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Infrastructures, incentives, and institutions: fostering distributed knowledge bases for the learning society ☆

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Abstract

While much attention has been devoted to information and communication technologies, a more fundamental change at the start of the new millennium is the increasing importance of innovation for economic prosperity and the emergence of a learning society. The analysis in this paper shows that innovation should be understood as a broad social and economic activity: it should transcend any specific technology, even if revolutionary, and should be tied to attitudes and behaviors oriented towards the exploitation of change by adding value.

We build on the idea of inclusive learning, which entails a process of shared prosperity across the globe following local specific conditions, and argue that it is crucial to understand the features of knowledge-induced growth in rich countries, as well as the challenges and opportunities for late-industrialized and less-developed countries. To achieve these objectives, we emphasize the relative importance of *infrastructures* and *incentives*, but considering the increasingly important role of *institutions* towards the development of *social capital*. This is because learning societies will increasingly rely on "distributed knowledge bases" as a systematically coherent set of knowledge maintained across an economically and/or socially integrated set of agents and institutions.

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This broad concept has motivated the work behind the present paper, which builds on material presented at the 5th International Conference on Technology Policy and Innovation (ICTPI), which was held in Delft, The Netherlands, in June of 2001. Under the broad designation of "critical infrastructures," the Conference brought together a range of experts to discuss *technology, policy and management* in a context much influenced by the dynamics of the process of knowledge accumulation, which drives learning societies. Thus, this special issue includes a set of extended contributions to the Delft conference, and the aim of this introductory paper is to set the stage for these contributions, with an original contribution on possible views on the role critical infrastructures play to foster innovation in the learning society.

Keywords: Infrastructures; Incentives; Institutions

1. Introduction: promoting growth through knowledge and learning

If it is unquestionable that technological progress has driven the overall improvements in the standards of living across the globe, it is also clear that many countries and many people have been excluded from the benefits of new technology and innovations. In this context, it has become common in recent literature to note that, beyond technology, it is "knowledge" (ideas and skilled and educated people) that is increasingly important for economic development, with the related incentives to reward and to stimulate the generation of new ideas and to promote the investments in education and training existing only in a limited part of today's world.

The need to promote "inclusive development," that is, a process of development that includes every citizen in any country, has become a problem that goes beyond the creation of conditions to generate knowledge [1]. Incentives to create knowledge have existed, but they need to be perfected and deepened, particularly in what concerns the sharing and diffusion of knowledge. The mere fact that in the economics literature this "diffusion" process has largely been explained in terms of *externalities* and *spillovers* shows that the sharing process is largely an unintended consequence, and in fact a disincentive for private agents to invest in knowledge creation. Thus, the logic of government intervention, namely, in terms of science and technology policies that tackle these market deficiencies, has been to provide incentives to enhance knowledge generation. The right incentive structure builds on the national science and technology infrastructure and enables the generation of virtuous learning cycles that promote the generation of new knowledge that ultimately lead to long-term growth. Learning, in this context, reflects the idea of sustainable knowledge creation and diffusion [2,3], and we contend that the challenge is to make this a feature not exclusive to a few countries but instead of the entire global economy.

A related question associated with the understanding of the emerging learning society regards the meaning of "knowledge intensity" in production, which per se may give rise to misleading interpretations of the exclusive role of innovation in the so-called "high-tech" sectors. It has been clear from many examples associated with different industrial sectors that their relevant knowledge base is not internal to any specific industry but is distributed across a range of technologies, actors, and industries [4]. In fact, they are generated via "knowledge systems" in the sense described by David and Foray [5] and are institutionally distributed. In this context, the concept of "inclusive development" referred to above involves also a process of development that includes every industry and related agents, institutions, and knowledge fields.

In addition, it should also be noted that it has become a "commonplace" to discuss the diffusion of knowledge and the "knowledge-driven economy" in general in close association with the introduction and use of information and communication technologies [6]. In this context, several national initiatives for the information society aim to achieve four broad objectives: to create a more open state, to link and make available to all the available knowledge, to promote Internet usage in education, and to support and develop digital technologies usage by firms. Nobody can effectively deny that digital technologies are important and are indeed changing the way people and firms interact and work. They are providing new ways to access to information and entertainment. Still, the question remains on whether digital technologies are indeed the chimera for development and growth that many seem to believe. The so-called Solow paradox—the observation that there is limited evidence of a positive productivity impact from the new information technologies—has returned on the agenda after the disappointing performance of high-technology firms following the "new economy" euphoria [7]. In fact, the association between information technologies and augments in productivity are increasingly being shown to be ambiguous [8–10] and associated with a learning path. Nevertheless, as demonstrated by Paul David [11], the Solow paradox tends to dissolve when it is taken into account that the new technologies will give rise to enhanced performance only after a prolonged period of adaptation of skills and organizations.

This short-term gap between innovation and productivity enhancement may not be restricted to information technologies. Recently, Conceição and Veloso [12] have shown that firms adopting generic innovation grow comparatively less in labor productivity in the short run when compared to the rest of the population, at least when both variables are considered during the same period. Their hypothesis is that the focus of "attention" in a firm may not be simultaneously devoted to both "exploitation" of existing technology and to the "exploration" of new technologies.

In general, the various issues above bring new questions about the full understanding of knowledge-based economies and the processes that allow learning societies to be sustainable, requiring deepening our understanding of the combined and evolving role of infrastructures, incentives, and institutions. The remainder of this paper attempts to frame these aspects from the perspective of science and technology policies. We begin by bringing empirical evidence on the relative importance of infrastructures and incentives to highlight the increasingly important role of institutions and social capital. We focus the analysis on the reality of the Portuguese situation, as a specific case study within EU. Clearly, Portugal has significant quantitative shortcomings, but at the same time the country has been making good progress in a catching-up dynamics that is well known. This combination of rapid catch up but persistent shortcomings make the Portuguese case useful to illustrate the main point of the paper: where have new effective institutions been created—and what their effect has been—and where have the ''old'' institutions remained—to the detriment of progress. The third section, informed by the empirical evidence associated with the analysis of the Portuguese situation, discusses current broader challenges for science and technology policy, including the need to consider the context of social interactions and institutions that govern the behavior of individuals and organizations. Thus, we establish a relationship between learning and the idea of social capital, and discuss how the concept of social capital has increasingly been brought into studies that aim to explain and provide policies to enhance innovation-based growth and development. Finally, we conclude by briefly presenting the various papers included in this special issue.

2. Incentives, infrastructure, and institutions: building on empirical evidence

This section presents selected evidence on the importance of institutions (the emergence of new and the persistence of old), discussing the way in which they have influenced the process of economic development of Portugal. To provide coherence to the presentation of evidence, we take the conceptual insights of endogenous growth theories as an organizing framework. Despite often-noted shortcomings, endogenous growth theories provide key building blocks for understanding the process of economic development. They elaborate on the neoclassical perspective that expected returns determine investment patterns on scarce factors, establishing how achieving long-term growth requires opportunities for a balanced investment in physical capital, human capital, as well as in specific knowledge that leads to the generation of new products. Moreover, they provide the necessary intuition regarding the mechanisms through which learning and knowledge accumulation may drive economic growth.

Following Veloso and Soto [13], we argue that endogenous growth models also provide important building blocks and intuition to understand some of the key microprocesses associated with economic development whether in the context of a particular company, industry, region, or nation. Our argument is that the necessarily simple concepts of expected returns and relative factor scarcity used to work with macromodels can be understood and analyzed in a microenvironment by looking at incentives and infrastructure. Incentives guide the allocation of resources and the effort to develop new knowledge; they are related to the overall market conditions, the structure of competition, as well as government policies. Infrastructure is the potential to generate capabilities and arises from physical assets, human capital, and general technical structure [14].

Under this framework, we analyze below three different sets of empirical evidence in order to better illustrate the main argument of this paper in terms of the requirements for infrastructures, incentives, and institutions to allow building the necessary distributed knowledge bases for the learning society. We refer to different institutional frameworks (namely, universities and firms) requiring different incentives and policies, but we refer to the common Portuguese context of catching-up with the average European performance. Next we justify the three case studies analyzed.

First, we look at university research because, as Pavitt [15] notes, ''innovation studies confirm Tocqueville's prediction that continuous technical change in business firms in modern society would require the development in close proximity of publicly funded basic research and associated training.'' In this context, analysis has shown that the main practical benefits of academic-based research are not ''easily transmissible information'' but involve the transmission of tacit and noncodifiable knowledge with a tendency for geographically localized benefits [16]. Furthermore, following Hicks [17], countries and firms benefit academically and economically from basic research performed elsewhere only if they belong to the international professional networks that exchange knowledge. This requires high-quality foreign research training and a strong presence in basic research mainly because academic research is certainly not a ''free good,'' although it has some attributes of a ''public good.'' In this context, Pavitt [15], among others [18,19], conclude that public expenditure on academic research is a necessary investment in a modern country's capacity for technical change. At a different level, one must consider the nature and extent of the influence of national patterns of technological change on the national science base. The analysis suggests the coevolution of scientific performance with national technology and economy, in that ''the rate and direction of the development of a country's science base is strongly influenced by its level of economic development.'' Casual observations have however shown that patterns of scientific strength and weakness are strongly influenced by the nature of the societal and technological problems to be solved. In any case, current understanding of the complexities of the knowledge base that underlie future technological knowledge is very limited, and this led Pavitt [15] to conclude that ''policies advocating more central management and choice based on foresight should be resisted.. . . The aim of policy should be to create a broad and productive science base, closely linked to higher (and particularly postgraduate) education, and looking outward both to applications and to developments in other parts of the world.''

Second, we look at results provided by an innovation survey because R&D data tend to rest on a view of innovation that overemphasizes the discovery of new scientific or technical principles as the point of departure of an innovation process (i.e., the so-called ''linear model of innovation''), while modern innovation theory considers knowledge creation in a much more diffuse way, with learning being central to innovation [4]. It is also clear that the measurement of the innovative performance of an entire country, namely, in a way comparable across the diverse realities of many countries, is a demanding challenge, which has been addressed by a joint effort of the OECD and the Eurostat through the development of innovation surveys at the country level according to a set of criteria that values cross-country comparability of results. Portugal has been an integral part of this effort for which there are results for several European countries. This European effort is designated by Community Innovation Surveys (CIS), and its framework of enquire has been adopted both in official and autonomous research surveys in many countries, from Eastern European countries to Latin America.

Third, we present an industry case study of the autoparts industry to ground the argument of the paper to the microrealities of firms and industries purposefully focusing in an area not traditionally recognized as technology or knowledge intensive. We consider two moments of the sector. The first pertains to the recent history of a foreign automaker investment in Portugal and provides a clear example of how the interplay of incentives, infrastructure, and institutions can leverage the local development of an industry. The second looks at the current realities of the sector, discussing the trend towards the integration of disparate knowledge bases in ever more complex sub assemblies of a car known as modules. It uses the example of the car sear seat to explain how this tendency poses new challenges to industry players, especially the smaller ones and those that have traditionally focused at excelling in a narrow set of manufacturing technologies. To be able to compete, companies are now required to articulate distributed and ever more complex knowledge even in areas where they do not have in-house production [20]. As a result, it is argued that the local business and policy environment have to recognize and adapt to these demands to be able to foster local industrial development.

2.1. Case 1: rethinking higher education institutions as knowledge infrastructures

Looking at higher education, we must start by noting for the need to preserve institutional integrity of the higher education system as a knowledge infrastructure where research and teaching activities should be guaranteed under diversified actions and policies, especially at a time where knowledge creation is increasingly important and our societies are increasingly dominated by market-based economies [21]. While this may seem like a platitude, the fact is that in many countries, such as Portugal, the social standing of the research in universities is still undervalued in comparison with education.

Under this context, the aim of this case is to suggest a model to define the operation of higher education institutions and to guide a funding methodology and the establishment of related incentives. This set of principles not only valorizes the research activities, according to the first aim, but also promotes a funding philosophy that goes against the traditional way in which public university funding has been regarded in many countries, including Portugal. In fact, while in Portugal, universities have been regarded as "equals" receiving funding according to a criteria that do not allow for distinctions among institutions; we propose here the viewpoint of the institution itself in terms of the single university that is preferred. Recognizing the individuality of each institution leads to differentiation between universities. This differentiation should be allowed and even promoted, stressing the individuality of each institution and assuring the respect for the identity and history of each university. Each institution's ambition, whatever it may be—from academic excellence to educational proficiency—should be acknowledge, and the institution's ability to achieve its goals should be considered and support given accordingly. The way by which the differences between universities should be revealed, we argue, is through the results of the university's activities.

Our analysis is based on empirical evidence brought by the national assessment exercise of university research centers, which has been aimed to critically review the research units and activities, encouraging the strategic optimization of activities in progress, and the reorganization of research units based on recommendations from external international experts with experience in scientific assessment. As well as enabling the implementation of a stable funding model, both for multiyear base funding and specific programmatic funds for research units, the assessment process has led to the adoption of assessment and monitoring practices in Portugal designed to encourage a "culture of rigor and quality" in the context of increasingly demanding internationalization [22].

The results of the assessment are reported in detail by Heitor [22], but there are a number of general observations that were clearly expressed during the evaluation that is of particular interest. In general, the considerable potential for scientific development in Portugal was stressed, relating to the marked increase in numbers of PhDs working in research units (namely, from a total of 3465 in 1996 to 4068 in 1999, based on December 1998 figures) and to the improved structuring of activities in progress. Several research units include specialists of international renown, as reflected in the number and quality of publications, the high degree of involvement in European consortia, and the significant number of international conferences and other events held in Portugal.

In many areas, the assessment panels noted considerable progress in the way research units define their strategic goals and present their activities. In particular, several assessment panels found a dynamic for change and considerable enthusiasm, the result no doubt of the high proportion of young postdocs and doctoral students, as well as an increase in international links. In the opinion of the assessors, these points have contributed to increasing the international profile of Portuguese research units.

The continued increase in the number of PhDs working in research units represents an average annual growth rate of around 5.5%, with materials science and engineering and art and architecture reaching the highest figure of around 14% (see Fig. 1). In general terms, the increase in PhDs researchers has been seen mainly in the areas of engineering sciences and technologies and in arts and humanities (6% average annual growth rate) and also in exact sciences, natural sciences, and health sciences (5%), being slightly lower in social sciences (4%). This significant increase, especially when seen in European and international terms, was consistently cited by the majority of assessment panels as a decisive factor in reaching the

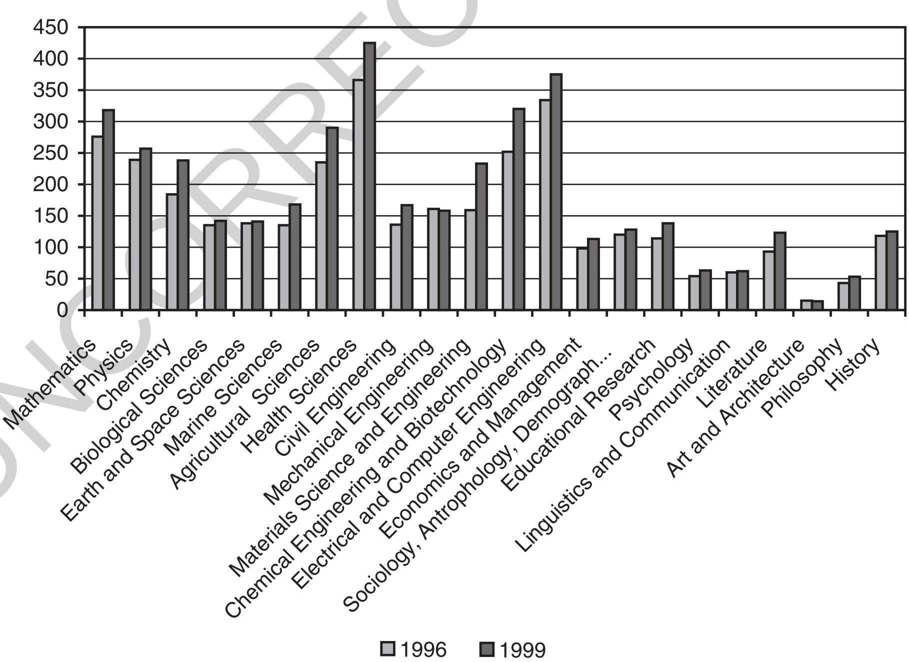

Fig. 1. Number of PhDs in units for each scientific area in 1996 and 1999. Source: Heitor [22], Available at: http://www.fct.mct.pt.

critical mass essential to scientific development. This is despite the fact that the overall values for Portugal in 1997 in terms of number of researchers as a proportion of the workforce were around half the European average (2.9 and 4.9 per thousand inhabitants, respectively).

The comments made by the various assessment panels regarding the increase in the number of researchers in Portugal should also be considered in relation to the increase in the size of units, there having been a relative reduction in the number of units with less than 10 postdocs, the typical size now being between 10 and 15 postdocs. Indeed, many assessors noted acquiring a minimum level of staff in order to operate effectively as a unit as a crucial factor in developing the national scientific base. Examples of areas for which observations of this nature were clearly expressed include history, educational research, sociology, agricultural sciences, and mechanical engineering in which there are units that are seen as academic structures in administrative terms, but which in reality are no more than groups of microunits in scientific terms with little contact between them.

This situation obviously requires a new approach to institutional development, a point that was consistently made by the assessors, with particular emphasis on the need to foster institutional cooperation at various national and especially international levels as a way of encouraging scientific activity in networks that promote institutional interrelations. Besides helping to combat the effects of the limited size of some units, developing such science-based networks will certainly encourage the creation and dissemination of new knowledge and stimulate scientific development in a climate of constant change and growing internationalization of the scientific base.

The overall assessments of units in 1999 are shown schematically by scientific area in Fig. 2 in terms of the number of units and the number of postdocs, respectively, covering

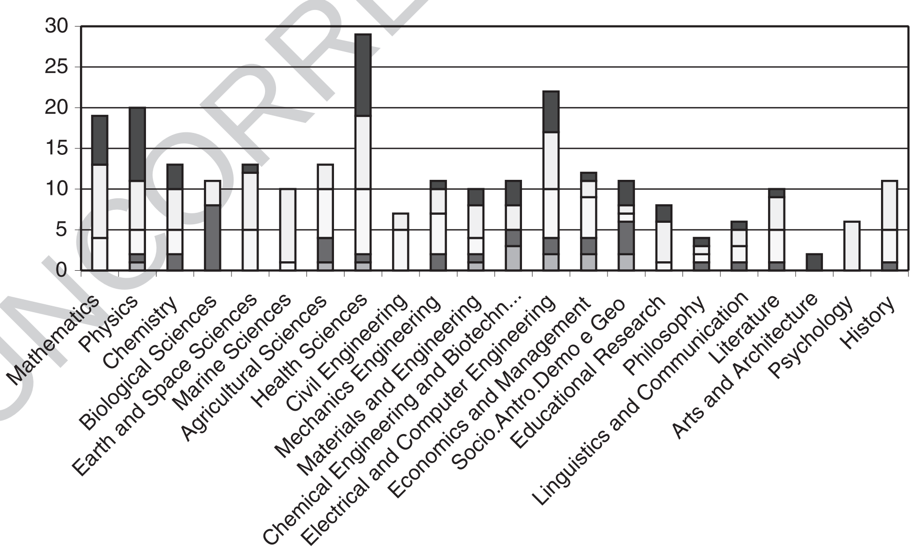

Fig. 2. Classification of research units in each scientific area in the 1999 evaluation. Source: Heitor [22], Available at: http://www.fct.mct.pt.

those units assessed in 1999 (thus excluding those units assessed as poor in 1996 and which ceased to be funded under the Portuguese S&T Foundation's Multi-year Funding Program). The results are presented based on the five levels of classification used in the assessments and show considerable variation between scientific areas as had also been observed in 1996. However, any comparative analysis between scientific areas should be treated with caution and put into context given the specific nature of the areas studied, possible variations in the criteria used by different assessment panels, and above all, differences in the average size of units in the various areas. Nevertheless, an analysis of variations in classifications between 1996 and 1999 clearly shows the previously mentioned trend towards a developing culture of high scientific standards as quantified by significant improvement in classifications.

The results clearly show that the most common classification for research units went from good in 1996 to very good in 1999. In fact, while 44% of the 270 units were classified in 1996 as excellent or very good, 57% of the 248 units assessed by February 2000 received these two classifications. Similarly, the percentage of postdocs working in units with the two highest classifications went from 56% in 1996 to 65% in 1999. Of all the units assessed by February 2000, 10 units were classified as poor, their size varying between 5 and 17 postdocs, involving a total of 87 postdoctoral researchers (i.e., around 2%).

In general terms, the reports from the various panels show that the impact of activities of excellence is naturally affected by the still limited dimension of the science and technology system despite the considerable increase in numbers of PhDs over recent years. However, the international reputation of certain research groups could be used to greater advantage in promoting the quality of research in the country as a whole. This is an important point that led many of the assessment panels to suggest the development of cooperation networks at the national level. Furthermore, attention was drawn to the need for units to further develop existing international links, particularly through granting sabbatical leave to researchers and university teachers, together with efforts to attract foreign researchers especially at the postdoctoral level. In this context, it should be stressed that the majority of panels repeatedly referred to the need to encourage national and international mobility for researchers particularly within Europe. If any conclusion can be taken with direct application to developing and even late-industrialized countries, it is that allocation to resources between broad fields of science should remain incremental, and that inadequacies in the rate of technological change should not be claimed to academic research. However, important questions remain to be solved, mainly in terms of the way academic governance influences the performance of basic research activities and the linkages between basic and applied disciplines. Also, the way the demands for knowledge influence research policies remains to be examined.

However, for the purposes of international comparison, the performance of the system should be analyzed from the standpoint of existing resources and structures, which are obviously dominated by a rigid university system, requiring considerable structural changes as extensively discussed by Santos et al. [23], Caraça et al. [24], and Conceição and Heitor [25]. As pointed out by one of the evaluation panels, "it is not the education mission that is being challenged or questioned, but the lack of flexibility in recruitment and in the management of teaching duties of each faculty member" [22]. Still in the realm of the relationship between the units and their host university institutions, several assessment panels made specific reference to the need to promote mobility of researchers and teachers through limiting the practice of universities of employing their own postgraduate students (so-called ''inbreeding''), which in turn led to various comments on the need to rethink the structure of doctoral programs and postgraduate studies, in general, in Portugal. Indeed, the need to expand the recruitment base and to encourage placements and postgraduate and postdoctoral programs abroad, and in general to promote an effective internationalization of the scientific community, was consistently stressed by the assessors, including those areas still undergoing rapid growth such as mathematics.

This leads us to move to the main aspect of this paper and focus our attention on the development of a specific model to illustrate the university activities, identifying its inputs and outputs, with the ultimate goal of better understanding the type of incentives to allocate to the university. Firstly, the relationship between the university and society is made explicit by means of flows associated with teaching and research based on what society supplies to and receives from the university. On the education side, society supplies applicants and receives graduates that are a group of people who have completed an academic course, which in educational terms means the undergraduate degree and in terms of research means postgraduate studies. Nevertheless, society's perception is of receiving back the same people who applied to and entered university but with an increased range of capabilities.

With regard to research, the flow is less obvious since the result of R&D is the creation of new knowledge. This knowledge is codified and disseminated by means of publications, patents, and communications, and despite the difficulties in defining the impact of university R&D, it can be considered that it is publications and patents that are responsible for that impact [26]. The starting point of the flow that results in knowledge may have various sources: from a direct request from outside to the endogenous ability of the university to generate ideas and set themselves the task of solving problems. At the same time, the research process may take the form of an R&D project.

Fig. 3 illustrates activities and flows described in the tangible dimension but also considers the intangible dimension. With every element of tangible flow, there is an associated intangible component; in other words, a perception that can be associated with the university and that affects and qualifies the tangible elements. The intangible elements can be considered as intangible assets or nonrealizable rights or assets that the university controls, or with which it is undeniably associated, and that consist in opinions and perceptions that may bring future benefits [27].

Thus, the prestige of courses influences the characteristics of applicants and of students admitted [28]. Analogously, the scientific competence that the university is acknowledged to possess affects the R&D projects it carries out; meaning that in a climate of competition for the funding of a project, it is to be hoped that the university, which is known to have the greatest competence, will receive the funding [29]. In the same way, a perception of quality is associated with the outputs that, in turn, contribute towards the formation of the intangible elements associated with the inputs.

In the conceptualization of the relationship between the university and society, the institution was put forward as a processing unit capable of generating results from inputs.

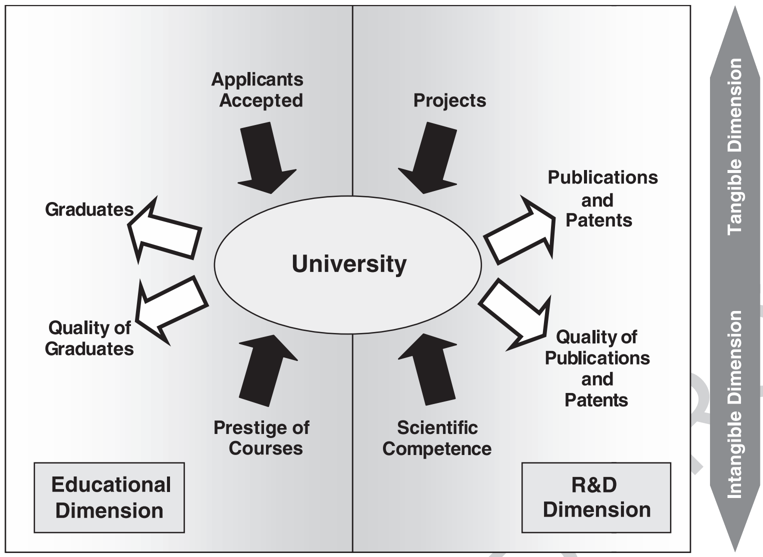

Fig. 3. The four dimensions of the relationship between the university and society (adapted from Caraça et al. [24]).

What is now required is to conceptualize the internal functioning of the university, describing the elements and relations that produce the effects described above.

In the context of this paper, it is important to separate out financial resources and to explain their relationship with other factors relevant to the operation of the universities. It is therefore intended to separate real resources from monetary resources. A traditional approach is presented in the model of Fig. 4. In this representation, resources (faculty, administrative staff, students, R&D projects) and the university's facilities directly generate income. The latter, in turn, must be spent on maintaining the resources.

This model can be applied to the past and some of the present reality of university funding. In fact, in many funding systems, resources are the only element considered in determining public core funding; the logic of determining income being limited to supporting resources. In support of the indicators and the new funding methodology, an alternative model of the

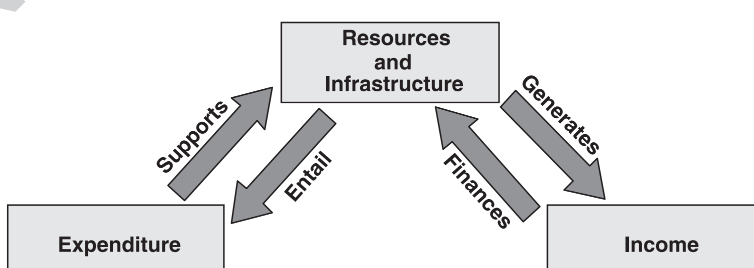

Fig. 4. A traditional perception of the financial flows in the university.

university financial flows is presented that explicitly deals with activities and results as well as resources and infrastructure. Fig. 5 illustrates the proposed model.

The only link common to both models is that of support for resources through expenditure since all other links pass through activities or results. In the upper half of the figure, the model of the university's operation presents the idea of the institution as a productive system, that is, resources and infrastructure (inputs) are used in activities producing results. But these results in turn will generate income that finances activities, which as they unfold entail expenditure in order to support resources. This second part of the cycle, shown in the lower half of the figure, represents the financial flows associated with the operation of the university.

Besides this overall view, the model also enables two smaller cycles to be distinguished: the income cycle and the expenditure cycle. The income cycle, shown on the right of the figure, demonstrates how funding should be associated with results with the purpose of sustaining activities and not of direct financing of resources. This cycle represents the university's interaction with society and should be linked to performance indicators as described in detail by Caraça et al. [24]. The expenditure cycle is associated with the university's internal dynamic, showing how resources are used and how expenditure is dealt with.

The model also allows another approach. Considering the two diagonals in the figure, it can in fact be established that resources and infrastructure and income are on the same diagonal, representing inputs to the university, while expenditure and results—outputs—are to be found on the other diagonal.

To summarize, the model was developed in the general framework of a "context-input-process-output-outcome" system. The unit of analysis for modeling was the university, with a view to selecting indicators that characterize the institution in such a way as to allow differentiation between universities following the principles of theories for education modeling based on the school. The perspective for the modeling tends towards the economic since it is intended to treat financial aspects separately, especially funding aspects. The model

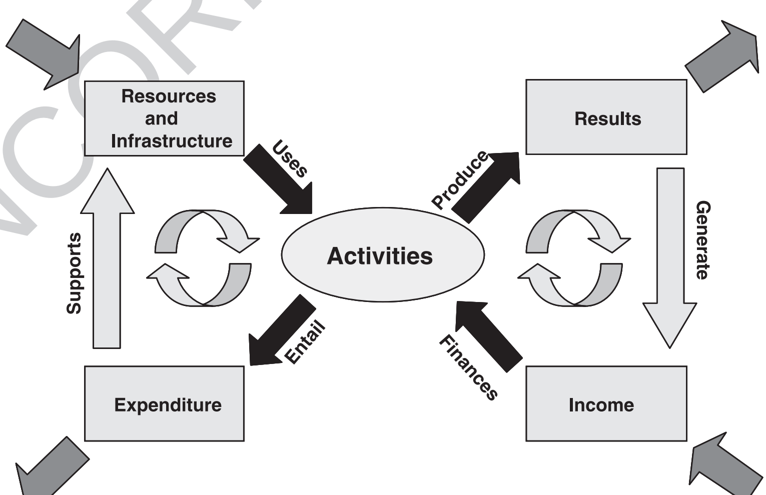

Fig. 5. A new model of operation of university incentives identifying main financial flows.

itself is based on the conceptualization of the university's relationship with society and on the modeling of the university's operation. The relations between the university and society are represented schematically in Fig. 3, which highlights the existence of intangible flows as well as the tangible flows identified with teaching and research.

Our aim is to reinforce the role of the university as a knowledge infrastructure that is able to create knowledge and promote creativity, namely, through public funding policies since the well-established ability to disseminate knowledge through teaching has been traditionally well supported. We argue that diversified weights should be given to teaching and research activities through the development of a model that characterizes the functioning of each institution. This model defines the value flows that are created by the institution. Additionally, we argue that incentives should be based on the results of the activities rather than on the existing resources. This would shift the emphasis to a new policy where higher education institutions need to be more responsive and responsible by its activities. Outstanding performance should be rewarded, allowing for excellent institutions to set increasingly higher standards. The purpose is to introduce in the higher education system a dynamics where innovative and excellent institutions are rewarded and set standards to the less performing. Ultimately, the higher education system might have the conditions to lead its way to the prominent role that the emerging knowledge-driven economies and societies are demanding from it.

2.2. Case 2: fostering innovation for productivity growth

We now move to the characterization of the Portuguese situation in terms of innovation in order to go beyond R&D data and to address other central activities to innovation. To achieve these objectives, we look at results from the second CIS as reported in detail by Conceição and Ávila [30]. By giving more importance to cross-country comparability, the CIS looses somewhat of its potential ability to probe into the dynamics of innovation within each country since it only asks broad and generic questions, which can be accepted to have similar meanings in different economies. However, it provides a reliable way to compare national innovation performance across countries. Fig. 6 shows the overall innovation performance of countries in Europe measured by the share of firms that have introduced innovations over a 2-year period. The horizontal axis indicates the innovative performance in manufacturing and the vertical axis in services. The results show a general close relationship between innovation in the services and in manufacturing since countries are located across a 45° diagonal. In general, innovation rates are lower in services than in manufacturing.

Portugal appears towards the bottom of performance being the least innovative country in manufacturing. However, in the services, Portugal innovates more than Belgium, Finland, and Norway. Slightly more than a quarter of Portuguese manufacturing firms are innovative, while almost 30% of the services' firms are innovative, again an indication of the duality. Unlike other countries, services in Portugal—which have grown as a share of the economy at rates higher than the EU average—are more innovative than manufacturing firms, which are largely dominated still by the traditional sectors of the Portuguese economy.

Knowledge of the process of innovation in Portugal and of the way in which it contrasts with the innovation process in Europe can be gathered from other aspects of CIS. For

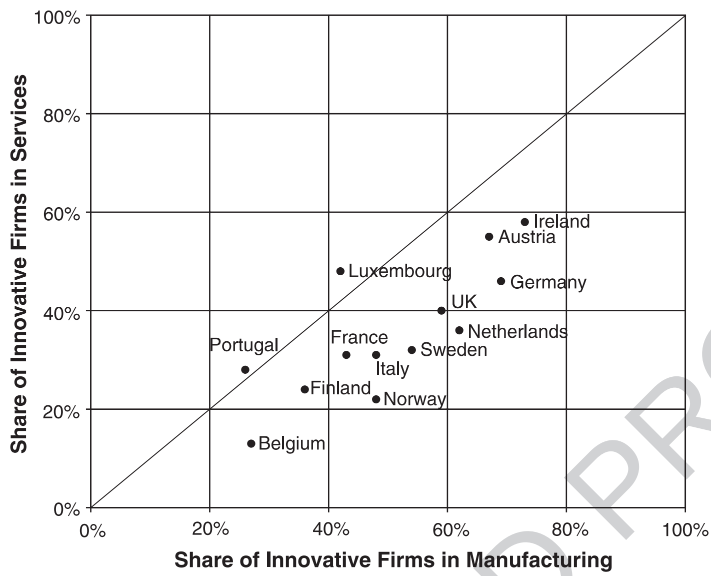

Fig. 6. Innovative performance of EU countries. Source: Conceição and Ávila [30].

example, Fig. 7 shows that Portuguese firms rely much more on resources external to the firm 443
as information sources for the innovation process than European firms (on average). Fig. 8, 444
on the other hand, shows that issues related to high costs and difficulties in funding are much 445

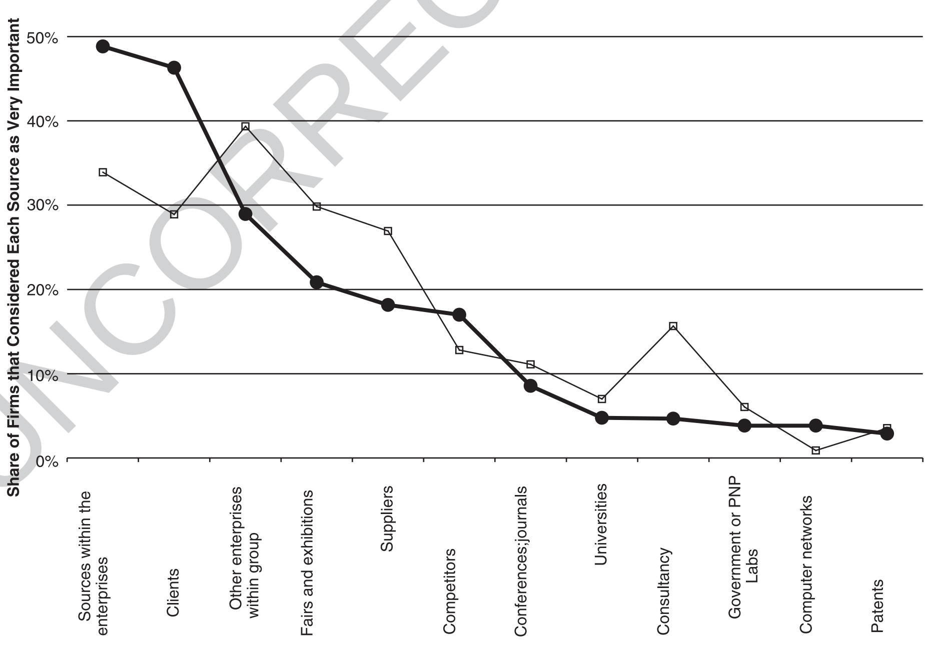

Fig. 7. Sources of information for innovation. Source: Conceição and Ávila [30].

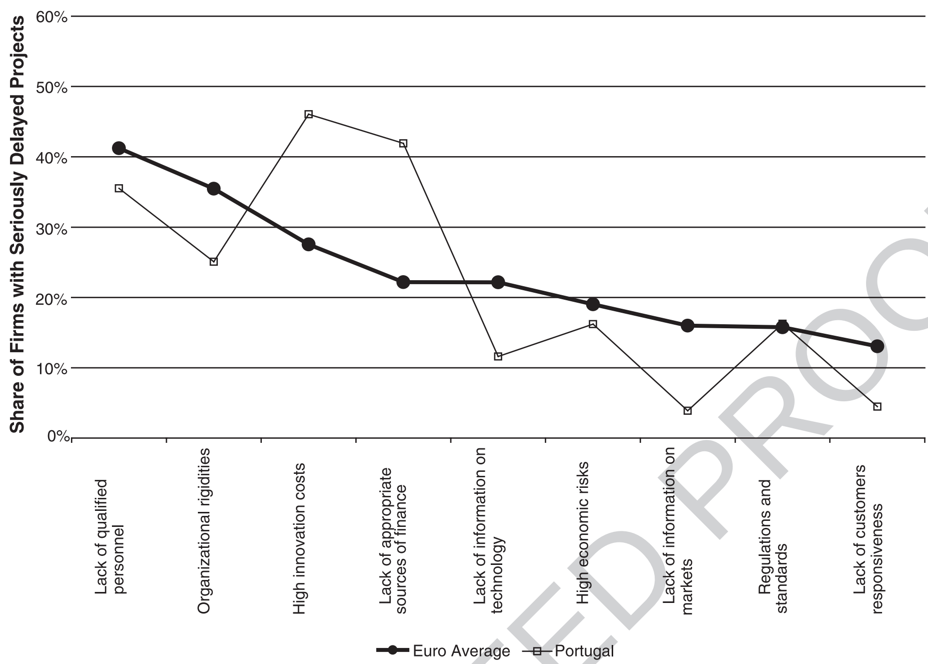

Fig. 8. Factors hampering innovation. Source: Conceição and Ávila [30].

more prominent in Portugal than on average in Europe. Even though there is a large consensus across Europe that the lack of qualified personnel is the most important factor hampering innovation, still this factor pales behind high innovation costs and lack of financing as a deterrent of innovation in Portugal.

However, it is important to look at the diversity that exists within Portugal. We concentrate on manufacturing only. Even within manufacturing, though, there are substantial differences across sectors. The machinery, electrical, and optical equipment sector exhibits almost 50% of innovative firms (the rate of innovation in this sector is comparable to the average rate in countries such as Italy and Norway).

Innovation in Portugal seems to be associated with a number of characteristics of the firms in a way that conforms both with theory and to results in other countries. A descriptive analysis of the results of CIS shows that size classes of large firms have a higher share of innovative firms than size classes composed of small firms. A descriptive analysis also shows that firms that are part of a group of companies show higher rates of innovation.

Including these two variables (firm size and ownership) in a multivariate model, with the dependent variable being dichotomous (1 if the firm has innovated, 0 otherwise) shows (without any other conditioning variables) that large firms and firms that are part of a group do have higher probability of innovating than small firms and firms that are not part of a group of firms (first column in Table 1).

However, there is large diversity of innovative performance across manufacturing sectors. Still, when industry dummies are added to the model (second column in Table 1), none shows

Table 1
Regression results on the characteristics of innovative firms—first model[a]

	Unconditioned (1)	Industries dummies (2)	Technological intensity (3)
Intercept	− 1.576 **	− 9.104	− 1.773 **
	(0.2448)	(− 0.0001)	(0.2562)
	[.0000]	[1.0000]	[.0000]
Firm is part of group	0.529 **	0.318 *	0.474 **
	(0.1423)	(2.0834)	(0.1435)
	[.0002]	[.0372]	[.0009]
Log of number of employees	0.213 **	0.262 **	0.224 **
	(0.0613)	(4.0365)	(0.0625)
	[.0005]	[.0001]	[.0003]
High/medium–high technology		Conditioning	0.757 **
		Industries	(0.138)
		Dummies	[.0000]
		None is significant	
Medium			0.163
Low			(0.1163)
Technology			[.1614]
Concordant	84%	87%	85%
Observations	820	820	820

[a] Dependent variable: 1 if the firm has introduced any type of innovation, 0 otherwise. Standard errors in parentheses, *P* values in square brackets. Logistic regression. Results with a normally distributed link function (Probit) were not dramatically different. Manufacturing only.

** Significant at 1% or less.

up as significant. This can be interpreted by saying that the sector effects are not strong determinants of innovation (when the size of the firm and whether the firm is part of the group are included). However, when we consider only two groups of firms—those that are high or medium–high-technology, on the one hand, and those that are low or medium–low-technology, on the other—the results show that firms in the high/medium–high-technology group do indeed exhibit a much higher probability of innovating than the average firm (note that the coefficient associated with the dummy for the low/medium–low-technology firms is not significant).

The results indicate the existence of a diversified situation. Note how large and statistically significant the coefficient associated with high/medium–high-technology is, even after controlling for the size of the firm and the fact that it may belong to a group. Thus, more sophisticated firms in markets with higher demands seem to have a substantially higher probability of innovating than other firms. This is not tied, one should stress, to a mere “sector effect” (the sector dummies were not significant), it is really a characteristic of a large group of sectors that have in common belonging to the high/medium–high-technology category.

Naturally, other factors, beyond size and belonging to a group, influence innovation. We tested a further more sophisticated model to test the robustness of the previous conclusions. The new model has, in addition to the variables of the first model, also the firm level of productivity and the importance of exports. Both of these variables are known to have important effects on innovation. The results of this second model are in Table 2.

The results tell exactly the same story (although the fact that exports are not significant is surprising). Even after controlling for productivity and exports, the sector dummies are not significant: none of the dummies is. However, when the differentiation is made according to the technological intensity, a duality emerges again, not as strong as before (part of the variation is now picked-up by productivity), but it is still present.

Of course, the models above have merely descriptive value; we do not make any claims in terms of causality, much less explanation. They are understood as showing the correlations among the variables included. In more recent research, some of us have attempted to link the innovation results with the productivity performance of Portugal [12]. The preliminary findings indicate that, somewhat surprisingly at a first sight, innovative firms grow less in productivity than their counterparts that do no innovate. In other words, it looks like innovation harms productivity growth. This result, however, needs to be qualified: this

Table 2
Regression results on the characteristics of innovative firms—second model[a]

	Unconditioned (1)	Industries dummies (2)	Technological intensity (3)
Intercept	− 5.297 **	− 13.745	− 5.201 **
	(0.5784)	(157,449)	(0.5922)
	[.0000]	[.9999]	[.0000]
Firm is part of group	0.095	− 0.039	0.070
	(0.1612)	(0.171)	(0.1626)
	[.5551]	[.8188]	[.6674]
Log of number of employees	0.211 **	0.241 **	0.224 **
	(0.0645)	(0.0676)	(0.0653)
	[.0011]	[.0004]	[.0006]
Log of productivity	0.423 **	0.410 **	0.390 **
	(0.0584)	(0.0661)	(0.0593)
	[.0000]	[.0000]	[.0000]
Share of exports	0.018	0.112	0.048
	(0.1451)	(0.1674)	(0.1488)
	[.9031]	[.5019]	[.7493]
High/medium technology		Conditioning	0.621 **
		High industries	(0.1409)
		Dummies	[.0000]
		None is significant	
Medium			0.152
Low			(0.1214)
Technology			[.2106]
Concordant	84%	88%	85%
Observations	820	820	820

[a] Dependent variable: 1 if the firm has introduced any type of innovation, 0 otherwise. Standard errors in parentheses, *P* values in square brackets. Logistic regression. Results with a normally distributed link function (Probit) were not dramatically different. Manufacturing only.

** Significant at 1% or less.

negative relationship holds only in the short run. In the long run, we do find evidence of a positive relationship between innovative firms and the level of productivity.

If we accept this result, then the situation in Portugal, seen from a firm point of view, is clear. If a firm cannot ''see'' long into the future or cannot afford to do so or does not face the incentives to do so, then the firm is better off not innovating since to innovate means that the firm will pay a price in terms of productivity. This would launch the Portuguese economy into a vicious cycle of low innovation and low productivity growth, which is what we observe.

To break the cycle and to suggest policies that may help to do so, one has to know the causes of the negative relationship. Is it that Portuguese firms are myopic? Are Portuguese firms resource constraint (and unable to face the adjustment costs or learning costs that normally come with innovation)? Or is there something else going on? The prevailing explanation has assumed that, indeed, Portuguese firms are resource constrained and, in some cases, myopic. Thus, the public policy (that is, the institutions and incentives that have been put in place) is aimed at breaking the resource constraint (giving subsidies for investment, R&D, and so forth) or reducing the information asymmetries that provoke the ''myopia'' (diffusion of information programs, helping firms to pay for consultants, to buy and access information, and so forth).

However, it may very well be that the explanation is different. The incentives firms face may not provide them the signals to see innovation as a competitive edge. If a firm believes that a competitor is going to innovate, then it is more likely to innovate than if it believes otherwise (see Baumol [31]; we describe the positive innovative record of the U.S. economy in terms of a positive cycle of innovation that is the symmetric of the one that could explain the low innovation, low productivity in Portugal). Thus, the low innovation/low productivity cycle in Portugal may not be a problem of resources not even of information: it may very well be purely a problem of incentives and institutions that do not provide the ''right incentives'' to innovate.

This discussion, while focusing on Portugal as the empirical case being analyzed, obviously intends to make a broader point about the importance of understanding the problems, which often may be associated with the existence of institutions and incentives that provide perverse signals.

2.3. Case 3: incorporating knowledge and innovation in the auto supplier industry

Looking at a particular industry where Portugal has been able to harness some success provides a complementary perspective of the university and the general view of the industrial base described in previous sections. The Portuguese autoparts industry has experienced an important growth in the last 2 decades. As seen in Fig. 9, the industry has grown almost 10-fold in 15 years, a significant value. Not only has it shown a considerable dynamics in itself, but it has also been able to establish itself in a relative strong position given a relatively small assembly base in Portugal.

Portugal and Spain are striking success cases in different ways. Spain has seen the assembly and autoparts industry grow to a size that matches or even surpasses Italy, the smallest of the countries with indigenous assemblers. Portugal has been able to build a

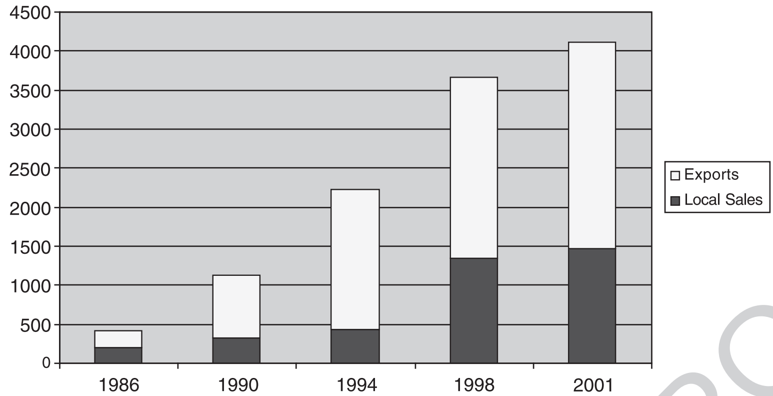

Fig. 9. Sales of autoparts manufactured in Portugal (million euros).

relatively strong supplier industry given the small size of the country and the limited amount of assembly performed there. The right hand side columns of Table 3 represent the ratio of component sales and exports to the volume of cars assembled in the country, a rough control for size effect. As can be observed, for every 1000 vehicles produced, there is an average US$10 million of revenues in autoparts sales. Nevertheless, the differences are extremely relevant. Germany is clearly the heart of the European automotive industry, leading in absolute and relative terms. In relative terms, Portugal is in a strong position in the autoparts industry. The figure of sales per 1000 vehicles assembled is quite above the average and it is the highest in the sample when taking in consideration exports. This means that Portugal has been able to establish a strong components industry, particularly in the international market, and positively disproportionate to the size of the local market. Table 3 also shows that the components business in Eastern Europe is still rather small, both in absolute and relative

Table 3
International comparison of the auto industry in selected countries (1996)

Country	Assembly	Components industry		Turnover	Exports	Autopart sales	Autopart exports
	Vehicles	Workers	Firms				
	Units	Number	Number	Millions of US$	Millions of US$	Per 1000 vehicles	Per 1000 vehicles
France	3,571,049	600,000	n/a	40,262	14,291[a]	11.3	4.0
Germany	4,842,909	800,000	3000	112,500	28,611[a]	23.2	5.9
Italy	1,545,365	n/a	n/a	19,734	9011[a]	12.8	5.8
Spain	2,412,308	180,000	2000	19,105	10,054	7.9	4.2
Portugal	233,132	24,000	160	3500	2275	15.0	9.8
Hungary	63,033	16,200	160	720	340	11.4	5.4
Czech	263,263	n/a	n/a	n/a	350	n/a	1.3
Poland	433,422	n/a	n/a	n/a	232[a]	n/a	0.5

Sources: US Chamber of Commerce; AFIA (P); UNCTAD; Mondaq (Czech); Hungarian Ministry of Economic Affairs; The Economist Intelligence Unit.

[a] It may underrepresent true values because it is based on UN trade data; n/a—not available.

figures. Nevertheless, their evolution has been rapid and they are expected to be increasingly important, particularly as the volume of assembly grows in these regions.

The relevant issue for this paper is to understand how the interplay between incentives, infrastructure, and institutions plays a role in the development of the local industry. Two different dimensions will be explored. The first, on a more historical note, describes a defining moment for the local industry; an example of excellent interplay between these three dimensions to foster a qualitative jump in the industry. The second, on a contemporary basis, looks at how existing infrastructure and institutional settings may be hampering the required jump of industry into the next stage of development.

In 1988, the first specific program for the development of the Portuguese industry (PEDIP) was initiated. PEDIP was an European cofunded industrial policy initiative aimed at speeding the catch-up process that Portugal was undertaking to join their new European union partners. It included a number of measures ranging from R&D to export promotion or financial support to the existing firms as well as strong incentive for the establishment of foreign firms. Although it did not have explicit sectoral priorities, the Portuguese government considered the establishment of a major car assembler as major opportunity for the development of this industry and, because of the perceived effects in the economy, the overall national industrial capabilities. In 1991, ending a long period of negotiations, the Portuguese government signs an agreement with Ford and Volkswagen for the establishment of the AutoEuropa joint venture in Portugal. This investment turned out to be not only very important for the auto industry, but for the overall economy representing, in 1997, 2.5% of the Portuguese gross national product. AutoEuropa has a capacity of producing up to 180,000 multi purpose vehicles (MPVs) per year. It is the single most important FDI in Portugal, having generated almost 5000 direct jobs and 7000 indirectly. By 1996, the AutoEuropa assembly line was responsible for approximately 82% of all passenger cars produced nationally (for a full description of the case, see Veloso et al. [32]). AutoEuropa was important, not only because of the plant itself but also because it induced a number of related initiatives by national and international firms targeted at becoming suppliers of the large plant. The relevant aspect is the fact that it induced a collective and coordinated effort to seize the opportunity.

As part of the contract, the government gave an important set of tax benefits and subsidies to the investment, an aspect that undoubtedly played an important role in the final decision of the OEM. AutoEuropa joint venture received a total of PTE 158,000 million of incentives in an overall investment of PTE 453,000 million. Benefits associated to the construction of port, rail, and road infrastructures amounted to another PTE 14,000 million. But, together with the strong benefits package, the government also negotiated an unusual high level of domestic content, at least 45% of the value added increasing over time to 55%.[1] The negotiating team on behalf of the government was quite knowledgeable of the industry. They were aware that it would be difficult to respond to the level of commitment in terms of domestic purchases because most of the local industry was not ready to become a supplier to the plant. But they

[1] A subsequent ruling of the EU rendered the domestic content clause of the contract moot on the basis of free circulation of people and goods in the union, but AutoEuropa said it would keep the compromise, which it has so far.

had at least 3 years to prepare, so they went on a coordinated campaign to harness both local and foreign industry to take part in the process. To prepare local firms to supply AutoEuropa, a large number of quality and productivity initiatives involving hundreds of manufacturing companies were enacted with the help of PEDIP funds. These initiatives aimed at assessing firm productivity and quality practices and involved the government, which played a cofunding role, national and regional technology centers in related manufacturing and quality areas, and the firms themselves. The result of this initial effort was a group of companies labeled as potential suppliers. Either because of previous experience or intrinsic capabilities, several of the assessed firms showed from the beginning that they were ready to work with AutoEuropa. But most of them still had important technical and managerial upgrades to be performed. The subsequent step was to use the technology centers available in the country and other companies, sometimes foreign ones, to develop improvement plans that would enable those firms to meet the supply requirements of the OEM.

By mid 1995, the year the plant started to operate with complete capacity, 44 national firms had achieved the highest quality certification level (Q1) from Ford and were supplying parts and components that corresponded to more than 40% of the value of the car. Foreign firms also played an important role. There were 22 new plants to supply AutoEuropa installed in the Palmela region where the OEM plant was to be located, virtually all of foreign origin. In addition, 12 joint ventures or technical cooperation agreements with Portuguese firms were established to bring the capabilities of local firms to levels that could enable them to enter the production of components with technical complexity above their current capabilities and experience.

These excellent results were achieved through a favorable institutional setting visible through the articulated effort between economic agents, in particular, government, firms (both local and multinationals), as well as the national technology infrastructure. Throughout this process, the knowledge of the industry imbedded in government agencies played a key role, in particular, in the negotiations with multinational companies. In a context of international subsidy races among regions to attract global firms, having informed negotiators can make a substantial difference in the outcomes. In the case reported, the government was able to establish the right incentive structure for both national and international suppliers firms, leverage the national technology infrastructure, and still let the market work through the excellence supply standards established by the OEM.

The recent successful history of the autoparts industry in Portugal epitomized through the AutoEuropa story presented above is now facing a new set of challenges. The previous stages of the local industry, in particular, the beginning of the nineties when AutoEuropa was established, were mostly about acquiring manufacturing capabilities, i.e., being able to produce a particular component, often simple, without failures and to deliver it according to a tight OEM schedule. The local companies proved themselves in these requirements and most of the success of the industry predicates on this acquired ability, which enabled firms to sell in Portugal and abroad. As the decade ended, the structure of the components business entered a process of major transformation. Traditionally, the industry supply chain was organized in well-established tiers. OEMs would design and assemble the car and its components. First tier would manufacture and supply components directly to the automaker (e.g., the fuel pump).

Second tiers would produce some of the simpler individual parts that would be included in a component manufactured by a first tier (e.g., the housing of the fuel pump), and third and fourth tiers would supply raw materials. This simple configuration no longer fits the actual structure of the industry.

To respond to growing customer requirements, increasing regulatory pressures, and financial constraints, the industry is undergoing dramatic changes. OEMs are aiming to concentrate efforts in marketing and design, shedding their involvement in manufacturing and assembly [33]. As a result, first tier suppliers are becoming large global firms that are either specialized in complex systems such as the ABS or the powertrain or integrators of several simpler subsystems into what is called modules of which the cockpit and the seats are examples (for a discussion of these issues, see Fixson [34]). Direct suppliers are expected to have a substantial responsibility in the design and engineering of the systems they sell and to coordinate the supply chain necessary for their manufacturing and assembly.

To respond to these new challenges, global players are emerging across the world, with operations dictated by strategic objectives and client demands as opposed to nationality. At the same time, labor-intensive tasks until now, done in regions such as Portugal and Spain, are being redirected to Eastern Europe and the North of Africa. The critical issue to thrive in the industry nowadays is no longer the ability to manufacture, as in the past, but the ability to find new technologies and innovative solutions to OEM and end-customer requirements. These range from the use of new materials such as aluminum, alternative processing technologies such as hydroforming, or advanced electronics to reduce engine tail-pipe emissions.

This poses a significant challenge to the majority of the suppliers that participate in the automotive supply chain, in particular, for a region like Portugal. They are often small, work at a second or third tier level, and manufacture simple parts and components. They are quite successful and competent at manufacturing but provide limited added value. In the AutoEuropa example, multinational companies assure the gross participation in terms of direct supply and overall value of the supplies. Local firms supply at a second tier and mostly simpler parts. The important transformation in the automotive supplier business creates a potential cap on the continuous growth of an industry based in firms supplying simple parts. The question then is what should the local suppliers do?

To better understand the avenues of development and their requirements, one should look at the several stages and roles of the supply chain, in particular, at lower levels. As seen in Fig. 10, two levels below the system or modular supplier can be considered:

- *Component manufacturer.* “Process” specialists, such as a metal stamper, die caster, or injection molder. A component manufacturer often has the responsibility for design and testing of the component(s) it manufactures, but not the design of the entire subassembly where the components fit (“gray box” design).
- *Subassembly manufacturer.* A process specialist with additional assembly, integration, and design capabilities. Supplies may include a steering column, a pedal system, as well as product type subassemblies such a radiator or a battery. Firms often elect a subsystem as a target and nurture the necessary technological competencies to excel in its design and manufacturing.

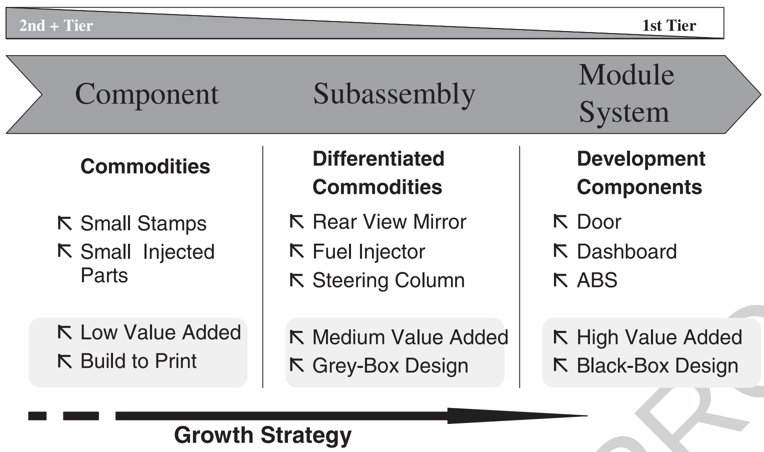

Fig. 10. Company positioning in the supply chain.

The actual position and objectives of a supplier company determine the strategy it ought to pursue. If the objective is to be a small component-oriented firm, which is the actual position of most of the Portuguese national firms, then they should focus on an array of low-value products, continue to operate in facilities in one or two locations, excel at manufacturing, have a lean business structure, and limit involvement in engineering. They will be paid for their efficient operations and low overhead, in particular, if competing with suppliers in Eastern Europe or elsewhere. As suppliers begin to move from component to subassembly manufacturer, it is important to have capabilities in several manufacturing processes needed to produce the component, ability to manage its own supply chain, and improved presence in regions where automakers are assembling the vehicle where the subassembly will be incorporated. Nevertheless, it is the enhancement of engineering capabilities that often becomes the crucial issue. Design, test, validation, and prototyping have to be part of these firms' capabilities. Therefore, to work at a subassembly level, suppliers need not only to be able to supply at low prices but also to demonstrate significant engineering capabilities and enough financial resources to withstand financial outlays on product development for several years before having any revenues.

Moving to a complete module requires an additional layer of competencies. The complexity of the modules associated by today's automobile requires firms to amass a large number of different technologies that have to be harnessed together. For example, a module that is becoming increasingly common in most automobiles is the seat. As shown in Fig. 11, even a simple seat (i.e., without heating, airbag, and electric adjustments) involves 30 different components, 10 materials, and at least 15 different technologies, from injection molding to stamping, nonwoven processing welding, among others. This has several important implications. First, firms trying to enter the business of seats must acquire competencies in a very diverse set of knowledge bases and they must be able to make them work in close coordination. Second, it also means that the firm should be able to leverage competencies residing elsewhere. Very diverse knowledge bases will necessarily mean that the firm will not be able to lead in all the areas. While it is required to have a certain level of competence in all of them [20], firms

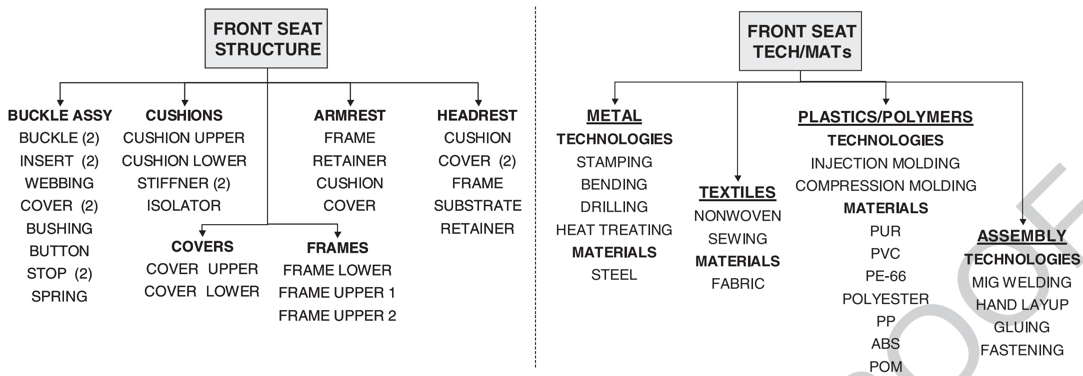

Fig. 11. Components and technologies in a simple seat.

will often choose areas where it will excel internally and establish a network through which they can rapidly access new technologies and solutions developed elsewhere. This will be assured through subcontractors as well as wider links to the science and technology system, including universities, research centers, etc. Third, designing a system with such complexity requires more than just competence in a collection of areas. There is crucial knowledge associated to the interfaces and integration that is often at the core of a successful product. This metacompetence has to be nurtured in the firm aiming to supply a product such as a seat, but it is important that it recognizes that it lies somehow distributed in the network of agents that own part of the knowledge and collaborate in its development and manufacturing.

All these requirements stress the need to articulate embodied flows of knowledge (associated to the supply of equipment and components) and also disembodied flows of knowledge (associated in the people), systems, and artifacts (e.g., a CAD drawing). The disembodied flows are of particular importance in design stages where the product boundaries are open and moving, and the objective is to incorporate as much as possible the latest and more adequate technologies, regardless of whether they lie internally or externally to one or all of the agents.

The new set of challenges associated to the automotive supply chain makes it very difficult for firms that have mostly been focused on individual components and technologies to play in this competitive game. Most of the successful companies that have been able to evolve from individual components to modules have done so through mergers and acquisitions [33]. Breeding internal competencies in companies that have had a life of specialized knowledge has proven difficult. A path that several of the Portuguese firms have been exploring is a several stage engagement process between companies that could evolve towards a module producer [35]. At a first level, they try to establish competence-building projects where they can share knowledge around the objective of developing a particular module as simple as it can be. This can be, for example, gathering a stamping firm, another that works in textiles, and a third that does injection molding around the development of seat. This is seen as test bed to develop the coordination and innovation competencies that go beyond the individual knowledge of each firm and is also a prelude for further business engagement that could eventually lead to outright merger.

So far, the discussion has been mostly about required competence, but it is important to stress an associated critical dimension. In fact, current conditions are such that only companies with a certain minimum critical size can play an active role in the supply chain. Fig. 12 presents an estimate of the relationship between sales volume and commitment to development activities. It shows that the development of one simple product, with 1500 hours of engineering work, requires a Portuguese company with 7.5 million euros of turnover to commit 3% of its sales to development. If one considers that a company may want to work in three products simultaneously, it must sell 22.5 million euros to use only the same 3% of sales in development. This is also the same level of sales required to be involved in one product with a fair level of complexity with 8000 hours of engineering. For one product and 3% of sales climb to over 50 million euros if we consider 15,000 hours of development, the engineering effort for a product with a relevant degree of complexity. The required sales volumes for products beyond the simple product are far from the reality of most Portuguese suppliers who have a turnover below 12.5 million euros.

This means that firms must make clear choices about their strategy. As noted above, they can remain as small process-focused company and perhaps be competitive at doing so, although with diminished growth expectations. On the other hand, if firms want to move into being a larger process focused company, then the firm has to acquire size and actually become part of a group either by tight cooperation, merger, or acquisition. Moreover, their characteristics have to evolve. The focus is an arrow array of high value products with full product engineering, several plants, and a special ability to integrate technologies. Several firms in Portugal have realized and understood these constraints. As a result, the last 3 years have brought an array of mergers and acquisitions in the local industry. Most of the events have been sellouts to foreign groups, but there are also interesting examples of local firms acquiring others, establishing joint ventures, or investing in new areas to gain the required critical mass.

The contrast between the early story of competence building and the current challenge in the industry is the breadth and depth of the knowledge space. The early development stages, exemplified with the AutoEuropa example, were ones of building manufacturing capabilities.

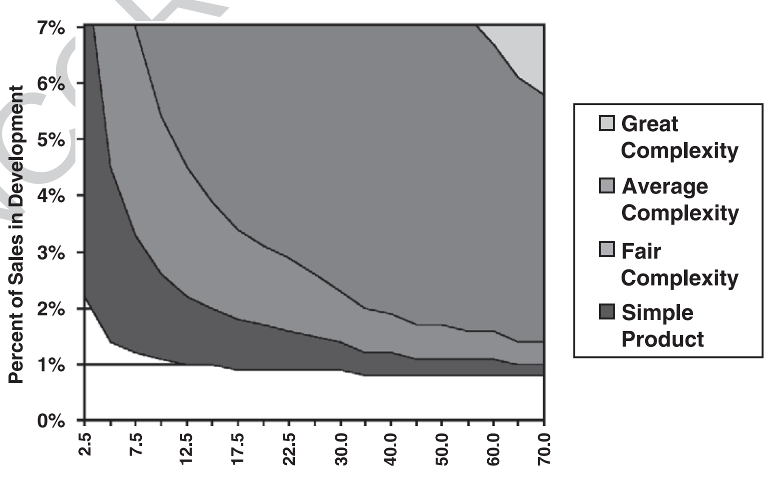

Fig. 12. Company size and required commitment to development.

By enabling a favorable environment of incentives, the involvement of specialized technical centers and the help of multinational firms, a substantial number of Portuguese suppliers, was able to thrive and expand. The recent challenge is one of innovation and leveraging distributed knowledge bases. This relies on innovation and coordination competencies, a new set of challenges that local firms are now struggling to overcome.

Although focusing on Portugal, the example presented here is far from unique. Most industries where the auto supplier base experienced in an important and successful growth in the late eighties and early nineties are now experiencing similar challenges. An excellent example of regions where a very similar story to the one told about Portugal are Asian ones; in particular, Taiwan and Korea as well as, to a lesser degree, Thailand and India [13,33]. In addition to geography, this example of the auto industry can be extended in a different direction. It shows very clearly how the knowledge base in sectors traditionally seen as "mature" is becoming deeper in cognitive dimensions and much more complex. Competitiveness requires a very diverse competence base, not all of it internal to the company and such that must be tightly interconnected. This means learning to manage a large portfolio of loosely unrelated knowledge, accessing distributed knowledge, and leveraging it all in a rapid and interconnect manner into new products and solutions.

3. Policy implications and learning

The paragraphs above considered empirical evidence on the need to rethink infrastructures, incentives, and institutions to foster a path towards a system that effectively promotes innovation. The objective of this last section is to stress the idea that if an effective innovation system is to be considered, then there is the need to promote social capital together with specific competence building. This conclusion is based on the broad innovation framework of Smith [4], who suggests that the knowledge bases of mature and traditional industries are cognitively deep and complex as well as institutionally distributed. Thus, rather than relying exclusively on "high-technology" sectors, there is a need to integrate policies relating to education, science and technology, and social and economic development so that there is a diversification of actions to support the creation and diffusion of distributed knowledge bases. This is particularly applicable to catching-up countries and regions, with the practical consequence that growth will not be based just on the creation of new sectors but on the internal transformation of sectors that already exist, namely, by exploiting their distributed knowledge bases through adequate incentives and institutions.

3.1. Incentives, infrastructure, and institutions: the necessary conditions for knowledge and learning

To frame the empirical evidence provided before in an unified conceptual framework of analysis, we now consider, first, the incentive structure of "the market," which is determined by competition. Competition in product and factor markets provides signals to economic actors about the potential returns among alternative options, thus determining their investment patterns. Endogenous growth theories, because they are based on the existence of dynamic externalities and imperfect markets, require a careful understanding of the structure of competition. On the one hand, because of the nature of knowledge, investment of private agents often fails to acknowledge spillover effects or may not be able to anticipate the full extent to which there is further learning potential in a new technology. On the other hand, incentives to invest in new knowledge depend on the existence of some degree of monopolistic rents. These rents may not exist in latecomer countries exposed to international competition if they are solely adopting foreign technology.

As a result, private investment levels (which result from the incentive structure provided by the market to economic agents) in activities with learning or spillover potential tend to be lower than the social optimum and may even generate what is known in the literature as ''low-level equilibrium traps'' [36,37]. This happens when private but not social returns from productivity-enhancing investments—i.e., accounting for spillovers—are below those of non-productivity-enhancing investments, causing stagnation in growth. This situation may be overcome by inducing decision makers to include the spillover effects in their accounting processes or by creating monopolistic markets that generate above-normal returns.

In principle, these shortcomings of the market mechanism call for some sort of government intervention—a second major factor affecting the firms' incentive structures. Governments are concerned with making sure that societal costs and benefits are endogenized in the decisions of private firms. In a learning environment, this may mean subsidizing research activities, investing in education, protecting infant industries, promoting exports, or even disciplining firms [38,39]. But government intervention must balance the potential distortions on competition that may come from intervention with the needs to ''correct market failures'': artificial restraints on competition can also divert profits to activities other than building technological capabilities. In relatively closed regimes with strong pressure to substitute imported for local goods, there may be little incentive for firms to improve since they can capture the local market regardless of their own productivity [39,40].

In the neoclassical view, infrastructure is related with the existing amount of labor, capital, and natural resources. The new theories bring to stage other important factor inputs, in particular, human capital and R&D expertise embodied in firms, universities, and laboratories. Thus, infrastructure will encompass, in addition to labor and capital, what we call technology infrastructure or technostructure. Tassey [41] has proposed a definition that suits our discussion: technostructure consists of science, engineering, and technical knowledge available to industry. It is embodied in human and organizational forms. Considering a distinction between labor and capital on one hand and technostructure on the other enables a separate analysis of the roles played by each of these aspects in the development path of a particular industry or region.

The examples discussed in the previous section show how the interaction between sets of incentives and the technostructure of a particular region, industry, or nation fosters and hampers the patterns of knowledge accumulation and the development process. Nevertheless, it will also be clear to the reader that although incentives and infrastructure greatly inform our understanding of the behavior of firms, government policies, and industrial trajectories, they do not tell the whole story about the differences across countries and regions. That is because both incentives and infrastructure do not operate in a vacuum, being shaped by and shaping the particular context where they operate. In other words, for a market system to function well, the country or region must have embedded a set of social capabilities that allow it to function according to the theoretical principles of allocative efficiency and Pareto optimum social welfare.

3.2. The critical aspects

If one considers innovation as a broad social and economic activity, as we suggest here, two key questions need to be considered. First, the understanding of conditions for integrated learning processes. This has led Conceição et al. [3] to build on Lundvall and Johnson's [2] learning economy, and to discuss the learning society in terms of innovation and competence building with social cohesion. They view innovation as the key process that characterizes a knowledge economy understood from a dynamic perspective, while competence is the foundation from which innovation emerges and which allows many innovations to be enjoyed. In other words, it contributes both to the "generation" of innovations (on the supply side of the knowledge economy) and to the "utilization" of innovations (on the consumption side of the knowledge economy). Conceptually, the foundations for the relationship between learning and economic growth have been addressed in the recent literature [42], with learning being reflected in improved skills in people and in the generation, diffusion, and usage of new ideas [25].

Further, the ability to learn seems to be the main driver of long-term growth, but learning can occur at different levels. Individual people, firms and organizations, and countries are all dependent of learning for development. Lamoreaux et al. [43] write, "more than any other factor, the ability to collect and use information effectively determines whether firms, industry groups, and even nations will succeed or fail." There are also different ways through which people, firms, and countries can learn. Learning can be an unintended consequence of experience and augmentation of scale, as formalized at the firm and then country level by Arrow [44]. On the contrary, formalized and intentional learning methods such as education, training, or R&D are often the result of a utility maximization rational decision from the point of view of the firms. The new growth theories attempt to formalize the way in which learning mechanisms can impact on economic growth [45].

Second, the relevance of considering distributed knowledge bases across economically and/or socially integrated set of agents and institutions, which leads us to the concept of social capital. In the broadest sense, social capital is associated with the "social capabilities" [43] that allow a country or region to move forward in the process of development. In a more sophisticated treatment, Coleman [46] states that social capital is "a variety of different entities, with two elements in common: they all consist of some aspect of social infrastructure, and they facilitate certain actions of actors—whether personal or corporate actors—within the structure." The relationship of social capital for the economic performance of nations was recognized by Olson [47] and North [48] in broad descriptions of the process of development.

None of the case studies analyzed provides single and definitive answers to the problem of achieving learning societies. But it was our aim in this section to argue that social capital is the key and that infrastructure (in the broad sense described above) and institutions are the elements out of which social capital is born. Different types of institutions can be effective as long as they enable collective learning and collective innovation. As in every situation where institutions are important, history matters. Path dependence and increasing returns lead to self-reinforcing cycles, whereby events, often sporadic and serendipitous, define current patterns of development. But the good news is that if we understand the dynamics of institutional change and evolution (that is, of "collective learning"), we can also create conditions for future development.

3.3. Challenges for technology policy

As we emphasized earlier, learning can occur in many shapes and forms; some of which are informal, some formal. As described before, the institutions and organizations that comprise the national and regional systems of science and technology formalize the technological infrastructure critical to generate the learning processes for individuals, firms, and nations that ultimately lead to long-term development. Thus, looking at a particular set of organizations, their capabilities and related institutions provides important lessons for development. Moreover, we may be able to suggest routes for policy that generate the right set of incentives capable of positively influencing the conditions for inclusive development through learning and knowledge accumulation.

The challenges for policy in order to move toward inclusive development are really twofold. First, what can be done at regional and national levels to start and enhance learning networks and trajectories that can lead to development? Second, how can the overall global learning processes be made more inclusive so that fewer countries/regions are excluded, extending the reach of the learning networks globally?

With the hindsight gained from the earlier discussion and that of Conceição et al. [49], we can "explain" the need of public intervention for science and technology policies as resulting from the nonrival character of knowledge. Market mechanisms do not yield the allocation efficiency to be expected from competitive exchange. This opens the need for the establishment of policies that can correct the incentive structure of the agents or complement for their short sights. Expanding on the ideas proposed by Nelson [50], Dasgupta and David [51] suggest three ways to yield conditions for the effective production of nonrival knowledge. The first is patronage, consisting of a mechanism by which the government gives direct subsidies to producers of nonrival knowledge on the condition that it becomes publicly available at virtually zero cost after it has been produced. The second, procurement, is based on the direct production of the goods by the government, awarding specific contracts to private agents whenever necessary. Finally, the third, property, is associated with the privatization of the nonrival knowledge, awarding the producer monopolistic rights that yield returns large enough to cover the fixed costs of production. Both patronage and procurement rely on a direct intervention of the government by which the nonrival software remains nonexcluded, and therefore effectively a public good. Property grants private producers of new knowledge exclusive property rights in the use of their creations.

It is clear from the analysis above that it is crucial not only to make available financial resources (namely, public resources), but to do so in a way that provides the right incentives for S&T organizations to hook up in learning networks that can generate localized social capital and endogenous growth dynamics. That way is definitely not unique and depends on local conditions, roots, and trajectories, which raise the question of inclusive development.

At the global level, growing trade liberalization and the increasing reliance of information and communications technologies will certainly contribute to a wider and faster diffusion of knowledge, amplifying the reach of successful learning trajectories. Wolf et al. [52] show how financial flows from the United States into Europe have helped to foster the launching of biotechnology start-ups in Europe. This is a typical example of the broadening of the scope of a learning network that we have been mentioning. Financial resources and management expertise from the United States, coupled with public support for R&D and education in Europe, help to implement creative firms in Europe. Financial returns will go to the United States, but human capital and knowledge will remain in Europe.

3.4. Building on specific contexts towards innovation

The analysis above emphasizes the importance of knowledge creation and diffusion as a major driver of economic growth in a context where incentives, technological infrastructure, and also social capital are shown to be critical. Here we attempt to discuss the conditions that foster innovation and the related processes of knowledge sharing in local contexts. Traditional neoclassical approaches in industrial economics have emphasized the analysis of the microeconomic behavior of firms and built theories specialized in the American and Anglo-Saxon systems and related market dynamics. It provides an excellent context to understand incentive structures and outcomes but ignores most of the remaining issues associated with learning discussed in the paper. Evolutionary economics focuses on routines and capabilities rather than incentives to improve our understanding of learning processes and the role of institutions in economic development. Nevertheless, they have not addressed the specific historical context of any region, namely, those characterized by late industrialization [53]. Building on the evolutionary approaches and in system theory, the concept of "national system of innovation" [50,54,55] has led to numerous studies of individual countries, but there is still a long way to go in order to assess the specificity of transition economies, late industrialized regions, and above all developing countries.

The importance of the learning dynamics of firms and related routines has been increasingly considered as key to the processes of knowledge accumulation, innovation, and growth [56]. In this respect, "firm competencies" affect the ability of firms to innovate and shape their technology trajectories.

The spatial patterns of innovation and the related geographical dimension of economic and social development have witnessed a renewed and increasing interest in the literature [53,57], but attention is to be focused on the ability to build social capital, including interactive learning, local externalities, and networks among institutions [58]. This focus on relational assets is part of the "institutional turn" in regional development studies as a result of the relative failure of classical approaches, which sought to privilege either "state-led" or "market-driven" processes regardless of time, space, and milieu.

Besides a common trend of considering geographically localized knowledge externalities and the spatial clustering of innovative activities, analysis has continuously shown the sectoral specificity of industrial and technological change [59,60]. In fact, the so-called technological regimes, defined in terms of the knowledge base and of opportunity, appropriability, and cumulativeness conditions, are major determinants of differences in the patterns of innovation across industries [61].

A great deal of effort has been devoted to analyzing the contribution of academic research to the generation and diffusion of knowledge, with particular applications to business firms, and the related questions associated with the importance of public policies [62,63]. Among others, Pavitt [15,64] has shown that technological knowledge is not just "applied science" but a capacity to solve complex problems including a strong component of tacit knowledge.

A prevailing view [65,66] has been that of industry amalgamation through a process of technological convergence, namely, centered in digital technologies. Although there is still no evidence of success in moving toward a fusion of technologies at the corporate level [67,68], the close relationship of innovation and industrial dynamics and the opportunities for e-commerce, the emergence of a "new economy" [69], and the related market for internet services [70] call for the need of a renewed framework for the analysis of technological innovation, namely, in terms of firm competencies and the "dynamic capabilities" as suggested by Von Tunzelman [66].

4. Introducing this special issue

The analysis above shows that it is thus legitimate to question the traditional way of viewing the relative importance of infrastructures and incentives and considers the increasingly important role of institutions towards the development of social capital. This broad concept has motivated this special issue, which integrates a set of new contributions addressing complementary aspects of relevance towards improved understanding of knowledge and learning towards innovation.

Stefan Kuhlmann and Jacob Edler discuss scenarios of technology and innovation policies in Europe arguing about the need to foster new governance. The authors speculate about the future governance of innovation policies trying to pave ways for empirical analyses. They discuss three scenarios stretching from (1) the idea of an increasingly centralized and dominating European innovation policy arena to (2) the opposite, i.e., a progressive decentralization and open competition among partly strengthened, partly weakened national, and regional innovation systems, and finally to (3) the vision of a centrally "mediated" mixture of competition and cooperation between diverse regional innovation cultures and a related governance structure. Whether a new governance structure will be robust and sustainable or weak will depend, not least, on the consciousness and openness of the involved actors and the flexibility of the related institutions of the political systems.

In the third paper, James Riggle and Roger Stough describe a methodology implemented in mid-1990s in the United States to evaluate critical institutional infrastructures in terms of state-level cooperative technology programs. The analysis is based on programs that were increasingly being focused on technology and commercialization rather than primarily on basic or pure research and bring new insights on the way local innovation policies and institutions may cope with national and transnational policies.

Knut Blind and Christiane Hipp, in the fourth paper, discuss the institutional framework brought by the introduction of quality standards to promote innovation in services companies. They report an empirical analysis for the introduction of ISO 9000 in a sample of innovative German service companies, which were selected on the basis of the European CIS. Besides marketing effects, the introduction of the quality standards has impacts on the internal processes of the service companies in that they contribute promoting flexibility especially towards the preferences of the customers and in reaching project deadlines.

In the fifth paper, Toshio Mitsufuji discusses sources of innovation at the firm level and proposes an innovation–diffusion model on the assumption that an innovation interacts with a social system, which shows dynamic and self-organizing characteristics. The author refers to the diffusion process of Japanese word processors into the Japanese society around 1980s, calling our attention for the meanings of the critical mass and the dichotomy of the innovator–imitator model as well as for the characteristics of the potential adopters.

5. Closure

We described a conceptual understanding of the relationship between learning and knowledge accumulation leading to economic prosperity. Our analysis led us to suggest that while the role of institutions needs to be reexamined, the variety of demands and the continuously changing social and economic environment is calling for diversified systems able to cope with the need to produce policies that nurture and enhance the learning society.

6. Notes

1. This does not mean, however, that now informal networks exist in SV, much less that the informal networks that do exist are not important. Still, the foundations of business relationships in SV are much more strongly based on formal contracts than in Northern Italy.
2. Available on the Internet at http://www.worldbank.org/wdr/2000/overview.htm.

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