Chapter 1
Introduction

There is a wide consensus that technology contributes to create economic value, yet that process is not well understood and so technology's contribution to growth has never been assessed objectively. Why? There are ambiguous and controversial issues about what is technology.

This book proposes a conceptual framework that will allow dealing with the concepts of knowledge, technology, and capital as autonomous operational concepts. Its intended audience are managers, economists, and engineers, either in academia, or solving everyday problems in industry and services. First, it clears up the semantics, which is fundamental in any communication system. Moreover, it provides understanding a significant taxonomy for technology dependence and allows and modeling of how knowledge, technology, and capital individually contribute to production and to value adding.

1.1 Issues and Goals

There is a semantic problem with the concept of technology, in other words, there are different perceptions of its meaning. Being a new word, induced from the older word technique, the word technology was introduced to extend the meaning of technique to a wider field. However, the difference between the two meanings is not at all clear, and above all is not consensual. Specifically, management, engineering, and economy understand technology in three particular ways. Putting it in the simplest form, managers know they cannot run a process competitively without continuous technological innovation; engineers consider technology to be what they produce; and economists, as the production factors they know best are labor and capital, say that technology is everything else that may contribute to value added. Additionally, finance and accounting completely ignore the concept of technology. Nevertheless, everyone agrees that it is fundamental for production and a most important factor for growth.

Semantic problems are best studied by philosophers tracing the concepts' epistemological evolution, an analysis concerning many sociological elements as well. Those

A. S. C. Fernandes, *The Contribution of Technology to Added Value*,
DOI: 10.1007/978-1-4471-5001-5_1, © Springer-Verlag London 2013

analyses have had important contributions from the sociology of sciences, but the results are not in a format on which objective production models could be built. In fact, the results show technology as a complex concept describing a web of skills, knowledge, and artifacts interweaving the whole of society. Apparently, they say technology is the structure we all leave with and within. Changes in technology will change society's structure; it may develop it to unimaginable ways or quickly destroy it. It is part of us, humans in society. This is thorough, interesting, most probably true but not operational.

Additionally, there is another problem which is directly related to some production models that use the concept of technology: a problem that leads to dubious conclusions. It is related to a basic scientific rule, which states that whenever we apply a mathematical identity to a tangible relation, the dimensions of the identity's left term must equal the dimensions of its right term. It is a fact that many mathematicians do not worry about dimensions when dealing with algebra and calculus. This happens because mathematics is an auto-correcting structure, meaning that errors and omissions are quickly spotted internally without the need to apply the analysis to the real world. Mathematical constructs, such as multidimensional analysis and tensor calculus, were developed with no clue as to what purpose to which they could be applied. Physics and engineering, however, are not self-correcting: we engineers have to be extremely careful when using mathematical functions, for instance, to model a cable-stayed bridge, write an information compression algorithm or apply the Einstein equation $E = m.c^2$. For energy (E) to be measured in Joule, and for the velocity square c^2 to be measured in square meter per square second, the parameter m must be measured in mass (kg). Also we cannot mix meters with inches or mass with weight. Nor in economics, where a Cobb-Douglas production function relating value or volume to technology, in which labor and capital must have, for the same reasons, identical dimensions on both sides of the equal sign. This basic, universal, and unavoidable rule has not always been attended to for the past 50 years, resulting in many questionable conclusions. This fact has also contributed to the current ambiguity surrounding the meanings of technology, in so far as it has been often represented by the parameter A, and A has been used with different dimensions, which makes comparisons doubtful.

These issues are the two immediate motives for the analysis presented in this book. In summary, the main goal is to contribute to a better understanding of the meaning of technology and proposing one way its role could be operationalized, building a model that would consider technology as a growth factor, assessed objectively and independently. In that way, it would be possible to compute the contribution of technology to that of added value.

1.2 Technology Versus Knowledge

After the World War II, economists and managers focused their attention on technology, and hence technology management was born. This new area triggered the research into cybernetics and later informatics and robotics even before the information age and the silicon revolution. Technology became the pulsing heart of the corporation and technological management the most pertinent area to reach high growth rates. Production productivity stretched new upswings especially in the USA and Japan. Along the next 20 years, the importance of both the individual knowledge contribution to technological development, and the whole knowledge base corporations were building upon, slowly became obvious. The paradigms of the knowledge creating company and the knowledgeable organisation are good examples. Technology management somehow gave way to knowledge management, which takes on an organic, almost human, and holistic view of the organization, promoting, and validating innovation by technology and developing strategic decisions.

Technology, technical progress, knowledge, and technological knowledge are terms that, in a number of contexts, have been and still are synonymous, clearly evidencing an overlapping of the concepts of technique, technology and knowledge. Furthermore, technology is often listed as an asset and so considered a form of capital. Such a vision makes it difficult to discriminate between technology and knowledge, let alone to use one as an independent and objective growth factor. However, in their essence, they have different meanings. A technique is a somewhat simpler succession of actions with a well-defined goal, while technology is more complex and so involves specific skills as well as material artifacts. Knowledge, finally, is in a stricter sense, mostly used to refer to intellectual information, which includes anything necessary to operate a technological artifact, for example. There must be a way of discriminating between them.

1.3 The Role of Technology

Historically, the sociological understanding of technology is predominant and has imposed its view on management, economy, and to some extent, on engineering. The word came from the minds of philosophers in the context of analyzing manufacturing management. Thus, it is above all a sociological concept. But sociological arguments are seldom objective and operational. For instance, they were used to entertain the post-modern illusion that technology might drive history as an autonomous causal agent of social change. Moreover, management, engineering, and economy need more down-to-earth concepts to deal with. Regardless, the word technology was easily and quickly adopted by management and engineering, even if differently, and eventually by economists who saw it as a good representation for the idea of technical progress.

The role of technology is understood by managers and engineers in a more prosaic manner. For engineering the matter is even simpler, because technology is the typical output of engineering work: design, soft, or hard products. They use their knowledge and skills and embody them in material, so that a specific function may be performed. This output is a product meant to have a specific role in the production process. It is a technological form, or technology. For a manager, technology is part of a firm's resources, just as people and assets, however and similarly to engineers, he is not sure how to distinguish between them.

The resource-based view of the firm, following traditional strategic business policy, started by considering assets and people and their unique specificities as the classical resources, and evolved throughout the last 25 years to the current multifaceted understanding of the technological and knowledge type of resources, from tools to human capital, including what they name as specific capabilities. This view takes resources and their particular endowments, to be leveraged by management in order to attain the firm's goals, achieving the competitive advantage that would assure the envisioned success. Technology, inimitable or not, is just one type of resource, and again is not objectively detachable from the lot. Also, that school considers knowledge as just another resource without special characteristics. However, technology and knowledge are not treated separately because management cannot objectively distinguish between them.

Innovation-driven growth in the context of free market economies is an almost consensual idea both in the mainstream and in evolutionary theories. The subject matter is wide and transversal but it can be traced back to Schumpeter and his "creative-destruction" principle. By innovation, it is technological innovation that is meant, which is, after all, the same notion as of technical progress. Neither Schumpeterian economics, whatever this means, nor evolutionary economics make a difference in the way in which the concept of technology and its role in production are understood.

Technology has been a keyword in the so-called national innovation systems, developed and monitored at the international level by OECD, where science and technology play the most important role and innovation is the chief concept [1]. The analysis of these systems targets the innovative performance of the knowledge-based economies by measuring all sorts of knowledge flows, such as industrial linkages, human resources, publications, patents, technological diffusion, etc. They are mainly concerned with private and public investment in R&D, stressing *that the flows of technology and information are key to the innovative process* (summary). The definition of these systems uses the words technology, knowledge, technological learning, skills, and artifacts as equivalent as far as the system is concerned. Knowledge, as embodied in human beings, is human capital but it is also embodied in technology. *Disembodied technology or knowledge also includes other know-how, patents, licences, trademarks, and software* [2]. Technological diffusion may be measured by purchases of machinery and equipment; and knowledge flows by either personnel mobility or the technology balance of payments (patents, R&D services, know-how, etc—OECD Glossary). Equipment is referred to as embodied technology, but also as technology, and technology as embodied knowledge, and so on. The OECD glossary defines technology as follows: *Technology refers to the state of knowledge concerning ways of converting resources into outputs*. In other technology related definitions, this state of knowledge can be processes, facilities, and methods of operation.

In summary, the current situation is that there is no way to understand the meaning of technology and its role in production and value adding without overlapping with the roles of human knowledge and capital.

1.4 Approach and Methodology

My view and initial hypothesis is that the intricate current social system and the complexity of what we now call technology, hinders a clear vision of the different roles played by human knowledge, technological forms, and capital. Also, I know that knowledge is a concept whose meaning is as old as humanity and surely can be addressed and understood without the need for such relatively new concepts as technology or capital. Thus technology, not merely a skill and being somehow embedded in material form, should be separable from knowledge: Firstly, knowledge is itself an autonomous concept; and secondly, because technology has a physical existence that is independent of individual humans. Furthermore, even if technology and capital could sometimes overlap, from a functional point of view, there must be sensible criteria that could separate them.

There is no need to distort, remake, or create new concepts using already existent words. On the other hand, I propose to use these words with more exacting meanings so that they can be disentangled.

For this purpose I propose the following methodology: To start by conducting epistemological analyses of the three concepts throughout history and covering all the relevant scientific fields. This examination will produce lists of central attributes and extensions for each of the three concepts, such that it will be possible to focus on the central attributes, and only then attempt to separate them clearly, meaning that each should have a central group of attributes different from the attributes of the others. Once this deconstruction is done, it will be necessary to reconstruct the three concepts accordingly to a specific criterion. This will result in three new operational concepts, maintaining their original central attributes with the added quality of being operational in a specific context, that is to say, they can be used as autonomous factors in an economic production model.

In summary, to relate technology to growth and measure its contribution to value added, one should redesign, reinterpret or reconstruct the concept of technology in a way that it becomes independent of knowledge and capital while remaining compatible with its present meaning. This reconstruction will be accomplished by taking advantage of the methodological difference between a concept and an operational concept and building, out of the current concepts, new operational concepts for the three ideas of technology, knowledge, and capital. This is the contextual approach and the basic methodology sustaining the analysis described in this book.

1.5 The Process of Value Adding

Value adding describes a society's production system, the output of which is everything we consume and its value is termed as the gross value added (GVA). The gross domestic product (GDP) of a national economy is equal to the GVA added to indirect taxes, like the value added tax (VAT). As such, a production system is mostly assessed by analyzing the process of value adding, in other words, how the total GVA is achieved. In a single economy, like a national economy, or in a specific economic activity sector, like the manufacturing industries, the total GVA is the sum of all GVA contributions from each economic activity unit, such as a firm. Therefore, analyzing the value adding process in one firm is sufficient an effort to understand the whole value adding process. This is done using a rather objective language, accounting, which corresponds to international standards and is structured as a self-correcting system, just like mathematics.

By definition, the GVA in a firm is the subtraction of the cost of materials and consumables as well as other operating taxes and charges, from the total operating income. This difference is equivalent to the sum of four contributions: Staff costs, value adjustments on non-financial assets, taxes on profit, and profits on the ordinary activity. This algorithm plus a number of fundamental identities are the pillars of all financial and accounting information about firms, sectors, and economies. All indexes and ratios, as well as all the growth accounting models are based in this accounting language and system. We will also use this system to assess and compute the technology contribution to value added.

1.6 How can Technology Contribution be Assessed

I propose a model to describe the value adding process, where GVA equals the sum of the value contributions of the use of three independent production factors: Knowledge, technology, and capital. In other words, my hypothesis is that the GVA originates in the use of knowledge, in the use of technology and in the use of capital. Of course this model presupposes that knowledge, technology, and capital are independent and autonomous factors, which can only be true if they are independent operational concepts.

Next, I compare the standard GVA accounting algorithm with the one I propose, verifying, for each account, how much can be interpreted as originating in either knowledge, technology, or capital. In this way, we can compute the value contributions to GVA of the use of each of the three factors.

1.7 How the Book is Structured

Chapter 2 is dedicated to growth models, where it is shown how the idea of technology has been interpreted and used so far. Classic and more modern models are explained, with particular focus on the difficulty their authors demonstrate when discerning technology. It is also demonstrated why some of the conclusions from these models are not trustworthy, namely total factor productivity analyses. Following that, a new linear model (KTC model) is proposed, building it qualitatively step by step, fully justifying why the GVA can be calculated from the contributions of the use of knowledge, technology, and capital.

Chapter 3 is dedicated to the KTC model. Firstly, the operational concepts of knowledge, technology, and capital are constructed while a summary of the deconstruction analyses is described and the full study placed in a final annex. Secondly, the final algorithm needed to compute the values added through the use of knowledge, technology, and capital is established. Concurrently, the knowledge index, technology index, and capital index are defined, expressing their relative contribution to GVA. This rationale is also used for deduction of the main economic growth conditions.

Chapter 4 shows the technology index values for different economic activity sectors in Portugal and for manufacturing sectors of several European countries, clearly expressing their technology dependence.

In Chap. 5, a full new technology dependence taxonomy is proposed based on a statistical analysis of the technology index. Furthermore, the OECD technology intensity factor currently in global use is explained, as well as how it compares with the technology index proposed here, showing why the latter reflects better the technology dependence. Finally, how this model allows the computing of the technological content of any product is explained, by adding the technology contributions along the value chain.

Chapter 6 explains the concept of value, its origins and different types, including economic value. Definitions of consumed, restored, and created value are proposed, computing for the latter, the value created or destroyed during the last decade by several European countries. The knowledge-value-knowledge cycle is explained, and consequently why human knowledge is the direct origin of the value concept and so how economic value reflects the knowledge contribution to production. It is concluded that value is the metric for assessing knowledge.

Chapter 7 draws the main conclusions of this investigation. Comparing the initial hypotheses and goals with the results, the usefulness of the proposed model and its yields is concluded.

A long annex is placed at the end, where full deconstruction analyses of the concepts of knowledge, technology, and capital are described as well as how the respective operational concepts are rebuilt.

References

1. OECD (1997) National innovation systems. Paris. http://www.oecd.org/science/innovationinscienceteclmologyandindustry/2101733.pdf. Accessed Oct 2012
2. OECD Glossary. http://stats.oecd.org/glossary/search.asp. Accessed Oct 2012