BEYOND THE DIGITAL ECONOMY:

A PERSPECTIVE ON INNOVATION FOR THE LEARNING SOCIETY

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ABSTRACT

In view of the current socio-economic context, in which innovation is a key driving force for the sustainable development, which challenges are facing education and research to enhance and nurture innovation and better contribute to help developing and exploiting engineering, science and technology? This broad question has motivated the work behind the present work, which reviews the strongest themes of the 3rd International Conference on Technology Policy and Innovation (ICTPI), which was held in Austin, Texas, in August of 1999.

Under the broad designation of "creating value for the 21st century in the globalized learning economy," the Conference brought together a range of experts to discuss *technology policy* and the *management of innovation* in a context much influenced by a *dynamic of change* and a necessary *balance between the creation and diffusion* of knowledge. While the idea of inclusive development developed in previous Conferences entails a process of shared prosperity across the globe following *local* specific conditions, it is crucial to understand both the features of knowledge-induced growth in rich countries, as well as the challenges and opportunities for late-industrialized and less developed countries. Thus, this special issue includes a set of extended contributions to the Austin conference that are largely grounded on empirical experiences of different regional and national contexts.

The aim of this introductory paper is to set the stage for these contributions, with an original contribution on possible roles for science and technology policy in the globalized economy. While much attention has been devoted to digital technologies, a more fundamental change at the start of the new millennium is the increasing importance of knowledge for economic prosperity and the emergence of a *learning society*. The analysis shows that *innovation* should be understood as a broad social and economic activity within the framework of that society: 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.

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Pedro Conceição, David Gibson, Manuel Heitor and Giorgio Sirilli

Introduction

In previous papers we have discussed policies to enhance the contributions of education and research to national and regional development [1,2]. Our approach has been guided by an attempt to conceptualize "learning" as the mechanism through which knowledge is produced and diffused [3,4]. Through this approach, under the "umbrella concept" of learning, we provide our interpretation of relevant theoretical developments and empirical evidence associated with the contribution of education and research to economic development.

Our effort has been driven, in part, by our perception that traditional suppliers of knowledge, such as schools, universities, and training organizations, as well as businesses and other organizations, which are becoming growing users of knowledge, are urgently seeking fundamental insights to help them nurture, harvest and manage the immense potential for their knowledge assets [5-7].

This paper continues in the style of our previous papers but this time it is focused on innovation. The understanding of innovation adopted in this paper encompasses the way in which firms and entrepreneurs create value by exploiting change. Change can be associated with technological advances, but also with modifications of the regulatory framework of an industry, shifts in consumers tastes, changes in the demographic makeover, or even major alterations of global geopolitics. In this context, we go beyond the perspective that looks at innovation as being tied with information and communication technologies, under the context of the emerging digital economy. In earlier papers we have already insisted in separating the emergence of the digital economy – although its importance should be recognized – from the broader idea of a learning society.

The paper is divided in four parts, as follows. After this introduction, we look, in section 2, at a conceptual formulation of the innovation process, which stresses both the technological and the social and economic aspects of innovation. We provide a context for the emergence of the digital economy, but the specificity of the digital economy is discussed in section 3. Section 4 explores the idea of the learning society as a broader concept than that of the digital economy, and discusses efforts under way to characterize quantitatively the elements and performance of the learning society. This section ends with a discussion of the context of innovation in the learning society. Finally, section 5 introduces the remaining papers of this special issue.

Looking at Innovation Over Time and Across Space: The Techno-Economic Paradigms Approach

The interaction between the emergence of new technologies and the larger economic and social patterns of behavior can be understood, following Schumpeter, as a process of *creative destruction*. At a first approximation, this statement is obvious: new technologies disrupt and often replace older ones. At a higher level of analysis, the implications of new technologies are broader. The impact is often felt not only as a replacement of older for new technologies, but brings with it opportunities for new firms and difficulties for existing firms, the obsolescence of some occupations and shifts in the structure of employment, changes in the terms of trade between regions and countries. On the other hand, it is clear that not all advances in technology are disruptive to the point of creating substantial changes in economic and social conditions. In fact, most technological advances and innovations make their impact felt in a relatively smooth way, when analyzed from a macro perspective.

One way to conceptualize the interaction between technological change and shifts in economic conditions, together with the process of sometimes-disruptive innovations, but most often-smooth adoption and diffusion of new technologies, is the idea of techno-economic paradigms. A techno-economic paradigm embodies a relatively stable cluster of core technologies, around which innovation and economic activity take place. The core technologies have a strong impact in the economy and society, being defined as core given their potential for generalization and penetration across a wide number of products and processes, across all sectors of economic, and often human, activity.

Within a paradigm, the core technologies are virtually unchanged over time, but this does not mean that there is not economic and technological progress. On the contrary, these core technologies provide a positive heuristic that defines the knowledge and incentives for innovation and economic activity to occur. At the same time, this progress in inherently limited by the conditions set by the interaction of the core technologies with the dominant modes of economic activity, from the organization of firms, to the distribution of employment. Therefore, progress exists within a certain techno-economic paradigm, but occurs within a framework defined by a set of core technologies and modes of organizing economic activity.

Thus, within a paradigm, innovation occurs as the core technologies become more and more pervasive and influence ever-wider realms of production and distribution. When a major technological advance occurs, disrupting the existing core technologies and modes of economic operation, then a new techno-economic paradigm emerges. The displacement of the core technologies of the old paradigm creates a new wave of invention and innovation and is no longer tied to the previous paradigm core technologies. The emergence of a new core technology requires, and creates the opportunity for, an entire new set of small and incremental innovations that permit the widespread usage of the new core technologies. Thus, when a shift in techno-economic paradigm occurs we have not only a “substitution effect”, but also an expansion of the creative frontier that allows the emergence of new technologies and enables, in the end, a shift to yet another techno-economic paradigm.

Additionally, beyond the technological and purely economic factors, the social and institutional frameworks that fit a certain techno-economic paradigm may not be adequate for a new one. Indeed, the process of emergence of a new techno-economic paradigm results from the interaction of the technological, economic, institutional and social spheres. Having just a new technology coming in may not have any effect if a set of changes in the other dimensions does not accompany the technological novelty. A certain set of institutions and social features may provide enough contexts for innovation within a certain paradigm; in other words, it is not necessarily needed to create institutions and social rules at the same pace that technological innovation progresses. But when there is a shift in techno-economic paradigm, a new institutional framework may be needed.

A number of authors, working together and independently, developed the theory of techno-economic paradigms beginning with Schumpeter, who argued that the expectations of profits would drive the “entrepreneur” to innovate. The entrepreneur’s drive towards innovation is motivated by the temporary monopolistic position from which the innovator would benefit. Schumpeter regarded this position as temporary because the advantages from this privileged position would eventually “perish in the vortex of the competition which streams after them”, since other firms would copy the innovator [8]. To this process Schumpeter called *creative destruction*.

Therefore, for Schumpeter, innovation appears at the forefront of economic progress, driving prosperity. In a later version of these same fundamental ideas, Schumpeter refined this earlier simplistic version of an entrepreneur in a perfect market composed by a multitude of competing firms that destroy any persistent market advantage. In his final work [9], he acknowledged that some large corporations could sustain a market advantage by an institutionalization of the effort to innovate through the establishment of large R&D facilities.

The reinterpretation of Schumpeter's fundamental ideas of innovation as a process of disequilibrium in the broader context of techno-economic paradigm is due primarily to Christopher Freeman and his co-authors. Often called a "neo-Schumpeterian" approach, this perspective is articulated in Freeman, Clark and Soete [10], Freeman and Perez [11], Dosi [12] and, more recently, in Mcnight et al. [13] to cite a few representative examples. Freeman and his co-authors generalized the concept of Schumpeterian innovation to the national level, making an analogy between innovation at the firm level and a change in a techno-economic paradigm at the country level [14, 15].

This macroeconomic definition of innovation corresponds to what is, at the firm level, a radical innovation. Under this extreme there are milder types of innovation, like incremental innovations, that correspond, at the micro level, to improvements in existing products and processes. Freeman builds a similar hierarchy for his macro analysis of innovation, leading to a conceptual framework that has some similarity to the evolutionary perspective of Nelson and Winter [16].

It is important to stress two important dimensions of the techno-economic paradigm theory: *time* and *space*. Time is, indeed, crucial, as we saw, since the process of technological change and its economic and social impact is seen as a progress, more stable within a certain techno-economic paradigm, and very different across techno-economic paradigms, which differ over time. Space is equally important, since it is not clear that a certain techno-economic paradigm will not affect all the regions of the world similarly. Certainly there will be different rates of adoption of new core technologies when there is a paradigm shift, or even, within a paradigm, different ways in which specific innovations and modes of economic organization develop in different countries and different regions. Some countries may originate or lead the development of a new techno-economic paradigm, and others may lag behind, or even stay closer to older than the new techno-economic paradigm.

An important idea joining the time and space dimensions of the techno-economic paradigm theory is that of technological trajectories within national innovation systems. The idea of trajectories in national innovation systems (developed, with a comparative analysis across countries, in Nelson [17], for example) speaks to the fact that each country follows its own developmental path, within the general framework of the existing techno-economic paradigm, but also – and this is crucially important – influenced by the past history and specific conditions of the local context.

This brings to the discussion the asymmetries in country performance, which, according to our interpretation advanced in earlier papers, can be seen as being dependent on what we could call with generality knowledge accumulation through "learning" processes. Conceptually, the foundations for the relationship between learning and economic growth are well established in the recent literature [18], and stem from a combination of the pure neoclassical perspective of growth with the Schumpeterian view. Learning is reflected in improved skills in people and in the generation, diffusion, and usage of new ideas. Likewise, organizational learning reflects social processes driven by collective cultures and appropriate management attitudes. The ability to continuously generate skills and ideas (which is to say, to accumulate knowledge through learning) is the ultimate driver of an economy long-run prospects (World Bank, 1997).

The fact that countries have different levels of income is clearly self-evident. Therefore, it is equally obvious that each country has followed its own trajectory, within the context of an existing techno-economic paradigm and the specific innovation system of the nation. We look here at some evidence on the translation of different paths in the economic performance of countries. But we begin with an interpretation of the major techno-economic paradigms, illustrated in Table 1.

Table 1- Tentative Sketch of Major Techno-Economic Paradigms

Approximate Period	Description	Key Sectors	Economic Organization
1770s to 1840s	Early Mechanization	Textiles, Canals, Turnpike Roads	Individual entrepreneurs and small firms; local capital and individual wealth
1830s to 1890s	Steam Power and Railway	Steam Engines, Railway, World Shipping	Small firm competition, but emergence of large firms with unprecedented size; limited liability corporations and joint stock ownership
1880s to 1940s	Electrical and Heavy Engineering	Electrical Engineering, Chemical Process Industries, Steel ships, Heavy armaments	Giant firms, cartels, trusts; mergers and acquisitions; state regulation and enforcement of anti-trust; professional management teams
1930s to 1980s	Fordist Mass Production	Automobiles, Aircraft, Consumer Durables, Synthetic Materials	Oligopolistic competition; emergence of multinational corporations; rise of foreign direct investment; vertical integration; technocratic management styles and approaches
1970s to …	Information and Communication	Computers, Software, Telecommunications, Digital Technologies	Networks of large and small firms based increasingly on computer networks; wave of entrepreneurial activity associated with new technologies; strong regional clusters of innovative and entrepreneurial firms

Source: Adapted from Freeman and Soete [15], Table 3.5.

The table shows five important techno-economic paradigms. While the paradigms presented result from one interpretation, they serve now to illustrate with some empirical evidence the features of techno-economic paradigms presented before. Let us consider, for example, the first techno-economic paradigm. This corresponds to the emergence of the Industrial Revolution, as mechanization was increasingly incorporated in manufacturing, especially in some industries such as textiles. However, the technologies well diffused and used within this paradigm presented some important limitations for the increase of the scale and output of the productive activity. Most firms remained small and local. Process control was poor and hand operated machines did not allow for output of reliable quality. Naturally, advances in steam engine technologies and machinery were already taking place, but it took a long time until they were ready for fruition. When these important technologies matured to the level that made their economic utilization possible, they became the core technologies of the second techno-economic paradigm. The new techno-economic paradigm based on steam engine and on machinery ameliorated some of the previous limitations, and created in itself the germ for new types of economic organization, as the table details.

If we cross the techno-economic paradigms with geography, then we start joining together the ideas of technological trajectory and national innovation system. The two first techno-economic paradigms were led by Britain. In this context, the US and Germany, for example, were "latecomers". Still, they became leaders in the third techno-economic paradigm, with Japan also leading in the fourth and the US arguably retaining the lead alone in the fifth, although we will be looking at this claim in more detail below.

Still, the manifestations of the current differences in the paths followed by different countries are dramatic. Even taking a set of relatively homogeneous countries, such as the OECD, shows great disparities in income per capita and productivity. Productivity, in a way, is probably the best indicator of the extent to which a nation is taking full advantage of the conditions provided by the existing techno-economic paradigm. A recent study by Ark and McGuckin [20] tackles international comparisons of productivity and income in a particularly careful way, especially in finding comparable measures across countries. They also link labor productivity with output per capita following a common decomposition procedure. While the relationship between these two variables may seem obvious, in fact there are many subtleties involved. For example, a country that is very productive but where workers engage in productive activities fewer hours than a less productive country can result in an output per capita that is higher in the second country. Table 2 shows the results presented in this work. Column (1) indicates labor productivity and column (8) provides the level of GDP per capita.

Table 2- Decomposition of GDP per Hour Worked into Effects of Working Hours, Labor Force Participation and GDP Per Capita, 1997

	GDP **per hour worked** as a % of the OECD Average	Effect of working hours	GDP **per person employed** as a % of the OECD Average	Effect of unemploy-ment	Effect of labor force as a % of the working age population	Effect of working age population as a % of the total population	Total effect of labor force participation	GDP **per person** as a % of the OECD Average
	(1)	(2)	(3)=(1)+(2)	(4)	(5)	(6)	(7)=(4)+(5)+(6)	(8)=(3)+(7)
Australia	**96**	0	**96**	-1	2	0	1	**97**
Austria	**102**	-4	**98**	3	-2	1	2	**100**
Belgium	**128**	-5	**123**	-3	-19	-1	-22	**101**
Canada	**97**	2	**98**	-2	2	2	2	**100**
Denmark	**92**	0	**92**	1	9	1	11	**103**
Finland	**93**	0	**94**	-7	2	0	-5	**88**
France	**123**	-9	**113**	-6	-9	-2	-17	**97**
Germany	**105**	-5	**100**	-3	-4	2	-4	**96**
Greece	**75**	-4	**71**	-2	-11	1	-12	**58**
Ireland	**108**	5	**113**	-4	-12	-3	-18	**95**
Italy	**106**	-11	**96**	-5	-1	2	-5	**91**
Japan	**82**	10	**92**	4	6	4	14	**106**
The Netherlands	**121**	-26	**95**	2	-4	2	0	**96**
New Zealand	**69**	8	**77**	1	3	-1	2	**79**
Norway	**126**	-17	**109**	4	12	-4	12	**122**
Portugal	**56**	2	**58**	0	1	1	2	**60**
Spain	**84**	13	**97**	-14	-13	2	-26	**71**
Sweden	**93**	-3	**89**	-3	6	-4	-1	**88**
Switzerland	**94**	0	**94**	3	12	1	17	**111**
Turkey	**36**	2	**38**	0	-8	-1	-9	**29**
United Kingdom	**100**	-9	**91**	0	3	-2	0	**92**
United States	**120**	-1	**118**	3	9	-2	10	**128**
EU-14	**103**	-5	**98**	-4	-4	0	-8	**90**

Source: Ark and McGuckin [20]; Summations may not add exactly due to rounding errors.

Portugal and Turkey have the lowest hourly labor productivity rate of the OECD. Portuguese hourly productivity is about half of the OECD average. Productivity in Greece is 19 points above Portugal's and Spain's productivity is 28 points above the Portuguese hourly labor productivity. Still, when one looks at column (8), Greece's GDP per capita is actually lower than Portugal's by two points and Spain's GDP is only 11 points above Portugal's.

The decomposition of the table shows the variety of effects involved. Column (2) shows the impact of the number of hours worked. The summation of columns (1) and (2) produces the GDP per person employed. We see that Spanish and Japanese workers work longer hours than in most of the other countries. Per worker productivity in Spain, measured as GDP per worker, raises almost to the OECD level. Portuguese workers also work long hours, adding 2 points to the per hour productivity measures. In Italy, France, The Netherlands, Norway and the United Kingdom less hours of work reduce per employee productivity. Standards of living are determined not only by the number of hours worked and the productivity of each hour of work, but also by the "number of mouths to feed". The effect of the labor force participation connects per worker productivity and GDP per person. It is the effect of the labor force participation, for example, that brings down the income per capita of the productive and hard working Spanish workers: the combined effect of unemployment and the low level of labor force in the working age population take 26 points to the per worker productivity. The same happens in Greece, where 12 points are taken to the per worker GDP. In Portugal, both the effects of hours worked and labor force participation are small and positive. It is, therefore, clear that the real challenge to increase the level of GDP per capita in Portugal is not so much a reduction of unemployment or, more generally, an increase in labor force participation (as in Spain, for example), but that it is really the increase in the fundamental hourly labor productivity. To understand these differences it is important to look at the existing dominant techno-economic paradigm, to which we turn in the next section.

The Emergence of the Digital Economy: Facts and Hype

The advent of new digital technologies has captured the minds of businessmen, policy-makers and many academics alike. The computer, new telecommunications devices and, more recently, the Internet are, indeed, powerful and impressive technologies. They are affecting people and firms in fundamental and permanent ways. There is a sense of unprecedented opportunities for many firms and individuals, confronted with technologies that enable new venture creation with relatively few barriers to entry and possible quick and huge financial gains. For existing firms, these new digital technologies are being equally perceived as providing ways to increase efficiency and market reach. This perception has equally affected policy makers and other parties interested in promoting broader economic development in cities or regions. As successful Internet start-ups, such as Amazon.com, and their promoters, like Jeff Bezzos, work as role models for firms and individuals, Silicon Valley and other poles of technology-driven economic prosperity inspire regions across the world.

At the country level, most eyes look towards the US. The US is considered the benchmark against which the generation and adoption of digital technologies by other countries and regions is to be measured. The US are seen not only a leader in US generation, but are equally taking the leader in the adoption. An OECD report provides several measures of the US dominance in information and communications technologies. The US accounts for about 36% of the world production of these technologies, and the share of patents and innovations in these technologies is substantially higher. The US has equally 50% of the world's software market.

NUA Surveys (as available at www.nua.com) estimates that about half of the world's Internet users live in North America. According to the estimates of the US Department of Commerce, between 1995 and 1998 information technology-producing industries accounted for an average of about 8% of the US GDP level, but were responsible for 35% of the US GDP growth rate. Estimates by Hecker [21] put the share of broadly defined high technology employment (which is dominated by information technologies and telecommunications) at 14%. The US Department of Commerce estimates that reductions in prices in IT related products and services contributed to keep US inflation in check, being responsible for about 0.7% drop in inflation in 1996 and 1997. American companies increased their annual investment in information technologies fourteen times in the 1990s, in a context where most investment remained stale.

The popular press and imagination has been captured primarily by the impact of the Internet on business. Some of the new opportunities of the Internet are associated with the diffusion and adoption of the new technologies that are the infrastructure required to sustain the Internet. Other opportunities are associated with the growing demand by firms and households for Internet access and other services (from web designers to web advertising). In 1996, when the Internet was starting to become popular, infrastructure, ISPs and other activities represented more than 90% of a combined 15.5 billion US dollars market in the United States, according to Forrester Research (www.forrester.com). The remaining market, under 10%, was accounted for by transactions made via e-commerce. By 2001, e-commerce in the US will be almost 60% of a combined 354.5 billion US dollars total Internet-related market. Within e-commerce, business to business (B2B) will be dominant, and is expected to account for 186.1 billion US dollars by 2001 (or 52% of the Internet economy), while business to consumer (B2C) will account for 5% of the Internet economy at 18.4 billion US dollars.

While B2B has the largest share, and will have even a larger share in the future, of e-commerce, B2C is important in many ways. It represents in itself a major economic opportunity. But also important is the potential to shape attitudes and consumer practices with implications that can re-shape the current business environment. According to Cyber Dialogue, by 2001 almost one half of the Internet users in the US are expected to be on-line shoppers, corresponding to almost one fifth of the population of the country. In 1996 only 3% of the US population were on-line shoppers.

Within this context, it is not surprising that many countries, regions and cities around the world are trying to catch the wave of the Internet and of digital technologies. By most accounts, the achievement of regional economic development based on new information technologies results from a combination of efforts from the private and the public sector. Recently, public officials and decision makers have been heavily pushing the development of initiatives geared towards the enhancement of the conditions that can lead to IT-driven prosperity. The European Commission, for example, through his Commissioner for Enterprise and the Information Society, said in a recent speech: “Europe is in the middle of an economic revolution. This is the time for a call for action to both the private and the public sector in

Europe. We must work for a strong European e-economy which realizes electronic services for the benefit of all"[1].

While the US took the lead in the development and diffusion of digital technologies, and especially in finding and promoting ways to derive economic benefits from its usage[2], Europe is now catching up fast. By any measure, digital technologies are not as diffused and are not used with the intensity that occurs in the US, with the exception of mobile phones. But the growth rate in Europe is attracting investors and creating a boom that does compare with the one that the US has gone through in the last few years [22]. In fact, the European advantage in mobile telephony is seen as a potential important advantage in comparison with the US, since wireless Internet application are forecasted to increase in importance. Kramer and Simpson [23] estimate that Western Europe has more than 30% of the world cellular phone market, with North America having only 20%. These analysts also forecast that mobile phones will be the e-commerce platform of the future, and most consumer devices will get wireless connectivity.

The impact of the digital technologies is expected to extend much beyond improving the economic performance of economies. Their impact is said to be creating an Information Society, justifying the title of the European Commissioner responsible for the promotion of the use and creation of digital technologies in Europe. 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 could 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. These questions emerged during the downturn of the NASDAQ stock market in April of 2000. The cover of the 2000 April 17-30 issue of *Industry Standard* – one of the most sober and reliable publications of the "digital economy" – read: "The End of the Beginning- After a gravity-defying run, the

[1] Cited in Cordis Focus, March 13, 2000. Cordis is available at www.cordis.lu.

[2] In reality, two European researchers at CERN, the large European research lab for particle physics, invented the World Wide Web.

Internet business is falling back to earth. Now we'll see what's really new about the new economy." In fact, many for a long time have been asking this question. From a macroeconomic point of view, fundamental changes associated with technology should be visible in increases in productivity. While digital technologies may have indeed made many millionaires and billionaires the world over, as well as improved the efficiency of many firms, the real question is whether the benefits have been entirely internalized by the producers and users of technology or, in contrast, if there were spillovers that translated into structural improvements of the economy.

This question has been researched more extensively in the US, where, as we saw, the economic impact of digital technologies is perceived as being deeper than in other countries. A White House conference on the New Economy held in April of 2000 revealed the range of opinions that circulate in the country[3]. A recent convert to the "new economy" hypothesis is Alan Greenspan, who said at this conference[4]:

> *While there are various competing explanations for an economy that is in many respects without precedent in our annals, the most compelling appears to be the extraordinary surge in technological innovation that developed through the latter decades of the last century. In the early 1990s, with little advance notice, those innovations began to offer sharply higher prospective returns on investment than had prevailed in earlier decades. The first sign of the shift was the sharp rise in capital investment orders, especially for high-tech equipment, in 1993. This was unusual for a cyclical expansion because it occurred a full two years after the troth of the 1991 recession.*

Most skeptics on the validity of the new economy hypothesis are academic economists, especially those that devote their efforts to empirical work. For example, Jorgenson and Stiroh [24], in an empirical assessment of the relationship between information technologies and economic growth, write: "*We conclude that the story of the computer revolution is one of relatively swift price declines, huge investments in IT equipment, and rapid substitution of this equipment for other inputs. Perhaps more surprisingly, this technological revolution has not*

[3] See http://www.whitehouse.gov/WH/New/html/20000405-a.html.

[4] See http://www.pub.whitehouse.gov/uri-res/I2R?urn:pdi://oma.eop.gov.us/2000/4/6/5.text.1

been accompanied by technical change in the economic sense of the term, since the returns have been captured by computer producers and their costumers."

In essence, the conclusions of Jorgenson and Stiroh and others can be better grasped by looking in some detail at a recent study by Robert Gordon [25]. This work looked at the evolution of output per hour (the productivity measure that we used to compare several countries in the section above) in the US since the 1950s. The study looks at the rates of growth in productivity in three periods. The first period, from 1950 to 1972, is considered the post-WW II Golden Age of productivity growth. Then, from 1972 to 1995, comes the productivity slowdown[5]. Finally, from 1995 to 1999 comes the era of the so-called "new economy".

Looking first at the line for the annual growth rate in productivity in non-farm private businesses, the three periods are markedly different. During the Golden Age (column 1) productivity increased at an average growth rate of 2.63% per year. In the next period (column 2) the growth rate decreased to 1.13%, and thus the slowdown period. Finally, since 1995 productivity growth picked-up in the US, and grew at 2.15% a year. The values for manufacturing reveal a slightly different story. In fact, the productivity growth rate was approximately the same during the Golden Age and the Slowdown: approximately 2.5% a year. However, productivity growth in manufacturing almost doubled during the recovery, reaching an annual average growth rate close to 4.6%. It was in the services that the productivity slowdown was more severe.

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[5] A constant theme in economics research has been associated with attempts to explain the productivity slowdown, especially the apparent paradox between the perception of accelerated and profound technical change during and the lack of improvement in the American economic performance. This is sometimes referred to as the Solow paradox, after Solow's now legendary statement that "one can see the computer everywhere except in the productivity statistics".

Table 3- Percentage Average Annual Growth Rates for Productivity (Output per Hour Worked) in the US, by Sector for Different Intervals, 1950-1999

	Q2 **1950** - Q2 **1970**	Q2 **1970** - Q4 **1995**	Q4 **1995** - Q1 **1999**	Slowdown	Recovery	Recovery/ Slowdown (%)
	(1)	(2)	(3)	(4)=(2)-(1)	(5)=(3)-(2)	(6)=(5)/(4)
Non-Farm Private Business	**2.63**	**1.13**	**2.15**	**-1.50**	**1.02**	**-68.0**
Manufacturing	2.56	2.58	4.58	0.02	2.00	10000.0
Durables	2.32	3.05	6.78	0.73	3.73	511.0
Computers	-	17.83	41.70	-	24.22	-
Non-Computers	2.23	1.88	1.82	-0.35	-0.06	17.1
Non-Durables	2.96	2.03	2.05	-0.93	0.02	-2.2
Non-Farm non-Durables	2.68	0.80	1.50	-1.88	0.70	-37.2

Source: Gordon (1999: Table 1); Qi refers to quarter i.

However, the most remarkable result from Gordon's study is the realization that the manufacturing productivity recovery is extraordinarily concentrated in a single small sector of the US economy. First, note that there has not been hardly any recovery in the productivity of non-durable manufacturing (the annual growth rate remains around 2% since 1995). The recovery does exist in the durable manufacturing sectors, where the annual growth rate more than doubled from 3% during the slowdown period to 6.8% during the recovery. But if we probe even at a lower level, we can see that all of this increase in productivity is accounted for a single sector: computer manufacturing. Non-computers, again, exhibit similar productivity growth rates in the slowdown and recovery periods (about 1.8%). Thus, Gordon concludes:

> *There has been no productivity growth acceleration in the 99 percent of the [US] economy located outside the sector which manufactures computer hardware, beyond which can be explained by price remeasurement and by a normal (and modest) procyclical response. Indeed, far from exhibiting a productivity acceleration, the productivity slowdown in manufacturing has gotten worse; when computers are stripped out of the durable manufacturing sector, there has been a further productivity slowdown in durable manufacturing in 1995-00 as compared to 1972-95, and no acceleration at all in non-durable manufacturing.*

There have been mostly two interpretations of Gordon's results. The first, largely advocated by Gordon himself, is that the "new economy" conjecture has been over-hyped. In particular, Gordon [26] argues that digital technologies are not comparable, in their social and economic impact, to other inventions with roots in the 19th century (such as electricity, the internal combustion engine, among others). In particular, the Internet, while clearly increasing the welfare of people, does not necessarily increase the economy's productivity[6]. This rather skeptic view on the benefits of the Internet and of digital technologies entails a somewhat pessimistic outlook concerning the prospects of the benefits of the "new economy" in Europe. In essence, the argument is that the huge productivity gains are to be absorbed by the IT producing firms, sectors and countries. In other words, benefits will go primarily to firms such as Cisco, Microsoft, Dell, Oracle, IBM, and so on, which are located in the US. The IT using firms and countries cannot expect to benefit from productivity gains. The IT benefits are not spilling over the entire economies. If this is the right conclusion, then adopting digital technologies in Europe, embracing the Internet and promoting an information society may be important for many reasons, but not to spur productivity and growth, since Europe is a net user (not producer) of these technologies. Countries that are mostly users of IT will benefit less from digital technologies than those countries that produce IT. According to this hypothesis, betting on the adoption of digital technologies as the magic wand of development would be, indeed, a *chimera*.

However, there is a more optimistic view. The fundamental question to be asked is that if computer associated firms can benefit from IT technological advances, why should not firms in other sectors do the same? It may take some more time for these benefits to reveal themselves statistically in other industries, but eventually a spill over to other industries is likely to arise. As we discussed above, anecdotal evidence already suggests that digital technologies are gaining momentum in terms of their economic weight and in the changes they are driving in people and firm's behavior.

According to some, the computer and its associated digital technologies are part of a transition in techno economic paradigm, following the discussion of section 2. This hypothesis suggests that the emergence of a new radical technology, such as the cluster associated with digital technologies, requires a number of minor technological improvements, as well as institutional and social adjustments, to make its impact noted in the economy. In a word, the emergence of a radical technology requires time. Historical analysis proposed, among others, by Paul David

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[6] The argument for this statement is complex, but two fundamental ideas stand out. The first is that while the Internet cuts many intermediation, it is not clear that it will benefit the final economic outcome. In other words, businesses may move their transactions to the web, but it is not clear that this entails a higher productivity in the provision of final goods. Secondly, the benefits of the Internet from the consumer's point of view are time-

[27], shows that previous important technological breakthroughs took decades until they had a measurable economic effect. In his 1990 work, Paul David focused on the substitution of electric motors for steam engines, and established a historical equivalence with the computer. More recently David [28] suggests that the same type of "delaying" mechanisms is at work today with digital technologies and the Internet[7].

This understanding of the relationship between digital technologies and economic performance has two important implications. The first is associated with the acknowledgment that a major technological breakthrough needs many minor technical advances beyond the technological frontier to make the technology economically useful. In particular, the technological frontier often needs to be customized to the unique demands of users and investors in particular places and contexts. Bresnahan and Trajtenberg [29] call these "customization innovations" *co-inventions*.

Therefore, these localized co-inventions are, in the end, the engines of economic growth at the local level. Consequently, different countries may have considerable different paths in the production of co-invention. Some will be able to take advantage of the emergence of a technological breakthrough and to produce a number of co-inventions that can lead to a preeminent position in certain segments. That seems to be the, to a large extent, the history of Finland in cell phones. The technologies that made the cell phone possible were not invented by the Finnish, but they were still able to co-invent with enough vitality to impose their products worldwide. Bresnahan and Greenstein [30] argue that these localized dynamics of co-invention need to be studied in more detail outside the US. The fundamental implication is, though, that beyond technological revolutions, there is **ample** margin for innovation at the local and regional level, even for countries where rarely technological breakthroughs occur.

The second implication of the Freeman-David understanding of the relationship between digital technologies (or technological breakthroughs, more generally) and economic performance is that the process is not policy neutral. In fact, David [28] writes: "*a new general purpose technology requires the development and coordination of a vast array of complementary tangible and intangible elements: new physical plant and equipment, new*

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constrained. People have only so much time available, and the Internet is probably a substitution for other forms of entertaiment.

[7] There have been attempts to formalize these hypothesis, under the emerging field of the study of General Purpose Technologies. The collection of essays in Helpman [31] provides a snapshot of the literature in this area.

kinds of workforce skills, new organizational forms, new forms of legal property, new regulatory frameworks, new habits of mind and patterns of taste". Given this context, David concludes later that a translation of a new technological breakthrough into better economic performance "*is not guaranteed by any automatic market mechanism and that it is foolish to adopt a passive public policy stance and simple await its arrival*."

In the paragraphs above, we have been focusing primarily on digital technologies, for reasons that should be obvious by now. Many see in the evolution of information technologies the foundation for a "new economy". Most advocate for policies and initiatives to deepen and promote the development of the "information society". But there is another more fundamental dimension that needs to be addressed. As a first approximation, it is clear that digital technologies are **not** the only ones that are having an economic and social impact. Other areas, such as the life sciences (biotechnology included) and health have seen dramatic improvements over the last few years.

An even broader point is associated with the increasing importance of knowledge. The emergence of "knowledge-based economies" is, in fact, a larger concept than the one associated only with digital technologies and the Internet. This may be, indeed, a **stronger** idea than that of only just a techno-economic paradigm, but also a profound change in the way well-being, wealth and prosperity are generated and sustained. We look at this hypothesis below.

The Learning Society: A Framework to Understand the New Demands for Being Innovative

Recent models of long-term economic growth have been able to explain the increase in per capita income in developed countries (see Johnson [32], for a summary perspective, and Landes [33] for a broader treatment) with extremely parsimonious models based exclusively on the growth of knowledge. The factors behind the increase of knowledge are equally simple: the increase in population and the emergence of specialization in the production of knowledge. Kremer [34] uses a model exclusively based on population growth, where more people means that there are more individuals capable of making a significant discovery and that the larger the population the larger the benefits from those discoveries. In other words, technological improvements make population growth possible which, in turn, creates more possibilities for new discoveries. A slightly more complex model by Hall and Jones [35] includes also the effect of the specialization of growing proportion of the population in activities associated exclusively with the creation and transmission of knowledge. This entails the need to include *institutions* and *policies* – a combination that the authors call *social infrastructure* – which, according to this model, explain difference across countries in their level of knowledge generation and income per capita.

The gradual transition towards knowledge-based economies has intensified in the last part of the 20th century. According to the OECD [36] more than 50% of the OECD countries' GDP is associated with knowledge-based industries[8]. Lundvall [4] asserts that the intensity of the acceleration of knowledge creation and diffusion requires a more dynamic characterization. In Lundvall's opinion, we should speak about the emergence of a *learning society*.

In summary, while much attention has been devoted to digital technologies, the association between information technologies and augments in productivity remains ambiguous. Still, it is undeniable that the spread of the computer and the Internet is changing in profound ways the way people and firms behave and interact, with important consequences for policy and strategy. A more fundamental change at the start of the new millennium is the increasing

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[8] Even if the definition of knowledge-based industries is rather generous, including a large part of services and the high and medium-high technology manufacturing.

importance of knowledge for economic prosperity. This feature of current developed countries corresponds to the continuing of a trend of acceleration of the importance of the creation and diffusion of knowledge throughout the century. Beyond digital technologies, other technological breakthroughs, in many areas from the life sciences to the many fields of engineering, are likely to be seen in the future.

In this context it is important to look both at the *level* of the measures that indicate the extent to which a country is engaged in the knowledge economy and to the *growth* in recent years. Figure 1 provides a first illustration, with the horizontal axis representing the intensity of knowledge-based industries in the mid 1990s and the vertical axis the growth rate of these industries in the previous decade.

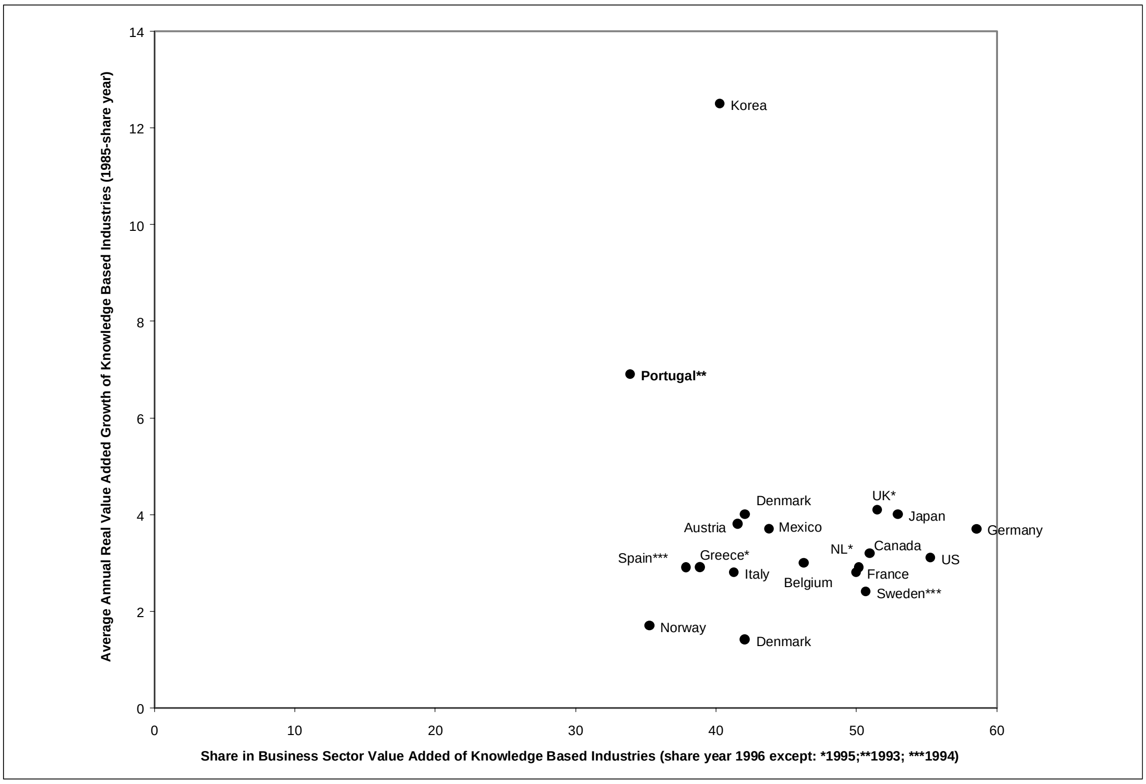

Figure 1- Knowledge Based Industries Intensity and Growth

Source: OECD [37]

Most countries are clustered at the bottom of the figure, with growth rates between 2% and 4% a year. The horizontal distribution of the countries shows Germany, the US, Japan and other leading developed countries to the right, with Spain and Greece to the left. In this context, Portugal and Korea stand out. The intensity of the knowledge-based industries in these countries is relatively low, especially for Portugal, which has the lowest level of knowledge-based industries. However, the growth rates for Portugal and Korea are remarkably higher, with the knowledge based industries in Portugal growing close to 7% a year, and Korean knowledge based industries at more than 12% a year. The rate of growth of knowledge-based industries in comparable periods was of 3.1% for the European Union and of 3.5% for the entire OECD.

The difference between the growth rates of Portugal and Korea is not as extraordinary as it may seem. In fact, the business sector as whole rose in Korea at 9.1% a year, while in Portugal the growth rate of the entire business sector was 4.6%. Consequently, the difference between knowledge-industries growth rate and the entire business sector growth was of 2.3% for Portugal (or 50% of the business sector growth rate) while in Korea the difference was 3.4% (a higher difference, but only 37% of the entire business growth rate). The case of Portugal and Korea are relevant because they are illustrative of latecomer industrialization and may represent indications of the process through which these latecomer countries become engaged in the new techno economic paradigm.

Turning our attention only to information and communication technologies (ICT), Figure 2 presents essentially the same framework of the previous figure, but now with the intensity of ICT expenditure in 1997 on the horizontal axis and the growth rate of this intensity from 1992 to 1997. Again, most countries are clustered in the bottom of the figure, with growth rates below 4%. The levels, as indicated by the horizontal distribution of countries, confirm the perception that the US is a leading country. The expenditures on ICT as a percentage of GDP in the US are about 2% above the European average. Individual countries, such as Sweden, outperform the US, but most countries lag behind.

But, as with knowledge-based industries, the growth rate in expenditures provides a different picture. In fact, Portugal is the leading OECD country in the growth rate of ICT expenditure from 1992 to 1997, with a growth rate of more than 10%. Most of this growth rate can be accounted for by increases in expenditures in telecommunications (about 9%). Expenditures in IT services and software are particularly low, below 1%. Only Turkey, Greece and Poland have shares of expenditure on IT software and services below the Portuguese value. The growth in this category has been equally dismal, below 2% a year.

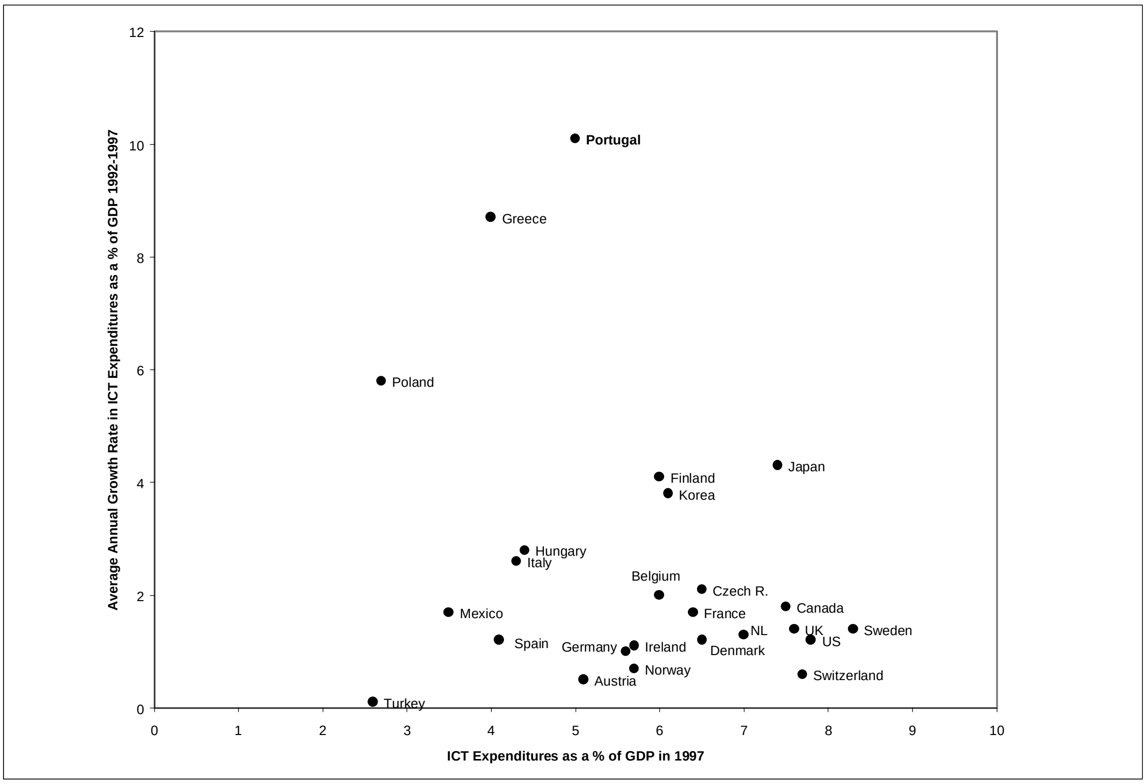

Figure 2- Information and Communication Technology (ICT) Intensity and Growth

Source: OECD [37].

Going back to the conceptualization of the knowledge-based or learning economy that we presented above, it can be said that, fundamentally, the performance in this knowledge-rich competitive environments depend on the **quality of human resources** (their skills, competencies, education level, learning capability) and on the activities and incentives that are oriented towards the generation and diffusion of knowledge. But beyond human capital, which corresponds to the **aggregation** of an individual capacity for knowledge accumulation, developing a collective capacity for learning – as suggested by Wright [38] in the context of the US – is as, if not more important, than individual learning. Instead of individual or even aggregated human capital, a further important concept for learning seems to be *social capital*, a topic already developed in our earlier paper in this journal, [2].

The importance of social capital, while still controversial, is increasingly being seen as an important determinant of economic performance and, especially, of innovation and creativity. Temple [39] discusses the impact of education and social capital together as determinants of growth; noting that evidence is still thin, Temple argues that there is an growing number of works suggesting that social capital is at least as important as education as a driver of economic growth.

Education is used often as a proxy for human capital. For social capital, the equivalent indicator is the level of “trust”. Figure 3 shows the results of a survey conducted in the early 1990s on each country’s citizens’ perception of the internal level of trust. Respondents in each country were asked if their countrymen could be trusted, and the percentage that replied yes is reported in the chart.

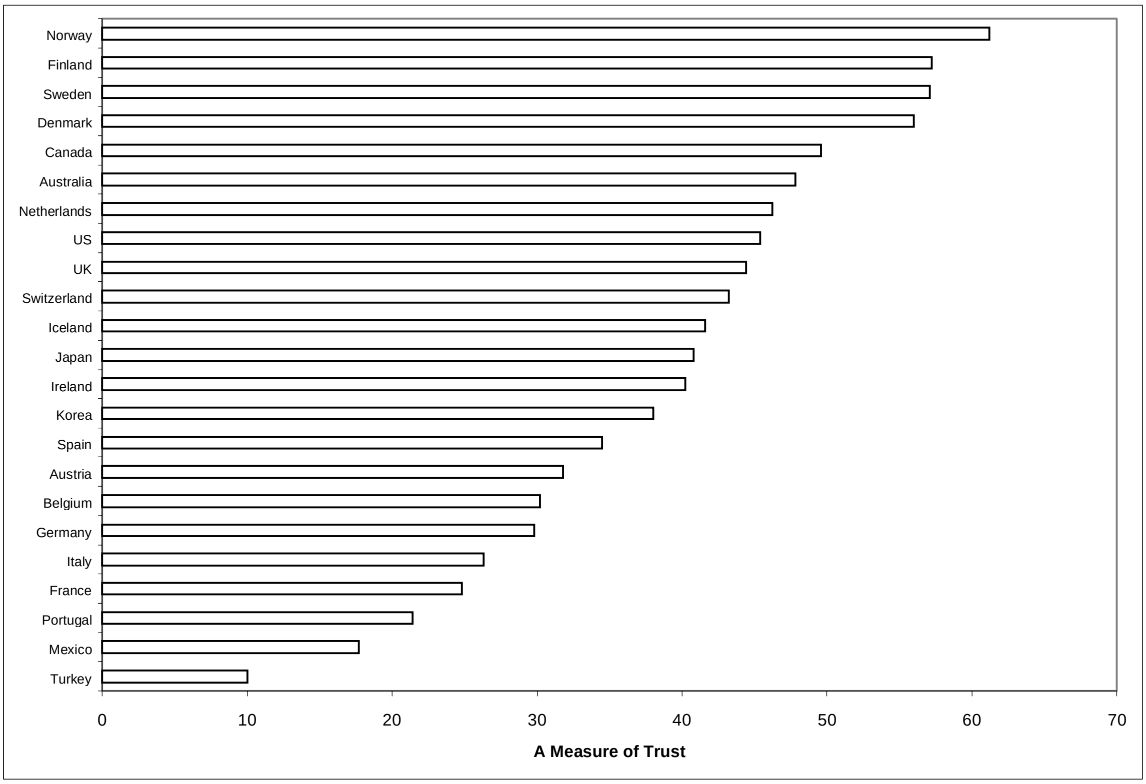

Figure 3- Level of Social Capital Measured by Trust.

Source: World Values Survey. Percentage of people who responded in the affirmative to the question: “Generally speaking, would you say that most people can be trusted?”

The next question is, then, to find out what are the determinants of social capital. Glaeser [40] suggests that education is strongly associated with social capital, which indicates that an important component of policies aimed at increasing social capital necessarily needs to go hand in hand with policies aimed at increasing the educational level. The reason is not only the fact that there is an association between human and social capital, but also the fact that being in school provides a context for social interaction and learning that has important spillover effects in strengthening social relationships and networks. Alesina and Ferrara [41] confirm the important role of education as a determinant of social capital, but show also that beyond individual characteristics, the characteristics of the community are equally important. These characteristics include dimensions associated with the way people compare themselves with each other, such as income inequality.

One other important dimension of the learning society includes the activities expressly oriented towards the generation and diffusion of knowledge. It is, as with education, risky to reduce a complex set of activities to a single educator, but the national effort on research and development provides an indication of the commitment, at the country level, to activities explicitly oriented towards the generation of new knowledge. These activities tend to occur in institutions, such as universities and research labs, or within institutional settings, such as the R&D unit within a firm, that provide incentives that foster the specialization on exploration and discovery, as well as exchange of knowledge [7].

Figure 4 shows both the scale and the intensity of national expenditures on R&D for several OECD countries, with the horizontal axis, representing the scale of the expenditure, having a logarithmic scale. The relationship between scale and intensity shows decreasing returns: as the scale of the investment grows, the increase in intensity also grows but at a decreasing (in fact, logarithmic) rate. The results also suggest that there are **three different** “paths” in which this relationship is expressed.

In the lower left-hand corner of the figure we identify a line that includes the Southern European countries. The thick line in represents a simple fitting of the position of most countries. Nordic countries have a path of their own, with a much higher responsive intensity to increases in scale. For Ireland the scale of R&D expenditure is almost the same as for Portugal, but the intensity for Ireland is comparatively much higher. The large intensity of R&D expenditures in Ireland is largely due to the fact that the R&D that is performed in the business sector, which in 1997 accounted for almost ¾ of the total R&D expenditure in Ireland. Ireland showed the largest increase in business R&D expenditure of all OECD countries in the 1990s, at an annual growth rate of close to 20%. However, most of this growth is being driven by foreign affiliates doing business in Ireland. The share of foreign affiliates in manufacturing R&D in Ireland in 1995 was close to 70%. This large share indicates a very low capacity of domestic firms to innovate. Ireland is, in this regard, an exception, since for most OECD countries domestic firms take the largest share of R&D performed in the business sector.

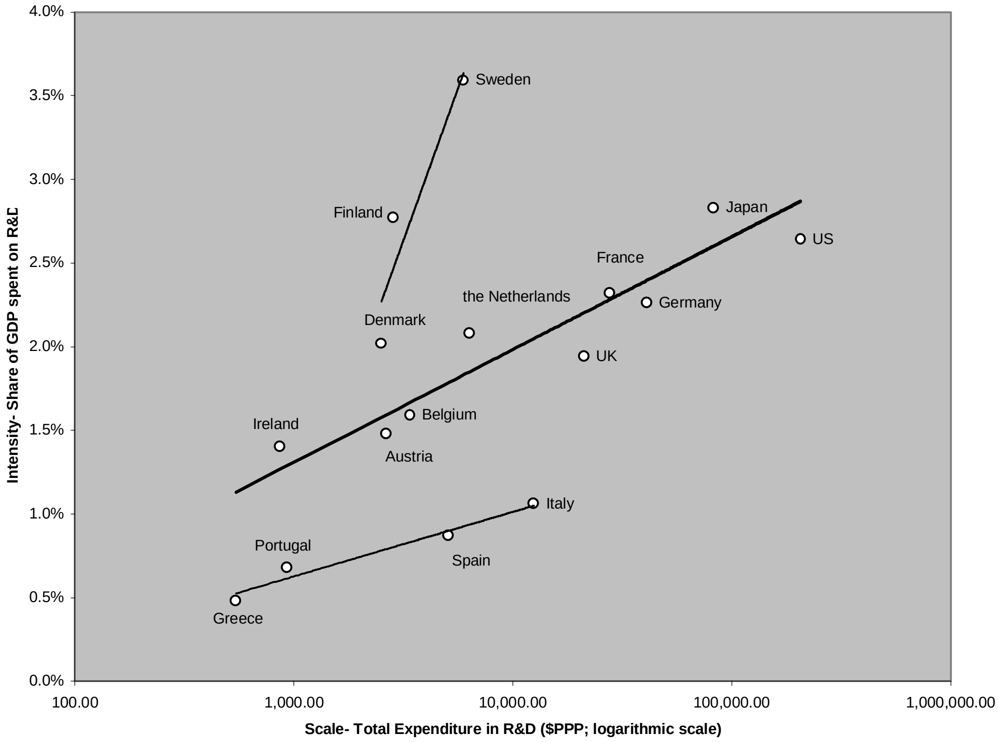

Figure 4- Intensity and Scale of R&D Expenditure in the OECD (1997).

Source: OECD [37]

R&D efforts are understood as an input; an important outcome of R&D expenditures is scientific papers. Scientific articles are, in themselves, important to diffuse and deepen innovation. Figure 5 shows the same countries as Figure 4, and the horizontal axis is also the same: the logarithmic absolute expenditure by country. In Figure 5 the vertical axis is also presented in logarithmic scale. As when we analyzed scale and intensity of R&D, we fit a straight line, which fits well with the data[9]. Given that both axes are in logarithmic form, scientific production follows a power law, a feature known to be associated with scientific publications.

[9] The R-squared is 0.95.

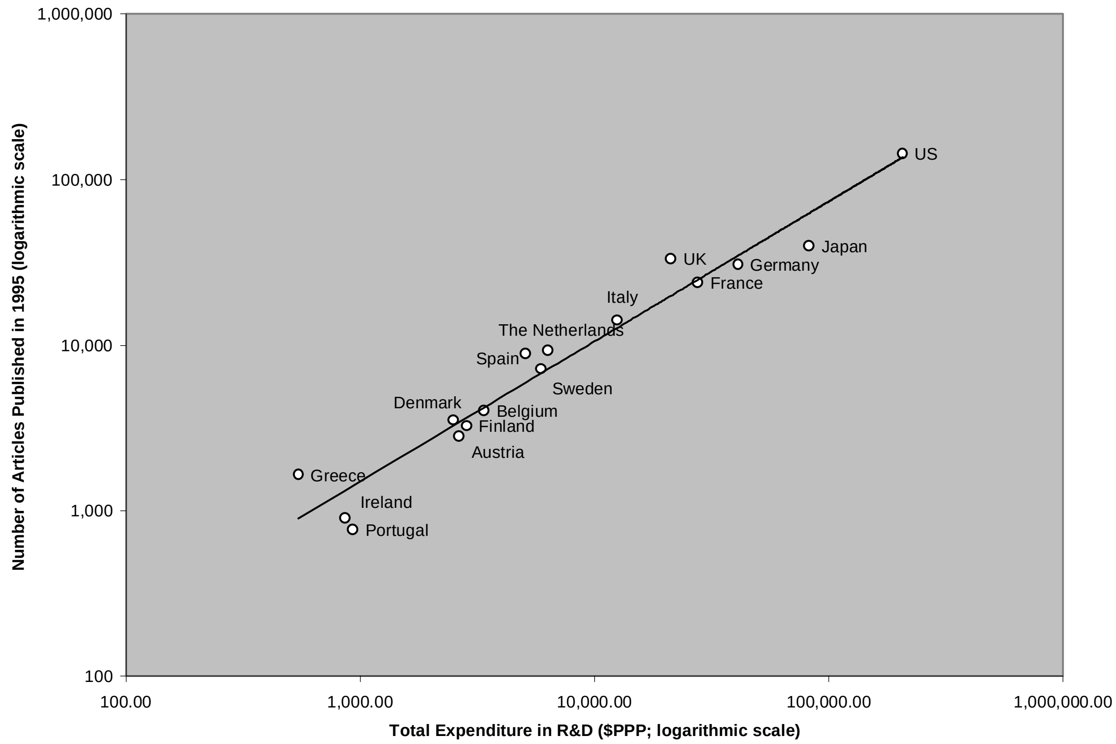

Figure 5- Absolute R&D Expenditures and Scientific Production in the OECD (1997).

Source: OECD [37]

R&D expenditure is an important indication of the commitment and resources a country devotes to knowledge production and diffusion, but the growing importance of knowledge extends beyond those activities traditionally associated with creativity and learning. Innovation performance, in particular, depends on conditions that foster technology-based entrepreneurship. Mechanisms such as venture capital and high growth start-up stock markets (like the NASDAQ) are ways to mobilize private capital for investment in knowledge economies [42]. Gomper and Lerner [43] show that venture-capital backed start-ups appear to have a disproportionate positive impact on innovation.

However, following Antonelli and Calderini [44], “the internal bottom-up learning process based upon the improvement of design and technological processes plays a major role in feeding the continual introduction of technological and organizational innovations”. In this respect, the authors conclude that technological knowledge is embedded in the specific circumstances in which the firm operates, and its generation is the result of a joint process of production, learning and communication, of which R&D activities are only a part [45, 46]. In more general terms, the analysis of the innovative performance of countries in the learning society calls for the need to consider all the processes of learning (both “formal” and “informal”, [7]).

This brings us to the issue of *measuring innovation*. How to measure the innovative performance of an entire country? Furthermore, how to measure this performance in a way that is comparable across the diverse realities of many countries? These demanding challenges have been addressed by a joint effort of the OECD and the Eurostat, who have promoted the development of innovation surveys at the country level according to a set of criteria that values cross-country comparability of results. This European effort is designated by Community Innovation Surveys (CIS) [46], 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.

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. Figure 6 shows the overall innovation performance of countries in Europe measured by the shares of firms that have introduced innovations over a two-year period.

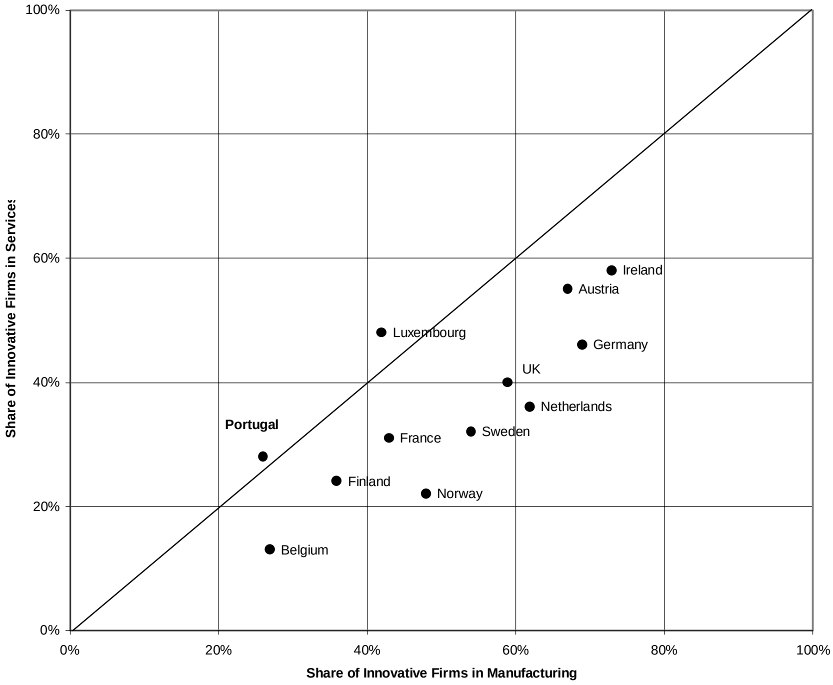

Figure 6- Cross-Country Comparisons of Innovation Performance in Europe

Source: Conceição e Ávila [45].

The horizontal axis indicates the innovative performance in manufacturing, and the vertical axis in services. There is a close relationship between innovation in the services and in manufacturing, since countries are located across a 45-degree diagonal. In general, innovation rates are lower in services than in manufacturing.

Measuring the ability to innovate in a country, difficult as it is, could very well provide among the most important information needed to characterize the innovation performance in the learning society. Clearly, these indicators on innovation should be analyzed in conjunction with others, including both the more traditional indicators associated with shares of national resources devoted to R&D, and to newer and emerging indicators, such as those that relate to the level of social capital.

In summary, innovation should be understood as a **broad** social and economic activity within the framework of the learning society. 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. Recent work within the framework of the OECD International Futures Program suggests two broad policy-related conclusions. The first is that if one is to build on the opportunities offered by the considerable progress that has been made in key technological sectors, if one is to reap to the full the economic benefits of rapidly integrating markets and the emerging knowledge society; and if solutions are to be found to tackling the challenges that the management of such a rapidly changing world raises, then what is needed are **innovative**, creative societies. The second is that in achieving that higher degree of innovativeness and creativity, policy will matter. The way ahead does not necessarily mean less government, not less policy but – certainly in some key areas – **different** policy.

The remaining Contributions to this Special issue

The remaining papers in this special issue were selected among those presented at the 3rd International Conference on Technology Policy and Innovation. They all touch, more or less directly, on issues revisited in this paper, from the measurement of innovation, to the institutional aspects associated with the emerging learning society.

The second paper, following this introduction, is by David Mowery, who describes the emergence of a worldwide “multipolar technological environment”, where the US is “first among equals” rather than “technological preeminent”. While differences among countries still persist, with the US still maintaining a significant lead especially in terms of new technology creation, Mowery argues that, as with the world’s economies – which are increasingly integrated – the national systems of innovation are becoming ever more interdependent.

Mowery’s paper has a clear US perspective, and the author’s intention is always to compare the US situation with global trends and, in the end, to derive implications for US science and technology policy. Mowery argues that the US policy that was behind the “Golden Era” of progress that followed WWII inevitably created a convergence between the US and other industrialized countries’ levels of development, standards of living and, of course, science and technology capability. Thus, the gradual emergence of the current “multipolar technological environment” creates problems that are “legacies of success” of, precisely, the US policy that promoted endogenous development in post World War II Europe and Japan. These problems are associated, in part, with a bent towards technological protectionism that is defended by some factions of the US polity. This protectionism is manifested in, at least, two ways: an attitude to restrict the access to technologies developed in the US, and, on the other hand, an attempt to be always the first to develop new technologies. In a way, these attitudes are anachronistic, since, fundamentally, they are looking at establishing again a preeminent US position in terms of science and technology. Finally, Mowery argues, in his recommendations, that it would be better for the US to accept that the leadership it enjoyed in the early fifties could never be maintained, and open itself more to the integrated science and technological system that is emerging around the globe.

The next paper in the special issue, by Marcela Miozzo and Luc Soete, looks at the implications of several aspects of change on the service sector. These authors argue that a major weakness of the theoretical and policy treatments of services is the neglect of the impact of technological change on the changing nature of the sector, as well as of the increasing internationalization of services and of the role played by transnational corporations. Their paper proposes a taxonomy for the service sector based on their technological linkages with manufacturing and other service sectors. This taxonomy identifies a number of technology-intensive service sectors closely related to the use of information that are essential to growth. The effect of recent technological changes on the transformations in business organization, industry structure, internationalization and the role of transnational corporations in these technology-intensive service sectors are explored. The paper concludes with policy implications for less developed countries.

Junmo Kim is the author of the fourth paper in this special issue. Kim attempts to provide an empirical application that measures the growing integration of the world's economies in a few large blocs. While, as he makes clear, many theories exist on why regional economic integration has emerged, few empirical studies attempt to analyze the historical pattern behind this development. Thus, the major contribution of the paper is the empirical framework that is proposed. The empirical application consists in applying cluster analysis to wage data at the country level to get at country groups, and then use discriminate analysis to attempt to establish the driving forces behind the establishment of these groups. Countries are considered in their entirety and also by industry. Kim finds that the European and the Pacific Rim groups clearly emerging, with evidence suggesting also a differentiation, within the Pacific Rim group, between and Asian and a Nafta group. Furthermore, a single macroeconomic variable, the US money supply, can be identified with the first root of the discriminant analysis when countries are considered in their entirety. This variable can also be identified with the first root of 5 of the 6 industry-only analyses that are performed.

The next paper is by a team of Brazilian researchers led by Rui Quadros, which includes Furtado, Bernardes and Franco. These authors report on the results of an innovation survey performed in the Brazilian state of São Paulo. The survey was performed in 1997, within the context of a larger exercise executed by the state's statistical agency. Results are for manufacturing only; the major survey results refer to 1996, and the innovation questions to the period 1994-1996. The questions concerning innovation follow the norm of the innovation surveys that have been performed in several OECD countries, under the framework of the Oslo Manual and the CIS framework, of which we also used results above. Only firms with more than 5 employees were made part of the innovation study. The paper follows what has become a somewhat standard practice in the presentation of results of innovation surveys. First, the rate of innovative firms is discussed, both in terms of the number of innovative firms and the weight of these firms in the economy (measured, in this case, by the value-added generated by innovative firms). The innovation rate is broken down by firm size (including an analysis of product and process innovation), sector, and type of ownership (national or foreign). Following the analysis of the "extension" of innovation, the authors report on inputs (although only on people employed on R&D), sources of information for innovation and, finally, the objectives of innovation. This paper is particularly important since it reports, for the first time – to the best of our knowledge – on results of innovation surveys performed in Latin America.

The sixth paper in this special issue is by Edwin Nijssen, Rik van Reekum and Henriëtte Hulshoff. Nijssen et al. examine the nature of the search process in firms to identify partners for technological cooperation, and, in particular, the extent to which systematic information collection on potential partners can enhance the choice of partners. The empirical results are based on data obtained from 118 Dutch companies and suggest that only a few firms have formal procedures to find technological partners. A firm's pro-activeness and experience in finding partners have a positive influence on the final selection of an appropriate partner. This is also true for an extensive evaluation, when preceded by intensive search, while direct top management involvement and company size are negatively correlated with successful partner selection. Finally, the results indicate that companies are less successful in identifying potential partners in technologically similar areas, but more successful in finding appropriate partners that cover technologies not related with the firm's activity.

The next paper, by Veloso and Fixson, provide a new framework to analyze the decision of the automakers on how to get a new component: either to develop a new one in-house or to subcontract it to a supplier. Traditional frameworks associated with transaction costs or principal-agent theories have often been associated with contradictory empirical evidence on make-buy development decisions. These authors' perspective follows some recent insights proposed by the property rights theory of the firm, whereby a decision to pass the development of the innovation from the assemblers to the suppliers exists when the supplier product shifts from being complementary to being independent of the assembler product. The hypothesis they explore is that modularization of the automobile is a strong enabler of product independence, being the key driver of increasing supplier responsibility. The analysis is based on case studies of two important innovations that were introduced in the automotive over the past decades: the Anti-lock Brake System (ABS) and the Airbag. The paper evaluates the role of the suppliers and the assemblers in the introduction and development of the innovation and explains how this role can be understood in light of the proposed framework.

Finally, the last paper is by Nikolaus Thumm, who has the objective of observing a "real world picture" of how European biotechnology firms manage their inventions and, in particular, how they make use of patent protection. The author's intention is to compare the behaviour and the requirements of the biotechnology industry with the existing legal framework in Europe, to determine industrial needs and to identify insufficiencies in the institutional settings. The analysis focuses besides the general competitive performance of Europe in comparison to the United States on the use of patents by firms in different European countries, the decision to keep inventions secret or to patent, the different procedural ways to apply for patent protection as well as the importance of patenting related costs and strategic uses of patenting.

Summary

Based on the conceptualization of the *learning economy* and the related need to promote *systems of innovation and competence building*, it can be said that, fundamentally, the performance of knowledge-rich competitive environments depend on the quality of human resources (their skills, competencies, education level, learning capability) and on the activities and incentives that are oriented towards the **generation and diffusion of knowledge**. In a context of globalization, we argue that the development of research and education agendas on *technology policy* and the *management of innovation* have become critical for the successful use of engineering, science and technology to promote innovation.

In general, our argument is that while much attention has been devoted to digital technologies, a more fundamental change at the start of the new millennium is the increasing importance of knowledge for economic prosperity and the emergence of a *learning society*. The ways new competencies, namely in conventional engineering, economics and management, may positively influence the development of a country and/or region depend on the institutional framework, which is currently particularly determined by regulation policies and the process of market liberalization. Again, this calls for the need to promote education and research in *technology policy* and related challenges are presented and discussed in a context where *innovation* should be understood as a broad social and economic activity within the framework of the learning society.

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