The contribution of technological inputs and spillovers to competitivity and economic growth: the case of the Spanish regions

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Abstract

This paper analyses the importance of technological activities in explaining the differences in productivity among Spanish regions. It quantifies the effect on regional development of the regions' own technological innovation and ICT infrastructures, and the externalities associated with technological capital and ICTs. The analysis is based on the estimation of a production function.

Key words: growth, R&D, spillovers, ICT

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1. Introduction

The importance of analysing the effect of technological activities on the competitiveness, social and economic progress of an advanced country is evident. The reason is that the growth of productivity is the basis of income growth and those countries or regions that are in a better condition to make it grow are those that most easily incorporate technological knowledge and progress. Current economic scenarios are also affected by the intensification of the phenomenon of globalisation and the multiplication of new technologies, particularly of ICTs. For this reason, in this paper we focus on analysing the role of these two aspects of technology (ICT capital and technological capital) on the competitiveness of the Spanish regions .

Competitive advantage resides in the capacity to possess know-how and to innovate. Possessing know-how means being able to add to codified knowledge an exclusive specific knowledge from one's own productive experience. The advantages of using superior technologies and know-how are clear: competing using the differentiation and qualification of the products and the utilisation of all kinds of organisational innovations capable of coping with the phenomenon of globalisation and the increasing integration of markets. The new theories of international commerce are clear about this: the qualitative differentiation of products gives firms a certain market power, and consequently, they enhance their activity to develop more active strategies of competition in international markets. By way of example, Grossman and Helpman (1991) asserted that the ability of firms to develop higher quality products and to orientate production towards more dynamic markets and sectors is closely related to the technological capacity and the endowment of human capital of their countries or regions.

But this is not the only channel of technological diffusion. The soft parts of technology, based on the intensive use of ICTs, are crucial in firms' production, administration, logistics and distribution. For this reason, it is also essential to analyse the effect that the diffusion of technology from ICTs has on economic growth and competitiveness. Although in countries like the United States a positive relationship has been observed between ICT-based economic sectors and increased productivity, this relationship must also be demonstrated in the case of regions.

For this reason, in this paper we analyse the importance of ICT capital and of technological capital in explaining the differences in the growth of production in the specific case of the Spanish regions, additionally including the externalities of both types of capital. To the best of our knowledge, this is the first empirical attempt to examine these channels of knowledge transmission simultaneously. Thus, the empirical results obtained are less likely to suffer omitted variable biases, which might be present in other previous work in the literature. In section 2 we offer an overview of the studies that describe the connections between productivity and ICT, and of those between productivity and technological capital, including spillovers. Section 3 presents the theoretical model on the basis of which we analyse the effect of the endowments of technological and ICT capital on the increase in productivity and economic growth. Section 4 describes the data and introduces the main results, and section 5 offers the conclusions and the recommendations for economic policy with the aim of reinforcing the connections existing between economic growth and the endowments of technological and ICT capital .

2. Empirical evidence

It has been argued that countries or regions can obtain dynamic gains from the technological knowledge developed inside or outside the region and that this can result in increased productivity growth. Reviewing the related literature we start by mentioning the theoretical studies of Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992) and the extensions of some of these models made by Jones (1995). The model of Romer (1990) posits that technological change derived from internal investment combined with human capital determines the rate of growth but an open economy will help to increase the growth rate. Also Grossman and Helpman (1991) consider commercially oriented innovation efforts as the engine of technological progress and productivity growth. On the other hand Aghion and Howitt (1992) conclude that growth is generated by a sequence of quality improving innovations that result from uncertain research activities while Jones (1995) extends Romer's model to analyse the long run growth rate of industrialised countries, i.e. the effect of the R&D process in a time series.

From the empirical point of view, authors such as Verspagen (1992, 1994) and Silverberg and Soete (1994) have highlighted in their applications that technological change is one of the basic factors for the development of a country, and can therefore be considered one of the factors that differentiate its economic growth. Eaton and Kortum (1999) model the invention of new technologies and their diffusion across countries. In this model, research effort is determined by how much ideas earn at home and abroad. When they fit the model to data from the five leading research economies, they find that research performed abroad is about two-thirds as potent as domestic research. So that together the United States and Japan drive at least two-thirds of the growth in each of the other countries in the sample. Also empirically, Keller (2002) analyses the relationship between productivity and R&D in different industries and finds that technology in the form of product designs is transmitted to other industries, both domestically, and internationally through trade in differentiated intermediate goods.

It is well known that one of the main difficulties faced by firms when they carry out research activities is the appropriability of the resources invested. However, these negative effects on the investing firm may at the same time increase the productivity of other firms or sectors of industry. This concept can also be applied in a framework of higher aggregation, considering the existence of spillover effects among countries or territories. One current of the literature affirms that the more backward countries may grow more quickly than the more advanced ones if they develop their capacity for imitation or absorption of other countries' technological capital, converging at similar levels of per capita income[1]. In this study we will try to verify whether the regions are more productive as a result of capturing spillovers from outside the region.

A further question is to identify where these spillovers come from. Among the first authors to introduce the concept of spillovers of technological capital were Scherer (1982), Spence (1984) and Jaffe (1986) at the level of the firm, while the existence of spillovers at international level is reflected in the studies by Lichtenberg (1992), Berstein and Mohen (1994) and Coe and Helpman (1995). These studies define alternative measurements for spillovers such as the R&D expenditure made by other firms or industries, weighted where appropriate by “technological distance" or "technological opportunity". In this paper we follow several approaches to test the hypothesis that productivity is increased by different measures of R&D spillovers.

1 See Dorwick and Neguyen (1989).

On one side, to measure "technological distance" among regions we follow Krugman (1991a and b) and Glaeser et al. (1992) who affirm that transmission of technological knowledge occurs within a limited geographical unit. We also follow Bottazzi and Peri (2003) who find that spillovers are very localized and exist only within a distance of 300 kilometers even when simultaneity problems, omitted variable bias, different specifications of distance functions and country and border effects are considered. That is to say, location and the closeness of the productive agents matter, as the cost of transmitting information may be invariable with distance but the cost of transmitting new technological knowledge, which is not generally done explicitly, does vary with distance.

On the other side, following Jaffe (1986) and Jaffe et al. (1993) the relevant activity of the other regions can be summarized by a weighted sum of other firms' R&D, with weights proportional to the "proximity of the regions in technology space". To measure this proximity we follow Grossman and Helpman (1994) and Coe and Helpman (1995), supporters of the idea that new theory of economic growth underlines trade as a transmission mechanism that links a country´s productivity gain to economic development in its trade partner. More precisely, a region's productivity depends not only on its own technological research, but also on the technology of its trade partners, i.e. foreign or neighbouring R&D may have a stronger effect on domestic productivity the more open an economy is to trade.

This paper adds to the above literature by also examining technology diffusion through ICT. Authors such as Bailey (2003), Colechia and Schreyer (2001), Jorgenson and Stiroh (2000), O'Mahony and Van Ark (2003), Pilat (2003), Stiroh (2002) and Van Ark and Timmer (2004) have studied since the late nineties the role played by ICT in the reversal of the TFP slow down. Thus, in the United States there exists a broad consensus that the expansion of ICT products has clearly driven the productivity growth of recent years, when most of the growth of the economy was attributable to high technology sectors. However, in Europe, investments in ICT have also accelerated the growth of production, but have not reinforced productivity with the same intensity as in the United States. For these ICT investments to be effective beyond the impact generated on their own production activities, it is necessary to generate a sufficiently broad process of dissemination of such technologies among the different economic agents .

In the case of Spain there are also authors who have analysed the relationship between productivity and ICT. Hernando and Núñez (2004) examine the role played by ICT capital as an input factor and show the importance of this input on output and productivity growth of a sample of Spanish firms. Although they find that ICT capital growth rates have been notable, they are still well below those observed in the US economy. Consequently they are not sufficiently high to narrow the gap in new technology capital observed between the Spanish and the US economies. However they do not obtain conclusions about the link between ICT growth and TFP growth rates.

Mas and Quesada (2005) compute the contribution to output and labour productivity growth of employment, non-ICT and ICT capital, labour qualification and TFP. The main conclusion that they reach is that in Spain the presumably beneficial effects of ICT capital on TFP growth are not observed in the period 1985-2002 but there is evidence of a more positive influence in rising output and labour productivity.

3. The model

The economic growth of countries or regions differs to the extent of their different growth rates of factors of production and of technological innovation. The most important way of accessing technology is through their own R&D activities. However, scientific and technical advances cannot always be used by the entity that makes the expenditure, and therefore generate externalities (spillovers). In this sense, the R&D activities generated by other nearby agents and the imports of foreign innovations through trade in goods and services are also a way of accessing technology, and consequently favour economic growth.

Simultaneously, we examine if apart from these channels of knowledge transmission, the substantial ICT capital invested in the Spanish economy during the last years has been another way of access to technology. ICTs can influence economic growth through different paths or mechanisms of transmission. The first of them is the production of the ICT sector itself. The effect of technological progress on the ICT sector with its consequent reduction of prices and increase in the productivity of the products of the sector brings, in turn, an increase in the TFP of the country or region where the sector is located, in proportion to the importance of that sector. The second path is the use of ICTs or accumulation of ICT capital as a contribution to the process of production, independently of whether or not the equipment and software are produced in that country or region. Thus, a bigger and better investment in ICT per worker will improve the productivity of the country or region. And the third route is that of the externalities or spillovers derived from the use of ICT. Thus those sectors that most use ICT capital will also be the ones that incorporate most technological progress, thus obtaining greater productivity gains, principally in the form of savings in the costs of search and transport. Data on the ICT-producing sector is not available, so the analysis in this paper is limited to the impact of the new technologies on the ICT-using sector. However, as pointed out by Mas and Quesada (2005), Spain in not a big ICT producing country thus the big impact on productivity may arise from their use in other branches of the economy.

There are alternative approaches to the analytical procedure. In this paper we consider technological capital and ICT capital as ordinary inputs in the production function. Assuming that the technology underlying the production function is of the Cobb-Douglas type, the production function for the Spanish regions, augmented with technological capital and ICTs capital, is:

$$Y_{it} = A_{it} L_{it}^{\alpha} K_{it}^{\beta} T_{it}^{\rho} R_{it}^{\gamma} \qquad (1)$$

where:

Y_{it} = private production of region i in year t.
$A_{it} = A_{i0} e^{\mu t t}$
A_{i0} = initial level of efficiency or productivity for each region i in year 0
μ= rate of desembodied technical progress
L_{it} = employment in region i in year t
K_{it} = physical capital of region i in year t.
R_{it} = technological capital of region i in year t.
T_{it} = Information and Communications Technology capital of region i in year t.

The technological capital of each region is formed by the technological innovations generated in that region, but following the most advanced economic literature we can also include the spillovers associated with technological capital produced outside the region but "absorbed" by each region. Also, ICT capital can generate growth of production due to its contribution to the growth of production as one more input of the production function and to the externalities that the ICT capital of other regions may generate towards the region being studied through their spillover effects. We therefore aim to estimate an expanded production function including both spillover effects. Taking logarithms and including the different types of capital we can estimate the following equation.

[illegible] (3)

where S_T and S_R are, respectively, the spillovers of ICT and R&D capital.

4. Data and variables used

In order to analyse the contribution of R&D and ICT capital to regional development, we present below the variables that are to be used in the empirical analysis. These correspond to the seventeen *Comunidades Autónomas* (regions) of Spain in the period 1987-2004 and are expressed in euros of 1990**.** To deflate the production we have used the deflator of national production, since a deflator at regional level is not available. Likewise, the technological capital series have been deflated by the deflator of the Gross Formation of Fixed Capital provided by the *Instituto Nacional de Estadística* (INE).

The variables and statistical sources used are:

a) Production of each region (Y): measured by private Gross Value Added (at factor cost) and obtained from the Regional Accounts of Spain (base 1986) of the INE. Since the INE only offers regional information on GVA until 1996, the values of total GVA until 2004 have been estimated using the growth rates of FUNCAS.

b) Employment (L): obtained, as above, from the Regional Accounts of Spain (base 1986) of the INE.

c) Private capital (K): obtained from the estimations made by the IVIE for the *Fundación BBV*. As usual, residential capital is not considered. The latest information currently available at regional level is for 2004.

d) Stock of technological capital (*R*): R&D activity must be considered as a flow of investment in an intangible activity, the accumulated volume of acquired knowledge.

Thus the influence exercised on a country's production comes from the accumulated stock of the results of investment in R&D. This stock is what we know as technological capital. To generate this technological capital series we consider that this input is accumulated, according to the perpetual inventory method, as follows:

$$R_{i,t} = (1-\delta)R_{i,t-1} + I_{i,t-\theta} \qquad (4)$$

where R_t is the capital stock of period t, δ is the depreciation rate of technological capital and I_t the annual investment in R&D capital. Nevertheless, following Pakes and Schankerman (1984) it is assumed that the effects of R&D investments on economic growth are not immediate, but that there is an average delay of two periods between making the expenditure on R&D and noting its effects (θ=2). Alternatively, R_t can be defined more completely so that it includes as technological knowledge the payments for transfer of technology as well as the R&D capital costs for the period. Nevertheless this study, as remarked above, aims to use the INE's publications on technology expenditure. In this case, the statistics do not offer a dissaggregation between expenditure on R&D *per se* and payments for transfer of technology. This is because the bodies surveyed do not distinguish in most cases between these two terms, responding generically with regard to total intra-mural expenditure.

The perpetual inventory method of computing the stock of technological capital presents some problems. The first relates to the determination of the initial capital stock. The solution adopted in the studies quoted above is to begin the process of perpetual inventory in the first year available, which in this case is 1986. In this case, if technological capital accumulates as in (4) and we further consider that investment in R&D capital increases year on year by a proportion g, we find that:

$$R_{i,t} = \frac{I_{i,t-\theta}}{g+\delta} \qquad (5)$$

The second of the problems occasioned by the use of the perpetual inventory formula for calculating the stock of technological capital is to decide the rate of depreciation of such capital (δ) and the rate of growth at which it accumulates (g). In Spain, there are no studies in which d is quantified. We take two references: firstly, that of the studies by Pakes and Shankerman (1984) and Hall (1988) who obtain a maximum value for the depreciation of technological capital of 0.25. Secondly, it is also common to use a depreciation rate similar to that of physical capital. Spanish authors usually take a measurement intermediate between the two. The reason is, on the one hand, that a depreciation rate of 0.25 would indicate an investment dynamic in Spain similar to that of countries like France, the United Kingdom, Switzerland and Holland, which in practice is not so. On the other hand, considering an indicator similar to that of physical capital would imply assuming that the rate of obsolescence or the speed at which new inventions are introduced is similar to the rate of ageing of physical capital, when it is logical to suppose that the former is much higher than the latter. Other studies, e.g. Hall and Maraisse (1992) for the case of France, assume a depreciation rate of 15%. This is the rate used here and in Beneito (2001)[2]. Finally, the growth rate of capital in R&D (*g*), necessary for calculating the stock of capital according to the perpetual inventory method, was calculated according to the data of the sample.

e) ICT capital (T): we use new data on investment and capital services from the EU Klems project: *EU Klems Growth and Productivity Accounts* (http://www.euklems.net/)

f) Spillovers associated with ICT and R&D activities (S): two different measurements have been constructed which take into consideration the possibility that the spillovers captured by each region may come from other regions. The spillover effects of each region are constructed as a weighted sum of the technological inputs of the rest of the regions:

$$SPILL = W_{NxN} S_{Nx1} \tag{6}$$

where W_{NxN} is the matrix of weightings of the ICT or R&D inputs (S) of the rest of the regions.

In this study, the matrix used is based on the volume of trade flows between regions and on geographical proximity. Specifically, we use two alternative matrices of weightings which result in several alternative measurements of spillover effects. The weightings of the matrix are constructed as follows:

$$f_{ij}^{1} = \frac{F_{ij}}{\sum_{j=1}^{N} F_{ij}} \tag{7}$$

2 However, in empirical applications the results are not usually sensitive to the rate of depreciation used.

$$f_{ij}^{2} = \frac{KM_{ij}}{\sum_{j=1}^{N} KM_{ij}} \tag{8}$$

where F_{ij} measures the flow of trade between regions *i* and *j*, and *KM* is the distance in kilometres between regions *i* and *j*.

On the basis of the two weightings matrices, several measurements of spillover effects are calculated, both for R&D and ICT capital:

1) (*R&D-KM*) and (ICT-*KM*) measure spillovers taking into account the geographical proximity (distance in Kilometres) between regions, such that the nearer the other region, the greater the weighting given to its R&D expenditures. The same analysis is applied to ICT capital.
2) (*R&D-TF*) and (ICT-*TF*) measures spillovers taking into account the intensity of the trade flows between regions, such that the greater the value of the trade flows with another region, the greater the weighting given to its R&D expenditures. In other words, interregional R&D spillovers are specified as a trade-share weighted sum of the R&D expenditure in other regions. This specification implies that the more a region trades from a foreign region, the more R&D spillover benefits are received by the importing region. Thus, each element of the weightings matrix measures the importance of the trade flow between regions *i* and *j* in relation to the total volume of the region of origin *i*. The same analysis is applied to ICT capital.

5. Results

5.1. Technological capital and ICT capital

To show the technological position of the Spanish regions we will start by presenting the main indicators of technological activities.

Graphic 1 shows the evolution of the different types of capital considered (private capital, ICT capital and technological capital), each variable taking the value 100 in the starting year (1987). The table shows that in the 17 years considered all the variables grew at a considerable rate. While technological capital was multiplied, in real terms, by more than 3.5, technological capital was multiplied by 4.20. The investment effort in both types of capital was therefore considerable, though the starting levels were very low. The private capital in the economy experienced lesser growth, being multiplied by only 2.2 between 1987 and 2004. Figure 2 shows us the average annual growth rates of ICT and technological capital. We can appreciate that the average annual growth rate of ICT capital is 8.93%, slightly higher than the average annual growth rate of technological capital (8.93%). In both cases, we can see the investment made by all the regions during the period considered.

Table 1 contains the regional distribution of R&D capital. The information shows that in 1987 three regions (Madrid, Catalonia and the Basque Country) concentrated almost 75% of total R&D expenditure, while some regions did not even reach 1% of the total (the case of the Balearics, the Canaries, Cantabria, Castilla-La Mancha, Extremadura, Navarra, Murcia and La Rioja). However, in 2004 Madrid, Catalonia and the Basque Country concentrated a lower percentage of R&D expenditure (around 62%) while the regions that started from less favourable positions have improved.

Table 1 also contains the regional distribution of ICT capital. Various points stand out. The first is that although there is a substantial concentration of ICT capital in certain regions, this concentration is not as marked as in the case of R&D capital. Secondly, in 1987, four of the regions (Andalusia, Catalonia, Valencia and Madrid) each possess more than 10% of the ICT capital, outstanding among them being Catalonia which comes close to 20% of the ICT capital of the whole of Spain. Only one region, La Rioja, has a percentage of ICT capital of less than 1%. When the variable is analysed across time we observe that in most regions the percentage represented by ICT capital in the total for Spain remains stable.

Table 2 shows the evolution of the stock of ICT capital and technological capital per worker. ICT capital is observed to have increased considerably per worker in all regions between 1987 and 2004. Furthermore, in 2004 all the regions have a value for ICT capital per worker that varies around the average for Spain. On the other hand, the regional differences in respect of technological capital per worker are much greater than in the above case.

5.2. The effect of ICT capital and technological capital on economic growth

In this section we present the results corresponding to the effect of knowledge - based assets (R&D and ICT) on the production of Spain's regions. For this, we estimate the expanded production function incorporating ICT capital and technological capital. Given the data panel structure of the sample used, fixed effects and temporal effects are introduced into the estimation.

Table 3 presents the effects on the regional production from each of the potential channels of technology diffusion. Firstly, all columns suggest a positive elasticity of production with respect to either R&D capital and ICT capital. ICT capital has a largest effect on production than R&D capital. Concretely the elasticities of production respect ICT capital vary between 0.05 and 0.11 while the elasticities of production respect R&D capital vary between 0.01 and 0.02.

The elasticities obtained are strikingly low. However, there may be many reasons for this. First, investment in R&D and in information technologies is still on a small scale in many of the Spanish regions even though, in recent years, there has been considerable investment in ICT in many of them. Second, there possibly still exists a lack of connection between the ICT sector and the rest of the economy, i.e. there may be greater availability of mobile phones or assets such as Internet, but the penetration of these technologies has not yet propitiated major organisational changes in numerous firms, especially small ones. Firms and their managers have not always exploited the enormous possibilities offered by ICT to improve the management and control of businesses, and hence to increase production. Thirdly, the low R&D may have made it difficult for the regions to absorb productively the technology incorporated, even when the investments in physical capital have been considerable thanks to both national and international investment. Finally, low elasticities usually occur when the territorial areas are of small size, as in the case of the Spanish regions, given the high degree of spillover effects between geographically close areas. Therefore, we now focus on such spillover effects [3].

Results of columns 2 and 3 show that spillovers of R&D and ICT capital are positive across all specifications indicating that the bigger the investment in R&D and ICT capital of other regions, the faster the production growth, although the last one is not always significant. Notable, then, is the moderate effect that the region's own two channels of diffusion of technology, in isolation, have on production, whereas the spillover effects on production are wide-ranging and significant.

When we compare the different types of spillover effects, different results are obtained. In the case of R&D spillover effects, we find that these are significant when weighted by the distance in kilometres, so that spillovers tend to be limited in clusters or areas in the close vicinity of the source. We could say that part of the knowledge that generates externalities relies on formal contacts and remains more localized (Audrestch and Feldman 2004, Sonn and Storper 2008, Charlot and Duranton 2006, Ianmarino and McCann 2006). We also find trade-related interregional R&D spillovers confirming that the more commercial regions improve their production compared to those that have few trading relationships. It is therefore confirmed that trade partners are an important way of transmission of knowledge among regions.

In the case of the spillover effects of ICT capital we observe that they are not significant when weighted by trade flows. The diffusion of ICT technologies may have been significant in some segments (increased penetration of Internet, spread of mobile phones, etc) but the low level of such investment compared to the size of trade flows and the paucity of telematics work in many Spanish regions means that a higher proportion of trade between regions does not translate into a greater effect of ICT on production. It could be affirmed that there is a failure of the capacity of the environment to take advantage of the new technologies, i.e. there is a lack of connection between investment in ICT and utilisation of such technologies for trade. On the other hand, the ICT capital of the neighbouring regions does generate a positive effect on the region. In this case, the same reasoning can be applied as in the case of R&D spillovers. It can be

3 Nevertheless, authors like Eaton and Kortum (1999) also find that when the five leading world economies are analysed, knowledge spillovers are almost as important as domestic knowledge.

said that having ICT capital is not automatically equivalent to economically useful knowledge diffusion. Codified information can be transmitted over increasingly large distances, but tacit knowledge tends to be geographically bounded and a key factor behind the concentration of new communication infrastructures.

5. Conclusions

In this paper we present the results corresponding to the effect of knowledge-based assets (R&D and ICT) on regional production. Using the regional information provided by INE from 1987 to 2004 and using new data on investment and capital services from the EU Klems project we estimate a production function. The main results are, first, a positive effect of R&D capital and ICT capital on production, though as a whole their contribution to production growth is moderate. Besides, ICT capital has a greater effect on production than R&D capital.

Second, we find evidence of a greater effect of the spillovers of R&D and ICT capital on regional production. Spillovers are always significant when they come from nearby regions. This confirms, as do other authors in the literature, the existence of clusters or technological districts. When spillovers are weighted by the importance of trade between regions, these are observed to affect production positively in the case of R&D capital; however we do not find evidence of significant effects of inter-regional commerce in the case of ICT capital .

Therefore, the greater availability of telecommunications infrastructures has not propitiated organisational changes at a general level, so that firms have not always exploited the enormous possibilities offered by ICT to improve their management and control, and consequently to increase production.

In terms of economic policy, given the existence of wide spillover effects, we defend a common, not only regional, policy of innovation to take advantage of the interconnections among regions. In addition, measures must be taken to create an environment that can exploit the new technologies, especially in improving education and training with the aim of absorbing the rapid diffusion of these new technologies.

References

Aghion, P. and Howitt, P. (1992) "A model of growth through creative destruction", *Econometrica*, 60(2): 323-351.

Bailey, M.N. (2003) "The sources of the economic growth on the OECD countries: a review article", *International Productivity Monitor*, 7, autumn 2003

Beneito, P. (2001) "R&D productivity and spillovers at the firms level: evidence from a sapnish panel data", Investigaciones Económicas, vol 25(2): 289-313.

Berstein, J. and Mohen, J. (1994): "International R&D spillovers between U.S. and Japanese R&D intensive sectors" *Working paper NBER No. 4682*

Bottazzi, L., Peri, G. (2003). Innovation and spillovers in regions: evidence from European patent data. European Economic Review, 47: 687-710.

Christensen, L.R.; Cummings, D.C. and D.W. Jorgenson (1981): "Relative Productivity Levels", *European Economic Review* 16: 61-94

Coe, D. and Helpman, E. (1995): "International R&D spillovers". *European Economic Review, 39:* 859-887.

Colechia, A. and P. Schreyer (2001) "ICT Investment and economic growth in the 1990's: is the United States a unique case? A comparative study of nine OECD countries", *Reviewf of Economic Dynamics*, 5 (2): 408-42.

Denny, M. Fuss, M. and J. D. May (1981). "Intertemporal Changes in Regional Productivity in Canadian Manufacturing," *Canadian Journal of Economics*, 14(3): 390-408, Canadian Economics Association.

Dorwick, S. and Neguyen, D. (1989): "OCDE comparative economic growth 1950-85: catch-up and convergence", *American Economic Review*, 79: 1010-1030.

Eaton, S., Kortum, S. (1999). “International Technology Diffusion: theory and measurement”. *International Economic Review,* 40: 537-570.

Freund, C. and D. Weinhold (2004) “The effect of the internet on international trade” , *Journal of International Economics*, 62 (1): 171-89

Glaeser, E., Kallal, H., Scheinkman, J. and Schleifer, A. (1992): “Growth of cities”, *Journal of Political Economy,* vol. 100: 1126-1152.

Grossman, G. y Helpman, E. (1991) *Innovation and growth in the global economy*, MIT Press, Cambridge.

Grossman, G., Helpman, E. (1994). “Protection for sale”. *American Economic Review,* 84: 833-850.

Hall, B. (1988): “L´effet des depenses en R&D sur la productivité du travail au Quebec”, *Acutalité Economique, 64(3).*

Hall, B. and Maraisse, J. (1992): "Exploring the relationship between R&D and productivity in French manufacturing firms", *NBER Working Paper* No. 3956.

Hernando, I. y S. Nuñez (2004): **"**The contribution of ICT to economic activity: a growth accounting exercise with Spanish firm-level data**",** *Investigaciones Económicas*, 28(2): 315-348.

Jaffe, A., Trajtenberg, M. and Henderson, R. (1993) “Geographic localization of knowledge spillovers as evidenced by patent citation”, *Quaterly Journal of Economics,* 108 (3)*: 577-598.*

Jaffe, A. (1986):"Technological opportunity and spillovers of R&D", *American Economic Review*, 76: 984-1001.

Jones, C. (1995) “ R&D based models of economic growth” *Journal of Political Economy*, 103 (4): 759-784.

Jorgensen, D. W. and Nishimizu, M. (1978), "U.S. and Japanese economic growth 1952-74, an international comparison", *Economic Journal*, 88 (352), 707-727.

Hulten, C.R. and Schwab, R.M. (1993). "Endogenous growth, public capital, and the convergence of regional manufacturing industries", *Working Paper No. 4538,* National Bureau of Economic Research.

Jorgenson, D.W. and K. Stiroh (2000) "Rising the speed limit: US economic growth on the information age" *Brookings Papers on Economic Activity,* 19 (2): 347-420

Keller, W. (2002) "Geographic localization of international technology diffusion", *American Economic Review,* 92 (1): *120-142*

Krugman, P. (1991a): "Increasing returns and economic geography", *Journal of Political Economy,* 99 (3): 483-499

Krugman, P. (1991b): *Geography and Trade,* Cambridge, Mass. MIT Press

Lichtenberg, F. (1992) "R&D investment and international productivity differences" *NBER Working Paper* No. 4161.

Mas, M. and J. Quesada (2005) "ICT and Economic Growth in Spain 1985-2002". *EU Klems Working paper series,* number 1

O'Mahony, M. and B. Van Ark (eds) (2003) *EU productivity and competitiviness: an industry perspectivie,* European Comission.

Pakes, A. and Schankerman, M. (1984): "The rate of obsolescence of patents, research gestation lags and the private rate of return to research resources", in *R&D, patents and productivity.* The University of Chicago Press.

Pilat, D. (2003) "ICT and economic growth. Evidence from OECD countries, industries and firms", DSTI, ICCP (2003) 2, OECD Paris

Romer, P. (1990) “Endogenous technical change”, *Journal of Political Economy,* 98 (5)*:* S71-S102.

Scherer, F.M. (1982): "Demand pull and technological innovation: Schmoockler revisited", *Journal of Industrial Economics,* 30: 5-237.

Silverberg, G. and Soete, L. (1994): *The economics of growth and technical change.* Edward Elgar Press ed.

Solow, R. M. (1957): "Technical Change and the Aggregate Production Function", *The Review of Economics and Statistics* 39 (Aug.), 312-320.

Spence, A.M. (1984): "Cost reduction, competition and industry performance", *Econometrica*, 52: 101-121.

Stiroh, K. (2003) “Information technology and US productivity revival: what do the industry data say” *American Economic Review*, 92(5): 1559-1576.

Van Ark, B. and M. Timmer (2004) “Computers and the big divide: rpoductivity growth in the European Union and United States”, in Mas and Schreyrer (eds) *Growth, capital stock and new technologies***,** BBVA Foundation, Bilbao

Verspagen, B. (1992): "Endogenous innovation in neoclassical growth models: a survey", *Journal of Macroeconomics* 14(4): 631-662.

Verspagen, B. (1994): "Technology and growth: the complex dynamics of convergence and divergence" en *Silberberg, G. and Soete, L. (eds.) The economics of growth and technical change*.

Figure 1. Evolution of Capital stocks in Spain. 1987=100

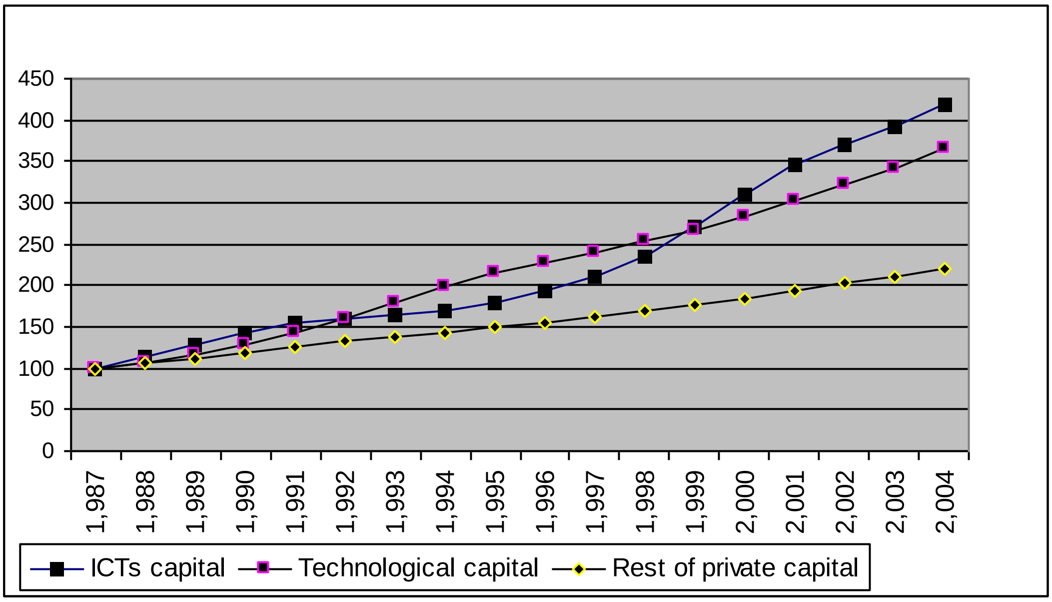
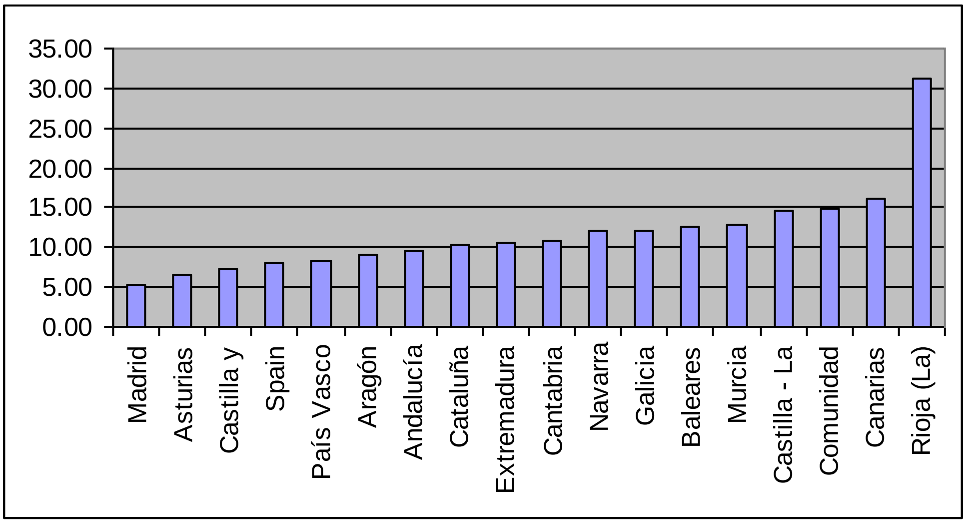


Figure 2. Annual growth rates of Capital stocks in the Spanish regions: 1987-2004

a) Technological capital



b) ITCs capital

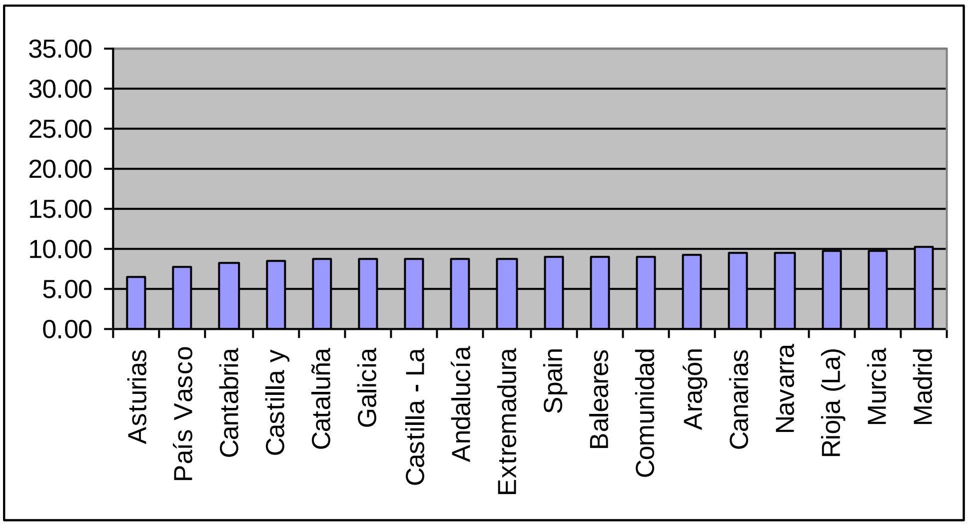


Table 1. Regional distribution of ITCs capital and technological capital

	ITC Capital			Technological capital		
	1,987	**1,995**	**2,004**	**1,987**	**1,995**	**2,004**
Andalucía	13.33	13.25	13.09	7.13	8.02	8.91
Aragón	3.22	3.28	3.40	2.00	2.37	2.35
Asturias (Principado d	3.25	2.48	2.24	2.03	1.70	1.59
Baleares (Islas)	2.65	2.95	2.71	0.28	0.29	0.57
Canarias	4.26	4.78	4.69	0.58	1.44	2.11
Cantabria	1.48	1.26	1.31	0.49	0.67	0.77
Castilla - La Mancha	3.88	3.82	3.79	0.52	0.71	1.47
Castilla y León	6.16	5.83	5.68	4.76	4.18	4.15
Cataluña	19.39	19.11	18.50	15.20	18.93	21.60
Comunidad Valencian	10.00	9.86	10.27	2.28	4.66	6.71
Extremadura	1.96	2.02	1.94	0.59	0.65	0.88
Galicia	5.58	5.51	5.39	1.82	2.45	3.46
Madrid (Comunidad d	13.12	15.26	15.97	52.48	42.64	33.40
Murcia (Región de)	2.19	2.10	2.53	0.71	1.27	1.50
Navarra (Comunidad F	1.61	1.76	1.78	0.91	1.48	1.69
País Vasco	7.24	6.02	5.96	8.21	8.39	8.48
Rioja (La)	0.67	0.70	0.75	0.01	0.15	0.36
Spain	100.00	100.00	100.00	100.00	100.00	100.00

Table 2. Capital stock per worker (euros)

	ITC Capital			Technological capital		
	1,987	**1,995**	**2,004**	**1,987**	**1,995**	**2,004**
Andalucía	1,874	3,115	4,856	470	1,067	1,353
Aragón	1,740	3,132	5,572	507	1,281	1,575
Asturias (Prin	1,999	3,059	5,599	583	1,186	1,621
Baleares (Isla	2,629	4,401	5,645	131	247	487
Canarias	2,323	4,010	5,983	149	682	1,101
Cantabria	2,109	3,217	5,382	326	971	1,294
Castilla - La l	1,758	3,125	5,005	111	328	792
Castilla y Leó	1,601	2,903	5,371	579	1,178	1,608
Cataluña	2,079	3,206	4,983	763	1,798	2,379
Comunidad V	1,762	2,875	4,972	188	769	1,328
Extremadura	1,530	3,043	5,416	215	556	1,001
Galicia	1,158	2,285	5,003	177	574	1,314
Madrid (Com	1,957	3,634	5,520	3,665	5,747	4,724
Murcia (Regi	1,691	2,630	4,796	257	900	1,164
Navarra (Con	1,878	3,405	5,500	493	1,621	2,127
País Vasco	2,385	3,370	5,593	1,266	2,661	3,256
Rioja (La)	1,461	2,759	4,911	9	340	976
Spain	1,867	3,168	5,212	871	1,787	2,126

Table 3. The effect of Technological capital and ICT capital on economic growth

	(1)	(2)	(3)
LnL	0.232 (0.023)	0.215 (0.022)	0.205 (0.020)
LnK	0.197 (0.041)	0.123 (0.043)	0.057 (0.039)
LnT	0.081 (1.965)	0.055 (0.040)	0.115 (0.036)
LnR	0.008 (0.004)	0.016 (0.004)	0.025 (0.004)
LnS_R(R&D-TF)		0.145 (0.109)	
LnS_T(ICT-TF)		0.158 (0.035)	
LnS_R(R&D-KM)			0.407 (0.150)
LnS_T(ICT-KM)			0.337 (0.041)
R2	0.99	0.99	0.99
Hausman test p-value	0.00	0.00	0.00

V.dep: Ln(Y)

Standard errors in parentheses

Estimation with fixed effects and time effects