TECHNOLOGICAL ACTIVITY AND PRODUCTIVITY IN 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 in the period 1986-96. It quantifies the effect of the regions´ own technological innovation, and the externalities associated with technological capital, on regional development. The analysis is based on the estimation of production functions and an equation explaining total factor productivity. Although a positive significant effect is obtained at national level on a long term horizon, the significance of the effect of technological activities on the productivity of the Spanish regions in the period 1987-96 depends on the indicator used. However, the technological spillover effects between regions are always highly significant regardless of the indicator used.

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1. Introduction*

Reviewing the economic literature it is easy to find affirmations that technological innovation influences the economic position of innovating agents: firms, industries or countries. The empirical evidence shows, on the one hand, that this strategy has positive effects on the economic results of these productive units, and on the other hand, that it increases the productivity of the factors used by them in the process of production.

Solow (1957) was a pioneer in suggesting that national economic growth could not be satisfactorily explained in terms of private inputs, capital and labour, attributing part of the unexplained growth to advances in technological knowledge. But, whereas neoclassical theory treated technological progress as an exogenous process and focused on capital accumulation as the main endogenous source of output increase, the new theories of economic growth consider that economic progress should be understood as an endogenous process, so that the formation of physical, human and technological capital becomes an essential factor in growth, i.e. economic growth is due to the technological change resulting from the investment in R&D and human capital made by the economic agents themselves, the transfer of technology through an import-oriented economy, the existence of increasing returns to scale, spillovers or externalities or even government policies (e.g. infrastructure improvements). Authors like Quah (1999) even maintain that characteristics of demand such as consumers' attitudes to goods of complex technology, the process of learning in consumption, and consumers' tendency or ability to acquire technologically advanced goods, may also affect the economic growth of a country.

Nevertheless, despite the different approaches adopted in the literature, authors such as Barro (1998, p 25) conclude that studies based on growth accounting provide very useful information for framing the themes of endogenous growth so that such theories can be used as extensions of traditional growth accounting. Consequently, Barro maintains that the two theories of economic growth are complementary.

A common characteristic of some of these studies is that they do not explicitly consider the territorial aspect. However it seems safe to affirm that if the rate of technical progress differs among nations, industries and firms, it will also differ among regions due to

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variations in productive structures and the diversity of firms in them. In this sense, it can be maintained that the geographical region or territory is a strategic factor in development,due perhaps to regional differences in market relationships, forms of regulation, etc., leading to divergences in the organisation of production and in the capacity to innovate. The empirical studies carried out at regional level support the idea that technological change is a factor associated with the economic development of a region. The spatial effect/distribution of technological change has been analysed by Ciciotti (1983), Oakey (1984, 1985), Brugger and Stuckey (1987), Todtling (1990) and recently Wakelin (2001), finding a direct correlation between technological and economic development.

In accordance with these arguments, this study aims to quantify the effect of technological innovation on the productivity of the regions of Spain, which can be considered differentiated regions insofar as each is a territorial unit characterised by a productive specialisation and an endowment of factors that distinguish it from the rest.

With the results obtained we will be able to verify whether there exists a spatially differentiated process of innovation in the context of the Spanish regions, identifying those that have comparative advantages in technology, and the role of the regional technology policy. The importance of this analysis lies in the light it sheds when evaluating measures of economic policy aimed at reducing the inequalities among regions and favouring sustained long-term growth.

The paper is organised as follows. The second section sets out the context in which we analyse the effects of technological innovation on regional development. In the third section we present the statistical sources and variables used in the empirical analysis. The fourth section analyses a broad set of technological indicators in order to explore the technological reality of the Spanish regions. The fifth section shows the results obtained from the estimation of production functions and of the determinants of total factor productivity (TFP). Finally, the sixth section offers the conclusions of the study.

2. The contribution of technological innovation to development

Growth theory posits that among the sources of growth generation are increases in the factors of production and the appearance of technological improvements. Thus the economic growth of countries or regions differs according to their different rates of growth of the factors of production and of technological innovation. The latter allows new productive knowledge to be obtained which, once applied, generates new goods and services or produces the existing ones more efficiently. For this reason, technical change has been revealed as a substantial part of the growth of production in numerous countries.

A further question is how countries or regions access this technology. The most important way is by generating theirown technology 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 import of foreign innovations through the trade in goods and services are also ways of accessing technology, and consequently favour economic growth.

Reviewing the 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). Romer's model 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. Aghion and Howitt (1992) conclude that growth is generated by a sequence of quality improving innovations that result from certain research activities while Jones (1995) extends the Romer model to analyse the long run growth rate of industrialised countries that is 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 as 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 their 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 (2002a) 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 as well as internationally through trade in differentiated intermediate goods. This process of generation or application of technological knowledge cannot take place without qualified labour or human capital, as a significant part of technology is formed by the body of knowledge acquired by people with access to higher levels of education or to training programs established by firms. In this sense, then, the technical progress or technological innovation of each territory is made explicit not only in its expenditure on R&D but also in its human capital and its capacity to absorb the spillovers generated by other territories.

In relation to the spillover effects, Coe and Helpman (1995) estimate the external effect of R&D on countries' productivity. For the construction of foreign R&D capital stocks, they use import-weighted sums of trade partners' cumulative R&D spending, and their evidence suggests that at least in the smaller countries the effect of foreign R&D capital on productivity is greater than that of the domestic R&D capital stock. Keller (2001, 2002b) concludes that the international diffusion of technology is a major determinant of income in the world. Conley et al. (1999) and Ciccone (2002) consider human capital density as an externality correlated with productivity. Branstetter (2001), following the arguments of Helpman (1997), finds support for the contribution of R&D to technological advances and total factor productivity, and following Jaffe, Trajtenberg and Henderson (1992) and Branstetter (1996), supports the existence of R&D spillovers. However, he emphasises that location matters, because given the role played by multinational firms in global R&D, their location decisions are certainly worth. And, finally, Audretsch and Feldman (1996) and Bottazzi and Peri (2003) find positive effects from research externalities on countries' innovation rather than on countries' productivity.

Growth theory, in general, considers differences in the growth rates of factors of production to be the main cause of the divergences in production among countries or territories, and it has therefore been studied on numerous occasions. Technology has always played an important role in these models; however, there are alternative approaches to the analytical procedure. A first approach is to consider technological capital as an ordinary input in the production function. An alternative approach is to model technological progress, or the growth of total factor productivity (*TFP*) in terms, among other factors, of technological capital. In this study we use both approaches.

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, is:

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

where:

Y_{it} = private production of region *i* in year *t*.
$A_{it} = A_{i0} e^{\mu t}$
A_{i0} = initial level of efficiency or productivity for each region *i* in year 0
μ= rate of disembodied 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*.
H_{it} = human capital of region *i* in year *t*.

And taking logarithms:

$$LnY_{it} = LnA_{i0} + \mu t + \alpha LnL_{it} + \beta LnK_{it} + \varepsilon LnH_{it} + \gamma LnR_{it} \qquad (2)$$

On the basis of this equation it is possible to test the hypothesis of the existence of constant returns to scale in all inputs ($\alpha+\beta+\varepsilon+\gamma=1$). To test this hypothesis, equation (2) will be re-parametered as follows:

$$\begin{aligned} Ln(Y/L)_{it} = LnA_{i0} + \mu t + (\alpha + \beta + \varepsilon + \gamma - 1)LnL_{it} + \beta Ln(K/L)_{it} \\ + \varepsilon Ln(H/L)_{it} + \gamma Ln(R/L)_{it} \end{aligned} \qquad (3)$$

If the coefficient accompanying the labour factor is not statistically significant, it is not possible to reject the existence of constant returns to scale in all inputs. Thus (3) enables us to obtain the effects of the factors of production considered over time on the labour productivity.

To calculate the value of *TFP*, Solow (1957) considers a production function with two factors (physical capital and labour) presenting constant returns to scale:

$$Y_{it} = A_{it} F(L_{it}, K_{it}) \qquad (4)$$

On the basis of (4), assuming perfect competition and maximization of profits, the total factor productivity *TFP* is calculated as a residual: the difference between output and the value given to the contribution of the inputs.

If dots above the variables denote growth rates and s_{ki} and s_{Li} the respective participations of capital and labour in output ($s_{ki} + s_{Li} = 1$), the growth rate of Solow´s residual (*TFP*) is expressed as:

$$\dot{TFP}_{it} = \dot{A}_{it} = \dot{Y}_{it} - s_{L,it}\,\dot{L}_{it} - s_{K,it}\,\dot{K}_{it} \tag{5}$$

and can be calculated as successive differences in logarithms and using average shares[1]:

$$\begin{aligned}\dot{TFP}_{it} &= [LnTFP_{it} - LnTFP_{i,t-1}] = [LnY_{it} - LnY_{i,t-1}] - [1/2(s_{Li,t} + s_{Li,t-1})][LnL_{it} - LnL_{i,t-1}] \\ &- [1/2(s_{ki,t} + s_{ki,t-1})][LnK_{it} - LnK_{i,t-1}]\end{aligned} \tag{6}$$

Of interest for our analysis of regional productivity is not only the behaviour of *TFP*, but also comparison of the *TFP* levels of regions at a given time. As shown by Jorgensen and Nishimizu (1978), Denny, Fuss and May (1981) and Christensen, Cummings and Jorgensen (1981), the expression corresponding to (6) in relative efficiency indexes would be given by equation (7). According to this expression, the difference between the technological level of region "*i*" in period "*t*" and region "*j*" in period "*b*" is equal to the logarithmic difference in output minus the weighted logarithmic differences of the inputs, where the shares are the simple averages of the shares in the two regions:

$$\begin{aligned}[LnTFP_{it} - LnTFP_{jb}] &= [LnY_{it} - LnY_{jb}] - [1/2(s_{Li,t} + s_{Lj,b})][LnL_{it} - LnL_{jb}] \\ &- [1/2(s_{Ki,t} + s_{Kj,b})][LnK_{it} - LnK_{jb}]\end{aligned} \tag{7}$$

From (7), the resulting indices of TFP_{it} of region "*i*" at time "*t*" can be expressed in relation to the efficiency of a base region ("*j*") in a base year ("*b*"). Spain has been taken as the base region and the initial year, 1986, as the base year.

The explicit consideration of human capital and technological capital transforms the standard production function into:

1 See Diewert (1976), Jorgensen and Nishimizu (19878), Christensen, Cummings and Jorgensen (1981), Hulten and Schwab (1993).

$$Y_{it} = A_{it} F(L_{it}, K_{it}, H_{it}, R_{it}) \quad (8)$$

From (8) and deriving with respect to time:

$$\dot{Y}_{it} = \dot{A}_{it} + \varepsilon_{L,it} \dot{L}_{it} + \varepsilon_{K,it} \dot{K}_{it} + \varepsilon_{H,it} \dot{H} + \varepsilon_{R,it} \dot{R} \quad (9)$$

where $\varepsilon_{L,it}$, $\varepsilon_{K,it}$, $\varepsilon_{H,it}$, and $\varepsilon_{R,it}$ are the elasticities of output with respect to labour (L), private capital (K), human capital (H) and technological capital (R), respectively. If we do not impose any restriction on the type of returns to scale and if we assume, extending Hulten and Schwab´s approach[2], that labour, human capital and technological capital receive shares in income according to their marginal productivity, that is, if we assume that $\varepsilon_{L,it}=s_{L,it}$, $\varepsilon_{H,it}=s_{H,it}$, $\varepsilon_{R,it}=s_{R,it}$, expression (9) can be written as

$$\begin{aligned} \dot{A}_{it} &= \dot{Y}_{it} - s_{L,it} \dot{L}_{it} - s_{K,it} \dot{K}_{it} + (1-\rho_{it}) \dot{K}_{it} - \varepsilon_{H,it} \dot{H} - \varepsilon_{R,it} \dot{R} \Rightarrow \\ TFP &= \dot{A}_{it} + (\rho_{it} - 1) \dot{K}_{it} + \varepsilon_{H,it} \dot{H} + \varepsilon_{R,it} \dot{R} \end{aligned} \quad (10)$$

where $\rho_{it}=\varepsilon_{L,it}+\varepsilon_{K,it}+\varepsilon_{H,it}+\varepsilon_{R,it}$ indicates the type of returns to scale implicit in the production function.

If we assume that ρ and ε are constant over time and equal across regions, and integrating (10) over time, we obtain

$$L\mathrm{n}\, TFP_{it+} = L\mathrm{n}\, A_{it} + (\rho - 1) LnK_{it} + \varepsilon_H LnH_{it} + \varepsilon_R \ln R_{it} \quad (11)$$

Finally, if we assume that disembodied technical progress grows at a rate μ,

$$LnA_{it} = LnA_{i0} + \mu t \quad (12)$$

expression (11) becomes

$$L\mathrm{n}\, TFP_{it} = L\mathrm{n}\, A_{i0} + \mu t + (\rho - 1) LnK_{it} + \varepsilon_H LnH_{it} + \varepsilon_R L\mathrm{n}\, R_{it} \quad (13)$$

2 See Hulten and Schwab (1993)

Equation (13) indicates that the level of *TFP* is determined by five elements: (a) the initial level of efficiency, $A_{io;}$ (b) the exogenous growth rate of technical change (μ); (c) the contribution of human capital, with elasticity ε_H; (d) the contribution of technological capital, with elasticity (ε_R); and (e) a term which reflects the discrepancies with respect to the case of constant returns to scale (ρ-1). This equation will be the point of reference in the estimation presented below.

The technological capital of each region is formed by the technological innovations generated in that region, and the spillovers associated with technological capital produced outside the region but "absorbed" by each region. That is, once the impact on productivity of the technological activities generated in each region has been analysed, we aim to analyse whether the increase in productivity can also be explained by the spillovers associated with technological capital produced outside the region.

One of the main difficulties faced by firms when they carry out research 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. Authors such as Dorwick and Neguyen (1989) affirm 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. For this reason it is important to verify whether the regions become more productive as a result of capturing spillovers from outside their territory.

A further question is to identify where these spillovers come from. Among the first authors to introduce the concept of spillover 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 spillover such as R&D expenditure by other firms or industries, weighted where appropriate for "technological distance", "technological opportunity" or "intention to innovate".

In this sense, it is difficult to measure the “technological distance” among regions of the same country. Nevertheless, according to Glaeser et al. (1992) the transmission of technological knowledge occurs within a limited geographical unit. And more recently, Bottazzi and Peri (2003) find that spillovers are very localized and exist only within a distance of 300 kilometres 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 to each other are important, as although the cost of transmitting information may be invariable with distance, the cost of transmitting new technological knowledge, which is not generally done explicitly, does vary with distance.

In this paper we test the hypothesis that productivity is increased by the technology or R&D of the "relevant" neighbours. 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", that is regions using the same or related technology (this can be easily measured by patents originated in one industry but used in another). But, to measure this proximity we follow Grossman and Helpman (1994) and Coe and Helpman (1995), who support the idea that the new theory of economic growth underlines trade as a transmission mechanism linking a country's productivity gains to economic development in its trade partner. More precisely, not only does a region's productivity depend on its own technological research, it also depends on the technology of its trade partners, i.e. the more open an economy is to trade, the stronger the effect of foreign or neighbouring R&D on domestic productivity. Coe and Helpman (1995) underline that beneficial effects from domestic R&D have been well documented in the literature, but evidence of the importance of trading partners' R&D is less developed.

In the same line, Engelbrecht (1997) extends the study by Coe and Helpman (1995) by including a human capital variable to account for innovation outside the R&D sector and other aspects of human capital not captured by formal R&D.

However, in an earlier work, Verspagen (1994) showed the association between different types of knowledge accumulation (R&D, patents and knowledge spillovers) and cross-country growth patterns. Although he found that traditional factors (labour and investment in fixed capital) and technology related factors (R&D and patent stocks) are positively related to growth, knowledge spillovers in technology payments or imports of capital in intermediate goods did not turn up significantly in the regressions.

Besides the importance of trade in the transmission of knowledge in innovative activity, and following authors like Audrestch and Feldman (1996) and Bottazzi and Peri

(2003), in this paper we also observe that knowledge spillovers are more likely to occur within close geographic proximity to the source of knowledge. It is therefore necessary to apply a weighting system to partners' R&D, as not all regions in Spain will have the same technological impact on, or from, each other due to geographical distance.

In this case we are accounting for knowledge spillovers in "geographical space" rather than in "technological distance", which is only possible between industries or firms that use the same patents or related technology. As Audretsch and Feldman (1996) and Peri (2002) argue, the "technological distance" only identifies the intensity and direction of knowledge flows but does not identify R&D externalities. In other words, "technological distance" does not capture non-technological sources of localized spillovers such as proximity to certain industry R&D, university research and skilled labour in which knowledge spillovers are presumably the most relevant. However, these spillovers are represented by geographical proximity.

3. Statistical sources and variables used

In order to analyse the contribution of human and technological 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 1986-1998 and are expressed in pesetas 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 Gross Value Added (at factor cost) and obtained from the Regional Accounts of Spain (base 1986) of the INE. In the course of the study, in some cases total GVA is used and in others private GVA. Since the INE only offers regional information on GVA until 1996, the values of total GVA for 1997 and 1998 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) Regionalised 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 1996.

d) The level of qualified labour of each region has been proxied through the percentage of the population with at least secondary education, this being the proxy used in Serrano (1996). This information is obtained from the *Fundación Bancaja* publication "Historical series of human capital: 1964-1992" by Mas, M., Pérez, F., Uriel, E. and Serrano, L.(1995). The last year available is 1998.

e) Regionalised R&D expenditure (R&D EXPENDITURE): obtained from the INE's publication "Statistics on activities in Scientific Research and Technological Development", except those for 1986 which were obtained from the estimations by Martin et al. (1991). The publication offers information both on total R&D expenditure and on disaggregated figures for the following sectors: Firms, Public Administrations, Higher Education and Private Non-profit Bodies (PNPB). The latest regionalised information available is for 1998, although in this year (as in 1996) no information is offered on PNPBs.

f) 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:

$$R_{i,t} = (1-\delta)R_{i,t-1} + I_{i,t-\theta} \tag{14}$$

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 (14) and we further consider that investment in R&D capital increases year on year by a proportion g, we find that:

$$R_{i,t} = \frac{I_{i,t-\theta}}{g+\delta} \tag{15}$$

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)[3].

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.

The use of the stock of technological capital as a proxy of technological activity can

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

have some limitations. In particular, it may occur that a part of the R&D spend does not materialise in new inventions or that there are problems with regard to the rationalisation of R&D because it is undertaken basically in headquarter locations. In this sense, it may occur that some small inventions obtained outside formal R&D laboratories are not considered as technological capital stock. In view of these limitations it is appropriate to use at the same time other measures of technological innovation to eliminate these problems.

Alternatively, the patents applied for by each of the regions (PAT) can be used as a proxy of the volume of innovation or of technological knowledge generated by them. Nevertheless, the use of patents as a measure of technological innovation is also subject to certain limitations. The first is that not all innovations are patented, as there are other ways to protect the output of innovation, such as industrial secrecy itself; the second is that the value of patents is heterogeneous, some being associated with great discoveries, others with less important novelties.

However, studies by authors such as Kamien and Schwartz (1982) specifically consider that these limitations are not an important part of innovation. Also, Griliches (1994) supports the use of patents as a measurement of technological capital, as he considers that patents can be taken as indicators of inventions, which are produced by a combination of the current R&D expenditure and the existing state of technological knowledge, incorporating the accumulated effects of science and the spillovers from previous research activities. More recently, Lach (1995) considered that patents are an alternative to a usual indicator of technological capital stock, the R&D stock. This author points out (p.101) that the parallel between the number of patents, the output of R&D, and the stock of technological knowledge, is subject to reservations, though it is the best information available at the moment. Patents, then, have been widely used as a measure of technological change in the economic literature, and will therefore be considered in this study as a proxy of the volume of technological innovation in a region.

g) Spillovers associated with technological activities: in order to analyse the contribution of spillovers of a technological nature to productivity at the regional level, two complementary measurements have been constructed which take into consideration the possibility that the spillovers captured by each region may come from other regions.

Specifically, the spillover effects of each region are constructed as a weighted sum of the technological capital of the rest of the regions:

$$SPILL = W_{NxN} R_{Nx1} \tag{16}$$

where W_{NxN} is the matrix of weightings of the technological capital stocks (R) 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 two alternative measurements of spillover effects. The weightings of the matrix are constructed as follows:

$$f_{ij}^{\ 1} = \frac{F_{ij}}{\sum_{j=1}^{N} F_{ij}} \tag{17}$$

$$f_{ij}^{\ 2} = \frac{Km_{ij}}{\sum_{j=1}^{N} Km_{ij}} \tag{18}$$

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, two measurements of spillover effects are calculated, both for technological capital and for patents:

1) SPILLR1 and SPILLP1 measure 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 stock of technological capital (and patents). 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.
2) SPILLR2 and SPILLP2 measure spillovers taking into account the geographical proximity (distance in Km) between regions, such that the nearer the other region, the greater the weighting given to its stock of technological capital (and patents).

To calculate the weightings matrix on the basis of the importance of trade flows we use the information supplied by the INE on trade flows by road (no information is available for other means of transport). Specifically, the variable that it supplies is the freight transported by road (thousands of tonnes) between regions (origin-destination matrix). In the case of weightings based on geographical proximity, we use the distance by road in Km. between the capitals of each region. Since the flows refer to road transport, there is no information for the island regions (Balearics and Canaries), so the sample consists of 15 regions.

4. R&D activities in the Spanish regions

To show the technological position of the Spanish regions we will start by presenting the main indicators of technological activities. The first problem to be dealt with is to determine which is the most suitable indicator of innovation. Technological innovation can be measured from two viewpoints: on the one hand, the input of the innovation, i.e. the volume of resources devoted to technological activities and on the other the output or the results obtained after investing in innovation. The most widely used measure of input to innovation is R&D expenditure or the stock of technological capital, while the output of innovation is usually measured by the number of patents or number of process or product innovations produced. Although both measures are a proxy for innovation they could represent different parts of the innovation process. For example, patents are more related to novel knowledge, while R&D may also be related to technological imitation as pointed out by Cohen and Levinthal (1989).

There are also several problems with R&D expenditure and patents as measures of innovation. Regarding the former, Geroski (1994) expressly points out that these are not an essential input into production as there are firms which innovate without spending on R&D or having a formal R&D laboratory. There are three major problems of patents as a measure of innovation. First, not all inventions are patented, because firms can protect the returns to their investment in other ways such as through secrecy, lead-time advantages, and marketing. Second, firms patent for different reasons, not all of them related directly to commercial exploitation, for example, to protect an invention from imitation, to block competitors from patenting or pursuing a line of research, or to evaluate the productivity of their R&D activities.And, third, patents have widely varying commercial value and therefore significance with respect to innovation.

From the point of view of input, table 1 shows the total expenditure on R&D by the Spanish regions, expressed as a percentage of GVA. In Spain this ratio shows substantial growth in the period 1986-1998: from 0.64% of GVA in 1986, over the next twelve years it increased by 0.4 percentage points to 1.03%. However, despite the substantial increase in R&D expenditure, the ratio is well below the average for the European Union (around 1.83% of GDP), only the Madrid region being near average European levels.

The information by regions shows the existence of substantial differences. Using the information for the last year available (1998), only three regions stand above the national average: Madrid, Catalonia and the Basque Country. The Balearic Islands, Castilla-LaMancha and Extremadura are well below the average. It can also be observed that the ratio has increased in all the regions with the exception of Madrid and Castilla-León.

With the aim of analysing whether the inequalities among regions in the effort to innovate (R&D/GVA) have reduced, we will use the concepts of Φ- and ∃-convergence[4]. Φ-convergence is said to exist if the inequalities, measured by means of a dispersion statistic, decrease over time. ∃-convergence exists if, in the regions that started from lower R&D/GVA ratios, the rate of increase in this ratio is greater than in the regions that started at higher levels.

Figure 1 shows the phenomenon of σ-convergence by representing the standard deviation of the ratio (R&D/GVA). The substantial process of σ-convergence can be clearly seen, as the standard deviation has decreased by more than 50% from 1986 to 1998. Convergence is observed to have been greatest in the late 1980s and slower during the 1990s.

Using the concept of β-convergence, figure 2 shows the relationship between the rate of increase of the ratio (R&D/GVA) in the period 1986-98 and the initial level of the ratio in 1986. Convergence will exist if the regions that started out in 1986 with lower ratios (R&D/GVA) experience higher rates of increase and thus converge with the levels of the more technologically advanced regions. The graph shows a clear negative relation between the two variables, thus verifying the existence of β-convergence. Outstanding on the graph is the La Rioja region, which started from the lowest level in 1986 and experienced the fastest rate of increase. Madrid stands at the opposite extreme.

Table 2 contains the regional distribution of total expenditure on R&D. The information shows that in 1986 three regions (Madrid, Catalonia and the Basque Country) concentrated almost 75% of total R&D expenditure, while some regions did not even reach

4 See Barro and Sala-i-Martin (1992).

1% of the total (the case of the Balearics, the Canaries, Cantabria, Castilla La Mancha, Extremadura, La Rioja and Murcia). However, in 1998 Madrid, Catalonia and the Basque Country concentrated a lower percentage of R&D expenditure (62%) while the regions that started from less favourable positions had improved.

The INE's statistics on R&D activities enable us to distinguish four sectors: Firms, Public Administrations, Higher Education and Private Non-Profit Institutions (PNPI). Table 3 shows the percentage distribution by sectors of the R&D expenditure of the Spanish economy in the period 1986-97[5]. R&D expenditure by firms is the highest, 48.8% of the total in 1997. It is followed by Higher Education (32.7%) and Public Administrations (17.37%). Finally, the expenditure by PNPIs accounts for only 1.1% of total R&D expenditure. The evolution of the percentage distribution over the period shows how expenditure by Firms and by Public Administrations has decreased in relative importance (by about 10 and 9 percentage points respectively between 1986 and 1997), a loss which has been absorbed by the notable growth of such expenditure by Higher Education.

Using the methodology described in the previous section, table 4 shows the importance of the technological capital of the Spanish regions in relation to GVA. For the Spanish economy as a whole, the technological capital / GVA ratio almost doubled from 1987 to 1998, representing 4.89% of GVA in the latter year. By regions, the high ratio of Madrid (11.7) stands out. Madrid, Catalonia and the Basque Country are above the average, and in the lowest position are the Balearics with a ratio of only 0.75% in 1998.

To sum up, the information so far verifies the existence of substantial differences among regions in expenditure on R&D, differences which have decreased over time. Thus the regions that in 1986 started from higher levels of the ratio (R&D/GVA) experienced lower rates of growth than the regions with lower initial ratios. Sector detail shows that there are important differences in all of them, though less notable in the case of expenditure by Higher Education.

The indicators of technological activity used so far in this section refer to what the literature calls the input of innovation. With respect to the output of innovation, the statistical information available only offers information on the number of patents applied for from the Spanish Office of Patents and Trade Marks.

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5 The INE does not offer the R&D expenditure of PNPIs for every year.

Table 5 shows the number of patents applied for in the different Spanish regions between 1986 and 1999, while table 6 offers the regional distribution of the total number of patents. As can be observed, the number of patents applied for in 1999 was 2404, and the number had increased during the 1990s more slowly than during the 1980s. The percentage distribution shows that Catalonia and Madrid concentrate nearly 50% of the total of patents applied for in 1999, as against 63% in 1986, having thus lost relative weight in the course of time. They are followed in importance, at a distance, by the Valencia region (14%), Andalusia (8%), and the Basque Country (8%).

5. Innovation as a source of productivity growth

The importance of gains in total factor productivity as a source of economic growth is widely known. The studies of the specific case of the Spanish economy (Pérez et al., 1997) show that gains in productivity (*TFP*) explain more than two thirds of the growth in production, the process of capitalisation (increases in the capital-labour ratio) being responsible for the remaining third.

Of the various sources of productivity growth (human capital, public capital, efficiency gains, etc.) a number of studies have centred on the importance of R&D. In the specific case of the Spanish economy, the limitations imposed by the scarcity of information on R&D expenditure mean that there is very little empirical evidence; those studies that have been made centre on the industrial sector or on the aggregate of the national economy[6]. At regional level, as far as we know, no study has been published quantifying the effect of technological activities.

Before analysing the effect of technological activities on the Spanish regions, it is of interest to analyse the aggregate of the Spanish economy, using the information provided since 1964 by the INE[7]. For this purpose we have estimated the stock of technological capital by the methodology detailed above. This analysis presents two advantages: a) by covering a large number of years (from 1964 to 1996) it offers a view of the long term effect of technological capital, as against the short term analysis possible with the information available at regional level; and b) the estimation of the elasticity of technological capital on a

6 See the studies by Beneito (2000), Grandón and Rodriguez (1991) for the industrial sector, and Fernández and Polo (1997) and Crespo and Velázquez (1999) for the aggregate of the economy.
7 The INE has provided aggregate information at national level on R&D expenditure since 1964, except for the years 1965, 1966, 1968 and 1977. In these four years, the information has been estimated by interpolation

national scale implicitly captures possible spillover effects between regions, and an aggregate elasticity can be expected to be higher than one obtained at regional level.

Table 7 offers the results of estimating the aggregate production function (expression 3) for the private sector of the Spanish economy for the period 1965-96[8]. The results show an elasticity of technological capital, 0.277, relatively similar to that of human capital, 0.269, both parameters being statistically significant. Consequently, the long term results show the importance of technological capital in explaining the evolution of the productivity of labour in the Spanish private sector[9]. Authors like Fagerberg and Verspagen (1996) and Fagerberg, Verspagen and Caniels (1997) using data on several regions of the European Union, also obtain results that emphasize the importance of R&D efforts for growth. In fact they remark that regional differences in R&D have a diverging impact.

Table 8 presents the results of the estimation of the production function at regional level for the period 1987-96. Since a panel of data is available we will explore the time dimension of the data with panel techniques (fixed effects models - FE - versus random effect models - RE). Both individual and time effects are introduced into the estimation. As shown by the value of the Hausman test, individual effects are correlated with the regressors, so we will centre the discussion on the results obtained using the least squares dummy variable estimator (fixed effects model), since the GLS estimator of the random effects model is not consistent. In this way we avoid biases due to possible unobservable effects attributable to firms, correlated with the other regressors. In the context of the production function, the unobservable variables refer to characteristics of the regional environment such as greater endowment of infrastructures, the existence of a regional policy to encourage innovation, etc.

Part (1) of the table gives the results referring to the total stock of technological capital. The results show an elasticity of private capital of 0.313, and of skilled labour of 0.306, a result in agreement with Serrano (1996). The first result is coherent with the results predicted by economic theory, indicating that the positive and significant coefficient of human capital suggests that knowledge produced and incorporated into work contributes positively to increasing productivity. On the other hand, technological capital does not appear as a relevant factor of production given its non-significance. The results obtained after estimating the spillover effects associated with technological capital are reported in parts (2)

8 The sources of information used are the INE's National Accounts for production and the estimations by *Fundación Bancaja* (based in turn on the EPA) for employment and human capital.
9 Both these results and those next offered at regional level are estimated imposing the hypothesis of constant returns to scale, since it is not possible to reject this hypothesis. The results are available to interested readers.

and (3); a significant effect is obtained when the spillovers are constructed both in terms of the intensity of trade flows (SPILLR1) and in terms of the geographical proximity between regions (SPILLR2). The importance of spillovers in the growth of a region is therefore verified.

An interesting result is the loss of explanatory power of human capital once the geographical spillovers are introduced. This result points to the possible existence of a complementary relationship between human capital and technological spillovers, in connection with the results of Barrio et al. (2001 and 2002). According to these authors, the high overlap between human capital and technological knowledge makes it impossible to separate fully the effect of each variable.

Hence the estimation of a production function augmented by the introduction of technological capital shows that this factor of production is not significant in explaining the differences in productivity among the Spanish regions in the period 1987-96. Authors such as Sterlacchini (1989) and Geroski (1994), studying the effects of innovation on total factor productivity, have affirmed that it is the innovations used by the firm and not those produced by it that have the greatest effect on the dependent variable being analysed. More recently, Scotchmer (2004) points out that it is easy to waste money on a futile R&D venture but hard to convince a committee that a worthless invention should be patented. In that case we might expect that patents would explain a larger portion of productivity growth than R&D spending. This possibility will be tested. Nevertheless, this result contrasts with the significance of technological capital obtained at national level in the longer period 1964-96. Consequently, the short time dimension of the regional information may be behind the result obtained. An alternative explanation of this result is that some of the regions considered may lack sufficient R&D to activate their economic growth; however, this technological capital may give them sufficient capacity to take advantage of the more advanced technologies available in other regions, as shown by the significance of the spillovers.

Although the majority of the literature on productivity growth uses R&D as an indicator to explain productivity, it is also possible, as mentioned before, that the technological capital invested by the firm, representing the input to innovation, may not be the key variable in the analysis, as not all the resources invested result in marketable innovations which in turn affect productivity. It may be that R&D expenditure takes place basically at headquarters locations, and technological activity measured in this way is consequently significant for the country as a whole but not when each region is examined separately. Also, Spain’s industrial fabric is characterised by a large number of small firms which claim to make small innovations without having a formal R&D laboratory as shown in Gumbau (1994). In the same direction, Fisher, Frohlich and Gaessler (1994) in an exploration into the determinants of patent activities in Austria, affirm that patents are a proxy for the early stages of the innovation process. However there is no unity in the literature on this point. In small firms, patents may not be a better indicator of innovation than R&D because not many small firms take out patents. To clarify this, table 9 replaces technological capital by a direct measurement of the results of innovation: patents. In this case, we observe that the new technologies do affect labour productivity positively, while the sign and significance of human capital is maintained. Table 9 shows the importance of patents as an explanatory variable of productivity differences between regions, and the significance of spillovers whatever the proxy used: SPILLP1 or patents from the other regions of Spain weighted for the trade flows among them, or SPILLP2 or patents from the other regions of Spain weighted by the distance in kilometres between them.

So, if we use patents as a proxy of innovation, the results with regards to a region's own innovation perform better than stock of R&D. The importance of innovation in productivity and the results concerning spillovers are also satisfactory.

An alternative way to analyse the importance of technological activities in the explanation of differences in productivity among regions is to analyse their effect on an indicator of total productivity (*TFP*) in the use of the private factors capital and labour. Given that the growth of *TFP* or Solow's residual merely captures the growth of production not explained by the increase of private inputs, this unexplained growth may be explained by other factors such as the higher qualifications of the labour force (human capital) or by investment in R&D (technological capital).

The results of the estimation of the determinants of *TFP* obtained from equation (13) are offered in tables 10 and 11. The results broadly show the importance of human capital in explaining differences in *TFP* among regions, and once again the effect of technological capital is not significant when the input of innovation, i.e. stock of R&D capital, is used. However, the weighted R&D stock of the remaining regions of Spain is significant, as shown by the expanded estimation using spillovers SPILLR1 and SPILLR2. However, when the output of innovation or patents is used as a proxy for technological capital, the positive and significant results obtained above from the estimation of a production function are maintained. Also using a *TFP* approach, Engelbrecht (1997), studying the effect of international spillovers among OECD countries, found smaller, though statistically significant, coefficient estimates for domestic R&D capital and international R&D spillovers when human capital is considered[10]. However, Griffith, Redding and van Reenen, (2000) present empirical results showing the important role played by R&D to explain TFP growth considering the two faces of R&D: technological innovation and the ability to identify, assimilate and exploit knowledge from the environment.

Finally, it is of interest to analyze the importance of technological activities in the convergence process of the Spanish regions11. For this, we will estimate conditioned β-convergence equations (in the terminology of Barro and Sala-i-Martin, 1992) introducing as conditioning variables the proxy variables of the technological activities used in the study (technological capital, patents and spillover effects):

$$\frac{\log[(GVA/L)_{it}/(GVA/L)_{i,t-T}]}{T} = a + b\log(GVA/L)_{i,t-T} + c\log(R/GVA)_{i,t-T} + d\log(SPILLR/GVA)_{i,t-T} \qquad (19)$$

Table 12 shows the results of the estimations of equation (19) using technological capital stock (upper part of the table) as well as patents (lower part) as a proxy for technological activities. Given the negative (and significant) sign that accompanies the initial labour productivity, the results show that in the period analyzed a β-convergence process in the labour productivity of the Spanish regions has taken place as a consequence of a faster growth of labour productivity in those regions that began with lower levels. On the other hand, the results show that the variables tproxying technological activity are in no case significant. The technological gap existing between Spain and the European Union is also manifest in the existence of important inequalities in technological activities among the Spanish regions. The concentration of technological activities in a few regions could act as a brake to the convergence among regions. Therefore, this fact can explain the lack of significance of the technology variables in the convergence in GVA per worker. Nevertheless, the results should be interpreted with great caution due to the small number of available observations (17 regions)[12].

10 The results obtained reveal that the analysis of the importance of technological activities in the explanation of productivity gains of the Spanish regions is sensitive to the technological change indicator used (R&D vs. patents). In order to explain more in depth this result, it is interesting to carry out a principal components analysis of the two indicators with the purpose of including a single factor in the regression (we are thankful to one of the referees for this suggestion). The results show that the combination factor of the two variables of technological activity has no significant effect on productivity. However, the spillovers effects have a positive and statistically significant effect when the proxy variable of the spillovers effects is built using the distance between regions as a weight factor.

11 See in De la Fuente (2002) an analysis of the sources of convergence across the Spanish regions over the period 1964-91.

12 The results remain the same when using employment (L) as a variable of reference for technological

6. Conclusions

The objective of this paper is to analyse the effect of technological activities on the growth of the Spanish regions. Using the regional information provided by the INE from 1986 onwards on technological indicators (R&D expenditure, patents, etc.) we estimate the effect of innovation on the basis of the estimation of production functions expanded with technological capital, and of equations that explain total factor productivity. This technological capital is proxied, alternatively, by the stock of R&D capital or innovation input, and by patents or innovation output.

The principal results of the study are as follows:

a) There is a positive correlation between the technological position of the regions and their per capita income level. Thus, the regions that make a greater effort in innovation are those that reach higher levels of income.

b) The existence of a positive relationship between the levels of total factor productivity (*TFP*) and investment in R&D (as a percentage of GVA) indicates the importance of innovation in explaining the differences in productivity observed among Spanish regions. Consequently, it is necessary to invest in R&D to reach higher levels of productivity.

c) The regional information available shows the existence of substantial differences in the technological positions of Spanish regions, even though the differences have decreased over recent years. Thus there has been a clear process of convergence in the different technological indicators used.

d) The estimation of a production function augmented with human and technological capital for the whole of the private sector of the Spanish economy in the period 1965-96 shows a positive and significant elasticity of technological capital around 0.2, a similar value to that corresponding to human capital.

e) In the regional estimation for the period 1987-96, technological capital measured as stock of R&D is not significant, although the use of patents as output of innovation does offer

activities (denominator in expression 19) instead of GVA. Also, introducing the initial human capital as an significant results. However, we have verified the importance of spillovers, i.e. technological capital and patents of other regions weighted by the distance in kilometres or by the trade flows between them. In this sense it may be that some of the regions considered lack sufficient R&D to activate their economic growth; however, this technological capital may give them sufficient capacity to take advantage of the more advanced technologies available in other regions. Besides, Spain's industrial fabric is characterised by a large number of small firms which claim to make small innovations without having a formal R&D laboratory and even some authors affirm that patents are a proxy for the early stages of the innovation process in which several Spanish regions may be involved. However there is no unity in the literature on this point. Patents may not be a better indicator of innovation than R&D in small firms because these do not usually take out patents.

f) When the *TFP* approach is used to explain regional growth, the results obtained are similar to the above case: the relevant variable for explaining productivity growth in the Spanish regions is R&D output measured by patents. Furthermore, the importance of the spillover effects associated with technological activities is verified, the results being positive whether R&D stock or patents are used.

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explanatory variable of the labour productivity growth rate is not significant.

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TABLE 1: R&D EXPENDITURE BY REGIONS (% GVA)

	1986	1988	1990	1992	1994	1996	1998
Andalusia	0.38	0.44	0.51	0.57	0.56	0.70	0.77
Aragon	0.39	0.53	0.59	0.74	0.66	0.63	0.77
Asturias	0.41	0.42	0.54	0.60	0.52	0.61	0.60
Balearics	0.09	0.10	0.11	0.12	0.14	0.22	0.31
Canaries	0.13	0.18	0.29	0.56	0.58	0.56	0.60
Cantabria	0.25	0.50	0.43	0.47	0.61	0.58	0.92
Castilla-La Mancha	0.12	0.16	0.15	0.21	0.22	0.46	0.55
Castilla-León	0.48	0.50	0.58	0.66	0.72	0.58	0.57
Catalonia	0.59	0.81	0.93	1.04	0.96	1.04	1.21
Extremadura	0.23	0.30	0.30	0.37	0.40	0.37	0.45
Galicia	0.24	0.29	0.35	0.57	0.43	0.55	0.61
La Rioja	0.01	0.13	0.14	0.21	0.30	0.44	0.59
Madrid	1.99	2.13	2.61	2.44	2.13	1.95	1.95
Murcia	0.22	0.42	0.45	0.65	0.51	0.55	0.65
Navarra	0.44	0.38	0.96	1.07	0.80	0.91	1.01
Basque Country	0.77	1.01	1.21	1.23	1.14	1.41	1.45
Valencia Region	0.19	0.35	0.36	0.60	0.60	0.64	0.72
Total	0.64	0.78	0.92	1.00	0.92	0.95	1.03

Source: INE and FUNCAS

TABLE 2: REGIONAL DISTRIBUTION OF R&D EXPENDITURE (%)

	1986	1988	1990	1992	1994	1996	1998
Andalusia	7.89	7.53	7.45	7.71	8.23	9.84	9.87
Aragon	2.10	2.41	2.19	2.55	2.47	2.26	2.54
Asturias	1.93	1.52	1.57	1.59	1.46	1.65	1.45
Balearics	0.34	0.29	0.26	0.28	0.35	0.55	0.73
Canaries	0.75	0.90	1.13	2.07	2.44	2.24	2.25
Cantabria	0.51	0.86	0.62	0.62	0.86	0.79	1.16
Castilla-La Mancha	0.63	0.74	0.61	0.77	0.85	1.73	1.91
Castilla-León	4.81	4.01	3.72	3.85	4.72	3.74	3.36
Catalonia	16.89	19.31	19.04	19.86	20.02	21.15	22.81
Extremadura	0.67	0.75	0.62	0.71	0.86	0.73	0.82
Galicia	2.17	2.11	2.05	3.11	2.57	3.20	3.24
La Rioja	0.02	0.12	0.11	0.16	0.24	0.35	0.42
Madrid	47.74	41.94	44.31	38.64	37.08	33.30	30.89
Murcia	0.86	1.28	1.22	1.59	1.34	1.37	1.48
Navarra	1.12	0.80	1.72	1.77	1.42	1.56	1.62
Basque Country	8.45	8.50	8.51	7.82	7.78	9.18	8.79
Valencia Region	2.97	4.33	3.85	5.90	6.32	6.35	6.66
Unattributable (to regions)	0.00	2.58	1.03	1.02	0.99	0.00	0.00
Total	100	100	100	100	100	100	100

Source: INE

TABLE 3: PERCENTAGE DISTRIBUTION OF R&D EXPENDITURE (%)

	Firms	Public Administrations	Higher Education	PNPI
1986	58.62	26.15	15.23	Na
1987	54.97	25.24	18.94	0.57
1988	56.79	23.18	19.25	0.79
1989	56.33	22.73	20.41	0.52
1990	57.83	21.26	20.37	0.55
1991	56.00	21.27	22.22	0.52
1992	50.51	20.01	28.91	0.57
1993	47.75	20.00	31.28	0.97
1994	46.76	20.70	31.58	0.97
1995	48.23	18.62	32.02	1.12
1996	48.35	18.30	32.26	Na
1997	48.80	17.37	32.73	1.10
1998	52.11	16.27	30.51	Na

Source: INE

TABLE 4: TECHNOLOGICAL CAPITAL BY REGIONS (% GVA)

	1987	1990	1992	1994	1996	1998
Andalusia	1.42	1.63	2.04	2.50	2.90	3.20
Aragon	1.61	1.91	2.38	2.96	3.37	3.41
Asturias	1.99	2.10	2.50	2.98	3.09	3.24
Balearics	0.31	0.41	0.46	0.55	0.61	0.75
Canaries	0.37	0.60	0.88	1.44	2.02	2.27
Cantabria	0.84	1.30	1.65	2.11	2.57	2.77
Castilla-La Mancha	0.31	0.44	0.58	0.80	0.95	1.50
Castilla-León	2.22	2.29	2.60	2.96	3.39	3.33
Catalonia	2.18	2.67	3.38	4.30	4.72	4.98
Extremadura	0.87	1.06	1.20	1.46	1.77	1.79
Galicia	0.85	1.07	1.34	1.89	2.13	2.43
La Rioja	0.02	0.18	0.40	0.69	1.09	1.51
Madrid	9.64	9.49	10.87	12.33	12.37	11.70
Murcia	0.74	1.14	1.60	2.19	2.59	2.75
Navarra	1.52	1.85	2.64	3.91	4.31	4.44
Basque Country	3.24	3.84	4.86	5.90	6.39	6.68
Valencia Region	0.60	0.94	1.32	1.96	2.50	2.76
Total	2.63	2.97	3.64	4.43	4.80	4.89

Source: INE, FUNCAS and own elaboration

TABLE 5: NUMBER OF PATENTS

	1986	1988	1990	1992	1994	1996	1998	1999
Andalusia	85	98	131	148	177	184	175	203
Aragon	59	64	64	69	56	80	96	84
Asturias	14	29	19	38	29	38	29	40
Balearics	11	12	18	28	17	32	27	23
Canaries	12	17	17	21	28	40	32	47
Cantabria	6	13	15	14	25	12	21	23
Castilla-La Mancha	20	24	22	35	32	43	44	49
Castilla-León	26	36	46	63	52	55	64	83
Catalonia	552	693	830	589	539	586	600	578
Extremadura	2	13	13	18	14	18	15	23
Galicia	8	28	36	50	52	69	77	76
La Rioja	9	7	13	17	18	15	21	15
Madrid	420	392	483	465	509	523	511	540
Murcia	20	23	25	36	31	33	41	33
Navarra	43	51	68	37	58	53	75	50
Basque Country	111	148	177	198	176	165	155	197
Valencia Region	158	179	223	222	271	307	273	340
TOTAL	1556	1827	2200	2048	2084	2253	2256	2404

Source: Oficina Española de Patentes y Marcas

TABLE 6: REGIONAL DISTRIBUTION OF PATENTS (%)

	1986	1988	1990	1992	1994	1996	1998	1999
Andalusia	5.46	5.36	5.95	7.23	8.49	8.17	7.76	8.44
Aragon	3.79	3.50	2.91	3.37	2.69	3.55	4.26	3.49
Asturias	0.90	1.59	0.86	1.86	1.39	1.69	1.29	1.66
Balearics	0.71	0.66	0.82	1.37	0.82	1.42	1.20	0.96
Canaries	0.77	0.93	0.77	1.03	1.34	1.78	1.42	1.96
Cantabria	0.39	0.71	0.68	0.68	1.20	0.53	0.93	0.96
Castilla-La Mancha	1.29	1.31	1.00	1.71	1.54	1.91	1.95	2.04
Castilla-León	1.67	1.97	2.09	3.08	2.50	2.44	2.84	3.45
Catalonia	35.48	37.93	37.73	28.76	25.86	26.01	26.60	24.04
Extremadura	0.13	0.71	0.59	0.88	0.67	0.80	0.66	0.96
Galicia	0.51	1.53	1.64	2.44	2.50	3.06	3.41	3.16
La Rioja	0.58	0.38	0.59	0.83	0.86	0.67	0.93	0.62
Madrid	26.99	21.46	21.95	22.71	24.42	23.21	22.65	22.46
Murcia	1.29	1.26	1.14	1.76	1.49	1.46	1.82	1.37
Navarra	2.76	2.79	3.09	1.81	2.78	2.35	3.32	2.08
Basque Country	7.13	8.10	8.05	9.67	8.45	7.32	6.87	8.19
Valencia Region	10.15	9.80	10.14	10.84	13.00	13.63	12.10	14.14
TOTAL	100	100	100	100	100	100	100	100

Fuente: Oficina Española de Patentes y Marcas

Table 7: National production function (1965-96)

Constant	61.423 (8.163)
K	0.154 (2.512)
H	0.269 (4.414)
R	0.277 (3.778)
Trend	0.025 (6.843)
R^2 adj.	0.99

Estimation under the hypothesis of constant returns to scale
In parenthesis, t-ratio

Table 8: Regional production function (1987-96)

	(1)	(2)	(3)
K	0.313 (4.512)	0.189 (2.645)	0.196 (3.581)
H	0.306 (4.398)	0.294 (4.473)	0.100 (1.770)
R	-0.008 (-1.029)	-0.002 (-0.284)	0.009 (1.516)
SPILLR1		0.220 (4.288)	
SPILLR2			0.428 (9.366)
R2 adj.	0.97	0.97	0.98
Hausman test	30.174 [0.000]	53.208 [0.000]	128.66 [0.000]

Notes: -Estimation under the hypothesis of constant returns to scale
-Fixed effect model
-In parenthesis, t-ratio
-In brackets, p-value of Hausman test

Table 9: Regional production function with patents (1987-96)

	(1)	(2)	(3)
K	0.286 (4.204)	0.271 (4.508)	0.252 (3.836)
H	0.255 (3.684)	0.144 (2.264)	0.204 (3.073)
PAT	0.016 (1.805)	0.010 (1.824)	0.030 (3.188)
SPILLP1		0.202 (6.423)	
SPILLP2			0.186 (3.328)
R2 adj.	0.97	0.98	0.98
Hausman test	24.393 [0.000]	64.198 [0.000]	42.689 [0.000]

Notes: Estimation under the hypothesis of constant returns to scale

-Fixed effect model

-In parenthesis, t-ratio

-In brackets, p-value of Hausman test

Table 10: Determinants of regional TFP* (1987-96)

	(1)	(2)	(3)
H	0.306 (4.411)	0.297 (4.504)	0.111 (1.947)
R	-0.008 (-1.015)	-0.050 (-0.676)	0.007 (1.101)
K	-0.010 (-0.654)	-0.060 (-1.419)	-0.070 (-1.461)
SPILLR1		0.188 (3.984)	
SPILLR2			0.412 (9.086)
R2 adj.	0.96	0.96	0.98
Hausman test	24.675 [0.000]	50.071 [0.000]	116.41 [0.000]

Notes: -Fixed effect model
-In parenthesis, t-ratio
-In brackets, p-value of Hausman test

Table 11: Determinants of regional TFP* with patents (1987-96)

	(1)	(2)	(3)
H	0.255 (3.695)	0.143 (2.275)	0.205 (3.098)
PAT	0.0164 (1.799)	0.009 (1.983)	0.029 (3.129)
K	-0.020 (1.224)	-0.025 (-1.326)	-0.002 (0.131)
SPILLP1		0.201 (6.426)	
SPILLP2			0.183 (3.288)
R2 adj.	0.96	0.97	0.97
Hausman test	20.55 [0.000]	60.581 [0.000]	37.743 [0.000]

Notes: -Fixed effect model
-In parenthesis, t-ratio
-In brackets, p-value of Hausman test

Table 12. Technological activities and β-convergence in the Spanish regions

a) Technological capital

a	*b*	*c*	*d (SPILLR1)*	*d(SPILLR2)*	R^2*adj.*
0.284 (2.266)	-0.079 (-2.612)	-0.008 (-0.152)			0.33
0.257 (2.032)	-0.074 (-2.346)	0.003 (0.425)	0.005 (0.826)		0.47
0.506 (2.187)	-0.131 (-2.336)	0.014 (1.152)		0.004 (0.607)	0.48

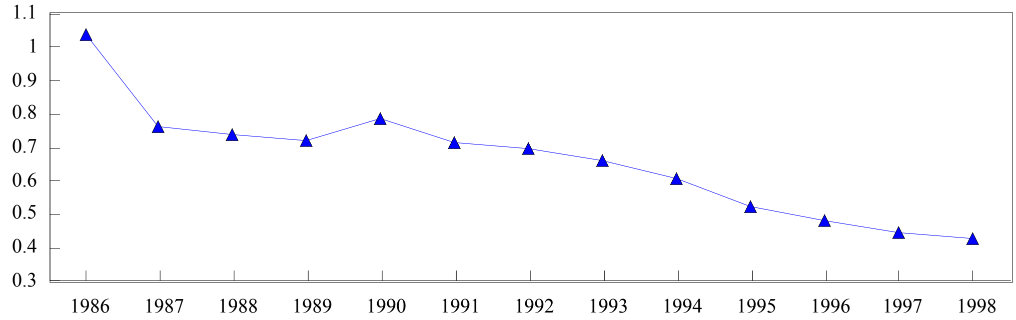
b) Patents

a	*b*	*c*	*d (SPILLP1)*	*d(SPILLP2)*	R^2*adj.*
0.205 (1.162)	-0.072 (-2.295)	-0.053 (-0.607)			0.35
0.272 (1.353)	-0.070 (-2.164)	-0.001 (-0.190)	0.043 (0.747)		0.32
0.785 (1.356)	-0.156 (-1.686)	0.020 (0.791)		0.001 (0.275)	0.33

Note: in parenthesis, t-ratio

Figure 1. Sigma-convergence in (R&D/GVA)

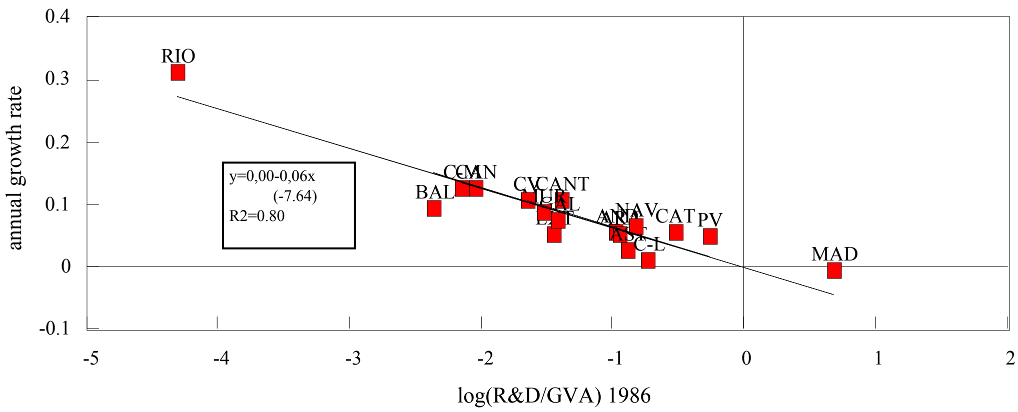
Standard deviation of log



Source: INE and FUNCAS

Figure 2. Beta-convergence in (R&D/GVA)

1986-1998



Source: INE and FUNCAS

Note: in parenthesis, t-ratio