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 distinguish – 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.

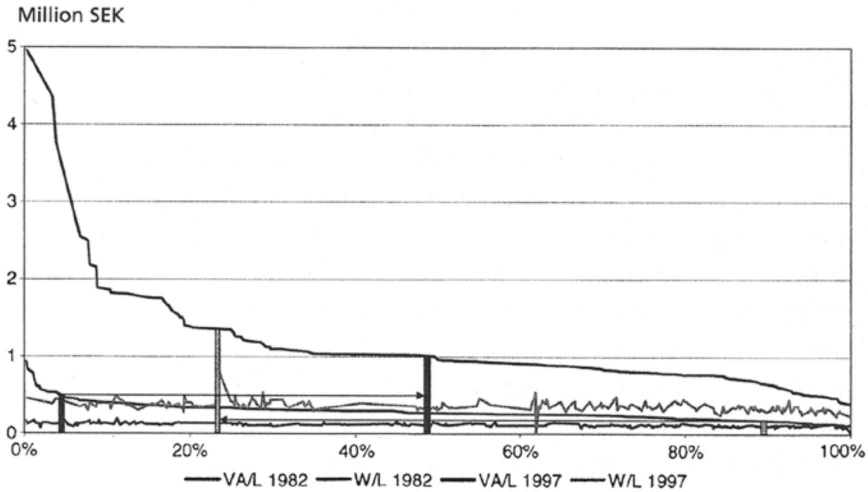

Fig. 3a Salter curves. Distributions of labor productivities in current prices (VA/L) and wage costs per employee (W/L) in Swedish manufacturing 1982 and 1997.

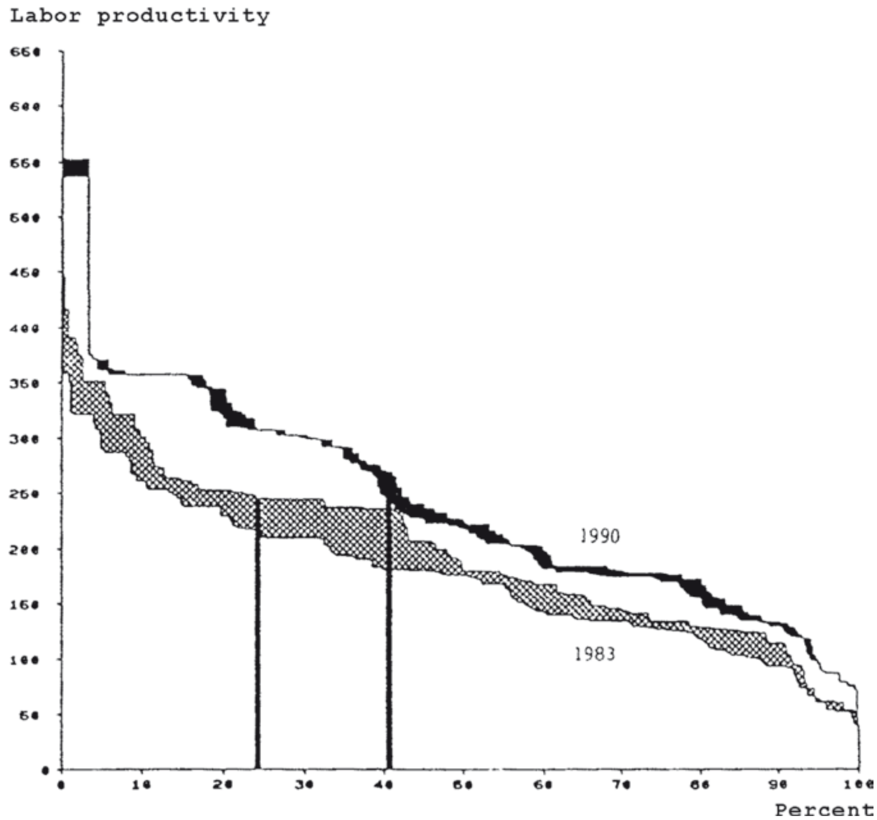

Fig. 3b (continued) Salter curves. Labor productivity distributions in Swedish manufacturing 1983 and 1990. Shaded/black areas denote unused labor capacity in firms. See further Eliasson 1996a:39.

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.

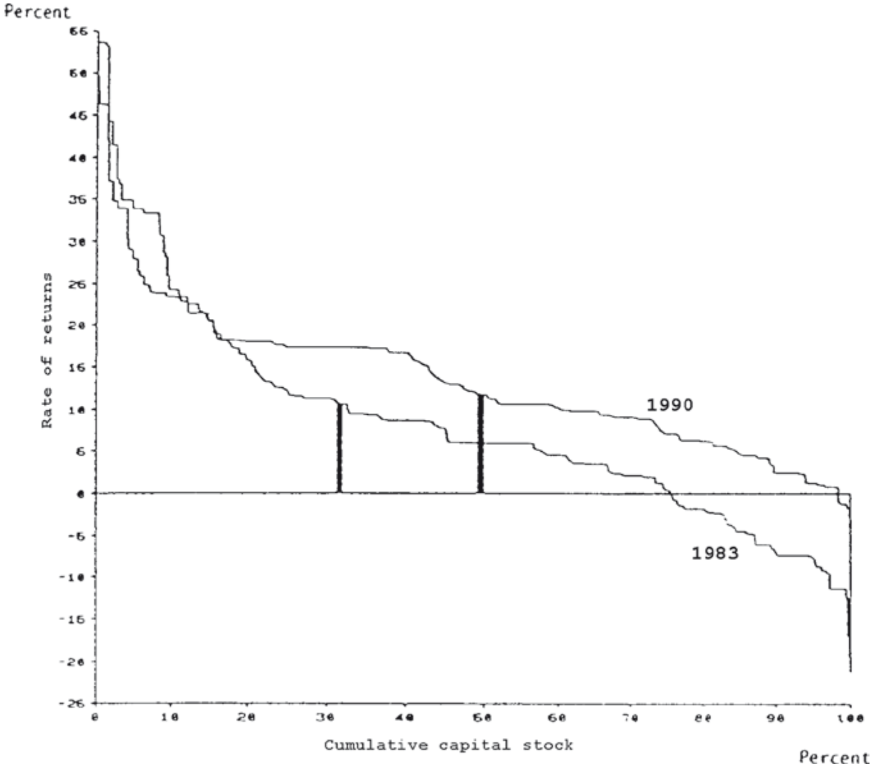

Fig. 3c (continued) Salter curves. Distributions of nominal rates of return on total capital in Swedish manufacturing 1983 and 1990.

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.