurement will be and for two reasons; the procured product itself will be of lower quality and more costly to develop and to produce, and *the spillover cloud will be smaller*. National political rigging of the public procurement process is a safe way to obtain lower quality products at a higher price.

The policy concern of the supra national (read EU) authority that oversees the public procurement therefore must be to prevent national and regional authorities from interfering with the optimal economic allocation of the procurement orders and to focus instead on the more difficult, but also (if competently done) far more rewarding task of raising the entrepreneurial capacity of the local economy and the rate at which spillovers are being captured and commercialized. This is synonymous with supporting[5] the local development of entrepreneurial capabilities through the building of more complete competence blocs capable of discovering, capturing, and commercializing winning spillovers. The best way of achieving that, for the EU again, is to rig competition games between the regions and nations to capture the spillovers. The only way to make that possible is through effectively suppressing other ways of attracting production, for instance through politically imposing "fair" national quotas in procurement orders, and national demands for local content.

If Europe becomes successful in reducing in this way the political content of advanced European procurement it will gain a competitive advantage on the US where state authorities have managed to divert orders for military procurement to the benefit of employment in their state, and to the detriment of the US economy at large.

7.6 Notes

1. In 2009, a new defense procurement act makes all research and technology development contracts open to all. National and civil security concerns may be a reason for exception. The reasons, however, have to be defended in the European Council. There will be a 2-year grace period to introduce these rules into national legislation. Different rules apply to R&D. Then, however, the problem of Government export promotion comes up that is infecting trade relations for instance between the USA and Europe when it comes to large commercial aircraft.
2. Also see Balaguer et al. (2008), Serfati (2001a, b), and Industrienwissenschaftliches Institut, Wien (2000).
3. See Case no. 5-0032 "Note on Private Equity in Israel" *Tuck School of Business at Dartmouth, Center for Private Equity and Entrepreneurship,* Dartmouth College and the Economist, August 31, 2006.
4. A note on terminology. I use the term spillover-intensity to denote the magnitude of spillovers that flow out of a given R&D investment. These spillovers may exhibit different qualities. However, and this is the distinction made above, local commercialization competence determines how much of the total that is captured. Econometric studies measure this outcome, and do not include the spillovers lost in the commercialization process.
5. I am writing "…supporting the local development..." in order to prevent the easy misinterpretation that the Government itself, through its agencies should actively engage in attempting to be entrepreneurial and pick winners.

Chapter 8
Private and Social Spillover Benefits from Advanced Procurement: Defining and Estimating the Spillover Multiplier

The economic analysis of the macroeconomic effects of spillovers around advanced firms is partly a matter of the free technology supply that they represent (addressed in the previous chapters) and partly (and not to be forgotten) the problem of capturing (commercializing) the technologies spilled. The latter capture problem is addressed in this and the following chapter as is the measurement of the spillover multiplier, first introduced in Sect. 1.1.

8.1 How to Capture Spillover Rents Privately and for Society

Spillover-intensive production carries an extra social value. Because of weak property rights the producer/supplier, however, has difficulties capturing this value privately. It is therefore partly available for free either to outsiders in proportion to their competence to identify and commercialize them and/or to consumers who benefit from the increased competition and lower prices. The difference between social and private values created is mirrored as a difference between social and private rates of return, and the ambition of any producer of spillover-intensive goods and services is to appropriate as much as possible of the social values created as private values, and be able to charge for them. This we have called innovative pricing. There are two sides to this ambition.

8.1.1 Innovative Pricing

First, the local economy may be more or less entrepreneurial and more or less capable of capturing the spillovers on its own. Then the producer of spillovers will have to compete with competent outsiders in capturing his own rents. This situation is, of course, ideal for society at large provided the private returns to the producers of spillovers remain satisfactory. If not, they will stop investing.

Second, however, the local economy may not be very entrepreneurial, featuring incomplete competence blocs and being therefore incapable of capturing more than

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a fraction of the spillovers on its own. This is the normal situation even for industrialized economies, but especially for developing economies that normally lack a market-based commercialization industry altogether. In fact, the experimentally organized economy (EOE) as I have theorized about it in Chap. 2, will never be capable of capturing potential spillovers more than to some extent, but will constantly offer opportunities to improve upon this situation. Constructive policy is one method of supporting the spontaneous development of a commercialization industry that can raise the pick up rate of spillovers. Examples of such policies are the enacting of adequate intellectual property rights (IPR) protection to raise the tradability of knowledge assets (patents etc., Eliasson and Wihlborg 2003), establishing institutions, tax regimes, etc. that encourage the development of an industrially competent venture capital industry and, of course, the active procurement of public goods and services that are privately demanded by the citizens of the country. Better knowledge about the opportunities should also give the producer of spillover-intensive goods and services an insider competitive advantage over the outsider. This should create an extra business opportunity for the producer of goods and services rich in spillovers to raise the social payoff to a national economy that invests in its product, and to negotiate a share in the increased social value created.

Two observations are in place here. *First*, I have likened the advanced producer of spillover-intensive products and services with a technical university. Technical universities, or universities in general are believed to generate knowledge in the form of educated students and new knowledge/technology. This technology generation around universities has been discussed and emphasized in economic literature (Adams 2001; Carlsson et al. 2009; Jaffe 1989; JEBO 2007; Griliches 1986), even though attempts by universities to commercialize their own technology spillovers have not been very successful (Carlsson and Fridh 2002; Eliasson 2000a). On this, Aghion et al. (2008) argue that the “fundamental trade off between academe and the private sector is one of creative control versus focus.” Hence, the benefits to society of academic research are best obtained at an early stage or from basic research. Theirs is a 100% theoretical inquiry tailored such that these conclusions are inevitable. I have observed elsewhere in this document and in Eliasson (2000a) that today at least, there is no way of characterizing academic research as typically basic and contrast it with applied research or development work that is predominantly conducted in industrial laboratories. It is furthermore somewhat presumptuous to suggest that the enormous investments carrying the attributes basic and creative currently made in academic research in Western universities should be protected from comparisons of usefulness with what goes on in corporate laboratories. And creativity is at least as typical of focused business laboratories as it is of peer-reviewed research in academia. The highly intellectual and creative IT revolution originated in business labs while the very applied biotechnology development to a large extent originated in academic laboratories. I have therefore argued (1996b) that the spillover generation of advanced firms may be more economically potent and interesting for the advanced economy than what is created around technical universities. When it comes to generating and capturing spillovers there is no principal difference between a 100% privately financed technical university and an advanced private firm except (1) that the private firm probably did not have any academic ambitions, for instance publishing the results, and (2) that the closeness to industrial practice and markets should make us expect the private firm to be a superior social value creator compared to research filtered through an academic peer review. Comparing a public technical university with advanced public purchasing is even more compelling. Now, public procurement money (e.g., for military aircraft) also funds spillover generation and "Saab as a technical university."[1] A sophisticated private firm that lives on its private return may therefore be more valuable to society per R&D dollar invested than the technical university.

Second, what I have already indicated to be rational business policy for a firm producing spillover-intensive goods and services is already being practiced, and demanded by the customer, notably by the public customer, and of firms marketing their products in industrially less-developed economies. Through clever incentive contracts the spillover-intensive firm may become helpful in commercializing the spillovers for a share in the extra social values created (offset trade).

So, this chapter will put theoretical structure on what is already industrial practice. My contribution beyond that is to offer a method of (1) marketing the cloud of spillovers for the producer and (2) a way for the customer/government to formulate the offset trade demands such that both parties to the deal will benefit by (3) being aware of the magnitude of the opportunities (method of calculating them) and (4) by suggesting ways of raising them, capturing them, and sharing them. Embodied in this ambition is the art of designing a rational economic incentive contract that pays a premium on long-term growth-promoting efforts on the part of both customer and supplier.

8.1.2 On the Principles and Practices of Offset Trade Requirements

To a rational economist offset trade commitments may look irrational. Why and how should regulators/bureaucrats team up with a particular producer to do something none of the two has the competence to do well?

There are two ways of countering this rational argument:

1. Offset trade is demanded by the customer. Accept it as a producer/seller and minimize costs. This is a matter the customer decides on and the supplier has to accept.
2. Offset trade requirements may offer a business opportunity to both parties in the transaction if the seller can create a win–win situation and convince the customer that both will benefit.

To illustrate let me look at three forms of offset arrangements associated with the sale of a military product. The offset commitment may be:

- Military product related
- Indirectly related to military technology
- Unrelated

From a long-term economic and industrial perspective it does not make sense for the public customer to

(a) Ask for local content in the military product delivered, or to
(b) Ask for a balance between export and import deliveries. The rational proposition is to
(c) Ask for support in building local industrial competence for future production and export growth related to the military delivery, that is for *capabilities that stretch beyond the military deal itself*.

(a) and (b) are common demands even though the "benefits" will disappear with the termination of military deliveries. Some customer countries, for instance Hungary, have not been interested in military-related production and instead asked Saab explicitly for commitments in developing future industrial capacity under (c).

So that leaves us with the problem; if the buyer of military equipment asks Saab for support under (c), as part of the deal, how is that support best and most profitably organized by Saab. How is the military equipment deal best bundled with the offset commitments to define a win–win situation that benefits both parties? Is Saab an expert vendor of its own spillovers to outside markets and/or an expert organizer of industrial projects in unrelated technologies?

Offset commitments are often unavoidable. When deals are being concluded with developing economies the supplier of advanced defense equipment therefore might as well make it his business also to be a competent performer in offset trading, and establish a track record of doing it well.

8.2 Estimating the Spillover Multiplier

The first task in selling own technologies in outside markets is to present a credible story of the value to the customer of the merchandize offered for sale. Intangible values are notoriously difficult to define and measure. To be convincing at the public customer level, furthermore, the presentation has to be nontechnical.

8.2.1 Beware of Calculation Biases Based on Oversimplification

The neoclassical model forms a systematic basis for economic measurement. One could even say that the standard neoclassical economic model constitutes a gigantic economic measurement system (Eliasson 2007). With that model, however, comes a number of a priori assumptions that are not easy to live with for an empirically minded person and that have to be kept in mind when interpreting econometric results. Present value calculations and all of finance theory are based on these same assumptions. This is also true for the modern options pricing models, on which the entire global market for financial derivatives and financial risk sharing is based, and the current (2008/2009) asset pricing crisis as well. The crisis in those markets in fact illustrates the importance of understanding the calculation methods used at all levels in those markets.[2] Another and fairly recent method of value estimation based on the same principles is real options theory designed to calculate how much to pay for increased flexibility in being able to modify real product designs in the future. Mathematical duality theory is the cornerstone of these models and has been a useful tool since in neoclassical equilibrium prices map one to one into quantities (the structure) and vice versa, quantities map exactly into prices. The interpretation problem arises when the economy is out of equilibrium, which is the normal situation. One problem is that when using that model for price analysis you have to assume quantities to be given (the structure to be fixed) and vice versa, when you study production economics you have to assume prices to be given (the standard price taking assumption of standard economic theory).[3] Partial methods like this, however, remove dynamic effects from the analysis and normally mean that the desired allocation effects are underestimated.[4]

When calculating the future using the standard economic model you therefore have to make assumptions today that will hold for ever, either prices (stationary price expectations) or structures. If those ex ante assumptions about the future do not hold up there will be differences between ex ante plans and ex post outcomes. To keep the standard mathematical tools it has become common to assume that ex ante ex post differences correspond to random white noise. Some neoclassical models therefore exhibit a stochastic rather than an external fixed point equilibrium. All the social value and social rates of return econometrics literature that I have used earlier is based on those assumptions, so it is important to understand what kind of biases have crept into these calculations when you use them.

The problem with a model with an exogenous equilibrium (stochastic or not) is that it implies that an optimum market allocation can be determined by an outside observer, and that business is an objectively calculable and insurable activity. Firms can insure themselves against negative business outcomes and this notion carries over to the standard recommendation of finance theory that you should spread your risks. Knight (1921) thought this whole idea was nonsense. Spreading your risks mechanically may be a good recommendation if you are completely ignorant of the business you are investing in. However, if so, maybe you should do something else with your money. If, on the other hand, you believe you are knowledgeable you should focus your investments on what you believe you know best. This is also what venture capitalists and entrepreneurs have been demonstrated to do, therefore appearing to the not knowledgeable outsider to be taking on great risks (Eliasson 2003, 2005a: Chap. 4).

By focusing on its core knowledge, the business firm is, therefore, appearing to do the exact opposite to risk diversification. No business man will feel comfortable with a calculation model based on the assumptions of the neoclassical model if s/he takes the time to understand what they imply. There is, however, for the time being no alternative. Since few learn to understand the principles of economic calculation, but increasingly use calculation in their decision making, bad consequences easily arise.

Pricing financial options or financial derivatives, designed for trading in financial risks, are commonly done through computers in trading rooms, the traders having only a limited notion of what the numbers represent. There are exact criteria on which to act, but these criteria only hold in financial (static) equilibrium, which is a rare circumstance.

The same principles of risk sharing also apply to risk sharing among business partners, for instance between the systems coordinator and his subcontractors. Now, however, the "traders" are more stably footed on the ground and understand the limits of their calculation methods better.

How much should I, as a customer of a complex product (an aircraft) be willing to pay for a platform design with built in extra flexibility for future expected modifications? Real options theory provides a method of calculating the value and the cost to the customer of that flexibility.

8.2.2 *Defining the Spillover Multiplier of the JAS 39 Gripen Development Investment*

The main concern of this study has been to estimate the spillover multiplier (introduced in Sect. 1.1) of the JAS 39 Gripen product development and explain the content of the spillovers. The value of the technologies that are spilled is partly appropriable by the supplier of the product, and partly a free good to society (social value) in the form of freely appropriable technology and/or to consumers through increased competition and lower prices. Hence there is an important intellectual property rights (IPR) problem that has to be addressed. The additional social value created, however, depends on the entrepreneurial capacity of society to identify and commercialize spillovers. That social value appears as a positive difference between the social and the private rates of return to the R&D investment. The spillover multiplier is the ratio between the additional social value created and the development investment that gave rise to that additional social value. If the spillover multiplier properly measured is larger than one more than the development investment has been returned to society in the form of additional social value creation. Chapter 3 included a survey of what the spillover literature has to say on the magnitudes of social value creation. The Technical Supplements S1 and S2 include a technical discussion on how to interpret the numbers in general, and on the JAS 39 Gripen R&D investment and the associated social value creation in particular.

To calculate the spillover multiplier as a multiple of the original R&D investment I estimate the present value at one point in time of all past and future net social values created and divide by the present value of the original development investment at the same time of the procured product. Obviously, the difficult part is to estimate the additional social values created because that requires that you know what would have happened in the absence of that particular development investment. In principle, you need a model that can be set up to incorporate both alternatives. The econometric studies reported on in Chap. 3 are based on partial such neoclassical models.

Ideally, a full-scale micro (firm)-based macromodel would do the job. I have access to such a model for Sweden (see below) but it was too large and demanding on data inputs to be set up for this study. But there are methods to approximate the dynamics of that model. This is the way I have proceeded.

8.2.3 Estimating (Approximating) the Spillover Multiplier from the Microlevel and Up

8.2.3.1 Procedure

Size of R&D Investment

1. Compute the value of the original (military) R&D investment as if it had instead been invested each year in the financial market, corrected for inflation and cumulated for each year at an assumed real interest rate. Add up at the year (say 2007) for which the present value calculation has been done to INV.

Magnitude of Social Value Creation (Identifying Spillover-Receiving Firms)

2. Identify spillover-receiving firms, assess their dependence on Gripen spillovers and compute the additional economic values created for society because of the spillovers from INV over and above the delivery value of the procured (military) product. They are:

(a) Domestic production for civilian markets.
(b) Military and civilian exports.
(c) Asset values of firms based on INV spillovers that have been spun off and captured a price.

Spillovers under a, b, and c may be captured and commercialized within the firm that has created them or by outside firms.

Identify value creation under a, b, and c that originates as spillovers from INV under (1). There are several methods; econometric, case studies, etc. (see Technical Supplements S1 and S2). This is the difficult part to which Chaps. 4 and 5 were devoted.

Opportunity Costs

3. Calculate opportunity cost, i.e., those values that would have been created by the resources gone into a, b, and c above in the absence of spillover-intensive investments INV under (1). This is the second difficult part for which I would have liked to use the Swedish micro- to macromodel to estimate opportunity costs

endogenously.[5] Instead, I make the assumption that labor and physical resources would have been fully employed at the average productivity in *related Swedish production*, in this case in engineering industry. I also assume that the INV under (1) above has not affected this average as measured ex post. If it has, it would have raised the average, which means that the net spillover values created have been underestimated.

Now take the difference between the productivity of spillover based production and the value the same resources would have generated in an alternative allocation. Here I have assumed that alternative allocation to be at the average productivity of Swedish engineering industry. These data are available both from official macro statistics and to some extent from the micro data of the Planning Survey of the Federation of Swedish Industries, the database on which the micro- to macromodel runs.

Compute the net extra values created in 2007 prices and assume that they have been invested in financial markets each year at the same real interest rate as under (1) above, cumulate and add up in 2007 to MV1.

4. Over the years entrepreneurial businesses may also have been started on the spillovers created and at some time sold off in the market, or kept as an internal activity (c above under (2)). As these businesses have been sold off, the (market) value fetched should in principle be the discounted present value at that time of all future profits from the same business activity. That value represents a net spillover value. I assume that the value captured in the market has been invested in financial markets at the time of sales, corrected for inflation and cumulated to 2007 by an assumed real interest rate. Similarly, there is a calculable economic value to civilian business activities nursed within the companies that have not yet (in 2007) been spun off in the market. Add up all such investments in 2007 to MV2.

5. MV1 + MV2 = MV is the total of spillover values created by 2007.

Compute the *spillover multiplier* as MV/INV.

8.2.3.2 Comments

If the military investment INV is the development expenditure (R&D) for the JAS 39 Gripen the spillover multiplier measures how many times the original investment value society gets back. If the spillover multiplier is 1 society has got the Gripen development done for free even though costs and benefits may have appeared in different accounts.

Three circumstances, addressed in more detail in the Supplements complicate the interpretation of the spillover multiplier measurements. *First*, the size of the social value created, and hence of the multiplier, depends on the capabilities of the local economy to capture and commercialize the spillovers. The potential value of a given spillover flow (innovation supply) is always larger than the realized social value creation. In general, the more entrepreneurial the economy, the larger the share of that spillover flow that is captured, commercialized, and turned into social value creation.

Second, both the econometric literature surveyed in Chap. 3 and the calculation method above are founded on theoretical models with an exogenous equilibrium (see previous section). This implies that the calculations have been based on a full information assumption, and that all numbers (quantities and prices) have been tuned to that equilibrium assumption. The best example is the real interest used that has been assumed to be known for ever. These assumptions may however be wrong, as they always more or less are in reality, and in the nonequilibrium setting of the Swedish micro- to macromodel (discussed in Sect. 3.3) that approximates an experimentally organized and largely unpredictable economy. At no point in time is the future fully known, and the standard way to deal with that in neoclassical analysis is to say that the calculation is based on what we happen to know right now, at the time of the calculation, and to recalculate when more information has become available. This, however, is no comfort for us since exceptional and unpredictable future circumstances will always influence the size of the spillover multiplier.

I have made a particular point of the fact that if the multiplier is estimated for the same period on two occasions the estimates will differ. This is something the neoclassical economist won't like. He wants the multiplier to be invariant to the time of estimation. We have, however, to recognize, as a realistic possibility, that it may increase with time, notably because our measurement instruments do not properly pick up the commercializing competence of the local economy, future peripheral (currently unknown) spillovers and a host of dynamic factors that are not accounted for in the static neoclassical estimation model.

Three, and related, the real interest rate assumed for the calculations is too high.[6] Historic evidence would suggest 3% rather than the 4% used. Compared to 3%, the 4% discount rate leads to an underestimation of the spillover multiplier because investments precede the spillover values created by them. The spillover values are therefore more heavily discounted.

On the social values created around the JAS 39 Gripen R&D investments I have also brought together additional material from external studies and my own estimates to construct a range. At the minimum end, using the method described above (which is in part similar to that of Fölster (1993)), the current estimate of the social values created by the JAS 39 Gripen R&D investment from 1980 through 1992 is at least 1.5 times the original development investment.[7] This compares with Fölster's (1993) estimate of 1.15. The reason for the difference probably is that Fölster's forecasts of social value creation for the period 1992 through 1998 (obtained from the firms) were significantly lower than my estimates based on actual records. The main explanation for the difference is to be found in Ericsson's phenomenal and not-expected surge into mobile telephony during those years (see Sect. 4.4). Continuing my calculations through 2007, I have documented a spillover multiplier of *at least* 2.6 times over and above the original development investment in the form of additional social value creation based on 45 interviewed and/or researched spillover-receiving firms. This is a smaller number than the 208 firms Fölster (1993) questioned in a postal survey. I have, however, interviewed and studied my smaller number of firms individually and evaluated their dependence on the Gripen project, rather than asking firm management in a postal survey to preselected firms make their own assessment as Fölster (1993) did.

My larger estimate also depends on the larger electronics content in the post 1992 development investments in the JAS 39 Gripen, but most importantly on the fact that some spillovers, notably into Ericsson mobile telephony have taken longer to develop, were not expected and continue to grow in importance. This is, however, still a low-end estimate. A large number of firms that have benefitted from Gripen spillovers have not been identified and therefore are not included. Furthermore, it has not been possible to directly estimate effects beyond 2007, long-term dynamical systems effects and peripheral technology diffusion throughout the entire industry. The missing firms are small firms and won't add much to the spillover multiplier as it can be estimated now. One cannot exclude however, the budding existence of an unknown winning (peripheral) Gripen technology of the Ericsson type that will some time appear suddenly. Long-term dynamical systems effects and peripheral technology diffusion throughout the economy, therefore, are not possible to estimate using my case study build up to macromethod. Those effects may, however, be very large. Autoliv and the Swedish automobile safety industry (Case 17 in Sect. 5.6) is an illustrative example. It has been impossible to associate particular military aircraft technologies to this industry or to Autoliv. Autoliv has therefore been excluded from my spillover multiplier estimates. We know, however, that Swedish automotive industry pioneered safety and that an automotive safety industry developed early in Sweden. We also know that a number of engineers that had been engaged in military aircraft safety designs were hired by Volvo Car and Saab Automobile and by related firms. Even though direct relationships cannot be established, the spillover effects may still be large.

The micro-based estimates are also small compared to what you arrive at when deriving the social values created indirectly from estimated differences between social and private rates of return to the private investment. Applying the econometric estimates on the social returns to private R&D investments in the US, notably the summary evaluation of Jones and Williams (1998), such peripheral spillovers can to some extent be captured, and I then come up with much higher estimates of the spillover multiplier for a US-type economy, or two to four times as a minimum bracket, perhaps even extending into an upper range of some five to six times the original development investment. The difference depends to a large extent on the fact that peripheral technology diffusion is particularly sensitive to the local commercialization competence. In an entrepreneurial economy of the US type you would, therefore, expect the spillover multiplier to be larger than in Sweden. Furthermore, the probability of losing spillovers is much lower within the larger capture area of the US economy compared to that of Sweden (see the European discussion in Chap. 7). One reason for the large differences between social and private rates of return estimated on US data, therefore, must depend on the higher incidence of peripheral technology diffusion in the US economy through new firm establishment.

The numbers on the US economy may, however, still be underestimates because the underlying econometric models used do not properly pick up long-term dynamical systems effects on the allocation of resources. Simulation experience from the Swedish micro- to macromodel on the magnitude of dynamical systems effects suggests that another 30% should be added to the spillover multiplier to capture the long-run effects (see Sect. 3.3.2 and Technical Supplement S2). A cautious estimate of the spillover multiplier for Sweden would, therefore, suggest that the documented minimum spillover multiplier of 2.6 be raised even further by some 30%. This takes us from the low end to the middle of the US range "estimated" by Jones and Williams (1998), which Jones and Williams still regard as a cautious low range.

On the whole, however, my conclusion is that even though JAS 39 Gripen spillover value creation won't reach US levels because the Swedish economy does not possess the US entrepreneurial capacities to capture spillovers, I would not hesitate to use a multiplier of 4 to 5 for Sweden in a social profitability calculation on this or a similar public procurement project. But it is not necessary to go that high since already 2.6 will make a project of the JAS 39 Gripen type socially very profitable. The case studies, furthermore, suggest that spillovers from the future developments from the Gripen platform, for instance the Next Generation Demonstrator, will be even more spillover intensive.

To put it bluntly, these numbers should be sufficient to motivate the public procurement of domestic technology platforms for advanced military aircraft on a large scale. And those who don't like this conclusion and rather want to see the money go to technical universities and/or government-run laboratories or institutions (The "Arrow 1962 proposition") will find that the evidence is against them. This may be considered a strong proposition that needs further empirical testing to convince. True. This is also the further research agenda that I propose in Technical supplement S3, namely to (1) obtain more exact measurements of the Swedish spillover multiplier to be used to calculate the social profitability of public procurement projects of the Gripen type and (2) to make the same social profitability calculations for alternative allocations of the same resources to compare with, for instance in academic research or in the development of advanced medical technology platforms.

Summarizing so far, the estimates I have reported have been based on two methods; a low-end estimate based on aggregated case study data on production based on identified JAS 39 Gripen spillovers and an upper benchmark based on statistics on actually registered private returns and observed social values created in North America. The potential social value creation may, however, vary from zero (in a "zero entrepreneurial" economy) to anything far above the observed or estimated value. The difference between potential and actual social value creation depends on the entrepreneurial and commercializing capacity of the economy. The numbers given above, nevertheless, are a well-documented story about what Swedish society at least will get in return from investing one SEK of R&D in the further development of the Gripen aircraft. Besides being the result of a very conservative economic calculation it will serve as a good argument for further public procurement of the same kind.

8.3 How to Turn Potential Rates of Return into Actual Rates of Return

The business ambition of a firm is to capture as large a part of the social values created around its R&D investments as possible privately through innovative pricing. The ambition of society ought to be to maximize social value creation by stimulating private R&D investments through advanced public procurement of privately demanded public goods (the story of this study) and by supporting the creation of an entrepreneurial society, or (which is the same) the spontaneous development of complete and varied competence blocs (see Sect. 2.4).

8.3.1 The Policy Issue

For the policy maker it is irrelevant whether spillovers from a public procurement program are captured privately by the supplier or by a third private party. In reality, the major part of social values created (more than 90%) appears to be captured by the final customers in the form of lower prices (Nordhaus 2004). The cost–benefit methods I have discussed in the Technical Supplements are concerned with estimating actual social values created. This section is concerned with the policy art of raising (social) benefits above costs, to make it a good social business for society or the public customer to increase procurement of privately demanded public goods that make private firms invest more in spillover-intensive R&D. Table 10 outlines the principles involved.

8.3.2 The Art of Rent Seeking

First (item 1 in Table 10), a private customer of the advanced product procured has no interest in the cloud of spillovers s/he creates and is not prepared to pay extra for those spillovers that will only benefit other parties. Society should therefore be concerned about the existence of both advanced customers willing to pay, and the private returns of local industries supplying the advanced products to be able to benefit, without paying for it, from the spillovers created. Maximum benefit under these circumstances can only be achieved in a vigorous and entrepreneurial

Table 10 Capturing the rents from spillovers

1. Establish in viable competence bloc
2. Joint production and customership
3. Integrate vertically downstream
4. Establish joint ownership
5. Engage in offset trade or industrial participation programs to support receiver competence (creating win–win situations)

economy featuring complete and horizontally varied competence blocs. This is the general industrial policy issue.

This situation, *second*, changes principally and practically under a public procurement program (item 2). Since the spillovers benefit society at large the public customer should be willing to pay also for them, at least to the extent that the private returns to the supplier are kept sufficiently high for him to be willing to invest in R&D.

The concerns about *significant underinvestments in private R&D* voiced by Nadiri (1993), Jones and Williams (1998), and others imply that the incentives to invest privately in R&D have been too low.[8] From this, however, it does not follow that any R&D investment will do. Before R&D-induced new technologies result in productivity increases in production, they have to be selected by profitability criteria and commercialized. Maximum productivity effects from R&D spending are achieved when it is both privately financed and privately done. Next best are R&D investments financed publicly but carried out in firms. The worst arrangement is publicly financed R&D investments that are carried out in public laboratories ("The Arrow 1992 proposition"). This leaves public procurement combined with the creation and support of public institutions that encourage entrepreneurship as the efficient industrial policy design.

8.3.3 The Art of Innovation Policy

There is a considerable industrial practice and some literature on various ways of capturing spillovers and keeping them from outsiders/imitators. All these arrangements may not be good for society since the consequence may be a low exploitation rate of spillovers. It would probably be optimal for society to pay handsomely for the products created through spillover-intensive production. On the other hand, and for the same reason, it is dysfunctional for society to do as implied by Arrow's (1962a) analysis, that is to subsidize the input (R&D spending) directly, or worse, having R&D carried out in Government operated and subsidized laboratories and then making the results freely available to industry. One hundred sixty years ago the French government was much more clever.

In 1837, Daguerre offered to sell his new photographic process to a single buyer for 200,000 francs, or to 100–400 subscribers for 1,000 francs each (Kremer 1997:11ff). Nobody was, however, willing to buy or rent, either because they did not understand the potential of photography and/or found the offer too expensive. Somebody close to the French Government, however, must have understood the economic potential of photography and convinced the French government to purchase the patent from Daguerre in 1837 and to make it freely available to the world for a lifetime pension offer, considerably larger than what Daguerre had tried to elicit from the private market.[9] Privately, this patent buyout may have looked generous. Socially, however, the deal was a winner for France and the world. In terms of economic insight it compared extremely favorably and fairly with the deal offered to the Swedish inventor Håkan Lans by the UN and the large IT companies in 2001 for his patent on a GPS-based global positioning & communications (GP&C)

system. For the GP&C system to become a global standard Håkan Lans had to turn over his patent to the UN and the world for free.

These examples illustrate the potentially enormous social values that may flow from intellectual property and that they are the underpinning of the underinvestment proposition. The Internet is itself an intellectual innovation with potential social value magnitudes that cannot even be imagined.[10] To realize that potential value conditions for establishing economic property rights to information on the Internet must be understood and clarified.

One method for the spillover-intensive producer has been to *integrate vertically* downstream (item 3 in Table 10) to capture as much spillover value as possible for itself within its own organization (Lewis and Sappington 1991). One example of this method is to establish internal venture capital firms to help nurse, commercialize, and sell off spillovers. Most large and R&D-intensive producers have established such internal venture finance businesses. This, however, has rarely been the best approach since the range of commercializing competence of the producer will normally be limited by the commercializing competence residing internally in the firm. A better arrangement should be to establish a joint ownership arrangement with the innovators in the firm and outside venture capitalists to broaden the range of commercializing competence (item 4). Israel appears to have excelled in pursuing that strategy when it comes to selling spilled technology from its military R&D to US venture capital firms (see above in Chap. 6).

8.4 Incentive Contracts

Incentive contracts is a method to elicit both efficiency and innovativeness. There are two sides to this. *First*, the incentive contract is a design to overcome the problem of asymmetric knowledge or information. *Second*, it may be designed as a substitute for competition.

As a rule the producer is more knowledgeable about the technology behind developing and manufacturing a product, and hence of the costs involved, than the customer. The competent customer should however be very knowledgeable about the product functionalities he desires, how the product should be designed to meet his demands and how much he is willing to pay for what he gets. In fact, *the art of competent procurement* very much has to do with the customer being able to *specify the outcome* in sufficiently well-defined contractual terms to prevent the supplier from shirking on quality.

Formulating an incentive contract therefore must be the result of a negotiation where the customer likes to see as much revealed as possible of the technical information the producer has. If the producer also lacks information about how to achieve certain functionalities the technical risks are high and there is a case for risk sharing.

Once an agreement has been reached future uncertainties can be handled through incentive clauses aimed at sharing the profits, if costs are lower, and the losses if they are higher.

The negotiation between customer and producer can of course be replaced by setting up a competitive bidding process, and producers may even be forced to compete by presenting prototype products to the customer to choose from. But this is costly. Open competitive bidding today is a normal requirement on public purchasing. However, the theory behind competitive bidding does not hold in situations when the customer and producer can improve upon the product through cooperation (see Sect. 1.7).

In the absence of direct competition between flying prototype aircraft of two or more suppliers, as was the case of Lockheed and Boeing for the US Joint Strike Fighter (JSF) contract, an extremely costly procurement process, the single supplier in a country can be played against a foreign purchase. This was the case during the JAS 39 Gripen procurement. The Gripen new development alternative was compared with the import and modification of foreign aircraft (among them the F18 Hornet) and the modification of the older generation Swedish combat aircraft Viggen. In all three alternatives manufacturing and assembly of the aircraft would take place in Sweden, a circumstance that simplified my analysis considerably since almost all spillovers originate during the product development phase. Given the performance functionalities demanded by the Swedish Government Defence Materials Administration FMV the costs for developing an entirely new aircraft compared favorably to the alternatives of modifying a foreign aircraft or the earlier generation Saab 37 Viggen. However, once the decision had been taken the experience is that such contracts will always be modified and cost overruns occur over time. On this, the Gripen contract was different and a fixed cost contract with an inflation clause, and the government covering exchange rate risks.

When developing the JAS 39B Gripen version a particular incentive contract was negotiated between FMV and Saab. The price was negotiated for keeping *time* and *costs* to achieve particular well-defined results. If cost overruns or delays occurred Saab had to cover a fairly high share of the additional costs. If Saab delivered ahead of time and/or at a lower-than-agreed-upon cost, Saab could keep a fair share of the savings.[11] The sharing of costs and profits was computed according to an agreed-upon algorithm. The outcome was in fact a success for both parties to the deal. Delivery was ahead of time and at a lower cost than calculated. In general, the entire JAS 39 Gripen project has been very successful in keeping up with time schedules and cost budgets (see JAS 39 Gripen, SOU 1993:119).

Quite commonly, the competence to commercialize the spillovers from an advanced procurement project does not exist locally. This is often the case even in advanced economies, and definitely so in developing economies. Lacking that local competence a different strategy on the part of both suppliers and customers is needed and it can be formulated in terms of an incentive or profit-sharing contract.

The strategy involves creating a win–win situation that will benefit both parties to the contract (item 5, in Table 10) by inviting the producer to not only supply the desired product but also to supply, for a price, or a share of profits, the competence to commercialize spillovers from the procurement program. The rationality of this strategy, recognizing that the supplier may not be the best party to such a commercialization program, rests on the fact that alternative commercializers may not exist locally. This is the rationale for offset trade (see Chap. 6 on South Africa).

The social value creation will benefit the customer's national or regional economy and the commercializing support won't be forthcoming if the customer does not pay extra for the support. The more rational the incentive contract the more both partners will benefit.

I have already demonstrated with reference to literature and cases that the social value creation may be very large if the economy is well organized to commercialize spillovers and if incentives in the offset trade contract are geared to future social value creation and growth. The numbers given above tell this story for Sweden which is reasonably well organized on both counts. The numbers would be larger for a US-type entrepreneurial economy. For a less-developed industrial economy such as that of South Africa (see Chap. 6) the outcome all depends on what the combined efforts of Saab and BAE Systems have accomplished and how sustainable South African efforts will be in supporting a viable low-risk business climate. The effects will also take longer to materialize.

The value creation desired may, however, not be productivity growth but something else, for instance more employment. Employment-oriented offset trade contracts may at best only lower long-term growth benefits, but easily turn an opportunity into negative outcomes. Generally the employment of an economy should always be managed through other forms of policy than public procurement programs.

This argument is, however, difficult to pursue in a locally distressed region, and we know that the different US states and counties compete for military employment-creating procurement contracts by offering different privileges and subsidies. The local benefits are, however, of dubious value. Ask, for instance, why there was a local economic problem to begin with. Perhaps that should rather be attended to first, because as long as it exists the region will neither be an adequate locality for spillover generation nor a competent receiver of technologically advanced spillovers.

In a fully employed economy the situation is entirely different. Additional employment will not be a policy concern. As I have argued in Chap. 3, the public procurement of advanced spillover-intensive equipment will raise competition for labor and other resources and force a reallocation of resources up the value chain. And the faster peripheral low-profit production is outsourced and/or shut down the better.

8.5 Notes

1. On this, Agrawal and Cockburn (2002) note that the establishment of a large, local R&D-intensive firm – what they call an "anchor tenant" – enhances local industrial productivity by making local university research more likely to be picked up by local industry. To this should be added the positive innovative influence of the advanced firm on the university and a newly established university, in particular, and for that matter on the entire local industrial climate that I addressed in Chap. 5. I there discussed how the symbiosis of Saab and the

Technical Institute of Linköping contributed to the creation of both an aircraft industry and a signal analysis/image recognition and microwave communications competence bloc in Linköping.

2. Broström (2003) demonstrates through simulation experiments on the Swedish micro- to macromodel that optimum prices derived from the standard options price setting algorithms are entirely unreliable when applied to data generated by an economy "out of equilibrium." The situation then becomes worrisome if the traders using these formulae to buy and to sell do not understand under what a priori assumptions they have been derived.
3. Wicksell (1923) believed that integrating the price and quantity determination within one single analytical model would eventually be possible, but not yet. I don't think it ever will in the way economists want to see it done, i.e., as solving a model of general monopolistic competition for an external equilibrium. The way out of this theoretical impossibility is to give up on establishing an exogenous equilibrium defined as a point or a steady state (which is an economic misconception anyhow), create a new definition and do simulation modeling.
4. This is what dynamical systems analysis in integrated production overcomes through the use of advanced simulation methods, for instance in aircraft design. Cf. Table 8 on page 139.
5. This would have been possible by running two parallel simulations on the Swedish micro- to macromodel, one with and the other without the INV investment (see Sects. 3.3.1 and 3.3.2).
6. Four percent has been assumed to achieve comparability with other estimates on social value creation around the Gripen development project. See Technical Supplement S2.
7. Since technology spillovers take so long to be commercialized and grow into sizable industrial production there has been a problem to keep Gripen spillovers separate from earlier military development investments, for instance the Viggen. I describe how this has been done through interviews in Chaps. 4 and 5. If all military development is included, the spillover effects become much larger. To obtain a net effect, furthermore, I have assumed that the alternative use of the resources now engaged in Gripen development, in the absence of Gripen, would have been employed at the average productivity registered for Swedish manufacturing data that have been available on an individual firm basis from the Planning Survey of the Federation of Swedish Industries. See further, Technical Supplement S2. The numbers only cover Gripen aircraft development including weapons integration, but not the development of the weapons. I am currently preparing a similar study on the spillover multiplier for the weapons development.
8. There is a theoretical and entirely unrelated earlier discussion of *overinvestment*, first voiced by Hirschleifer (1958; 1971) and staged in the pure full information neoclassical model with one unique equilibrium. This time R&D to circumvent protected technologies is regarded as a waste of resources. In the theory of the experimentally organized economy with no known best solution the same R&D investment is regarded as productive technological competition, leading to even better solutions since there is no unique, once and forever best solution. On this see Sect. 2.4 and

compare with Ballot and Taymaz 1998 who find that competing technologies may survive for years in the Swedish micro-to-macro model and that this may be growth promoting in a model economy that is not constrained by the neoclassical equilibrium assumptions. Also Cf. Schagerlund 1999 who pursues a similar line of reasoning with reference to empirical cases.

9. Daguerre got 6,000 francs per year, corresponding to some $1.8 million per year in 1988 prices.
10. Timothy J. Berners-Lee passed up great private wealth when he – in 1990 – decided not to patent the technology used to create the WWW (BW, March 4, 2002).
11. There is a certain similarity between this incentive arrangement and an incentive management system I learned about being used in the budgeting process of some very large US firms where division managers' salaries were partly linked to their ability or willingness to come up with realistic profit commitments for their division. If too optimistic to secure larger resources they earned a negative bonus, and vice versa, if too low. The "profit-sharing algorithm" was such that the division manager earned maximum income if the profit growth commitment was correct ex post. In one firm there was an additional income benefit to be earned if the same commitment was correct also in the longer term. The arrangement was said to reduce cheating in the budgeting process, to bring maximum information into the open for CHQ management and maximum competence into the business process (Eliasson 1976: Cases 2:41 and 8:121).

Chapter 9
Advanced Purchasing as Industrial Policy: On the Advanced Firm as a Technical University

If a privately demanded good or service cannot be supplied by the market, or will not be supplied by the market, it is often called a public good. For instance, you cannot normally shop in the market for defense services, so they are classified as a public service. Health care, on the other hand, is a private service you can buy in the market even though it is often called a public or collective service, or at least expected to be publicly provided.

9.1 Public Goods as Infrastructure

The reason for being classified as a public rather than a private good may be the characteristic of the good. It may be indivisible and cannot be supplied in the amounts demanded by the individual, or individually paid for. The general definition of a public good is that its consumption does not reduce the amount of service available to others, and that considerable costs have to be incurred to exclude the availability of the service to others (nonrival and nonexclusive). The definition indicates the critical problem associated with my analysis of placing an economic value on spillovers. If you cannot control supply there will be no incentives to invest privately in production for a market. The lighthouse has been the typically quoted example of a public good in economics text books since John Stuart Mill (1848) and still keeps coming up as an example in text books.[1] It signals the information it is supposed to give off to everybody that can see and understand the signals, so it qualified for a typical pure public good at least until Coase (1974) used the lighthouse as a counter example to argue that there are few pure public goods, perhaps none, and definitely not the lighthouse. The light houses in England and Wales had been in scarce supply and badly managed for decades as a public responsibility, until the government turned their public service into a private service in the seventeenth century by authorizing private light house operators and owners to collect a fee from all boats entering the harbor, whether they followed the lighthouse signals or not, and to keep them there until they paid up. A boom in light house building and service supply followed. The role of government was thereby limited to upholding and

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supporting the property rights of lighthouse owners to the services delivered by the light house. I would call that a form of innovative pricing.

Sometimes, however, the reason for an insufficient supply of public goods and services that are privately demanded is that the agents in the market have been too slow ("market failure") and/or incapable of capturing the opportunities ("public goods"). The government may then step in as a substitute customer and induce the supply of such privately demanded goods and services that the market has failed to supply, for instance a strong defense. This is often said to be the main reason for the existence of a central government. When, and if this has to occur, the market is said to have failed for natural or other reasons.

9.1.1 Market or Public Failure to Satisfy a Private Demand?

But also the *government might fail to represent the private demand for public goods and services* properly as a *substitute customer*. Then we should talk about *policy failure.* A related public good is infrastructure or spillover-intensive goods and services which are undersupplied because of weak property rights. The policymaker might then step in to overcome this underinvestment in infrastructure, such as in education or health care, defense, and, for that matter, lighthouses. A common view is that the provision of privately demanded goods and services that the market has failed to supply is the prime, perhaps only warranted task of government. The problem then of course is to determine what exactly to mean by privately demanded. Perhaps Government should conduct consumer surveys to determine what its citizens demand (see Sect. 9.3.3 below). At least, with such a constitutional directive Government should feel prevented from pursuing a political agenda that departs from that of its citizens.

Musgrave (1959), however, widened the theoretical role of government by introducing a "complementary" concept, *merit goods*, denoting socially merited goods and services that the market has failed to supply for rational economic reasons. Merit goods, such is Musgrave's argument, should be provided for social reasons even though there is little private willingness or ability to pay for them. Health care, education, culture, or health insurance (witness the ongoing (2009) policy debate in the US) are often given as examples of such merit goods and services. This opens up a more difficult arena for policy analysis and political debate, since now the task of the government is no longer limited to representing the private customer in organizing a supply of privately demanded goods and services that are not spontaneously forthcoming in the market, but to define, on political grounds, what the private customer needs or should consume.

Proponents of large public expenditures or socially motivated merit goods often confuse infrastructure and merit goods. While an infrastructure argument may be raised for increases in health care and education (which really are private goods), because it makes people more healthy and productive at work, and less dependent on social welfare, the provision of pure social help and foreign aid does not qualify.

A common case of market undersupply is when the market cannot supply because incentives and opportunities have been destroyed by public regulation. Then we have a case of public failure. Some would argue that European higher education, compared to US higher education, belongs to this category.

9.1.2 R&D Investment as Infrastructure: The Underinvestment Proposition

R&D investment has *public goods characteristics* because R&D-intensive firms "cannot completely appropriate the benefits from their R&D investment" argues Bernstein and Yan (1995).[2] Hence externalities or spillovers are associated with R&D capital accumulation (Bernstein 1991; Griliches 1991; Nadiri 1993; Mohnen 1996; Hall et al. 2010). In fact, Jones and Williams (1998) conclude strongly that optimal industrial R&D investment in the USA is at least two to four times the current investment, and that the US economy, therefore, is losing large economic benefits from spillovers. And the benefits lost to society by these underinvestments are so large that if they could be captured the wealthy industrial economies should overcome the difficulties competing with the low-wage economies, provided the wealthy industrial economies are capable of not only commercializing the technological spillovers but also of coping socially with the consequent industrial adjustments.

This text, so far, has been devoted to placing the aircraft industry as the foremost example of R&D-intensive and spillover-rich industrial activity featuring it as a technical university with superior and useful qualities compared to the corresponding academic institutions when it comes to providing useful services to the industry. Above all, the case studies demonstrate that *aircraft industry* in a large measure *already today uses the technologies of the future engineering industry.*

9.1.3 Technology Policy

During the post-oil crises economic stagnation of the 1970s, economists looked for new theory to guide policy makers in turning their economies back to growth and preferably, among economists with a leftist leaning, a policy that gave government the decisive central role. One such theory that was dusted off and returned to the research agenda was Joseph Schumpeter's (Schumpeter 1911; Schumpeter 1942) theory of economic development that gave the entrepreneur a central role. This dusting off was however done such that very soon Schumpeter's ideas had been converted into the need for central government policies supporting innovations through subsidizing R&D investment and the so-called linear Schumpeter was born. Feed the economy with public R&D financing, such was the message, innovative technology supply will be forthcoming and long-term sustainable economic growth will automatically follow. The innovation systems of Freeman (1987), Lundvall (1992), and Nelson (1993) carried that message in the name of Schumpeter. Keynesian demand theory that placed central government in theoretical control of economic growth through controlling total demand had been replaced by central R&D stimulation through subsidies. The notion of central government picking winners was a political winner during a brief period (Bray 1982; Hindly 1983). R&D-based innovation functions of a neoclassical type (see, e.g., Mairesse and Mohnen 2004), "with the implication that subsidies may influence the long-run rate of economic growth" (Jones 1995:759), were formulated and estimated, and big government was safely back in the policy saddle. The evidence in favor of subsidies to stimulate industrial R&D and growth is practically nonexistent. It is therefore to be noted that the *public procurement of privately demanded public goods and services,* the development of which requires large R&D investments, *is not a form of R&D subsidies* of the above type (see further below).

Even though I, therefore, don't subscribe to the underlying logic of the linear Schumpeterian and the neoclassical economic models as explanations of economic growth, I can still reinterpret the econometric results from their econometric estimation. They are both similar and can be interpreted as reduced forms of a very different dynamic model based on different priors. Hence, I do not interpret the econometric results in the same way, and draw the same policy conclusions from these models as their authors do. With my priors, the story changes. Above all, my interpretation has (1) to incorporate the effects on the reduced form estimates of the preceding economic dynamics which I am familiar with from my work on the Swedish micro- to macromodel. Second (2), and as important, there is a long way to go, and large development costs to incur, between R&D inputs and useful products ready to be launched in the market. That later commercialization phase is absent from all technology and growth treatises except some very recent ones. Third (3) the receiver of spillovers in neoclassical economic terminology and theory improves its cost performance (Bernstein and Yan 1995), such is the specification of the econometric models estimated. In the broader perspective of my analysis *spillovers above all improve the product technology of the receiver, and especially so if the receiver can benefit from close cooperation with an advanced customer*. In fact, spillovers originate primarily in product development investments and may be captured and turned into new products on the spillover-receiving side. Even though product development is absent from all econometric models I have seen, the econometric results from these misspecified neoclassical models can still be reinterpreted in terms of new product development.[3] This is important since – I repeat – spillovers predominantly originate during the product development phase in advanced firms. Taking all the above three qualifications into account gives very different policy implications compared to the stories of the linear Schumpeterian and the neoclassical models, which I will return to below.

9.1.4 Public Procurement as Industrial Policy: The Role of the Competent Customer

This broader perspective of ours should shift the attention of the policy maker from factor costs to the customer side and the creation of innovative new products. This turns public purchasing of useful and privately demanded public goods and services, instead of public R&D subsidies, into a meaningful and effective form of industrial policy, and all of a sudden the competence of the customer begins to matter for the spillover outcome. The problem is that the domain of policy attention also shrinks. There are no longer that many sophisticated public goods and services that can be purchased by government compared to the vast domain of general and badly defined support of R&D. Perhaps that is as well. Government can now focus its resources and attention on tasks which should be its priority concern. The public procurement of sophisticated defense equipment therefore becomes an industrial policy issue, and notably so in economies that already have a sizable engineering industry.

In general, Swedish industrialization during the last 200 years can be explained by reference to a trail of public purchasing programs and public industrial infrastructure development emphasizing the role of the competent customer. The most referred to examples are; the (1) electrification of Sweden through the creation of Vattenfall (the customer) and the foundation of ASEA (now ABB) 1883 as a private supplier of equipment; the (2) establishment of an advanced Swedish telecommunications network through the creation of Televerket (the customer) and the founding in 1876 of Ericsson as a private supplier of telecom equipment. During the WWII years (3) the rapid building of a strong and modern military defense and the creation of private Saab and other military equipment suppliers contributed to the downstream development of an internationally competitive Swedish engineering industry.

These presentations, however, tend to overlook the even earlier industrial history of Sweden. It is true that Sweden was a fairly backward economy by the early nineteenth century when compared to England and the US, and perhaps also to France and parts of Germany. But the rapid industrialization from the mid-1850s did not spring out of nowhere. During the imperial seventeenth century, Sweden built an impressive arms manufacturing industry to support its European war efforts. European industrial entrepreneurs and skilled workers were asked to immigrate and through Royal initiative and decree were given generous privileges. After the Wasa shipwreck disaster in 1628 an investigation committee was set up to look into the reason. The documentation shows that three different specialists, working independently of one another, had been responsible for the design of Wasa, one for the hull, another for the rigging, and a third person for the weaponry. On top of this, the king intervened and ordered a new upper deck with full armaments (cannons) to be built. With that, disaster had been defined. Systems integration had been an unknown shipyard competence which the investigation committee understood (using different terminology). Systems integration capability was a necessary competence to acquire when large war machines like the Wasa were to be built and the world's first military materials procurement agency was set up in 1630 to serve as the competent customer. It later developed into the Swedish Defense Materials Administration (FMV) of today.

Bofors was founded in 1646 and is still a well-known brand. Husqvarna, today the world's largest garden equipment producer, was founded in 1689 as a weapons factory for the Swedish military. The Åkers cannon works (founded in 1609) and Hälleforsnäs Bruk (founded 1659) supplied sophisticated artillery. Skultuna brass works (founded 1607) used the copper of the Falun mine (Stora Kopparberget), founded in 1288 as the worlds oldest joint stock company, to manufacture both brass plates and wire and church candelabras. It still exists as the world's oldest still active brass manufacturing firm. Together with export shipments from the Stora Kopparberg copper mine Skultuna Bruk had been helpful in paying off war debt to the Hansa incurred by Gustavus Wasa and served as a critical source of finance for "profitable" Swedish war ventures in Europe. These and other works were all very innovative manufacturers of weapons. Most of them have (probably) disappeared. Several of them are, however, still active businesses and some of them (like Husqvarna) large producers for civilian markets. These early manufacturers, supported by a sophisticated customer certainly played a role as a competence platform for the industrial revolution when the economic incentives for entrepreneurial action were created.

Swedish industry built the competence to develop, manufacture, and operate very complex products early and still has that competence. Competent customers contributed significantly to that positive development. When it comes to public procurement *the Swedish experience is that the less of political manipulation of the procurement decision and the more emphasis placed on product functional performance the better the product quality and the higher the spillover intensity*.

9.1.5 Are There Any Other Advanced Public Procurement Objects?

I have stated rather categorically that the public procurement of military aircraft stands alone as a powerful vehicle for industrial policy. I am not alone in arguing that (see, for instance, Hartley 1994), but that statement still deserves some further qualification.

I have documented and estimated the leverage on the rest of the economy of public procurement of military aircraft. One question to raise is: Aren't there other possible procurements that would match aircraft on those terms?

First, I have mentioned other now private procurements (that were earlier public) that have a similar and perhaps as large potential leverage on the economy; for instance, telecom systems and electrical generation and distribution systems. However, to the extent they are private the industrial policy potential is not there.

Second, civil security and terrorist defense may come in as a worthy candidate, and we are now close to military aircraft technology. New medical technology platforms are another industrial area where the customer is still largely public, at least in Europe.

One problem that distinguishes civil security from defense procurement is that most countries lack a central authority or body that is responsible and ready to act both as a representative and competent substitute customer for the private demand for public goods that exist. The US Department of Home Security has been established to serve in that public customer capacity, and it is obvious that it has also taken on an industrial policy role.

Third, health care is another candidate, but health care really is not a collective good or service – it is a private good – even though it is largely publicly provided for, for instance in Europe. The merit goods argument of Musgrave (1959) may perhaps be invoked here. True, health care is already a technologically advanced product.

It probably has large positive spillover effects on society, but there are few well-defined candidate goods or services to support through public procurement. The medical product, for instance, is infinitely more differentiated than defense when we discuss the equipment needed to provide that service. One could argue that improvements in the health and working capacity of the entire population of a country would be a privately demanded public good worthy of public support. This could perhaps be achieved through the advanced public procurement of medical technology platforms that require such large investments and such a long time to come to market that no private producer would find it economically meaningful to take on the risks.[4]

9.2 The Public Purchasing Contract: A New Demand Policy

A standard form of industrial support policies is direct subsidizing of R&D to lower production costs for particularly desired economic activities. It is generally agreed that such subsidies lowers competition and reduces both innovation and cost performance among producers. They are hence costly for society. Far more powerful social outcomes can be achieved if government engages in the public procurement of public goods that are privately demanded, but that won't be forthcoming spontaneously in the markets, and makes sure that spillovers generated by these procurement programs are effectively commercialized. Now the product and its functionalities need to be defined and developed as prototypes and the procurement contract may be canceled if the outcome is not up to specifications agreed upon.

The *first* part of this policy involves representing the private customer effectively in creating a market that won't come into existence spontaneously, or, to put it differently, to define government as a substitute customer of public goods and services representing the demand of their private customers, the voters. To many economists this should be the prime task of government, which it should attend to carefully before engaging in any other tasks. The *second* part involves *supporting the spontaneous development of an entrepreneurial economy, in my formulation facilitating the spontaneous development of complete competence blocs.*

The problems associated with the first role of representing the private customers well is how to assess the competence of central government in performing the role of a representative private customer and to monitor its performance. Who should do that? There might be better private representatives for the private customer than political government.

If we accept the government's competence to exercise that role we don't have to get involved in the *third* difficulty, namely the opportunity cost of pursuing one policy action rather than another in the form of given-up customer value. On the Swedish military procurement side I think we can conclude that the Government customership represented by the FMV has been competent.[5] The private customers have indicated, through their government representative, what they want to see produced. The point of my argument now is that if the private customers are properly represented we do not have to consider this opportunity cost since production will anyhow be moved in the direction desired by private customers and there is no need to worry about the allocative distortions on the demand side associated with traditional Keynesian demand policies financed over public budgets, so-called dead-weight losses that apparently may be very large (Feldstein 1999; Hansson 2007; 2009).[6] Such a new demand policy would also contribute to overcoming the large underinvestment in private R&D emphasized by Nadiri (1993), Jones and Williams (1998), and others and discussed in Sect. 1.2 and Technical Supplement S3.6.

On the surface this may look as a form of public subsidizing of industrial R&D that is known to be ineffective as a growth stimulus and generally wasteful. It is however not. Public procurement as an industrial policy instrument (as defined here) aims at providing privately demanded public goods that would otherwise not be supplied. The good is developed and demonstrated to function as demanded and sometimes also subjected to a market test, and in that sense effective as policy and welfare enhancing.

9.3 Aircraft Industry Already Today Uses the Technologies of Future Engineering Industry

Swedish Aircraft industry was established as part of the Swedish defense effort in the 1930s in preparation for what was expected to come. At that time Sweden was an industrialized economy but not a leading industrial economy.

To carry out an industrial project on the scale and complexity of, for instance, JAS 39 Gripen a large number of technical problems have had to be solved. Developing and manufacturing a military combat aircraft, therefore, is bound to be a broad-based technology driver. As a positive side effect, the IG JAS group of companies (notably Saab, Volvo Aero Corporation, and Ericsson. See Technical Supplement S1) together has been an impressive technology generator that has helped catapult Swedish industry to several leading positions in the last two or three decades. In general, looking further back, without a local Swedish military aircraft industry since the late WWII years a number of large international Swedish companies might not have existed as autonomous companies today. A large part of the spillovers during the last couple of decades has been picked up and been successfully industrialized within the IG JAS group of companies. Some, but not many success stories can be reported outside this group. Several attempts to commercialize spillovers have failed, but surprisingly many have left a permanent positive signum on Swedish manufacturing performance, not least a positive brand of Swedish industrial technological prowess.

9.3.1 The Large Firms Dominate as Spillover Receivers

The general picture, however, is that the spillovers from defense industry have been picked up and commercialized for civilian markets within large and closely related companies, and notably those companies related to Saab in different ways.

The absence, with some exceptions, of winners that have been commercialized in small companies or in the form of new establishment or in entirely unrelated companies depends on two things. *First*, they are few because the supply of commercialization competence in the market (see competence bloc theory in Chap. 2 and Table 2B) has been less than satisfactory. A *second* explanation is that it takes a long time for a small or a new company to grow to statistical visibility. After several decades the origin of success is difficult to identify (cf. Sectra case in Sect. 4.8) and the success may no longer appear spectacular. Furthermore, the large number of experienced engineers that have been trained in, and filtered through a military industry such as Saab often cannot be clearly linked to their origin if found related to an industrial success story many years later. Imagine, for instance, the difficulties of identifying the success of particular industries to the excellence of the particular university their engineers graduated from a long time ago.

When placed in the context of competence bloc theory these empirical facts and possibilities can, however, be systematically organized and presented in a consistent way to guide the policy maker.

Three circumstances in particular should be emphasized in this policy context. The *first* relates to advanced public purchasing as an instrument of industrial policy. The competent customer not only contributes to product technology through an advanced procurement process. The customer is also a critical guiding party in the selection of winning ideas and projects to be carried to industrial-scale production and distribution through the competence bloc. If the product procured is privately demanded per se and can be put into useful public service commanding an economic value comparable with the purchase price, the cloud of spillovers will come as a free bonus, and the more competent and free of political influence the procurer/customer the larger the spillover flow. If the procurement price, in addition, has been sufficiently high to generate a satisfactory private return to the producer society at large should consider itself the winner of the deal. But there is more to it. The economic magnitude of the free spillover gain, *second*, depends on the capacity of the economy at large to commercialize the cloud of spillovers. It is therefore in the interest of Government to do what it can to encourage the spontaneous development of local competence blocs. In addition, and *third*, the private producer may find it economically interesting and profitable to engage in that task by creating a win–win situation with additional profits to be shared with government. A critical element of this analysis therefore has been the need to build local receiver competence to make the local commercialization of spillovers possible. With joint production of the hardware product and associated spillovers and joint customership of the "dual character product," as is normally the situation with public purchasing of defense products, there exists a mutually beneficial situation between the producer and the public customer to optimize the economic value of the spillovers. Rational marketing of the dual character product then involves helping to support local competence (receiver competence) to commercialize spillovers. Only when the public customer understands the value of the spillovers and needs local support to commercialize them can the producer charge for the spillovers.

9.3.2 The Opportunity Cost May Be Negative

There is finally a need to say something on the alternative use (opportunity cost) of the resources that have gone into public purchasing projects such as the JAS 39 Gripen development investment. What would the 6,000 engineers employed by Saab have done in the absence of JAS 39 Gripen? Would a larger value than the JAS 39 Gripen purchase and the associated spillovers have been created elsewhere? There are three sides to this question. The *first* one concerns the utilization of development resources in the economy, the *second* is about developing the aircraft or buying it from, say, the USA. The *third* one is whether Sweden needed the JAS 39 Gripen to begin with.

The first question about the utilization of resources is the easy one. Public procurement of advanced products has no role to play in an advanced economy as an employment generator. Employment policy is an entirely different concern. Directing the public purchases politically to create local employment, to support a regional economy or to grant an unrelated favor to a supplier should in general be understood as a reduced concern for the quality of the product procured. As a consequence a lower spillover-intensity should be expected. Effective public procurement of advanced products should therefore be thought of as drawing on, or crowding out already employed resources to produce something that is in demand and reallocating them up the value chain to higher productivity employments.

The second question is the main concern of this study. The opportunity cost of crowding out looks entirely different if you recognize, or if you do not recognize the value to society of spillovers generated in product development, so buying a US combat aircraft and modifying it would, correctly calculated, come out very differently and less favorably to society than developing a new aircraft, the Gripen. Considering this, it should no longer be a puzzle that a small industrial country such as Sweden, with nine million inhabitants, has been capable of developing one of the world's most advanced combat aircraft systems without draining its industry of engineering resources. This question was never asked during the cold war when defense requirements were top priority. It was raised when the Gripen project was considered around 1980. It was never answered and the military situation was then still unclear. Today there is an answer. The spillovers from the Gripen project were so large and represented such a large extra resource (knowledge capital) input in production that neither society nor industry suffered. On the contrary, both society and industry benefitted from the completion of the Gripen development project, perhaps several times over.

On the third question, even though relevant in a wider political context, I have taken it for granted in this study that a private/political demand to acquire a new combat aircraft existed from the beginning. I discuss this further in Technical Supplement S3 when asking the question; how would the analysis come out if the combat aircraft had not been demanded privately, only the technology cloud. There is also the general "democratic" issue about private versus political demand that I will say a few words about.

9.3.3 Marketing the Cloud: Saab as an Agent of Democracy

Given a Swedish need to be able to defend its airspace, the JAS 39 Gripen development project has been socially and economically profitable and especially so after Gripen has become an export business. Also, the decision to develop the Gripen had already been politically taken without any apparent awareness of the technology cloud. So let us rather ask: What about future development of the JAS 39 Gripen platform with potentially larger spillovers?

In the future Saab is facing an intriguing marketing problem that was not addressed in 1980. Should the decision to invest in further JAS 39 Gripen development, or for that matter, in an entirely new military aircraft be left solely to politicians? *Suppose politicians have a decision agenda on their own that departs from that of the Swedish citizens*. Parliamentary democracy could stand for a biased representation of the true opinion of Swedish citizens.

Politicians may want to disarm Sweden and distribute the money to benefit their own purposes and/or purposes that the citizens might find less important if they were fully informed. Politicians would then not be interested in seeing the full economic value of the cloud presented to the citizens.

Who would? Well, there are two parties who would be concerned; the citizens themselves and the developer and supplier of the dual product (the Gripen and the cloud). Therefore Saab would be concerned about informing the public through marketing both the Gripen and the cloud.

If Saab, politicians and the citizens are all in agreement with one another, there would be no problem. *If politicians and Saab are at odds with one another, Saab would perform a positive democratic role by informing the public of the value creation around its activities.* On this we can note that Saab has sponsored surveys by the SIFO Institute (for instance, SIFO 1997) that has demonstrated a strong public desire for both a strong defense and the Gripen project, *even without being aware of the spillover cloud*. If politicians are pursuing a defense agenda that departs from that of its citizens, Saab therefore serves the important function of informing the citizens of the economic values that might get lost if the Gripen project is not pursued further.

Four conclusions now emerge from the previous analysis.

First, advanced customers define a competitive advantage for the national economy.

Second, advanced public procurement serves the double policy role of not only enhancing the cloud of spillovers, but also, and contrary to the advanced private customer, the public customer does it in its own interest.

Third, the aircraft industry already today uses the technologies of the future engineering industry. Public purchasing of advanced military aircraft therefore is a booster of both engineering industry capabilities and national competitive advantages.

Fourth, and finally, so while military aircraft development serves society very much as a *technical university*, and perhaps better, *the public defense procurer* *functions as an industrial policy maker* by buying its products, by participating in their development and by paying a price that makes the development investment privately profitable. If not, there won't be any spillovers.

9.4 The Advanced Firm as a Technical University

We have demonstrated that the aircraft industry already today uses the technologies of the future engineering industry. This is more the case with military aircraft than with civilian aircraft, and even more so with the development and upgrading of the fourth generation of military fighter aircraft compared with previous generations, because of its larger content of computing and communications (C&C) technology to achieve advanced product functionality. The increased use of "off-the-shelf" components and subsystems not only means a further increase in the potential civilian use of spillovers. It also reduces the rate of obsolescence of the entire aircraft because the market will be a more reliable supplier of upgraded spare parts that are compatible with the aircraft than the aircraft developer itself that will have to remanufacture old spare parts. The useful generic technology content, furthermore, lies more in the systems integration element than in the development of new specialized technologies. Military aircraft production therefore again functions as an advanced technical university.

But this is only part of the story. Compared to a university an industrial firm delivers technology embodied in products that both function (are operational) and to some extent have been tested in a market for commercial viability and/or usefulness. This means that an aircraft that has gone through both a functional and a market test spills industrial knowledge that has a greater economic value for civilian production than spillovers that are only technological. Technological spillovers therefore is a misnomer. The spillovers documented econometrically around advanced US firms are industrial. The data is from products already commercialized. These spillovers are therefore both technological and commercial.[7] The commercial dimension of industrial knowledge *also* represents economic value.

Altogether this allows us to talk about the aircraft industry as a technical university that spills modern and advanced technologies and educated engineers with experience from top-of-the-line engineering product development and manufacturing process techniques.

It is quite possible that the value creation around aircraft industry generates more social value per invested krona than the technical university because it has taken R&D closer both to the development of products that function and to final product markets. It is therefore surprising how much attention in research that has been paid to academe as a spillover source compared to the attention paid to advanced firms (see Technical Supplement S3). From the point of view of social value contributions to society any concern about costs should first be directed at the academe.

9.5 Notes

1. See, for instance, Paul Samuelson's widely used economics test book *Economics* and Hirschleifer (1976:454f).
2. Also see Griliches (1979, 1988 a, b).
3. See the discussion in Eliasson (2007). Most important to consider is that while increased process efficiency in the manufacturing of given products (the common specification of the econometric model) raises profits but not output, product development raises the quality and variation of output and allows the firm to charge a higher price. Even though a car is a car, the new car is a better car and that should count as an increase in output that is not necessarily accompanied by an increase in profits. The art of correcting output and price indexes for product quality change is a rapidly expanding area of national accounting statistics.
4. One such integrated PoC diagnostic and treatment medical technology platform based on molecular technology was developed together with a group of Swedish medical and biotech firms within the Swedish Academy of Engineering Sciences (IVA) in 2007, but the project was then not completed. See Eliasson Åsa (2007).
5. I will also conclude (see Sect. 9.3.2) that if the public procurement agency is politically manipulated to consider employment and economic concerns that have nothing to do with the qualities of the military product, spillover-intensity is lowered.
6. There is still one allocative distortion to mention. For privately demanded public goods there may be no other way than to finance them over a public budget. Then it has to be done. When receiving goods and services free of charge over a public budget, the private citizen, even though willing to pay, may however still be tempted to avoid the tax through shirking work or through other means. If government spending is dominated by *merit* goods the opportunity cost should be a dominant policy concern. A large number of citizens may not be willing to pay for politically decided public expenses and make the changes in their allocative decisions that they find appropriate.
7. Read commercially tested (in the market) technology.

Technical Supplements

S1 The IG JAS Investment

In this Technical Supplement the JAS 39 Gripen product concept is outlined, the procurement process documented, the Industry Group IG JAS presented and the critical role of the competent public procurement agency, the FMV, highlighted.

S1.1 The Procurement of the JAS 39 Gripen Aircraft with Swing-Role Capabilities

The JAS 39 Gripen multirole combat aircraft (J stands for fighter, A for Attack and S for Surveillance/reconnaissance) is a fourth generation aircraft that entered operational service in 1997. It replaced the Viggen, the last of which was taken out of service in 2006. JAS 39 Gripen is a combat aircraft with swing-role capabilities that can change mission in flight. This swing-role capability was unique when Gripen was launched but has later been introduced on the French Rafale and the Eurofighter. Other competing multirole aircraft first have to land to reconfigure its information, guidance, and weapons systems for a new role.

Gripen was the first "unstable" aircraft in the world which meant that in order for the aircraft to be stable at all speeds and in all maneuvers many more navigation surfaces are needed than the pilot can possibly control himself to minimize air friction at each moment. He needs incredibly sophisticated computer systems support to maneuver the aircraft effectively and safely.

Competing fourth generation combat aircraft are F-35/JSF (the USA, not yet (2009) delivered to market), the Eurofighter Typhoon (the UK, etc.) and Rafale (Dassault, France).

JAS 39 Gripen also competes with upgraded versions of the third generation aircraft of Lockheed Martin F-16 (the USA, first delivered in 1978), Boeing F/A18 Hornet (the USA, first delivered in 1983), Dassault Mirage 2000 (France, first delivered in 1983), and Mig-29 (the former Soviet Union, first delivered in 1977).

Both Norway and Denmark have to replace their aging F-16 aircraft, which has created a Nordic opportunity for Saab. The Next Generation (NG) Gripen with its more effective engine, heavier weapons load, and greater flying range that was presented on April 23, 2008 has been offered to Brazil, Denmark, India, and Norway.

In early 2007, French Dassault withdrew its Rafale aircraft from the competition in Denmark and Norway citing unfair competition. Just before Christmas in 2007, the Eurofighter consortium also withdrew from competition in the two countries, also citing unfair competition (*Militaer Teknikk*, 6/2007; SvD, April 15, 2008). Boeing visited Norway in 2008 to mention the existence of its F18 Hornet.

This left JAS 39 Gripen and the F-35 Joint Strike Fighter (JSF) in the competition. Since Lockheed Martin has been early to market its product, but has yet to deliver, it has had to ask for more time to be ready. To eliminate "wasteful competition" and save money, furthermore, President Obama has been canceling rival engine development program for the JSF. So when mishaps during tests of the Pratt & Whitney engine were reported, worries for even longer delays were voiced (*The New York Times: Business*, Sept. 15, 2009). Saab, on the other hand, has been ready for some time to deliver a comparable aircraft at half the expected price for the JSF. The JSF has partial stealth features and therefore claims to be a fifth generation combat aircraft. The stealth feature is, however, a mixed blessing. To carry all weapons inside the hull (as the JSF does) you get a bulky and slow aircraft. To fly fast it needs to turn on the after burner, and then the aircraft becomes very visible to the enemy. The Gripen, on the other hand, can fly very fast ("supercruise") without the after burner turned on. The range is about the same, but the Gripen is faster. Still, the Norwegian military, after decades of tuning in to US equipment has long been rumored to like the JSF aircraft more.

Industrial spillovers are a significant part of practically all procurement of this kind. An industrial argument can therefore be made for the greater area for picking up spillovers that the three Nordic countries or all EU countries make up together (see Chap. 7 on the European perspective). The long life of these types of aircraft, furthermore, means that the life time maintenance, repair, and modernization support that the supplier can guarantee is critical. This demand also makes it important that Swedish military also operates a large fleet of JAS 39 Gripen aircraft as a "pilot." On this the previous Norwegian defense minister Thorvald Stoltenberg emphasized that the Nordic countries have to cooperate within defense and disaster preparedness, or there won't be any defense at all (SvD, July 14, 2008).

In November 2008, Norway suddenly decided on Lockheed Martin and its JSF on grounds that still have to be fully clarified. Apparently, other circumstances mattered more for the Norwegian decision than cost performance of the aircraft and industrial spillover values. There has been a post "Norwegian decision" discussion about a rigged political investigation and unclear product feature and price commitments on the part of Lookheed Martin that have been unfavorable to Saab (*Ny Teknik*, No. 20, May 13, 2009). A Norwegian military expert and the Norwegian correspondent for Jane's Defence Weekly even claims in an article in Swedish daily *Dagens Nyheter* (August 30, 2009, DN Debatt) that the political decision makers, including the defense minister Stoltenberg, have been cheated. They will now get a not as good and much more expensive aircraft than the Saab NG Gripen. The decision, it was argued in the article, should therefore be canceled and a new and more open investigation conducted.

S1.2 Swedish Military Aircraft Procurement History

Saab and the IG JAS group would not have been capable of taking on the Gripen development project without the experience from a long history of developing very advanced military aircraft platforms and systems and before that modifying and manufacturing foreign combat aircraft on license.

Previous main Swedish combat jet aircraft fully developed and engineered by Saab are:

Saab J-29 (*Den flygande Tunnan*, or "The Flying Barrel" first generation fighter aircraft with jet propulsion. Six hundred and sixty one aircraft were delivered between 1948 and 1953).
Saab 32 (*Lansen*).
Saab 35 (*Draken*), both second generation and supersonic, 456 and 612 delivered, respectively, from 1952 to 1955).
Saab 37 (*Viggen*, third generation, first flown 1967. Three hundred and twenty nine aircraft were delivered from 1971 to 1990). The last Viggen aircraft was taken out of service in 2006.

The Saab J-29 replaced the piston-engined aircraft of the immediate post WWII period. It "competed," or rather compared, with the F-86 Sabre (the USA), the British Vampire, and the Soviet MIG-15.

The second generation combat aircraft featured integrated weapons and avionics systems. Some early computerization of systems were introduced. The supersonic Lansen and Draken from Saab here compared with the US F-5 Freedom Fighter and the Soviet MIG-21.

The third generation aircraft were all supersonic and relied extensively on digital computerization and advanced systems integration to achieve functionality. The Swedish Saab 37 Viggen could here be compared with the Soviet MIG-29, the US (General Dynamics/Lockheed Martin) F-16, the (McDonnell Douglas/Boeing) F/A-18 Hornet and the French Mirage 2000.

All Swedish combat aircraft had been specially configured to fend off an invading enemy, read the Soviet Union, and therefore carried a limited potential for export sales.

The JAS 39 Gripen was the first fourth generation combat aircraft that distinguished itself from the previous generation with its instability properties and multirole (in the air swing-role) capacity. This time the Swedish authorities demanded that both export sales and civilian production had to be made part of the economics of the project which put Saab (between 1969 and 1996 *Saab Scania*) under pressure to organize itself for a far more ambitious future than ever before.

The JAS 39 Gripen Aircraft, being a complex integrated platform in itself, was also the core element in the new Swedish central military command system which included specialized weapons, a surveillance system operating in real time, all integrated with a combat management system and road bases distributed over the entire country that together constituted an integrated and complex whole that was to be developed in parallel (RRV 1996:27:26). This integrated whole, based on the new distributed computing technology was an early forerunner of what was later to be called the *networked defense*, a critical part of it being the digital datalink of the STRIL 90 (later rechristened STRIC) combat management system. The new computer and communications technology intensive system has significantly raised the spillover intensity of the JAS 39 Gripen procurement compared to earlier combat aircraft procurement.

The first version JAS 39 Gripen contracted in 1982 and first delivered in 1992 featured a fully digitized infrastructure with sensors, weapons, aero dynamic surfaces, aircraft controls, and displays, all standardized and integrated. Above all, the basic physical structure of the aircraft had been designed for a high and flexible development potential that could accommodate a wide range of new future functionalities. This represents the result of a sophisticated integration of customer user competence and supplier flexibility that has guaranteed a long life of the aircraft through upgrading and modernization. The expectation is that the JAS 39 Gripen aircraft will be in operational service at least as late as 2035, perhaps as late as 2045.

In general, the different generations of aircraft differ in terms of installed computer capacity, a difference that is particularly characteristic of the change from Viggen to Gripen.

S1.3 The JAS 39 Gripen Concept

The JAS concept was to develop a small and relatively inexpensive multirole aircraft with half the weight of the previous third generation Viggen, but still carrying the same weapons load and with much improved performance capabilities. The multirole feature meant that only one (rather than three) type of aircraft had to be serviced, radically reducing lifetime maintenance costs. Above all, the new aircraft should have a greater operational capability at only 60–65% of the lifetime cost of the Viggen. The new aircraft had to be capable of landing and taking off on regular roads at least 12-m wide for 800 m, and be serviced in the field by regular nonprofessional conscript personnel. All this together radically increased the *availability of the aircraft* compared to competing combat aircraft for which a much higher proportion (of the total number) are constantly grounded for service and repair.

This concept could not be realized on the basis of currently available technology. To do it, significant new technology development over a broad range is necessary. The technical risks were thus large, although the potential spillovers to the companies involved and to society at large were also large.

In 1979, the Saab Scania group contacted the Swedish defense authorities to indicate that it would be feasible to develop such a light weight multipurpose military aircraft.

In 1980, the Swedish Parliament initiated a feasibility study on a lightweight multirole combat aircraft. Even though there appeared, at this time, to be few signs of the cold war to be coming to an end,[1] producers of military equipment were worried about future demand. The industry group around Saab Scania also indicated that they might be willing to take on a fixed price contract and thus carry more of the technical risks than in earlier military procurement. Compared to previous military aircraft procurements the new conditions therefore were that industry, this time, should take not only more responsibility than before for the performance characteristics, costs, and delivery times of the complete aircraft system but also more seriously than before prepare for the conversion of Swedish military aircraft capabilities for exports and civilian aircraft production.

This meant that the firms that were to take a dominant responsibility for the development of the fighter aircraft should form a "company" (a consortium) within which the risks of noncompliance with contract conditions should be absorbed. If this industry group (IG JAS) had not been formed in 1981 the JAS development project probably would not have been politically possible to realize.

S1.4 The Industry Group JAS

The Industry Group (IG) JAS was formed in 1981 in expectation/preparation of a Government procurement of the JAS 39 Gripen combat aircraft that was decided by the Swedish Parliament in 1982. The IG JAS was composed of Saab Scania (now Saab) that took on responsibility for the platform development, systems integration, the aircraft control system that defined the performance properties of the aircraft in the air and of delivering a complete aircraft with agreed upon specifications on time. Volvo Flygmotor (now Volvo Aero Corporation, VAC) modified and manufactured the GE RM 12 engine on license, Ericsson Radar Electronics was responsible for the radar and computer systems and for electronics, and FFV Aerotech[2] for testing and support equipment.

The IG JAS consortium was formally contracted in 1982 between Ericsson (project share 11%, ownership share in IG JAS 40%), Saab (66 and 20%, respectively), Volvo Flygmotor (Later Volvo Aero Corporation, 14 and 20%, respectively), Svenska Radio Aktiebolaget SRA, (Later acquired by Philips[3]) and FFV Aerotech (later acquired by Celsius[4]). The contract was signed on June 30, 1982. It involved the development of the platform, the production of five test aircraft and a series of 30 production aircraft (Series 1).

The contract specified the performance characteristics, costs, and delivery schedules. The parents of the contracting partners guaranteed the contract. In reality this was a fixed price contract (with an index clause). FMV, the representative customer, would absorb exchange risks. The dollar at the time was priced at 3.9 SEK.

Saab became the systems integrator that was responsible for the delivery of a complete and functioning aircraft system on time.

S1.5 Weapons and Communications System

The integration of weapons with weapons carrier and target identification system has become an increasingly sophisticated art in which computing and communications technology plays the dominant role. JAS 39 Gripen is a network-enabled aircraft. It was designed to be data linked and an important part of the STRIL 90 networked defense system.

This networking capacity cannot be developed over night. By the late 1950s, military strategists and the Swedish military procurement agency (Försvarets Materielverk, FMV) understood that odds in air combat would dramatically change if a linked flow of secure electronic data could be organized and communicated between the aircraft, the surveillance unit and the central military command. Even though this networked data system was a highly classified secret the Saab 35 Draken carried one of the world's first operational digital data links already in 1960/1961. The first data links connected the aircraft with a ground-based command central. Gripen was the first aircraft in the world to have several aircraft data linked in the air.

Tactical data links make information exchange in real time within a formation of Gripen Aircraft (up to four) automatic and continuous. Coordinates for the aircraft, the targets and (as the case may be) other information are exchanged and constantly updated between the aircraft and an airborne surveillance system (Erieye or US Awacs) and a ground or airborne command center (*Technology Transfer,* No. 4, 2007:28–29). The complexity of such a system is extreme, especially since weapons carrier, weapons and targets may each be traveling at supersonic speeds. Tactically such links offer great advantages since the aircraft in a formation can delegate tasks to each other (targeting, firing, surveillance, etc.) unbeknown to the enemy. (As it happens Saab Missiles, now Saab Bofors Dynamics, has come up with a number of sophisticated spillovers for civilian use. See Chap. 5.). JAS 39 Gripen's communications and data link system also has a modular design using standard interfaces between devices and systems, which make updating easy.

S1.6 The New IG JAS Procurement Method

The standard military procurement contract in the past was based on a cost plus pricing method, and separately negotiated charges for modifications. From the 1970s, electronics had entered manufacturing industry in a serious way and early and profoundly changed the aircraft industry. Technological change became overwhelming and cost overruns for modifications large. This had become a concern in the JAS 39 Gripen procurement negotiations, and the concerns even included the possibility of the purchase going abroad. So even though future technological change was expected to become even larger than before, the concerned industrial partners approached the Government customer in the late 1970s and offered to take on a fixed price contract. This made it extremely important for the supplier firms to come up with a flexible platform design that allowed easy future modifications of the aircraft.

The JAS 39 procurement, however, was different from earlier procurement of combat aircraft also in other ways. IG JAS was committed to delivering a complete aircraft with certain well-defined functionalities/properties at a fixed price or cost. The design contract was tougher than earlier and more loosely negotiated cost plus contracts. The IG JAS consortium thus had to take on a significant technical risk and therefore also wanted to pass some of the risks on to their subcontractors. Above all, such contracts require methods of calculating and pricing the risks.

IG JAS alone carried the risk of delivering the complete aircraft on time with the agreed upon properties. Saab was the coordinating contractor and therefore took on a considerably greater risk than the other participants/partners.

The sharing of risks between the systems coordinator (Saab), IG JAS, and the subcontractors was a new commercial practice at the time, but has diffused through the manufacturing industry in pace with the distribution and globalization of production. Today such risk sharing is common between the civilian aircraft and aircraft engine producers and their subcontractors when they engage Saab and Volvo Aero Corporation in the development and manufacturing of subsystems.

The consequence of this tougher procurement process was that Saab found few Swedish firms that were willing to engage in for them large risk-sharing ventures to develop advanced subsystems. Almost all Swedish subdeliveries therefore came to consist of components, and all subsystems contracts, except one, went abroad. Only one Swedish subcontractor (Nobel Plast, now ACAB) outside the IG JAS partner group took on a complete and very advanced subsystems contract, the radom nose cone of the Gripen that protected the radar antenna within a plastic nose, made of a material that could receive signals, but could be made to leak signals selectively.

Saab's argument when negotiating subsystems contracts was: This is your opportunity to become a global competitor/subcontractor in your field. That opportunity is valuable for you, so you should cover some of the financing and the risks yourself. IG JAS is only paying the global market price charged by already established volume producers.

Swedish potential subcontractors of subsystems were not used to this, and did not come forward. Motala Verkstad abstained from taking on the manufacturing of the landing gear that it had done for previous Swedish military aircraft quoting too high risks for the company[5] (Also see Sect. 5.10.) So in the end – except one firm outside the IG JAS partners, Nobel Plast (today ACAB, acquired by Volvo Aero in 2007; see case presentation in 5.5) – all potential Swedish subsystems contractors to JAS 39 Gripen were satisfied to manufacture components on specification.

The new procurement philosophy with JAS 39 Gripen was to acquire to the extent possible entire, functionally defined subsystems and to ask the subcontractors to perform significant technical development, to carry significant technical risk, and to contribute to the financing of its own development work. This meant a larger technical commitment than during previous procurement processes on the part of the subcontractors, tougher commercial conditions and the need (on the part of the subcontractor) to upgrade itself to become a specialist subcontractor and volume producer on par with foreign competitors.[6] The reason for the tough negotiations was that IG JAS had taken on a fixed price contract, and had to negotiate prices for components and systems downstream that were compatible with the economics of the entire project.

A fairly detailed account of the procurement is at place in this technical supplement since it illustrates both the role of IG JAS firms as competent "downstream" customers to Swedish subcontractors and the extreme complexity of the project and what is needed to get the entire act together.

For several reasons, it was considered impractical for the IG JAS partners to organize a central purchasing operation. The main reason was that components and subsystems from Saab, Volvo Aero engines, and Ericsson electronics were so different and required such specialized knowledge on the part of the purchasing agents that potential synergies would be small, the power to negotiate price concessions of little importance and a joint organization more a bureaucratic nuisance than an improvement.

The account below covers only the Saab purchasing responsibility. Saab engineers were responsible for assembling all subsystems into a functioning aircraft. In the presentation below I exclude the weapons systems. I have included this list to illustrate the complexity of the distributed and then integrated development and manufacturing of JAS 39 Gripen.

S1.7 Subsystems Categories Outsourced to Non-Saab Subcontractors

Below is a list of the main subsystems subcontractors for the Saab subcontractors:

1. Fuselage, composite wing	British Aerospace, UK
2. Air and cooling system	British Aerospace, UK
	High Temperature Engineers, UK
	Hughes-Treitler, USA
3. Fuel System	Intertechnique, France
4. Control system	Lear Astronics, USA
	Lucas Aerospace, UK
	Saab Instruments, Sweden[7]
5. Controls, reglage, etc.	Page Aerospace, UK
6. Electric generation	Sundstrand, USA
7. Electric back up systems	Microturbo, France
	Lucas Aerospace, UK
	Dowty Rotol, UK
8. Hydraulic systems	Abex, Germany
	Dowty Rotol, UK
9. Landing Gear	AP Precision Hydraulics, UK
	Loral Aircraft Braking Systems, USA
10. Rescue systems	Martin-Baker, UK
	Teledyne McCormick Selph, USA
1. Radom	Nobel Plast (today ACAB), Linköping
2. Cockpit hood and heating	Lucas Aerospace, UK
3. Instruments	Smith Industries, USA
4. Black Box	SLI Avionic Systems, USA
5. TILS Receiver	Telephonics, USA
6. Radio	Rohde Schwartz, USA
7. Navigation system	Honeywell, USA
8. Horizont gyro	SFENA, France
9. Oxygen supply	EROS, France
10. Fire; hazard warning and extinguishing	Systron-Donner,USA
	Walter Kidde, USA
11. External lights	FL Aerospace, USA
	Hella, Germany

Each of these subsystems categories in turn consisted of several subsystems that were each subjected to a separate procurement.

To develop the entire aircraft in terms of these subsystems and to specify their interfaces ex ante demanded a herculean effort on the part of Saab engineers to design the component modules and to make sure that they fitted together ex post and met agreed upon quality specifications. The ex ante cost and price calculations were almost equally demanding since they had to be almost exactly correct as were ex post delivery time and quality controls.

Saab was responsible for the airframe and systems integration and defined the parameters for the different subsystems and then invited potential vendors to submit proposals.

A *first* requirement of the contract was that *the subcontractor take on complete systems responsibility, including due consideration of its role in the functionalities of the entire aircraft.* A number of even large subcontractors backed out of this risk taking, forcing Saab in some instances to step in as a subcontractor.

The *second* requirement that subcontractors participate in the financing of their development work was more favorably received, even though many subcontractors wanted progressive payments.

At this time (1982) a general development toward more commercially oriented contracting methods could be observed in large and complex contracting projects. The experience of Saab and the IG JAS has been generally good, not least as a learning experience for future civilian subcontracting negotiations, this time acting on the opposite side as a subcontractor, except for the disappointment that so few Swedish subcontractors had been prepared to take on full-scale subsystems projects and to develop on the opportunity and take the risks to become a global competitor.

We can also take note of the fact that the Swedish Accounting Office (Riksrevisionsverket, RRV) when reviewing the JAS 39 Gripen project noted that ex post cost overruns had been unusually small (RRV 1996:27).

We also note that the commercially rational procurement methods adopted early for the JAS 39 Gripen procurement has since then diffused through the market for large and complex systems procurement. Learning how to do it had been a valuable spillover in itself.

S1.8 The JAS 39 Gripen Procurement Sequence

Not only the aircraft has a long life. Planning and procurement take almost as long.

Total procurement took place in six steps:

1. The 1982 (June 30) contract involved development of the (physical) platform for the A version of the aircraft, 5 test aircraft and the manufacturing of 30 single seaters (Series 1).

   Delivery of the 30 production aircraft should begin in 1992 and be completed in 1996.

2. The 1992 (June 30) contract involved a redesign of the A version to a two seater (the B version also called 39B) to be used essentially for the same purposes, plus training. This time an incentive contract was negotiated (see Sect. 8.4) that defined how cost overruns and cost savings should be shared between Saab and FMV. The contract covered 110 aircraft, 14 of them being two-seaters (Series 2).

   Delivery of the 110 production aircraft should begin in 1996 and be completed in 2003.
3. The 1995 contract (shared with British BAE Systems) involved the conversion of the A and B series platform to the "export" C and D versions. Among other things this involved modifying the JAS 39 Gripen aircraft to NATO standards and for in flight refueling. In 1998 BAE Systems acquired 35% (votes and capital) of Saab AB.
4. The 1997 (June 30) contract between FMV and IG JAS involved development and manufacture of 64 additional aircraft (Series 3) – among them 14 two-seaters – for the Swedish Government within an additional budget frame of 28 billion SEK in 1996 prices.

   Deliveries of the Series 3 aircraft should take place between 2003 and 2007.
5. In 1999 (Dec. 3) BAE/Saab and the South African Government signed a contract to produce 26 Gripen C and D (the export version), including additional modifications for the South African version and support systems (Logistics, ILS, etc.).

   Delivery should take place between 2008 and 2012.

   Together the Swedish Government now had committed itself to purchasing 204 JAS 39 Gripen aircraft. Aircraft 204 was delivered to the Swedish Air Force on November 26, 2008.
6. In 2007, a contract was signed between FMV and Saab to develop a new JAS 39 Demonstrator which would be the platform for the NG Gripen, and to convert 31 aircraft A/B to C/D.

S1.9 The JAS 39 Gripen Investment Budget

Table A below shows the JAS 39 Gripen development investment in (1) two periods between the years 1982 and 2007 in fixed 2007 prices and (2) cumulated investment after depreciation of 10% per year.

For the 11-year period between 1980 and 1992, total development investments amounted to 38 billion SEK in 2007 prices, or to 3.5 billion per year. For the 15-year period from 1993 up to and including 2007 the corresponding development investment was 84 billion SEK in 2007 prices or 5.6 billion SEK per year. For the entire period the investment amounted to 122 billion SEK.

The cumulated development capital in column two of the table is the private investment that will generate a private rate of return for the participating firms (the IG JAS group) and an additional social economic value that will be presented in Technical Supplement S2.

Table A The JAS 39 Gripen development investment (in 2007 prices)

Period	In 2007 prices (billion SEK)	Cumulated alternative value of investment in 2007 prices
1. 1982 through 1992 (11 years)	38.0	82.9
Thereof R&D	32.4	70.5
Manufacturing costs	5.6	12.4
2. 1992 through 2007 (15 years)	84.3	111.7
Thereof R&D	44.6	48.7
Manufacturing costs	39.6	63.0
3. 1982 through 2007 (26 years)	122.3	194.5
Thereof R&D	77.0	131.5
Manufacturing costs	45.3	63.0

No depreciation is used. It has been discussed whether knowledge should at all be depreciated as is the case with machines. This is probably all wrong. Knowledge may no longer be used and then carries no value for current production, or it may be obsolete and be in the way, and then may even carry a negative value (see Benkard (1999) on forgetting in aircraft industry). Also see von Weizsäcker (1986) and Eliasson (2000c) on making intangibles visible

When this additional spillover value is related to the cumulated investment we obtain the social rate of return to the private investment. This estimate is calculated in Technical Supplement S2 for the firms we have identified as receivers of JAS 39 Gripen spillovers and from which we have been able to obtain data. This, in other words will be a minimum estimate based on fewer firms and a different method than Fölster (1993).

S2 Estimating the JAS 39 Gripen Macroeconomic Spillover Multiplier: Going from Micro to Macro

This technical supplement is about the macroeconomics of technological spillovers and their quantification. I am identifying, measuring, and discussing the economic value of spillovers created by the JAS 39 Gripen military aircraft program, or *the JAS 39 Gripen spillover multiplier.* Key problems are to identify the production that owes its existence to spillovers from the JAS 39 Gripen development investment presented in the previous technical supplement and to determine the magnitude of the spillovers, i.e., net of the alternative economic values that could have been produced with the resources now engaged in the spillover-generating development of the Gripen project (the opportunity cost).

S2.1 The Different Estimation Methods

Stefan Fölster (1993) estimated the economic value of spillovers from JAS 39 Gripen development up to 1993. Fölster's estimate only included the development investment. It is also known that technological spillovers primarily originate in advanced product development (Moretti 2002 and cases). The manufacturing of aircraft comes later and carries a low-intensity spillover multiplier. Fölster's conclusion was that the additional value of commercialized spillovers was somewhat larger than the total development budget through 1992. His method was to combine a survey of firms' own estimates of the effects of spillovers on them and an econometric analysis on additional data. I am not overly enthusiastic about that method, which furthermore probably significantly underestimates the total spillover effects. Many indirect economic systems and dynamic effects are not picked up. Fölster was, however, careful to account for the opportunity costs to the extent possible. To be noted is that using the indirect method of deriving spillovers from the difference between estimated social and private rates of return (see below) gives much larger spillover values. But the problems of design and interpretation of such measurements are intricate. The rate of return calculations available, furthermore, have not been made on Swedish data. To begin with I will therefore spend considerable time and effort on discussing the different methods in this technical supplement. In the end I will bracket my results within a minimum and a maximum (believable) estimate and then, based on reasoning, taking in additional information, come up with what I consider a best judgment for a Swedish type economy. For a minimum estimate of the spillovers beyond 1992 I will use a modified Fölster estimate as a reference and compare the investments before 1993 and after.

I will not include the manufacturing costs for the aircraft in the analysis. Weapons development for the Gripen, furthermore, is also excluded. There is one important reason for that besides the difficulties of estimating the alternative use of production resources in the case that no new Swedish aircraft had been developed. Two alternatives to developing a new Swedish combat aircraft were discussed seriously; to import a foreign (read American) aircraft platform and to modify it in Sweden or to modify the Saab 37 Viggen. In all three cases manufacturing would take place in Sweden, thus making the differences in costs between the three alternatives a matter of development costs only. The development investment is what has generated the spillovers that we study. Spillovers from the manufacturing process are small and of similar magnitude in all three cases. Losing these spillover values would have made, as we shall see, the import and modification alternatives the by far socially most costly alternatives for Sweden.

Original plans were to "simply" update earlier estimates of Fölster (1993) for the period 1982–1992 for the period after 1992. This would have involved questioning the firms that had been part of Fölster's earlier study on how they now looked at the spillover effects from JAS 39 Gripen R&D investments. Unfortunately Fölster's data has been lost, including the list of firms questioned in the survey, and it turned out impossible to reconstruct both the list of firms and the data so many years later. Most people then questioned have now retired, have moved or are simply not available. A new method, or rather six alternative estimation methods are therefore discussed and a new compromise method chosen and devised. Fortunately for this new ambition several econometric North American studies are now available that report on estimates of social and private rates of return on R&D intensive industries.

Calculations for Sweden using North American data should at least make it possible to evaluate the reliability of my micro-to-macro aggregation method and/or to establish, as will turn out to be the case, upper end bench marks on the magnitudes involved.

So I approach the estimation problem discussing six different methods, two of which are at least in principle very sophisticated, but in my practical application rather crude. The *first* one is econometric and draws on objective ex post registered firm data on R&D investments and productivity performance in the same and chosen related firms. The *second* approach is also econometric and a variation on the first. It approaches the spillovers by way of estimating social and private rates of return in firms. This method is presented by, for instance, Bernstein and Nadiri (1993), Mun and Nadiri (2002), Jones and Williams (1998) and Hall et al (2010), and has been discussed in a non technical context in Chap. 3. The way Jones and Williams (1998) present it is a variation on so-called new growth theory. A *third* possible method is different and relates asset values of spillovers received from the R&D of the JAS 39 Gripen project.

None of these methods have been feasible within this limited study even though I will combine some of them and compare the results with those obtained when I apply social and private return estimates from North American studies to the JAS 39 Gripen R&D investments to obtain what will be seen to be upper end bench marks on the spillover multiplier.

I would have preferred the third method in principle, but data on market asset valuations from separate activities within firms are not possible to obtain from the firms involved, notably not for the civilian part of firms engaging in both military and civilian production. Furthermore, this principally correct method would in practice mean relying on business valuations of outsiders as reflected in the stock market that are notoriously uninformed, erratic, and unreliable when it comes to sophisticated high technology businesses. The current crisis (2009) in global asset valuations, furthermore, has little to do with the long-term business values that we are interested in.

So I have had to use more crude methods in the form of a combination of interview estimates and econometrics (*fourth* method) and the *fifth* case study approach collecting data on the large participants in the JAS 39 Gripen project and relating their civilian production and military exports of Gripen to the Gripen R&D investment. This is also the only way to obtain some comparability with the Fölster (1993) study.

I start from Fölster's original estimates (the fourth method) and project them forward using data on JAS 39 Gripen R&D investments after 1992 adjusting Fölster's estimate for the fact that post-1992 R&D investments in JAS 39 Gripen development have a much higher electronics, or rather computer and communications technology, content, and therefore are richer in spillovers (Greenstein and Spiller 1996; Lichtenberg 1993; Mun and Nadiri 2002). The fifth method is based on data obtained in interviews with and/or from separate analyses of 45 of the largest identified spillover receivers in Sweden from the Gripen project. I have myself estimated the dependence of these firms on Gripen technology spillovers and then computed net social value creation as described below. Aggregating these net values over the firm sample interviewed/researched gives minimum documented estimates of actual direct spillover value created. In principle, both the fourth and the fifth method should give higher estimates than those of Fölster (1993), since a longer period has elapsed and small successful spillover winners should have had the opportunity to both "appear statistically," be discovered and to grow. But on the other hand there is a risk that Fölster's estimates have picked up spillovers from pre-Gripen military aircraft R&D programs and that my more limited sample of firms has missed some major spillovers.

There is also the interview experience of conflicting stories. The long time that has elapsed since the Gripen procurement began means that most people involved are now retired or not available, while the current staff was still at school when it happened. I have therefore made an effort to find and talk to as many people as possible that were part of the early phases of the Gripen story. The fact that I was involved in an earlier interview study (Eliasson 1995) of a similar kind has also been helpful in getting the history right.

Next, I return to the second method mentioned above to apply estimates from US and Canadian econometric studies on social and private rates of return from R&D investments in those US and Canadian industries that come closest to aircraft industry. I apply these rate of return differences to R&D investment data from the JAS 39 Gripen project before and after 1992, also as described below. Unfortunately, no econometric studies on the aircraft industry or defense industry seem to have been carried out, and none whatsoever on Swedish data, so I have to substitute North American data for Swedish data from a broader industrial category to which the aircraft industry belongs. Doing this I risk both an underestimation and an overestimation of the spillovers. The broader industrial categories used in the North American studies suggest an underestimation. On the other hand the US economy in particular is far more entrepreneurial than the Swedish economy, suggesting an overestimation. This mixed method, however, based on the very large estimates of social and private rate of return differences on North American data, even very cautiously interpreted, gives extremely large estimates of the social economic value of the spillover cloud created around the JAS 39 Gripen project, far above the Fölster (1993) estimate and what I obtain from my case study aggregation. To find a reasonable middle way I base my considerations on Jones and Williams' (1998) summary assessment.

So I turn to the *sixth* method mentioned to discuss where, within the wide brackets obtained by the other methods, to land. The sixth method involves using data on productivity improvements in sophisticated firms (individual and in groups) generated in earlier simulation studies on the Swedish micro-to-macro model MOSES (Ballot and Taymaz 1998; Ballot et al. 2006; Eliasson 1981, 1991a; Eliasson et al. 2004; Eliasson and Taymaz 2000). This would have been the most sophisticated method of those mentioned if simulations could have been run on data on the real firms involved in the Gripen spillover process since MOSES model simulations account endogenously for indirect crowding-out effects and long-term dynamic effects on the macro economy. This model would also have made it possible to base simulations on real data from the generating and receiving firms. Such a study is possible in principle since many of the data needed have already been collected within the Planning Survey of the Federation of Swedish Industries (see *Moses*

DataBase 1992). To reconstruct all the data bases almost 30 years back for such a full-scale simulation of the effects throughout the entire Swedish economy was, however, not possible within the time frame and budget of this study. It will have to be done separately, if desired (see Technical Supplement S3). The principles of this simulation method and the model has, however, been verbally explained in Sect. 3.3.2. using so-called Salter curves as illustrations.

Bringing all this together means that the two reproductions of Fölster's method will give minimum estimates of the spillover effects, while the third method, to my judgment, will be in the neighborhood of the upper limits, since they are based on all commercialized spillovers to related and engineering industries. This is the way the data have been defined. Even so, using estimates on social and private rates of return gives very large macroeconomic effects, so the biases of the method have to be identified and carefully evaluated.

None of the above-mentioned studies or methods, however, picks up later *peripheral spillovers* that occur outside the statistical range of the econometric studies and take a long time to materialize. The micro-to-macro model offers a stylized way to capture even those, using a stylized *model of the commercialization process* (Ballot et al. 2006). This means that we cannot expect the additional commercialization effects so generated to have occurred in Sweden or in a developing economy, none of which is endowed to a satisfactory degree with these particular competences locally. In the USA, however, with a more entrepreneurial society and a far more advanced commercialization industry I would expect to see large such effects materialize over a long time span. And the micro-to-macro simulation method used offers a way to say something about their magnitude, and also the risk for overestimation when transferring estimated US social rates of return to a Swedish analysis.

So my estimation and final evaluation of the macro economic effects of the JAS 39 Gripen development investment is based on a combination of methods and aims at establishing a minimum benchmark and an upper reasonable range.

One ambition is to establish some comparability with Fölster (1993) and his conclusion that the 12 billion SEK R&D investment in JAS 39 Gripen R&D had generated a spillover value in other industries (including Saab civilian production) of 20 billion SEK up to and including 1992, including forecasts made by the spillover-receiving firms 6 years beyond that (up to 2000), all expressed in the same prices and discounted to the same year. After deduction of estimated crowding-out effects of 6 billion SEK, the net value created to Swedish society over and above the value to Swedish defense defined by the fact that the complete Gripen aircraft had been developed and tested, was roughly 15 billion SEK in the same prices. This meant that the economic value of spillovers to society generated by the JAS 39 Gripen military R&D investment was 115% of the military development budget. Fölster, therefore came up with a spillover multiplier of 1.15.

One general problem has been to keep spillovers from earlier military budgets separate from those generated by the JAS 39 Gripen development investment. Another problem is the long time it takes for spillover effects to diffuse and mature. This means that Fölster's effects must include some effects from earlier military budgets and that they to some unknown extent have appeared in his JAS 39 Gripen estimates.

Similarly, some spillover effects from the JAS development budget before 1990 will certainly be realized in the post-1992 years. For the same reasons large parts of the spillovers from the post-1992 JAS 39 Gripen R&D investment may not have appeared by 2007.

We know that the electronics content of the continued development after 1992 on JAS 39 Gripen has been much larger (in proportion to the total) than was the case prior to 1992; two-thirds rather than one-third. We also know from US studies that the spillover intensity around R&D increases with IT intensity on the order of magnitude of some 30% (Greenstein and Spiller 1996; Mun and Nadiri 2002). So a primitive first estimate would therefore be to simply raise Fölster's estimate for the period up to and including 1992 by at least 10% for the period 1992 up to and including 2007. Mun and Nadiri (2002) estimate the contributions from IT investments in electronics and transportation industries to TFP growth in other industries to be positive for all industries and largely originating on the supply side, rather than on the demand (customer) side.

Fölster's method was to ask a number of identified spillover receivers how much of their civilian sales value between 1982 and 1992 that owed its existence to the JAS 39 Gripen project. They were also asked about how large a share of their R&D investment that (according to their judgment) was associated with the JAS 39 Gripen project. Neither the list of identified firms nor these numbers have, however, been available for this study, so I have had to devise a different method.

I use a three-step approach to arrive at a spillover multiplier estimate. The *first* method (1) is a down to earth micro firm case aggregation that gives a minimum estimate. The *second* method (2) is an indirect derivation of the spillover multiplier from econometric estimates on social and private rate of return differences on North American data. This method, as we shall see, suggests upper bound estimates on the spillover multiplier.

The *third* method (3) brings in quantitative results from a micro-based simulation model on the Swedish economy that endogenizes opportunity costs and indicates the dynamics of spillover creation and diffusion through the economy (commercialization) in a more or less entrepreneurial economy. With sufficient time and resources this third method could have been the main quantitative method, and the suggestion in Technical Supplement 3 is that this should be a next research step in this investigation.

S2.2 Method 1: Identifying and Aggregating Over the 45 Spillover-Receiving Firms

The difficult part has been to identify in which firms the spillovers from JAS 39 Gripen R&D investments have been picked up and commercialized. We have the R&D investment data but the effects are distributed over a long period and mix with effects from earlier aircraft development and related defense investment. In the longer term, furthermore, the effects diffuse to the extent that they cannot be directly related to any particular Gripen technology. They are, however, still there.

One circumstance makes estimation easier this time. As far as I can see, the bulk of direct spillovers from the JAS 39 Gripen development program has been commercialized within the IG JAS partner firms Saab, Volvo Aero and Ericsson. This mirrors one industrial economic problem of Sweden, namely its dependence on the narrow competence base of a small group of large firms and the lack of a supporting broad range of commercialization competences distributed over the market. From the point of view of measurement, however, it makes things simpler. And to the extent I am wrong about the limited commercialization competence of the Swedish economy outside the range of its large firms I am underestimating the Gripen macro economic effects. A careful evaluation of the civilian production value created within the above-mentioned large firms because of the JAS 39 Gripen development program then gave a minimum estimate of the magnitudes involved, that could be compared with both Fölster's (1993) estimates, the US econometric studies on social and private rate of return differences (Method 2 below), and with stylized simulation results on the Swedish micro-to-macro model (Method 3).

S2.2.1 Calculation Method

The net calculation method is simple in principle but time demanding in practice. I estimate the value added in our sample of companies, notably Saab, Volvo Aero and Ericsson, the origin of which is the JAS 39 Gripen development, excluding weapons development or the R&D investment presented in Technical Supplement S1.[8] This is all civilian value added in Saab and Volvo Aero Corporation and a share of civilian value added in Ericsson, and all military exports. I assume that the resources employed in the Gripen development investment would alternatively, in the absence of Gripen, have been employed at the average productivity of Swedish engineering industry according to the planning survey of the Federation of Swedish Industries.

Net spillover values so calculated have been recomputed up to 2007 and assumed to have been invested from the year generated at a 4% real interest rate. Total cumulated spillover values are then compared with the total value in 2007 obtained if the entire Gripen R&D development investment would alternatively have been invested in financial markets at a real interest rate of 4%.[9]

This has been done for all companies that I have identified as Gripen spillover receivers. Since Fölster's (1993) list of surveyed firms has been lost and since a large number of these receivers cannot be identified at this late stage, many are missing, there will be a negative, albeit probably small negative bias in my spillover multiplier estimate.

But this is not sufficient. Now and then companies have sold off a business the origin of which can be traced to the military activity. The money received is thus again assumed to have been invested at the same real rate of interest up to 2007.

Similarly, an acquisition to boost the civilian activity or military exports should count as an investment. Fortunately, those complementary investments occur late and are few before 2008, the largest being Ericsson's acquisition of Marconi in 2005 and the Saab acquisition of Ericsson's military radio business in 2006 (see below).

S2.2.2 Identifying the Origin of Spillovers

For *Saab* it is easy to identify the origin of military spillovers. There would have been no civilian aircraft or aircraft subsystems production within the company today were it not for the JAS 39 Gripen development program and there would have been no military exports of aircraft-related products. The civilian aircraft Saab 340 and 2000 venture, however, failed and production was terminated in 1999. As a consequence Saab civilian production diminished for several years, then increased again as Saab began building up component and subsystems development and manufacturing for the two large commercial aircraft producers Boeing and Airbus, for which the military aircraft knowledge and experience, notably light weight structure technology, are critical. There are also significant military exports to add to the spillovers.

Over the years Saab has also sold off several businesses based on Gripen spillovers that were not regarded as part of its strategic focus. One recent example is the sale of the entire space technology business in 2008. The money received has been counted as spillover value that has been assumed to have been invested in financial markets (see further below).

Civilian aircraft development was started in parallel with JAS 39 Gripen development. This was a condition for giving a go ahead to the Gripen project by the customer, the Government. Civilian aircraft ambitions had been tried before but been aborted when military projects during the cold war absorbed all technical resources within Saab. The civilian project, furthermore, benefited from the same up-to-date technology as that going into the JAS 39 Gripen project. So the technology sourcing of all civilian aircraft activities within Saab during the 1980s and 1990s up to now originated in the Gripen project.

Volvo Aero Corporation is also a clear case. Volvo Aero Corporation in fact is the most clear example I have of a positive civilian pay off from military spillovers. Civilian production of the VAC group of companies went from 10% in 1970 to more than 90% in 2007. To this should also be added military exports. The explanation for this has already been presented in Chap. 5, but the unanimous opinion of management at Volvo Aero Corporation, when asked, was that the now small military part of VAC associated with the JAS 39 Gripen project was 100% critical to sustain the expanding civilian component and subsystems production, including space-related production and, of course, military exports.

The VAC calculation covers Volvo Aero Corporation itself and seven divested businesses. There is also ACAB that developed the Gripen Radom (since 2007 a VAC subsidiary. See case in Sect. 5.5).

Ericsson is more complicated. During the last four decades Ericsson has gone through a profound transformation from a basically civilian developer and producer of fixed line telecommunications transmission and electromechanical switching gear into the world premier developer and manufacturer of digital mobile telephone systems, gradually focusing on systems development and later installations, operations monitoring, and upgrading of the system, outsourcing manufacturing. This transformation also included the mobile terminal business that was spun off as a joint venture with Sony in 2001 into *Sony Ericsson*. Sony Ericsson, even though currently (2009) in a severe slump, has oscillated during the last decade between being the third and the fifth largest mobile terminal maker in the world, occupying the upper end of the market. None of this would have occurred were it not for Ericsson's military radio technology. Ericsson's military radio technology in fact saved almost all of Ericsson's telephony business during the critical change in its mobile markets during the mid-1980s. The digitization of mobile radio telephony is what relates most closely to the JAS 39 Gripen project, in particular the early networking military command system of which the Gripen system was the central part. Even though the digital tactical radio link was a top secret project within Ericsson in Stockholm, it was done within ERA which also had military radio, radar, and antenna development in Mölndal outside Gothenburg. People within both groups were known to share knowledge and experience and to move between the two locations. There, the Erieye air reconnaissance system that was part of the STRIL 90 system was developed. The civilian MiniLink was a civilian spin off from the Mölndal operation using the Gripen radar and antenna technology. The MiniLink became a civilian winner in the 1990s when the new competition among mobile telephone operators opened up the European markets and a now deregulated system needed fast and inexpensive connections to the fixed lines, not least to circumvent the attempts of the earlier telephone monopolies to fend off new competition (see further Sect. 4.4). While the role of Ericsson's military radio technology development is clear, it is still difficult to assign the importance of spillovers from the JAS 39 Gripen project in particular for that role.

The problem is as follows. There were three critical factors behind Ericsson's successful entry into the mobile telecom market; (1) a very competent and curious public customer with plenty of money, (2) the existence within Ericsson of one of the world's most sophisticated digital telecom switching technologies, the AXE system, and (3) military mobile radio technology. With any one of these legs missing Ericsson probably would not have been around today as an autonomous and global player, and definitely not without (3). Ericsson was the only telecom systems developer in the world, together with Nokia, with inhouse (military) radio technology. Furthermore, Gripen-related technology development (partly accidentally) helped Ericsson along on the rapid path to global dominance well into this millennium. In the last few years, however, new technologies have become critical and Ericsson has engaged in a strategic acquisitions round to complement its technology portfolio. While the importance of the Swedish (or rather Nordic) customer competence[10] and the AXE system faded long ago, also the military contributions seem to have grown less important in recent years. So even though Ericsson's growth continues the share thereof that I can assign to Gripen-related technology development will also diminish as this decade draws to an end. Ericsson in fact sold its military activity to Saab in 2006. It will indeed be interesting to see if the divestment of military technology will matter for Ericsson's future civilian success. If Ericsson (despite its perennial crises and successful recoveries) continues on the upward path it has not mattered. If the upward path is more permanently broken it might have mattered (the correlation will be there), but there could also be other reasons.

The semieconometric analysis of Fölster (1993) and the method of all US econometric spillover studies referred to would, however, automatically have correlated the JAS 39 Gripen development budget with the dramatic emergence of Ericsson as an entirely new mobile telephony giant. So while the link to military radio technology within Ericsson is clear it is impossible to establish more than a circumstantial relationship with JAS 39 Gripen. The JAS 39 Gripen radio communications system is based on US technology. Ericsson's breakthrough, notably into both the European and the US mobile markets, was based on the microwave and antenna radio communications technologies for moving military vehicles and for space applications developed by Ericsson. It depended importantly on four critical contributions among which the jamming-proof and robust digital tactical radio link mattered most, the development of which was part of the JAS 39 Gripen system development. A more detailed story of all this has already been presented in Sect. 4.4. The JAS 39 Gripen, furthermore, used a distributed internal computer system, rather than a central computer which was the case with the early versions of the previous Viggen, and the microprocessors of the Gripen aircraft needed very sophisticated and reliable internal data communications links to work. This job of internal data communication was done jointly by Ericsson and Saab engineers during the critical phase for Ericsson when its mobile telephone business became digital and was readied for the US market. The same Ericsson and Saab joint effort was instrumental in establishing real-time data communications interfaces not only from the aircraft to a ground-based command center but also between aircraft in a formation in the air. In this, Ericsson and Saab were pioneers. The aircraft-to-aircraft data communications has only very recently been introduced in the combat aircraft of other nations. Central information gathering and surveillance and central military command were all part of the overall radio-based communications and weapons network of which Gripen was the core force that was developed during the 1980s and installed during the 1990s as Stril 90 that will eventually link together forces in the air, on land, and at sea in a seamless network-based information and communications system.

So both JAS 39 Gripen and the digital radio communications systems technology of Swedish defense that made Ericsson's transition possible and (after some almost fatal top management blunders) successful were part and parcel of the same total project. The outcome is nicely illustrated by Ericsson's mobile telephone systems story that began with practically zero activity in 1980 to account for more than half of global sales in 1995 and for practically all sales in 2007. None would have occurred in isolation, so the correlation would have been well-established in an econometric study. I am therefore inclined to assign a significant part of the value added in both Ericsson mobile telephony systems business and in Sony Ericsson to the JAS 39 Gripen R&D budget and the military radio development from 1980. Hence, linking 100% to JAS Gripen would be an overestimation, but the one-fourth I have opted for is an underestimation.

The Ericsson strategic acquisitions and development story is a complicated one and I have had to neglect a number of transactions in my calculation. Their total influence is however small and close to negligible.

On the difficulty of valuing Ericsson's share in Sony Ericsson in the spillover multiplier estimate, see below.

The period began in 1980 with the generous cash flow originating in the Ericsson success with its fixed line AXE telephone switching system, and the bold but failed strategic venture Ericsson Information Systems (EIS) into the believed to be enormous business information systems market. This venture was based in the Ericsson's office switching technology and was announced as a separate business area in 1981.

To support that venture, Ericsson acquired *Datasaab* from Saab (50% in 1980) and the rest together with *Facit* from Electrolux in 1981. A few years later software firm *Programmator* was acquired. To support EIS development competing activities within Ericsson, such as (military) radio communication and a budding mobile telephone business were discouraged. In the 1982 annual report the CEO stated that he believed that Ericsson would capture a significant part of the global market for business information systems in competition with Xerox, Fujitsu, Honeywell, Nippon Electric, NCR, Burroughs, Univac, HP, Olivetti, DEC, Wang, and Northern Telecom, to name the most prominent competitors that were all entering the same market on the same logic (also see Eliasson 1996a, especially Technical Supplement S1).

The business information systems venture peaked in 1984 when it reached 30.5% of Ericsson global sales, but accounted for a much smaller share of total profits, if any. Radio communications (including mobile telephony) then accounts for 6.3% and defense products for 6.2%, but profitability was much higher for these activities and on the increase.

By 1985, Ericsson top management realized that the business information systems venture might be heading for a commercial disaster and that the mobile telephone systems business might be a golden opportunity which Ericsson had been close to missing. The situation continued to worsen for EIS and in 1988 the PC and Alfascope activities (once successful within Datasaab) and Facit were sold off as a new CEO took over. None of these activities had their origin in Gripen technology but all of them in earlier military aircraft and radio technology. It should also be noted that all of the above-mentioned competitors to EIS, and many more had by then failed (Eliasson 1996a).

Ericsson Hewlett Packard was formed 1993 to develop a monitoring and control system for telecommunications networks built on the experience gathered from a similar system on the Viggen aircraft. Ericsson needed the computer knowhow of HP to go on.

In 1995, mobile telecommunications accounted for more than half of Ericsson's global sales and rapid growth continues. Already in 1996 Ericsson management realized that the Internet would be a new commercial force in its market, and predicted a rapid expansion of the mobile internet.[11] Ericsson management now also understood that it would not be able to be competitive on its own in the mobile terminal business (Nokia's specialty across the Baltic) and teamed up with Sony in 1991 as a jointly owned separate company. This was getting close to Gripen technology and a case can be made for adding the market value of Ericsson's share in Sony Ericsson to the spillover multiplier calculation in 2007. The market valuation (by the market analysts) of Sony Ericsson was put at somewhere between 100 and 150 billion SEK in 2007 (DN April 27, 2009), half of it being Ericsson's share, but had shrunk considerably by 2009. This volatility of market estimations illustrates the valuation problem I have. I have chosen not to use market valuations in order not to stretch my assumptions too far, but instead opted for the value of its Sony Ericsson share that Ericsson carried on its books 2007, which was about 10 billion SEK.

To complement its mobile telephone systems activity and prepare for the Internet, Ericsson invested in *Symbian* (and in its operating system for mobile Internet) in 1998, in Qualcomm's CDMA technology in 1998 and in Juniper's router technology in 1997. These investments should all be entered as R&D development investments in the mobile systems business. The global telecom crisis, however, forced Ericsson to sell Juniper in stages in 2000 and 2001 realizing a huge capital gain. The net capital gain should be added to the multiplier calculation.

From 2005, Ericsson has been through a hectic strategic acquisitions and divestment program to focus 100% on its mobile systems business. Among the many acquisitions should be mentioned Marconi that was acquired for 17 billion SEK in 2005, Redback in 2006 and Tandberg in 2007 (see further Sect. 4.4). These acquisitions should also be added to the multiplier calculation as development investments.

In 2006 the entire military radio activity was sold (to Saab) for 3.8 billion SEK. Fortunately, for our total calculation what is a gain for Ericsson is a development investment for Saab so for 2006 and 2007 I assume that the two cancel out in the aggregate spillover multiplier calculation.

Just for the record (but outside the calculations) the office switching business (the technology base for the failed EIS venture) was unloaded in 2008 for 0.6 billion SEK.

In 2008, the 15% share in Symbian was also sold to Nokia for 1.2 billion SEK.

S2.2.3 On the Net Value Calculation Aggregated from Cases

Crowding out has to be addressed in the calculation of net social value creation for the Gripen development investment. In principle, I want to compare two full employment macroeconomic situations, one with and the other without Gripen. Gripen therefore has crowded out other allocations of resources by definition. We are not concerned with, and therefore not interested in a development program that has employed otherwise unemployed engineers. Society has made the choice to allocate scarce and highly skilled resources to the development of the Gripen platform. So in the absence of spillovers society has given up resources that could alternatively have been used for consumption or investment elsewhere. The presence of spillovers changes this comparison (C.f. the establishment of a technical university that also draws resources and is supposed to create spillovers in return), but the calculation still has to incorporate as an opportunity cost the values that would have been created by crowded out resources, had the Gripen investment not taken place.

Alternatively, I have therefore assumed that resources would have been employed at the average productivity in Swedish manufacturing industry. Such data are available from the planning survey of the Federation of Swedish industries.[12] In case a full-scale simulation method had been used this data base would also have been used to endogenize the spillover effects (see below).

Under a less than full employment situation the net effect would have been larger since otherwise unemployed labor would have been absorbed in the production of new value creation on the Gripen spillovers. Given that,

1. Very long-term effects and
2. Dynamical systems effects

are still unaccounted for, *together meaning an underestimation*.

The way output effects now have been defined spillovers from pre Gripen aircraft development have been excluded. Thus the R&D spillovers from the JAS 39 Gripen development investment of together 132 billion SEK (in 2007 prices and "discounted" with a 4-year real rate of interest) have given rise to at least 336 billion (calculated in the same way) in net increases in civilian manufacturing output and net military exports. By the assumptions made, this value would not have been created were it not for the JAS 39 Gripen development project. Spun off companies would add more than 14 billion.

For the reasons given above the spillover multiplier estimated by this Method 1 should be considered a minimum bench mark. Neither dynamic long-term effects nor serendipitous spillovers outside the range of related industries have been captured. The Gripen spillover multiplier thus is *at least* 2.6. The original Gripen development investment has been returned to society over and above the Gripen platform development investment with a large margin.

The way this spillover multiplier calculation has been set up neither the development investment nor these additional social values would have been incurred and created had the modification (of Viggen) and the import alternatives been chosen.

These alternatives, given that Sweden needed a new combat aircraft, and disregarding the spillovers were only slightly less costly, and would have provided the military with an inferior aircraft, compared to what they needed. Hence, taking social values created in the form of spillovers into account the Gripen investment was by far the most cost efficient alternative for Swedish society. And the low minimum benchmark estimated or the spillover multiplier under Method 1 is sufficient for that conclusion (Table B).

S2.3 Method 2 (Indirect): Econometrically Determined Social and Private Rates of Return

This second method is different from the previous two. Lacking direct Swedish econometric estimates on spillovers around advanced firms, I use estimates on North American data on social and private rate of return differences in related industries,

Table B The spillover multiplier

Period	Cumulated alternative value of investment in 2007 prices	Social net value creation
1. 1982 through 1992 (11 years)	82.9	105.7
Thereof R&D	70.5	
Production costs	12.4	
2. 1992 through 2007 (15 years)	111.7	
Thereof R&D	48.7	
Manufacturing costs	63.0	
3. 1982 through 2007 (26 years)	194.5	336 (349.5)
Thereof R&D	131.5	
Manufacturing costs	63.0	
Spillover multiplier		
1982 through 1992	105.7/70.5 = 1.5	
1982 through 2007 (excluding spin offs)	336/131.5 = 2.6	
1882 through 2007 (including spin offs)	349.5/131.5 = 2.7	

notably from Bernstein and Nadiri (1989) and Bernstein and Yan (1995) on Canadian data, Nadiri (1993), Hall et al. (2010) and Jones and Williams (1998) to indirectly derive a spillover multiplier estimate for Sweden. The latter summarize and evaluate the results from a number of US studies.

Jones and Williams (1998) come out with average estimates on social rates of return on R&D investment of *at least* two to four times the private rates of return and probably larger. "Conservative estimates" they conclude, "suggest that optimal R&D investment is at least two to four times actual investment." The underinvestment in sophisticated advanced and privately financed product development has been very large. In principle then a capital input of at least twice and probably significantly larger than the directly measured R&D capital has been received and commercialized by other industries such that a corresponding decrease in cost and increase in profits have been achieved. The chosen manufacturing subindustries in the Canadian study of Bernstein and Yan (1995) from which data are available are "electrical products "and "transportation equipment" and hence should be considered more spillover intensive than the average manufacturing firm, but less spillover intensive than military aircraft developement R&D for Gripen.

Aircraft industry is part of the "transportation equipment" industry, but carries on far more advanced and R&D intensive production than transportation equipment industry. Therefore the differences between social and private rates of return should be even larger for that industry. While many other studies report much larger differences between social and private rates of return than the summary conclusions of Jones and Williams (1998), Hall et al. (2010) settle on a somewhat more cautious evaluation.

For some subindustries, social rates of return (in Canada) five and eight times larger than the private returns, respectively, have been estimated.[13] These are very large differences that correspond to spillover effects (see below) much larger than those obtained by Fölster and in my calculation. But the large estimates are supported more or less by other studies (Griliches 1991; Nadiri 1993).

In the neoclassical equilibrium model of Bernstein and Yan (1995) social rates of return exceed private rates of return because spillovers from R&D investments in some defined and advanced industries/firms can *reduce costs (increase profits) in the receiving industry.* Hence, to achieve the same cost reduction (profit increase) in the absence of spillover contributions firms in that industry would have to add significant own R&D investment, earning on the margin (in equilibrium) at least the measured private return. A partial equilibrium calculation would then put the economic value of the spillovers generated in the electrical products industry to as large as five times the R&D investment in electrical products. These estimates are somewhat higher than the range given by Jones and Williams (1998) and are far above the minimum estimate of at least 2.6 I have come up with under Method 1 above. In principle, indirect and negative crowding-out effects have already been picked up by this method since the negative effects on costs and profits have been netted out.

Since these estimates have been derived on the basis of methods about which there is a great deal of consensus among economists I will pay serious attention to the results. Therefore, a technical discussion of the method will follow after a brief account of the third possible (simulation) method.

S2.4 Method 3: Micro-to-Macro Simulation

All the "effect "estimates mentioned are mixtures of gross and net estimates based on the neoclassical static price-taking model, i.e., not fully accounting for the crowding-out effects and not at all capturing the dynamics of the spillover creation and diffusion (commercialization) process. In addition the spillovers captured are restricted to related industries and realized at the time of measurement. They are in that sense underestimates. Furthermore, serendipitous or peripheral spillovers and the dynamic secondary long-term effects are not captured, and it is unclear how cyclical and long-term trends that have influenced the data appear in the results.

The Swedish micro-to-macro model (Moses)[14] attends to all this in principle but was found to require a much too large data collection effort to be used in this study. Above all the dynamics of that model integrating cyclical and long-term trend factors and endogenizing growth requires a very high quality *initial state measurement*, a problem that current econometrics has simply removed by assumption. The large data gathering effort of building the micro (firm) to macro Moses database (see *Moses DataBase* 1992) had the purpose of achieving exactly that. The situation would have been better if Fölster's (1993) database had been available because many of the spillover receivers are probably represented in the Moses database. It would then have been perfectly possible and practical to generate the macro economic (output) time profiles of well-defined spillovers, net of crowding-out effects.

Since both prices and quantities are endogenous in the micro-to-macro model the full dynamics of value creation would have been captured. It is my experience from simulation experiments on the micro-to-macro model that such dynamic simulations over the long-term generate much larger allocation effects than those obtained from static price-taking neoclassical general equilibrium models. A rough inference would be that the spillover multiplier estimate should be raised some 30% above the estimate obtained with Method 1 which takes us closer to the indirect estimates under Method 2 (For further references see Sect. 3.3).

If a full-scale inquiry into the dynamics of spillover creation around advanced firms and economic growth is desired I recommend that this model is set up for quantitative analysis because it would be as close as you can currently come to modeling the measurement of spillover generation, diffusion through the economy and the pick up, and of quantitatively capturing the economic dynamics involved. Such a study, even though it would involve a considerable research and data collection effort could also be organized to estimate the relative importance of advanced firms and technical universities as spillover generators for industry at large (see Technical Supplement S3).

S2.5 The Value of JAS 39 Gripen Spillovers: Analysis, Evaluation, and Discussion

Aggregating case study data from identified spillover receivers, I have arrived at a minimum reference spillover multiplier for the social value creation of the JAS 39 Gripen project of *at least* 2.6. Using estimates on social and private rate of return differences for North America an upper benchmark above 4 has been obtained. To judge from the reasoning of Jones and Williams (1998), it may be much larger. For various reasons to be expounded below I am not comfortable with such large numbers, even though Jones and Williams (1998) regard them as robust estimates. From the point of view of the evaluations of this book the very conservative low-end estimate of *at least* 2.6 that I have arrived at is however sufficiently high to motivate major further sophisticated public procurement to stimulate/induce R&D investments in advanced firms. Taking the Jones and Williams (1998) cautious estimate range of at least two to four times as a starting point the governments in advanced economies should be concerned about *their underinvestments in sophisticated private R&D*. They should be seriously looking for ways to help overcome it. These concerns, furthermore, should first be directed at supporting the commercializing industry that is not competitive even in the advanced industrial economies of Europe, compared to that in the USA. I still conclude, however, that the minimum bench mark mentioned above is too low for Sweden and go on to assess where in the neighborhood of Jones and Williams's (1998) estimates on North American data that we can place a reliable number for Sweden on the JAS 39 Gripen spillover multiplier. The reader now has to excuse me if my elaborations become somewhat technical.

The estimates from the econometric studies are based on a number of assumptions, the critical one being whether to *assume increasing, constant or decreasing returns to R&D investments in the decade before and after the current year.*

To begin with I accept the Jones and Williams (1998), as they call it, conservative estimate that social rates of return on average R&D investments in the USA are at least some two to four times the private rates of return on the same investment. If constant returns are assumed, the extra social value created, or the spillover multiplier around the JAS 39 Gripen project would then amount to some two to four times the JAS 39 Gripen R&D investment. Under the assumption of constant returns one should expect the same number to hold for the future, that is for additional R&D investments. If decreasing returns prevail, this would be a conservative estimate since marginal returns were higher up to then but on their way down, creating a downward bias, the extent of the bias depending on the rate of decrease in marginal returns over the period of JAS 39 Gripen R&D investments. As a consequence, however, smaller social returns should be expected from future R&D investments and the gap between social and private rates of return would be closing. The gap would, however, still be large because of the large initial differences between estimated social and private rates of return.

If increasing returns prevail, the values created will be afflicted by an upward bias. On the other hand, *further expansions of JAS 39 Gripen R&D investments* should be expected to generate increasing returns in terms of social economic values created. New growth theory (see the mathematics below) is based on the assumption that returns to R&D may be increasing.

The standard guesstimate, not having the information needed to say something else, would be to assume constant returns. There are, however, some additional considerations to factor into that conclusion. *First*, the Jones and Williams summary conclusion concerns macro industry estimates. The JAS 39 Gripen R&D program, while large, is still a micro investment in R&D. For the 26 years 1982 through 2007 it corresponded to 13.2 billion SEK/year or 0.17% of Swedish GNP. I would argue that this means more spillovers to the entire economy because of the greater leverage, but also less because there is no cumulative interaction from a broad-based massive industrial R&D expansion. There is also the *second* fact that while the J&W "estimate" is based on average R&D investments the JAS 39 Gripen R&D program is far more sophisticated and spillover intensive. *Third*, and this should be noted carefully, the US economy is more entrepreneurial than the Swedish economy and therefore more capable of capturing and commercializing spillovers (Competence bloc theory. See Sect. 2.4 and Eliasson 2005a:56ff). This would suggest a lower spillover multiplier for Sweden than for the USA. *Fourth*, the private and social returns to R&D investments are not independent of their financing and of how the R&D activities are managed. The highest returns are captured for privately financed R&D carried out in the investing firm. Returns to publicly financed returns in the same firm are (significantly) lower, and social and private returns to R&D investments both carried out and financed in separate publicly run laboratories are the lowest (Nadiri and Mamuneas 1991, 1994; Eliasson 1997a , Hall et al. 2010). The J&W summary evaluation has nothing to say on financing, but rather refers to average private R&D

data. Hence, JAS 39 Gripen spillover values should be placed at the upper end of their estimates. Finally, the neoclassical econometric models used on which J&W make their summary assessment and explain them are traditional price-taking models with an exogenous equilibrium. With endogenous prices (as in the Moses micro-to-macro simulation model) one would expect an increased rate of commercialization of spillovers to affect prices and increase competition in the economy driving down (if increasing or constant returns to R&D investments do not prevail) private returns to R&D investment, which was the source of spillovers to begin with.

How to deal with spillovers that come in the form of increased competition and lower prices to final consumers is a different matter. Nordhaus (2004) has calculated that as much as 95% of the entrepreneurial spillovers in the US economy benefits consumers in that way. Such direct consumer benefits would have entered the social rates of return if correctly incorporated as product quality change in price indexes, and thus appear as positive contributions to welfare and social rates of return. As a rule this is not the case, and, if so, we have yet another source of underestimation of the social and private rate of return differences.

On all this I now conclude in the main text that the increased IT content in further modifications of the JAS 39 Gripen platform compared to the original R&D investment up to 1992 mean continued spillover returns on the same order of magnitude as in the past.

Competence bloc theory (see Table 2B on page 43) now allows me to distinguish between two types of spillovers and three types of firm or policy strategies, namely:

A. Marginal returns to R&D are decreasing, but spillovers are nonrivalrous. R&D knowledge (ideas) created in one firm is captured and commercialized in other firms where it raises the productivity of other factor inputs. Social returns to private R&D investments increase. Private returns need not be affected. Let me call this *industrial spillovers*.
B. R&D knowledge (ideas) created through R&D investments in one firm are imitated by other firms (*imitative spillovers*) raising competition, increasing the productivity of other factors of production. While social returns increase, competition now lowers product prices and the private returns to the R&D investing firm.
C. R&D or ideas generation is cumulative and allows the R&D investing firm to constantly stay ahead of competition under A and B. Such knowledge spillovers (as distinct from industrial spillovers under A above) should allow the R&D-investing firm to earn a satisfactory private return on its R&D investment as long as the marginal increase in idea creation to further expansion of the stock of knowledge/ideas is positive.

This last remark under A is the assumptional foundation of so-called new growth theory. If empirically correct, or as long as it is empirically correct for a whole economy because of networking externalities, the advanced economy, say the USA should simply go ahead spending on R&D account and not worry about China which might even begin to lag behind if it doesn't get out of its imitating mode.

So we now have three business or policy strategies to consider:
Strategy 1: Under A the industrial spillovers represent value to the firm that generated them, but also an incentive to claim property rights (patents, etc.) to the nonrival spillovers created to be able to charge for them or earn a profit on them.
Strategy 2: Under B the private returns to the spillover-generating firm are threatened by imitators that compete down its private returns. The firm has a strong incentive to claim property rights to imitative spillovers to protect its private returns.
Strategy 3: Under C the business and/or policy strategy would be to disregard Strategies 1 and 2 and invest aggressively in private R&D. The imitators will constantly be lagging behind. If it does not disturb the carrying out of Strategy 3 (for instance, because of management overextension) the firm may however also pursue Strategies 1 and 2.

For the firm it is of course a great advantage to belong to category C. Schumpeter (1942) once envisioned the invincible firm that, once it had succeeded in taking a leading technology position, would be able to keep that position on the basis of routine R&D investment. Such a routine technology development established on the basis of a once pioneering success would create problems for the standard neoclassical model that does not accommodate increasing returns. Also the "new growth theory" model would suffer if the Schumpeter (1942) model would hold for individual firms. But not, as I will show below, for sequences of innovative births, successful lives, and final deaths of many firms. This is the micro-to-macro dynamics of Table 3 (on page 49) which is a particular rendering of the Schumpeterian creative destruction process for the endogenous growth mechanism of the Swedish micro-to-macro model (Eliasson 2005a:53ff). Fortunately, for both economic theory and society there is no, or little evidence to support the Schumpeterian (1942) proposition of sustainable (permanent) firm leadership on the basis of routine R&D investment. Innovative firms with extraordinary commercializing capabilities, once vigorous will always fade with time and success, as the once invincible IBM learned, after some 25 years of supremacy, toward the end of the 1980s, and we find ourselves in an Experimentally Organized Economy (EOE), where no firm, not even the best firm, can feel safe (Eliasson 1996a, 2005a).

The policy maker should of course be happy if it has a core of type C firms in its economy. In fact, my argument has been that sustainable positive development of an industry in an advanced economy requires one or more C firms in that industry. And the group of C firms does not have to be the same all the time. "Memebership" only has to be temporary. It is to be observed that public procurement of sophisticated public goods ("military equipment") has made it possible for a group of Swedish firms to pursue Strategy 3 for a considerable time. The policy maker should then:

1. Focus on sophisticated public procurement *of privately demanded public goods* in support of Strategy 3 to help overcome any underinvestment in private R&D.
2. Protect property rights to intangible technology assets to support Strategies 1 and 2.

3. See to it that a sophisticated commercialization industry develops locally. This must be a policy effort designed to improve the local entrepreneurial climate, and not to get involved in owning and managing public companies.

To explain this I follow Jones and William (1998) and introduce their industry level idea production function

$$A(t) - A(t{-}1) = G(\mathrm{R\&D}(t{-}1), A(t{-}1)) \tag{S.1}$$

$A(t)$ is the value of the stock of ideas at time t.

R&D investments raise the existing stock of industrially useful knowledge ($\delta G / \delta \mathrm{R\&D} > 0$).

Ideas then enter a conventional industry production function:

$$Q = Q\,(A, X) \tag{S.2a}$$

Where X is a vector of all other production factors.

To continue, *G might be both increasing and decreasing in its second argument. Whichever is an empirical question*. If society is running down its stock of opportunities as they are exploited in decreasing order of returns then $\delta G/\delta A < 0$. But idea creation might also be cumulative such that the more ideas already in the stock of knowledge the more productive further investments in ideas creation, everything else the same, or $\delta G/\delta A > 0$. We really don't know, although the pure Walrasian or standard neoclassical model would have a problem with such increasing returns.

New growth theory claims to have solved this problem of incompatibility within the Walrasian model and the solution is based on the internalization or endogenization of spillovers. Even though the individual firm may face constant returns, Jones and Williams (1998:1,125) allow for increasing or decreasing returns at the macro (industry) level. This, however, cannot be true if the proposition is assumed to apply to a single firm that will eventually dominate the market alone. Let us think of $\delta G/\delta A < 0$ as a short-term (immediate) effect, and $\delta G/\delta A > 0$ as a long-term effect, meaning that *an already advanced and wealthy economy entertains a constant competitive advantage over poorer and less advanced economies*. This interpretation is partly embodied in so-called new growth theory and in Marshall's (1890, 1919) discussion of his industrial district, where the notion (not the name) of what is now called networking externalities was first referred to. Schumpeter (1942), as I just mentioned, used the same idea when predicting that a firm, once it had gained a competitive advantage, would stay forever competitive through routine R&D investments and eventually dominate its market, for ever. This is a pure technological notion of industrial supremacy that is not convincing.[15] The possibility, however, remains that an entire industry could sustain its dominance over competing industries in other parts of the world through a "forever" viable innovation and entreprenurial process, its firms constantly climbing on top of one another competing one another out of business. In this EOE I have, however, brought in competition to sustain an endogenous Schumpeterian creative destruction growth process of constant firm birth, life and death (Eliasson 2005a:53ff).

We do, however, have to make up our mind on this (make an assumption) before we know how to calculate the spillover value from the JAS 39 Gripen R&D investment from estimated social and private rate of return differences. To do this systematically I introduce three steps in the spillover diffusion process.

Step 1: At each point in time t the G function has generated a stock of ideas or knowledge $A(t)$. These ideas (this knowledge) have (has) a more or less general applicability beyond the purpose for which they were created (The JAS 39 Gripen combat aircraft). The stock of ideas diffuses more or less effectively through the production system. As these ideas diffuse from their source, (S.2a) has to be rewritten to accommodate that fact to

$$Q = Q(A(t), S(t), X) \tag{S.2b}$$

The magnitude of those *production spillovers* $S(t)$ now depends on the *commercialization competence* of the economy as represented by items 3 through 6 in the competence bloc Table 2B (on page 43). A disaggregated competition-driven approach is required to represent this property such that Q in one firm or industry is affected by A through S in all other industries.

The faster ideas diffuse (everything else the same) the higher the social return to the R&D investment but the more the private rate of return is driven down by competition if spillovers are imitative and rivalrous.

Since the expected private rate of return had stimulated the R&D investment, one should expect future R&D investments to decrease, the further down the private rate of return is driven compared to some alternative return at which the same resources can be invested, for instance in the financial markets. Once the private rate of return reaches below that alternative rate one would expect the private R&D investments to cease. One erroneous implication would now be for government to enter to subsidize R&D and believe that it has then raised the spillover flow (see below).

The private R&D investing firm now has two options:

Step 2: Attempt to claim property rights to the spillovers (patents, secrecy, etc.) and charge for them. This will diminish the diffusion of spillovers, lower the social rate of return but raise the private rate of return in the R&D investing firm.

Step 3: An alternative strategy is to raise R&D investments and outrun imitators that exploit your spillovers. Now the sign of the partial derivative $\delta G/\delta(\text{R\&D})$ matters.

The strategy to go ahead with aggressive R&D investments will work as long as $\delta G/\delta(\text{R\&D}) > 0$.

Under Strategy 3 social rates of return will increase, both because of industrial spillovers from the larger stock A and because the larger stock of A raises the productivity of research today and hence gives more A for the same R&D input in the ideas production function (*knowledge spillovers*). To what extent this occurs is an empirical question that we cannot yet answer. If true, advanced economies like the USA and Sweden will underinvest significantly in R&D. There is no reason to worry about China since the Chinese will be forever left behind. No capital market equilibrium with social and private rates of return equal will be reached in the foreseeable future.

The Nadiri and Mamuneas (1994) results, however, indicate that not any kind of R&D would have those potent results. If undertaken in public laboratories (for instance in technical universities) there might be strongly decreasing returns to R&D. If financed by Government, similar results might obtain although not as prominent. Only privately carried out and financed R&D investments where the private investors carry the risks have the efficiency characteristics we ask for.[16] So the important point is to link the R&D process as clearly as possible to commercial and dynamically competitive markets and private customer's willingness to pay. *Public procurement of advanced products that trigger private investments in advanced firms should be expected to have that property.*

Steps 2 and 3 together suggest a clear strategy because of the large initial differences in social and private rates of return. Go ahead and invest in R&D and privately managed business risks and allow (under Step 2) social rates of return to be run down such that they close in with private rates of return, but only as long as private rates of return can be kept safely above the opportunity cost (of investing the money in financial markets) to make the R&D investments profitable. Eventually, in the neoclassical model, capital market static equilibrium will be reached when the stock of opportunities has been exhausted.[17] Under Step 3 this poses no problem since social rates of return may increase from increases in R&D investments.

So what should I assume in order to compare the extra social values created to society through R&D investment in JAS 39 Gripen?

S2.6 Summing Up

Within a practical policy horizon the numbers seem to suggest the strategy under Step 3. Go ahead, be bold. But there is a catch. The R&D investments we have considered are private and dependent on the private returns. They have been filtered commercially and bad projects weeded out. The US numbers are probably based on such empirical facts. And even though the USA is an entrepreneurial economy private R&D investments do not just increase. They have to be expected to be profitable after risk.

Can't we just throw in any R&D investment in (S.1) through an industrial policy program? No, these new R&D investments are unlikely to be of type $\delta G/\delta(\mathrm{R\&D}) > 0$, or are unlikely to be of the kind that create positive differences between social and private rates of return to R&D.

Public procurement of advanced and privately demanded public goods, preferably in competition, is the answer.

Given that I conclude that the JAS 39 Gripen procurement program, the way it has been organized and financed has generated social economic values over and above the user value of the development investment of the product. The case study approach (Method 1) resulted in a minimum spillover multiplier of *at least* 2.6 times the original investment. A number of circumstances discussed above make it reasonable to raise that minimum estimate, but I cannot document the higher number as well, except by saying that 2.6 is a large underestimate of the spillover multiplier. Simulation results based on the Swedish micro-to-macro model (see above under Method 3) suggest that another 30% be added to account for long run dynamical systems effects.

North American estimates of social and private rates of return differences, corrected downward for the higher (than in Sweden) entrepreneurial capacity of the US economy (Method 2) make it reasonable to raise the spillover multiplier estimate to maybe five times the original R&D investment. This would make it safe to engage in policy Strategy 3 of aggressively supporting demand that raises sophisticated private R&D investments. This policy evaluation is based on the assumption of constant or increasing returns to additional R&D investments achieved through advanced purchasing of sophisticated products such as military aircraft. It is a cautious estimate that does not incorporate the possible long-term peripheral spillover effects also discussed above.

There is one further positive and complementary policy to consider, namely creating a facilitating environment that is capable of effectively capturing and commercializing spillovers, and taking winning technologies on to industrial-scale production and distribution. If the Swedish economy could be reorganized politically to offer a more entrepreneurial environment the possibility of increasing the spillover multiplier even further would become a reasonable policy assumption.

S3 A Future Research Agenda: The Advanced Firm as a Technical University

The sustainable development of an industry in an advanced economy always requires the presence “at its helm” of one or more technologically and commercially leading firms. In the main text of this document the advanced business firm has been presented in its *double capacity* (joint production) of producing (1) a public good or service demanded by Government and the citizens and (2) in generating a cloud of technology, an infrastructure capital, of great potential economic value to society, and available for free to anyone capable of commercializing it. In that double supply role the advanced firms studied have also figured in the capacity of a combined technical and business university that compare favorably with the corresponding academic institutions in generating socially valuable services.

The implications of this study are also thought provoking. They are as well-documented as they can be at this stage. Since the policy implications are far reaching, however, to carry the policy proposals further, also further study is needed, and then three tasks in particular lie ahead; (1) more accurate econometric estimation of the spillover multiplier (according to Method 2 in Technical Supplement S2) is desirable and the econometric analysis should be complemented with dynamical systems simulation of the kind proposed under Method 3; (2) an inquiry into the spillover multiplier of alternative infrastructure investments of the resources now devoted to the procurement of sophisticated military systems, notably investments into academic research and/or into the development of sophisticated infrastructure of the public goods type, for instance medical technology platforms with time horizons so distant that no private business group, however large, would be prepared to embark on them; (3) development of a method to convert ex post spillover estimates for use in ex ante cost benefit calculations on planned projects.

It is commonly assumed without further argument that the principles of new technology have been developed by the universities engaging in basic research, while industry develops such basic understanding further into manufacturing practice (Aghion et al. 2008). I am more open minded about that and want future empirical research to clarify which way the causality runs, from theory to practice, or the other way, from experimentation to solve practical problem later to be generalized as theory by the practitioners themselves, or in the academic ivory towers. In renaissance Italy the practical rules of thumb learned from experience with experiments and measurement by the Italian artists/engineers/craftsmen were the precursors of the articulation of the laws of physics. The academics played a very subordinated role even when it came to formulating the principles and laws of nature, preoccupied as they were with divine problems of the other world and reluctant to be disturbed by the rapidly innovating reality.

There is also the additional dimension of this that has frequently been mentioned during the course of this study that should also be investigated, namely that the US economy and its academic institutions are far more entrepreneurial than those of the European economies (Carlsson et al. 2009). The US economy should therefore be more capable of benefiting from sophisticated military R&D investment than are the European economies.

The research agenda I propose here is also about addressing these important problems.

S3.1 The Double Customer Role of Government

On the demand side Government has figured as a competent customer in the double capacity of providing its citizens with a (privately) demanded public service (defense in this case) and with a cloud of technology that also benefits Government and its citizens, but that carries little interest to the private procurer of advanced products that also generates similar clouds of technology. In the capacity of a *double customership*, Government therefore also acts in the role of an industrial policy maker providing significant potential spillover benefits to its citizens.

Much of this insight was not part of the original hypothesis formulation of this study but has dawned on me during the course of the research being conducted. Hence, this study, as is often the case, has concluded with a much improved understanding of what one really should have known to answer the original research questions raised. The future research agenda suggested here is therefore designed to clarify the potential role of public procurement of advanced R&D intensive products and services:

- As an effective form of industrial policy to help overcoming the underinvestment in advanced private R&D, documented among the advanced industrial economies.
- To assess the capacity of the advanced firm to serve as a "technical university" for the rest of industry, and in particular to help reviving the "Old" engineering Industry as a growth engine in the New Economy.
- To introduce the notion of the technologically advanced firm in that capacity in the general context of a competitive teaching and research industry at large in the advanced economy.
- To clarify the optimal mix between the contributions to economic development of innovating advanced firms through "unintentional" spillovers, on the one side, and the academic institutions, on the other, notably technical universities and business schools (Eliasson 1996c).

The latter ambition will require an empirical study of the relative spillover-generating capacity of the two competing sources of new technology (the advanced firm and the academies). In addition, *an inquiry into the entrepreneurial capacity at large of the economy to identify, capture and commercialize the spillovers* from the academies and from the advanced firms will indicate how to maximize the effectiveness of advanced public procurement as industrial policy.

With this formulation it will be possible to distinguish between the "supply cloud" of new technology surrounding advanced production and how much of that cloud that will later be converted (commercialized) into industrial output.

S3.2 The European Dimension

The main text has been devoted to a study of the macro economic consequences (the spillover multiplier) of a particular case of sophisticated production. There is, however, a more general story to pursue to look at the economy at large and to assess the potential capacity of industrial policy in the form of public procurement of sophisticated spillover intensive public goods and services for which there is a large private demand. This possibility has a particularly interesting European dimension. Since the important part of the public procurement may often be the technology cloud created, an intriguing possibility will be to generalize the reasoning and the empirical results to the entire academic research and teaching area.

There is also the intriguing problem of nationalistic versus European policy interests to pursue. The Swedish experience as presented in the main text has been that the minimization of political involvement in the public procurement process, and the maximum dominance of user competence inputs, maximizes the spillover intensity of the R&D investments.

S3.3 Suggested Continuation of the Project

In continuing this project the ambition should therefore be to make the main objective of the further inquiry to (1) assess the competitiveness and the role of the "Old" engineering industry in the New Economy, (2) estimate the magnitude of the underinvestment in private industrial R&D in the advanced industrial economies and (3) determine the effectiveness of advanced public procurement as an industrial policy aimed at also enhancing the supplies of innovative technology to the domestic economy.

Since the effectiveness of policy action in turn depends critically on the entrepreneurial capacity of the economy to capture the spillovers, a fourth (4) objective should be to study the capacities of local firms in the commercialization industry to identify, select, and commercialize promising spillovers.

These four issues warrant particular attention in the current ongoing globalization of the world economies causing painful adjustments in the rich and structurally rigid economies, while also offering a promising future for developing economies with the appropriate political, legal, and institutional systems.

S3.4 The Spillover Multiplier

The main conclusions of this study are well-documented: the spillover multiplier from advanced product development such as the JAS 39 Gripen military aircraft is large. While the direct costs on the books also may appear large, the much larger spillovers are rarely considered, and never appear in the same cost accounts. Correctly measured, taking these "invisible" spillover values created into account, these invisible benefits dominate several times over.

When considering the effectiveness of industrial policy through competent public procurement of advanced spillover intensive products one should remember that this policy does not suffer from the same criticism as Keynsian employment policies. I am proposing the procurement of public goods and services that are privately demanded so there should be few distortions or misallocation effects. The cloud of technology furthermore changes the public procurement to an investment decision, even though the public good procured might be considered a consumption good. The prudent Chancellor of the Treasury therefore does not have to worry about budget deficits. His problem is how to finance a socially very profitable investment.

The estimated social value creation around advanced private R&D in fact makes it costly for society to abstain from enacting the measures it can to engage in stimulating advanced private R&D investments, a conclusion that tallies nicely with the R&D underinvestment proposition voiced early by Nadiri (1993) and summarized nicely by Jones and Williams (1998). In the long run, furthermore, it is socially wasteful to invest in public procurement of unsophisticated products requiring little product development, employing only low skill workers, because the spillover multiplier is insignificant and the only "benefit" to society is temporary employment that conserves old production structures.

The main story of this study has been the role of Government as a substitute customer that steps in to procure public goods and services demanded privately, but where regular markets won't develop due to their public goods nature. This is neither an argument to subsidize such production (only for Government to represent its citizens as well as possible as a substitute customer) nor an argument to lower the price or enhance the supply of socially needed private services ("merit goods") such as health care. Government may, however, see a need to improve upon a *privately demanded* infrastructure, for instance sophisticated medical technology platforms that may raise the health and capacity to work of the population and that will not be initiated in private markets because of their public goods nature. Again, this may sound identical to an argument for general university research, but this is the wrong impression. My argument is that the research should be focused on well-defined product outcomes (functionalities) and they can be specified as part of the public procurement. Therefore the proposed study should include an evaluation in terms of the relative economic usefulness (to society) of spillover generation through private industrial research and similar technology development in academia. To properly measure the spillover multiplier from these different R&D investments, however, the new proposed project should use the micro-to-macro Method 3 of Technical Supplement S2.

The size of the spillover multiplier, however, still depends significantly on how entrepreneurial the local economy is. To maximize the social returns to private R&D investments, policies should therefore be directed at, and politically encourage and support the development of local entrepreneurial environments.

S3.5 The Future Role of the Old Engineering Industry in the New Economy

The double theme of this treatise has been the advanced firm as a technical university (and for engineering industry in particular) and advanced public procurement as industrial policy.

The engineering industry has been the backbone of the industrialized countries since the industrial revolution some 200 years ago. Engineering is the "Old" Industry in the New Economy (Eliasson 2002a, b). New industries such as IT and biotechnology will take a long time to fill in where the old industries fail to grow. Engineering production also is far from old and features an array of sophisticated products that will make up a substantial part of future industrial production in the advanced economies. Engineering, furthermore has been the foremost user of computing and communications (C&C) technologies, integrating sensors, electronics, and mechanical devices with software in its products. Engineering industry therefore will remain the backbone of the rich economies for the foreseeable future. The inhabitants of the rich industrial economies will always buy increasingly sophisticated automobiles. Developing and manufacturing sophisticated automobiles at a profit today is probably one of the most difficult industrial tasks. The most advanced automobiles will continue to find customers willing to pay a high price not only to obtain a means of transportation but also for a convenient means, a pleasure tool, and a status symbol. Sophisticated automobiles will therefore continue to be produced in, and at the high wages, of the rich industrial economies. Patel and Pavitt (1994) very clearly expressed that opinion when making "the continuing, widespread (and neglected) importance of improvements in mechanical technologies" the title of their article.

S3.6 Overcoming the Underinvestment

The engineering industrial knowledge monopoly of the wealthy Western economies went virtually unchallenged for almost 200 years. It is now, after surprisingly many years, under attack by industrializing economies, witness the current crisis of the automobile industry. One result of this study is that industry at large, and engineering industry in particular in the rich industrial economies of the West suffer from serious *underinvestment in private R&D*. The story of this study is that it is partly a policy task to overcome that underinvestment and to keep the industrial economies ahead of the imitating industrializing economies. Further research is needed to determine *what* policy can do and *how* it can be done. It is clear that if the entire underinvestment could be overcome it would turn the worries about low wage competition from such economies as China into a nonissue,[18] and reduce it to a well-defined policy issue of how to overcome the social problems and the social resistance to the structural change that will be necessary.

S3.7 Advanced Firms and Technical Universities Competing for Public Resources

To refine the policy analysis three issues therefore warrant particular attention.

The *first* research issue is that many resource-drawing organizations are eying the same public purse, pushing the same argument of their benefits to society. Public bodies engaged in channeling R&D subsidies targeted for industry draw large and increasing resources in most industrial economies. The academic institutions, and in this particular context the technical universities are drawing research resources far beyond what can be motivated by their role in basic research. So a large part of the research budget of technical universities can only be motivated by their spillovers of directly useful research results ("new technologies") to industry at large. To say something on that the spillover-generating capacities of the academies have to be assessed and compared with those of the advanced firms.

This pits the advanced firm against the technical university in competition for resources, albeit available from different sources. The main difference between the public procurement of sophisticated products such as military aircraft and university research funding is that the purpose of the former is to obtain a useful product that works and preferably also has been tested commercially in the market, and can be sold for a profit. The latter, on the other hand, means subsidizing an input in production with an often undefined ultimate purpose. Very little academic attention has been paid to that comparison and their relative growth promoting potential, even though academic entrepreneurship has been on the research agenda for decades.

Second, there is an academic research and an industrial development side to economic growth, and the two of course contribute jointly to the development of a productive and innovative economic environment which one of them will be unable to do alone. In the academic environment classroom teaching furthermore takes place while the industry contributes the opportunity of systematic learning of top of the line industrial practices and experience building. The second question to be addressed therefore is to determine the *optimal mix* between the two and to what extent this mix can be achieved through the market, whether it requires deliberate policy action to become effective and/or to what extent it requires a significant reorganization of the academic institutions.

S3.8 The Optimal Public Procurement Area

The *third* issue is different and relates to the second theme, namely advanced public purchasing as industrial policy and the optimal procurement area when it comes to capturing the spillovers. The main text of this study has been devoted to the Swedish military aircraft Gripen as an advanced Swedish procurement project, but about half of Gripen subsystems and components have been purchased abroad, and increasingly in the form of standardized components “off the shelf.” This makes the Gripen system easy to maintain and modernize compared to Dassault’s Rafale that has a much higher specialized French content.

Hence, under an open procurement process, and especially so when it comes to nonmilitary procurement, which cannot be directed under EU rules, the capture area is much larger than that of individual nations. In a European procurement setting, therefore (see also Chap. 7) European policy makers need not be concerned that spillovers spill outside their area of interest. They only have to be concerned about European industry being entrepreneurial and dynamically competitive (without subsidies and preferential treatment) compared to Chinese or US industries. For the component nations of the EU similar rational logic rules. It should not be possible for their politicians to argue successfully for fair allocations or special benefits that would only reduce the spillover intensity of the R&D investments. The politicians should be concerned about the entrepreneurial and competitive capacities of their local producers. The better they are in that respect the more attractive their region will be when it comes to competing for, and capturing spillovers from their own industries and from industries elsewhere.

Great industrial opportunities are there to be captured and the economic values at stake are large. To make informed policy decisions

- The welfare potential for the rich industrial economies of overcoming their underinvestment in private R&D.
- The right balance in that respect between (public) academic R&D and the innovative spillover contributions of the most advanced firms to maximize spillover generation (the cloud).
- The possibility of kick-starting a spillover process through public procurement of advanced products that embody the potential of closing the underinvestment gap should be further investigated.

Notes

1. As late as 1989 an international security conference in the USA reflected no expectation of an end to the cold war, a few months before the collapse of the Soviet Union.
2. Since 1992 part of the Celsius group that was acquired by Saab in 1999.
3. The command management activity was later acquired by Ericsson, and is today owned by Saab Avionics.
4. Celsius was in turn acquired by Saab in 1999. In 2008 Saab AB owned 80% of IG JAS and Volvo Aero Corporation 20%.
5. There was even regional political pressure brought on Saab to give Motala Verkstad the order at a higher price than foreign competitors offered, but Saab resisted if the difference was not covered over a political budget.
6. The new subcontracting philosophy of the JAS Gripen project is presented and discussed in Schroder and Gissler (1982).
7. Moog Inc. developed the servo system.
8. I am currently carrying out a separate spillover study on Saab's weapons development for the Gripen.
9. A 4% real interest rate may sound a bit too high. I have chosen that rate to obtain comparability with Fölster (1993), who assumed 4%. In fact, the high real rate assumed is unfavorable for the spillover comparison because R&D investments occur long before the spillover values materialize, therefore tilting the spillover multiplier, or the net social payoff in a negative direction compared to the calculation with a lower real interest rate.
10. The previous Swedish telecom authority Televerket, the competent public customer, is now a private operator under intense global competitive pressure and with a much smaller budget than before for experimental technology development.

11. It should be recalled that the Internet was a virtually unknown commercial player before Mosaic Corporation (later Netscape) introduced its browser in 1994 (see Eliasson 1996a).
12. Assuming that this average has not been affected by moving from the one to the other allocation.
13. Net of social rate of return contributions from abroad. See Bernstein and Yan (1995: Table 4 on page 51).
14. See Eliasson (1977, 1978, 1991b), Taymaz (1991a, b), Ballot and Taymaz (1998), and Eliasson et al. (2005).
15. Simply because competitiveness is so much more than technology, and once invincible firms always eventually get sloppy and lose their competitive advantage, or make some disastrous mistaken choices. In the Swedish micro-to-macro model markets, furthermore, stop functioning, as they should, when the number of competing firms gets too small. The entire model economy gradually grinds to a halt, or collapses.
16. Professor Ishaq Nadiri has confirmed this interpretation in a recent telephone discussion. He then also mentioned that new econometrics in progress within his group, on a model with more dynamic features, strengthen this result, but adds that the lower spillover outcome from publicly financed and conducted R&D investments must depend partly on the investment objectives being different. Further support on this became available to me at the last minute in Hall et al. (2010). The smaller differences between social and private rates of return that they find, compared to Jones and Williams (1998), Furthermore, appear to depend on their survey also covering spillovers from publicly funded or subsidized R&D investments with generally smaller differences.
17. In the Swedish micro-to-macro model, on the other hand, such an exogenous equilibrium does not exist as an operating domain of the model. As the model economy gets close to such a "state," it gets increasingly destabilized and eventually collapses (Eliasson 1991b).
18. The assumptions needed to say that have been discussed in Technical Supplement S2. The most important assumption is whether future private R&D is subjected to increasing long-term returns (the critical assumption of new growth theory) or decreasing returns.

Glossary

Absorptive capacity Term introduced by Cohen and Levinthal (1990); see receiver competence

Acab *Applied Composites AB*, founded in 1957 in Ljungby as Trelleborg Plast to build radoms for the Saab Lansen, for a while called Nobel Plast and then Bofors Plast. After a series of mergers and divestments and name changes it was acquired by Saab and moved to Linköping in 2005 to be acquired by Volvo Aero Corporation in 2007 as part of VACs strategy to develop light weight industrial technologies.

Aerosud (*Aerosystems Solutions*) A South African firm and a spin off from Denel

AMPS (*Advanced Mobile Phone System*) US specifications for analogous mobile phone system issued by FCC in 1983

AMS (*Analysis Management System*) A South African firm

Armscor (*Armament Development and Production Corporation*) South Africa´s Government operated weapons manufacturer and military procurement agency established in 1968

ASD Aero Space and Defence Industries Association of Europe

ATE (*Advanced Technology and Electronics*) A spinoff from Denel South Africa

ATM (*Asynchronous Transfer Mode*) Digital switching technology originally developed for LANs, now needed to replace circuit switching technology for broadband mobile telecommunications

Autoliv Swedish firm, world leader in automotive safety

AXE Ericsson’s pathbreaking digital circuit switches from the 1970s

Bofors Swedish steelmaking company and arms manufacturer, founded in 1646

Brånemark method Pathbreaking titanium dental implantation method with a Bofors origin

BTDMA Broadband Mobile Data communication with TDMA technology, mid 1990s

CASA Spanish aircraft producer

C&C Technology Stands for the integration of computing and communications technologies, or the fifth generation of computing that ushered in the *Internet age* around the mid 1990s

CDMA (*Code division Multiple Access*) US digital mobile standard that competed with GSM system developed for military use in the Vietnam War in the 1970s

Cloud of technology Metaphor for the spillovers that surrounds advanced industrial development investments

CNC machines Computer numerical control. Term for computer controlled machine tools introduced in the 1970s when computers began to be used. Before that the term NCM (Numerically Controlled Machines) was used, for instance machines controlled by punch cards or punch tape

Commercialization competence The capacity of a firm or an economy to turn innovations or technology supplies into profitable production. Modeled in Competence Bloc Theory in Section 2.4. Related to *Receiver competence*

Competence Bloc Theory Model of the actors with (tacit) competences who are needed as a minimum to create, identify, finance and commercialize innovations. See Section 2.4

CSIR Council for Scientific and Industrial Research in South Africa

DA *Dassault Aviation*

DAMPS Ericsson´s TDMA system, accepted by FCC in the US in the 1980s

Datasaab Swedish computer maker, a spinoff from Saab, acquired by Ericsson in 1980 and 1981; Ericsson sold it on to Nokia in 1988 when it discontinued its failed EIS business; Nokia sold its computer business on to British ICL in 1991, which in turn sold it on to Japanese Fujitsu

Denel South African Armscor's weapons production and research facility, separated as a state-owned company in 1992

DGA *Direction General de LÁrmament*. The French military procurement agency

DI (*Dagens Industri*) Swedish daily business newspaper

DN (*Dagens Nyheter*) Swedish daily newspaper

Double customership Tells that the public customer is a customer of both the procured product and the cloud of technology that surrounds its development, to the extent it understands the value of that cloud

Double production Term used as synonymous to joint production of the procured product and the cloud of technology

Dovern A Swedish-developed jet engine by STAL

EADS (*European Aeronautic Defence and Space Company*) Formed in 2000 by German Daimler Chrysler Aerospace AG, French Aerospatiale, Matra and Spanish CASA

Ecole Polytechnique The first engineering school, established 1794 in Paris for the military

EDA *European Defence Agency*

EOE (*Experimentally Organized Economy*) Term used to signify a theoretical alternative to the mainstream neoclassical model, with radically different dynamic equilibrium properties. See Section 2.4 and Eliasson (2005 a,b, 2009)

ERA *Ericsson Radio Systems AB*

Ericsson Swedish telephone systems company, currently dominating the global mobile telephone systems market

ESA *European Space Agency*

Ethernet The first LAN developed by Xerox in the 1970s

EW *Electronic Warfare*

FMV (*Försvarets Materielverk*) The Swedish Defense Materials Administration, or the Swedish defense materials procurement agency

FT (*The Financial Times***)**

GSM (*Global System for Mobile Services*) Europe's mobile telephone systems standard

Huawei Chinese competitor to Ericsson

IG JAS (*Industri Gruppen JAS*) Originally composed of Volvo Flygmotor, Ericsson, SRA and FFV Aerotech and Saab, the latter with systems coordination responsibility

Internet age See C&C Technology

Investor The investment company of the Swedish Wallenberg group of firms and the SEB bank (see Wallenberg group of firms)

LAN (*Local Area Network*) Data communications technology first introduced by Xerox (the Ethernet) during the 1970s

Losec Astra's brand name for its stomach ulcer substance; the generic name is Omeprazol

LTE (*Long Term Evolution*), sometimes called Super 3-G or 4-G. A faster mobile broadband Internet-downloading technology, faster than Turbo 3-G. An Ericsson specialty

Micro-to-Macro (Swedish) model Swedish micro (firm)-based simulation model; see MOSES

Modulation A variation in the amplitude, frequency or phase of a carrier wave in accordance with another wave; important in radio communication when information is transmitted with a carrier wave

MOSES (*Model of the Swedish Economic System*) Micro (firm) based simulation model of the Swedish economy. See Sections 2.4. and 3.3 and page 260f

Netbooks Very small computers with mobile internet connection

NMT (*Nordic Mobile Telephone Network*) An analog Nordic mobile telephony standard for the 450MH-band, initiated in the late 1970s and ready for introduction in 1980

OCCAR (*Organization for Common Cooperation in Armaments*) Arms procurement agency founded in 1996 by France, Germany, Britain, and Italy to avoid costly duplication and to award contracts to the most competitive bidder

Omeprazol Generic name for Astra's Losec

PCS (*Personal Communication System*) US President Clinton's initiative in the mid-1990s to integrate mobile and fixed line telecommunications access in the United States

Production Defined throughout the text as value added creating activities from raw materials to final consumption, and hence consists of product development and manufacturing to begin with and later marketing sales and distribution

Public good or service Economic term for goods and services the consumption of which (1) does not reduce their availability to others, and (2) cannot be prevented without considerable costs being incurred (*non rival* and *non exclusive*). Related to *property rights* and *innovative pricing*. The classical example since John Stuart Mill (1848) was the light house, until Coase (1974) demonstrated that when the British Government in the 18th century allowed private lighthouse owners to charge every ship entering a harbor for the service, whether used or not, the badly managed public lighthouses were rapidly made redundant or taken over by private managers. See Section 9.1

Receiver competence The competence in the local economy or of the firm to capture and commercialize technologies available in the market (Eliasson 1986, 1990a); more or less the same as absorptive capacity (See Section 2.3.2)

RM2 jet engine for the Saab 29 ("*the Flying Barrel*") A modified RR Avon engine

RM5 jet engine for the Saab 32 (*Lansen*) A modified RR Avon engine

RM6 jet engine for the Saab 35 (*Draken*) A modified version of the RR Avon engine

RM8 jet engine for the Saab 37 (*Viggen*) A modified P&W JT8 engine

RM12 jet engine for the Gripen A modified GE F404 engine (NG Gripen uses a further modified GE engine called G414)

Saab Scania Saab and Scania merged in 1969 and had its CHQ in Linköping; in 1996 the dominant owner Swedish Investor took Scania back to the Stockholm Stock Exchange as an autonomous company

SARA (*Saabs Automatiska Räkne Automat*) Vacuum tube-based computer built by Saab in the early 1950s

SBD (*Saab Bofors Dynamics*) Saab's weapons developing arm. Formed in 2000 as a merger between Saab Dynamics and Bofors Missiles. From the first of January 2010 *Saab Dynamics* includes also Saab Barracuda and Underwater Systems.

Spillover Intensity stands for the additional technology supply per SEK invested in R&D. See Section 2.3.1 and Technical Supplement 2

Spillover multiplier Defined as the ratio between the estimated social values created net of opportunity costs from advanced product development and the development investment that has created them. See Section 1.1, Section 8.2 and Technical Supplement S2

SRA *Svenska Radio AB*, later ERA

Strategic acquisitions, market for Term used to cover the gradually emerging market for high technology R&D firms, notably in biotechnology and computer & communications (C&C) technologies

Substitute Customer Name for the role of Government as a representative for its citizens when it comes to creating a market for, and a supply of privately demanded public goods and services

Sv. D Svenska Dagbladet Swedish daily newspaper

TDMA *Time Division Multiple Access* wireless communication technology

Technology Stands for knowledge about techniques

Technology Transfer Saab technology periodical

Wallenberg group of firms The Wallenberg family, through its financial arms, the Stockholm Enskilda Bank (merged in 1972 with Skandinaviska Banken into SEB) and Investor, had significant (minority) controls of a large number of Swedish international firms, among them Alfa Laval, Asea/ABB, Astra/AstraZeneca, Atlas Copco, Electrolux, Ericsson, Saab, Scania, SKF, Stora, etc. (see further, Day et al. 1993:xiv ff)

VAES (*Volvo Aero Engine Services*) Founded by VAC to exploit its knowledge of the Viggen JT8D Pratt & Whitney commercially in the civil markets for engine maintenance and service. Profitable for a long term until a new generation of engines required much less servicing and maintenance. See Sections 4.3.1.3 and 5.7.2. VAES was closed down in 2007.

VAS *Volvo Aero Services* World leading provider of services for the aircraft industry. Built from VAC´s partnership with, and later acquisition of the US AGES group. See Section 4.3.2.2.

VOAC *Volvo Aero Atlas Copco* Company founded in 1992 as a merger between Volvo Hydraulik AB and Monsun Tison, an Atlas Copco subsidiary, to exploit the Hydraulics technology acquired by VAC for the Saab Viggen engine

Volvo Aero Corporation (*VAC or Volvo Aero*) Swedish aircraft engine manufacturer

Volvo Flygmotor Swedish Aircraft engine developer and manufacturer founded in 1930. Changed its name to Volvo Aero Corporation in 1994.

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