EFFICIENCY AND PRODUCTIVE SPECIALISATION: AN APPLICATION TO THE SPANISH REGIONS *

Regional Studies 34(9), 829-842, 2000.

Joaquín Maudos[a,b]

José M. Pastor[a]

Lorenzo Serrano[a]

Abstract

This paper shows the importance of the composition of production -productive specialisation- and sector inefficiencies when evaluating efficiency in aggregate production. For this purpose, a new approach is proposed for obtaining efficiency scores which enables two components to be differentiated: one associated with the degree of efficiency within each sector -intra-sector efficiency- and another associated with the composition of production -composition efficiency. The application of this approach and its break-down for the Spanish regions in the period 1964-1993, using a non-parametric approach -DEA- shows greater gains in composition efficiency as a consequence of the structural changes in productive specialisation. Also, the break-down of labour productivity convergence shows the increasing importance over time of composition efficiency as a source of convergence, being even more important than capital accumulation from the mid-1970s. Nevertheless, intra-sector efficiency gains was a significant source of convergence for the whole period analysed.

[a] Universitat de Valencia; Departamento de Análisis Económico. Edificio departamental oriental. Avenida de los Naranjos, s/n; -46022- Valencia. (SPAIN) Fax: +34 96 382 82 49; E-mail: joaquin.maudos@uv.es

[b] Instituto Valenciano de Investigaciones Económicas (IVIE). C/ Guardia Civil 22, Esc. 2, 1º; 46020 Valencia (SPAIN). Fax: +34 96 393 08 56

(*) Authors acknowledge the helpful comments of three anonymous referees. Authors also whish to thank the CICYT SEC95-0895 for financial support as well IVIE for data support.

1. Introduction

There have been many studies that show the importance of including, in the analysis of the productivity of economic units, the efficiency with which they use their resources in the productive process. Initially this type of studies was restricted to the analysis of different firms within one field of activity. However, the scope has been extended to the economic evolution of regions and countries, because the omission of the phenomenon of inefficiency causes conventional analyses to offer biased results, as pointed out by Grosskopf (1993). This would be the case, for example, of growth accounting analysis of total factor productivity (TFP) and its evolution over time.

Thus, Färe et al. (1994) investigate the growth of productivity at aggregate level in 17 countries of the OECD during the period 1979-1988 by means of Malmquist productivity index; Fecher and Perelman (1992) use the stochastic frontier approach (SFA) to evaluate the growth of TFP and analyze its causes with sector data relating to a sample of 13 countries of the OECD during the period 1971-1986. Finally, Perelman (1995) estimates the growth of TFP during the period 1970-1987 in a context of 8 industrial sectors and 11 countries of the OECD, using both SFA and Data Envelopment Analysis (DEA). In the case of Spain, Gumbau and Maudos (1996) demonstrate the existence of substantial levels of inefficiency in major sectors of production in the Spanish regions in the period 1980-1991 using the SFA; similarly, Maudos et al. (1998), using DEA and the Malmquist productivity index, also obtain high levels of inefficiency at aggregate level in the Spanish regions[1].

Another branch of the literature that show the importance of efficiency is the analysis of convergence in per capita income and labour productivity. Part of this wide literature has been devoted to checking whether poor countries tend to grow faster than rich countries, through the international diffusion of knowledge and technology: the catch-up hypothesis. However, this literature[2] does not take into account the importance of changes in efficiency as a source of convergence. The only two exceptions are the recent studies by Taskin and Zaim (1997) and Maudos et al. (1999) who show, for a sample of OECD

[1] All these papers confirm the importance of including inefficiency in the analysis. Thus, Färe et al. (1994) and Fecher and Perelman (1992) compare their results with the growth of TFP obtained by means of the standard growth accountancy approach, formulated with the Törnqvist index. In both cases significant differences can be appreciated, thus confirming the limitation implied by ignoring the existence of inefficiency when estimating TFP.

countries, that technical progress has been a source of divergence in labour productivity, just the opposite of gains in efficiency.

The methods that explicitly include the possibility of inefficient use of resources posit the existence of a frontier that defines the maximum production possible given the quantity of productive factors used. Individual inefficiency would be measured as the ratio between the maximum output as defined by this technological frontier, and the observed output.

The analyses of regions or countries in general consider a single product (aggregate production) and analyze its aggregate inefficiency from that standpoint[3], ignoring the multi-product nature of the economic activity of countries and regions. However, not to consider the existence of different branches of production, each one with different technologies and different degrees of inefficiency, may significantly influence the results[4]. This is because the frontier of aggregate production would not have been obtained as the aggregation of efficient sector productions, and in this sense would contain a certain degree of error attributable to the existence of different sector inefficiencies. The greater the differences of efficiency in each sector, the greater this error would be.

In order to avoid this error associated with the existence of inefficiencies at sector level, to estimate aggregate efficiency in this study we consider, instead of aggregate output, the sectorially efficient aggregate output, i.e. the aggregate of the outputs of all sectors after discounting intra-sector inefficiency. From this standpoint we can distinguish two different types of inefficiency. On the one hand, inefficiency of composition due to incorrect allocation of resources among branches of production given their particular technologies. On the other, a type of inefficiency which we will call intra-sector inefficiency, which is associated with deficient use of resources allocated to each sector. To measure properly the maximum achievable output of each economy, and its true overall efficiency, the analysis should include both sources of inefficiency, composition and intra-sector. If this is not done, as occurs habitually in aggregate analysis, the second type of inefficiency is

[2] See, among others, Dollard and Wolff (1994), Dowrick and Nguyen (1989), Bernard and Jones (1996a), etc.

[3] Or they analyse separately the individual inefficiency in each sector without drawing conclusions at aggregate level, as in Fecher and Perelman (1992) and Perelman (1995).

[4] Bernard and Jones (1996b) show the importance of the composition of production in technological convergence (TFP) in the industrial sector of a sample of countries of the OECD. They break down aggregate convergence into production gains within each sector and changes in the sector composition. Their main conclusion is that the variation in the sector composition explains one fifth of the total catch-up effect, there being a high degree of heterogeneity in the behaviour of convergence at sector level.

necessarily under-valued, and the true inefficiency therefore underestimated. A purely sector analysis would cause a similar problem by not considering the first type of inefficiency.

A break-down such as the above enables two components of efficiency to be distinguished. Intra-sector efficiency, due to a more or less efficient use of productive factors within each sector, and composition efficiency, associated with incorrect composition of production - productive specialisation in those sectors that are more or less productive. According to this second component, a region can gain efficiency simply by decreasing (increasing) the weight of those sectors which use a less (more) productive technology.

This study considers both types of inefficiency mentioned, and the way in which they can be estimated in a shared context. For this, we need to use frontier techniques. In this paper and without loss of generality, a non-parametric frontier technique (DEA) is used, in two stages. First the regional inefficiencies in each sector are obtained separately, as a basis for subsequently estimating the overall intra-sector inefficiency component for each region. Second, we use the aggregate level of production that would correspond to each region if it were efficient in each and every sector to obtain the true level of potential production and the inefficiency of composition. This procedure enables the proper measurement of inefficiency to be obtained, as well as its break-down into the part of inefficiency that is due to unsuitable productive specialisation and the other part that is due to inefficient use of the resources allocated to each productive activity. This break-down enables us to analyze the contribution of the evolution of efficiency and of each of its components to the process of convergence among the Spanish regions.

The paper is structured as follows. Section 2 describes the methodology used for the estimation of efficiency and for its break-down into intra-sector and composition efficiency. Section 3 discusses the sample and variables used and presents the results obtained for the Spanish regions during the period 1964-1993. The contribution of the evolution over time of both types of inefficiency to regional convergence in Spain during this period is offered in section 4. Finally, the principal conclusions of the paper are reflected in section 5.

2. Methodology

In order to illustrate the methodology let us assume that there are *R* regions and *N* sectors, and that $(X_{i1}^n,...,X_{iM}^n)$ is the vector of M inputs that region *i* uses in sector *n* for the production of Y_i^n. The efficiency of region *i* in sector *n* will be obtained by the following standard DEA problem[5]:

$$
\begin{aligned}
& Max \quad \theta_i^n \\
& s.t. \\
[1] \quad & \sum_{r=1}^{R} \lambda_r Y_r^n \geq Y_i^n \theta_i^n \\
& \sum_{r=1}^{R} \lambda_r X_{rm}^n \leq X_{im}^n \quad m = 1,...,M \\
& \lambda_r \geq 0 \quad r = 1,...,R
\end{aligned}
$$

where θ_i^n is the efficiency score of region *i* in sector *n*, and represents the potential increase that region *i* could achieve in the output of sector *n* without needing to increase the amount of input vector. This efficiency score is obtained from the comparison of each of the regions with efficient regions or with linear combinations of efficient regions. The linear combinations of the outputs of the efficient regions, $\sum_{r=1}^{R} \lambda_r Y_r^n$, represent for each region the maximum attainable output in sector *n*. Thus, if we call this maximum attainable sector output of region *i* in sector *n* as $\hat{Y}_i^n$, the efficiency score in sector *n* is the ratio between this maximum attainable output ($\hat{Y}_i^n$) and the observed output (Y_i^n).

$$
[2] \qquad \theta_i^n = \frac{\sum_{r=1}^{R} \lambda_r Y_r^n}{Y_i^n} = \frac{\hat{Y}_i^n}{Y_i^n}
$$

By definition, $\theta_i^n \geq 1$. If $\theta_i^n = 1$ indicates that no region, or linear combination of regions, produces more in sector *n* with the same or less inputs than region *i*, and therefore region *i* would be considered efficient in sector *n*. On the other hand, if $\theta_i^n > 1$ region *i*

---

[5] See Charnes et al. (1978).

would be inefficient in sector *n* because there is a region, or a linear combination of regions, that produces $(\theta_i^n - 1)$ more in sector *n* with the same input or less.

The aggregate output of region *i* (Y_i) is obtained as a sum of the outputs of region *i* in each of the *N* sectors, as follows:

[3] $$Y_i = \sum_{n=1}^{N} Y_i^n \qquad \forall i$$

However, as was pointed out above, the aggregate production frontier should not be obtained from data of aggregate production, as we would under-value inefficiency by not considering the multi-product nature of the activity and the possible existence of different levels of inefficiency sector by sector. For this purpose, in the first stage we must discount the inefficiency of each region *i* in each of the *N* sectors (θ_i^n) previously calculated in [1].

The sectorially efficient aggregate production of each region *i* ($\hat{Y}_i$) would be obtained as the sum of the maximum sector productions, i.e. as the sum of the sector outputs once the inefficiencies in each of the sectors had been eliminated,

[4] $$\hat{Y}_i = \sum_{n=1}^{N} \hat{Y}_i^n = \sum_{n=1}^{N} Y_i^n \theta_i^n$$

However, being efficient in each sector does not guarantee being efficient in aggregate production, since there is still one type of inefficiency associated with the sector composition of production. In other words, being efficient in aggregate production necessarily implies being efficient in each and every sector (i.e. to be intra-sector efficient), and also having a correct composition of production (i.e. to be composition efficient).

This aggregate measure of efficiency would be obtained from the aggregate production frontier, which would represent the maximum values of the aggregate production after deducting the sector inefficiencies and with the correct composition ($\hat{Y}_i^*$). The total efficiency score (θ_i) can be expressed as the quotient of this maximum attainable production, $\hat{Y}_i^*$, and observed production, Y_i, and can be represented as the product of the following factors:

$$[5] \qquad \theta_i = \frac{\hat{Y}_i^*}{Y_i} = \frac{\hat{Y}_i^*}{\hat{Y}_i}\frac{\hat{Y}_i}{Y_i} = \theta_i^{CE} \cdot \theta_i^{IE}$$

The second factor, $(\hat{Y}_i \ / Y_i)$, indicates the aggregate intra-sector inefficiency θ_i^{IE}, and is merely a weighted average of the different sector inefficiencies[6]. The first, $(\hat{Y}_i^* / \hat{Y}_i)$ represents the inefficiency due to the composition of production, (θ_i^{CE}), which would exist even if no technical inefficiency existed in any sector. This indicator of inefficiency of composition is obtained on the basis of the following problem for region *i*,

$$[6] \qquad \begin{aligned} & Max \ \ \theta_i^{CE} \\ & s.t. \\ & \sum_{r=1}^{R} \lambda_r \hat{Y}_r \geq \hat{Y}_i \theta_i^{CE} \\ & \sum_{r=1}^{R} \lambda_r X_{rm} \leq X_{im} \qquad m = 1,\dots,M \\ & \lambda_r \geq 0 \qquad r = 1,\dots,R \end{aligned}$$

Finally, the overall efficiency indicator (θ_i) is obtained either through the quotient between the maximum attainable production obtained from [6], $\hat{Y}_i^* = \hat{Y}_i \ \theta_i^{CE}$, and the observed output Y_i, or through the solution of problem [7][7].

---

[6] Indeed, since $\hat{Y}_i = \sum_{n=1}^{N} Y_i^n \cdot \theta_i^n$, it can be seen that

$$\theta_i^{IE} = \frac{\hat{Y}_i}{Y_i} = \frac{\sum_{n=1}^{N} Y_i^n \cdot \theta_i^n}{\sum_{n=1}^{N} Y_i^n} = \sum_{n=1}^{N} \frac{Y_i^n}{\sum_{n=1}^{N} Y_i^n} \cdot \theta_i^n$$

[7] Since we had that $\hat{Y}_i = Y_i \theta_i^{IE}$, we can re-write $\hat{Y}_i \theta_i^{CE}$, in the right hand side of the first restriction of problem [6], as $Y_i \theta_i^{IE} \theta_i^{CE}$. So, the optimum θ_i^{CE} maximises $\hat{Y}_i \theta_i^{CE}$ in problem [6] and also $Y_i \theta_i^{IE} \theta_i^{CE}$, what. is equivalent to $Y_i \theta_i$ in problem [7], being θ_i equal to $\theta_i^{CE} \cdot \theta_i^{IE}$.

$$
\begin{aligned}
& Max\ \theta_i \\
& s.t. \\
[7] \quad & \sum_{r=1}^{R} \lambda_r \hat{Y}_r \geq Y_i \theta_i \\
& \sum_{r=1}^{R} \lambda_r X_{rm} \leq X_{im} \quad m = 1,\ldots,M \\
& \lambda_r \geq 0 \quad r = 1,\ldots,R
\end{aligned}
$$

3. Data and results

The sample used is composed of the Autonomous Communities (regions) of Spain (excluding Ceuta and Melilla) and covers the period 1964-1993. For each sector we specify one output (GVA at factor cost) and two inputs: capital (K) and labour (L). The variables Gross Value Added (Y) and labour (L) are obtained from the information supplied since 1955 by the BBV, while the variable representing the stock of private capital (K) is obtained from the estimate by the Instituto Valenciano de Investigaciones Económicas (IVIE) published by the BBV Foundation, and excludes residential capital. This estimate of the stock of capital covers the period 1964-1993, which is consequently the period analysed in this study.

The information supplied by the BBV at sector level enables four sectors to be distinguished without problems of homogeneity over time: agriculture, industry, construction and services. However, within the industrial sector the energy sector is separated, thanks to the estimate made by the IVIE and used by Mas et al (1994b)[8] and Pérez et al (1996). Thus, the sectors for which a separate frontier production function has been estimated are agriculture, industry (excluding energy), energy, construction and services. In addition, the economy as a whole, obtained from the sum of the sector data, is also analysed[9].

[8]See in the appendix to Mas et al (1994b) the methodology used for the estimation of production and employment in the energy sector.

[9]In the absence of regional deflators, the deflators of the national accounting of the INE (Instituto Nacional de Estadística) have been used. Total GVA in pesetas of 1990 was obtained as a sum of the real sector GVAs.

A first approximation to sector efficiency levels (θ_i^n) of the Spanish economy[10] is represented for the national total in graph 1[11] . This graph shows the existence of substantial differences both of level and of evolution over time among the five sectors considered. Thus, the sectors with lowest efficiency levels are energy and agriculture, the average score for the period being 1.37 and 1.35 respectively (i.e. their GVA could increase by 37% and 35% respectively without increasing the inputs). On the other hand, the efficiency scores in the industrial, construction and service sectors are higher and relatively similar, around 1.13[12].

Table 1 shows the efficiency scores (θ_i^n) for the sectors considered. The information enables us to highlight that:

1.- In the case of the agricultural sector, the reduction in inefficiency levels in Spain is a phenomenon affecting most regions with the exception of Asturias, Cantabria, Valencia and Madrid. The lowest efficiency scores occur in the northern regions of the country (Galicia, Asturias and Cantabria), La Rioja, Valencia, Navarra and the Basque Country being on the other hand the most efficient. Nevertheless, these average efficiency levels should not mask the fact that the Valencian Community region has moved from being on the frontier until the mid-1970s to a level of inefficiency of 1.61 in 1993. At the opposite extreme, Andalusia moved from an inefficiency level of 1.77 in 1964 to stand at the frontier from the mid-1980s.

2.- In the case of the industrial sector, all the regions except Extremadura decreased their efficiency scores in the period analysed. In general, Asturias, the Balearic Islands and Madrid are the most efficient regions (for all the years of the period Madrid is situated at the frontier of production), while Extremadura, Murcia and La Rioja are the least efficient. The behavior of this last region is noteworthy, as in spite of being the second most inefficient region in 1964 (1.41) it stood at the technological frontier in 1993.

---

[10] The efficiency score of Spain has been obtained as the ratio between the maximum attainable output of all the regions and the observed output of the whole Spanish economy.

[11]If the efficiency score (θ) is equal to 1, the region is efficient, the higher the value of θ the greater the inefficiency. (θ-1)*100 indicates the percentage by which the GVA of the regions could be increased without increasing the inputs used.

[12] The ordering in terms of efficiency of the sectors of production considered coincides with that obtained in Gumbau and Maudos (1996) for the period 1980-1991 using the Regional Accounting (*Contabilidad Regional*) of the INE.

3.- Cantabria, the Balearics, Madrid and Navarra have the most inefficient energy sectors in Spain with scores above 1.6. The most efficient regions are Murcia and Asturias. With respect to evolution over time the cases of Extremadura and La Rioja are worth mentioning because of the effort made to reduce inefficiency, the opposite of what occurred in the Canaries and Cantabria.

4.- The construction sector has the smallest differences in the average levels of efficiency, the difference between the most efficient region (La Rioja) and the most inefficient (Asturias) is around 30%. Note are the steady gains in efficiency in Andalusia, Valencia, Galicia, Navarra and, above all, Extremadura.

5.- In the services sector, which together with industry is the most efficient, what stands out is the low levels of efficiency of the richest regions (Madrid, Catalonia and the Balearics) as well as the Basque Country. If we take into account the high relative importance of the services sector in the first three regions, it is logical that these regions should also be the most efficient at aggregate level.

For the aggregate of each region, the intra-sector efficiency (θ_i^{IE}) is merely a weighted average of the sector efficiencies[13]. These levels, which appear in table 2, show that there is no efficient region, as none are efficient in all sectors. The region with the lowest level of inefficiency is Madrid (1.02), since it is efficient in the industry and service sectors, which concentrate 90% of its production. At the opposite extreme are Extremadura and Galicia with average efficiency levels of 1.40 and 1.39 respectively, as a consequence of the high relative importance of the most inefficient sector (agriculture).

Intra-sector inefficiency indicates the percentage increase of production that each region could achieve if it were efficient in production within each sector. However, the maximum achievable output that a region could obtain by eliminating inefficiency within each sector - intra-sector efficiency - may differ from the maximum production that it could obtain by at the same time modifying in the best possible way its productive specialisation. As was shown in section 2, this second component of efficiency, composition efficiency (θ_i^{CE}), is obtained through the solution of problem [6].

[13] See note 6.

Table 2 also contains the levels of composition efficiency (θ_i^{CE}). The first thing to note is that only Madrid is efficient in all years, which implies that it presents the composition of production which is, among all the other regions, the most efficient. Although other regions have an efficient composition in certain years - such is the case of the Basque Country, the Canaries, Aragon and Castilla-Leon - only Madrid is efficient throughout the period analysed. The peculiarity of Madrid's productive specialisation is a high relative importance of the service sector and a very low relative importance of the least productive sectors, agriculture and energy. Also, as can be clearly seen in table 3, in real terms the composition of production of Madrid has scarcely varied with time, being always therefore the efficient composition of reference.

Reading tables 2 and 3 together will help to understand the causes of the differences in levels of composition efficiency between regions. In the least efficient regions - Extremadura, Galicia and La Rioja - the agriculture has a high relative importance. This fact, plus its high percentage of energy production, make Extremadura the region with most inefficient specialisation[14].

Total efficiency in production (θ_i) – which is the product of intra-sector efficiency and composition efficiency - represents the potential increase in output that a region could obtain by eliminating both the inefficiency with which it operates in each sector (intra-sector efficiency, θ_i^{IE}), and that resulting from the choice of an inefficient specialisation (composition efficiency, θ_i^{CE}). Expressed in other terms, it would be the ratio between the maximum attainable output $(\hat{Y}_i^*)$ and the observed output (Y_i). The levels of total efficiency (θ_i) whose values appear in table 4 show that no region is efficient in this sense, as even the most efficient - Madrid - has some degree of intra-sector inefficiency. Madrid is the most efficient region (1.02), as its specialisation is the most efficient, with inefficiencies in sectors (agriculture and energy) which are relatively unimportant in its vector of production. At the opposite extreme are Extremadura and Galicia with high degrees of inefficiency in sectors in which they specialize.

[14] As we know, the production structure of an economy is determined by several factors as, for instance, the availability of natural and human resources. This implies that there may be regions with problems for reducing their composition inefficiency for lack of productive resources.

The evolution over time of total efficiency (θ_i) and of its components θ_i^{CE} and θ_i^{IE} for the Spanish economy shows gains in efficiency that are greater in the case of composition efficiency. Graph 2 shows clearly that, although until the late 1970s both types of inefficiency were quantitatively similar, from then onwards the gains in composition efficiency are much greater, so much so that in 1993 the intra-sector inefficiency is four times greater than composition inefficiency[15].

The comparison of total efficiency with the efficiency that would be obtained if sector inefficiencies were ignored, as occurs in any analysis using aggregate output, is represented in graph 3. The graph shows, for the total of Spain, the total efficiency score calculated using the two-stage approach, expressed as a percentage of the total efficiency score resulting from the solution of problem [1] using the aggregate production of expression [3]. For the average of the period 1964-1993, the true inefficiency is 1.71% higher than would be obtained by ignoring the output composition and the specialisation.

4. Efficiency and regional convergence.

The study of convergence between countries in terms of per capita income and labour productivity has given rise to the development of a very wide-ranging literature (see Barro and Sala-i-Martin (1995) for a survey of the empirical evidence). In particular, the existence of convergence, though at a moderate rate, has been profusely documented in the case of the OECD countries, this question being at the center of the debate on economic growth.

With the aim of understanding better the forces underlying this process of convergence, a part of the literature has been devoted to analyzing the hypothesis of catching-up in the levels of total factor productivity (TFP) among the OECD countries[16]. This catch-up hypothesis claims that poor countries tend to grow faster than rich countries through the international diffusion of knowledge and technology. In the studies in which

[15] Historically, economic development implies a shift from less value-added activities in the primary sector to industrial and service activities. Thus, the structural change of the Spanish economy, with a decline in the share of agriculture and a rise in the share of services, could explain the rise of composition efficiency.
[16] See Abramovitz (1986 and 1994).

this hypothesis is tested, TFP growth is due to both diffusion of technology and innovation[17].

However, these studies that relate convergence to TFP usually obtain the latter by means of Törnqvist indices or other proxies such as growth accounting which, in the words of Grosskopf (1993), ignore efficiency. The underlying problem is that these methods, valid only in the case of technical efficiency, and allocative efficiency, lead to biased estimates of technical progress in the presence of inefficiency. Furthermore, it is not possible to break down the growth of TFP, thus omitting the fact that part of this growth is due to gains in efficiency and not only to technical progress.

To date, as far as we know, there are only two papers that analyze the importance of efficiency change on the convergence of labour productivity. Taskin and Zaim (1997) and Maudos et al. (1999) analyze the catching-up hypothesis for a group of countries of the OECD over the period 1975-90 showing that efficiency change is higher in poor countries.

In the case of the Spanish regions, studies that analyze the convergence process have focused on the study of σ and β convergence (Barro and Sala-i-Martin, 1991 y 1992) and the importance of human capital (De la Fuente, 1996 and Serrano, 1998a), public capital (Mas et al., 1994a and 1995), productive specialisation (Mas et al., 1994a; Raymond and García-Greciano, 1994; Sala-i-Martin, 1996; Marimon and Zibilotti, 1995, among others), diffusion of technology (De la Fuente, 1996; Mas et al., 1998; and Maudos, et al., 1998) and efficiency gains (Maudos et al, 1998) as variables that hold constant the steady state of economy (conditional convergence).

In this section we will analyze the contribution made by the evolution of the different types of inefficiency to the degree of labour productivity convergence experienced by the Spanish regions during the period 1964-1993. For this purpose we will use the results of regional inefficiency shown in the previous section to break down the economic growth of the Spanish regions. Thus, we can distinguish which part of the growth of labour productivity was due to gains in intra-sector efficiency and which to gains in composition efficiency. The remainder, which coincides with the rate of growth that would have been experienced by labour productivity if there had never been any type of inefficiency or it had

[17] Dowrick and Nguyen (1989), Dollar and Wolff (1994), Bernard and Jones (1996a and b).

been constant, is the growth that is to be attributed to technical progress and to increased endowment of capital per worker.

Indeed, the growth rate of labour productivity can be broken down as the sum of the growth rate of intra-sector efficiency, the growth rate of composition efficiency, the contribution of technical progress[18], and the contribution of the increase in inputs used per worker, the latter being obtained residually.

The analysis of the influence that each of the sources of growth may have had on regional convergence in Spain is the aim of this section. In the case of absolute β-convergence[19] it interests us to know whether the growth of labour productivity due to each of these factors was (i) greater in the regions with lower labour productivity initially, in which case this factor would have contributed to convergence, (ii) lower in the regions with initially lower productivity, in which case it would have generated divergence; or (iii) bears no relation at all to the initial situation, in which case it would have had no effect on convergence.

In each period we can estimate by OLS the relationship between the average labour productivity growth for the period, and of each of its components, to the logarithm of the initial labour productivity. The effect on convergence will depend on the sign of the parameter accompanying the logarithm of the initial labour productivity. A negative sign indicates convergence and a positive one, divergence. Furthermore, it is easy to see that the parameter of total convergence is equal to the sum of the parameters corresponding to the sources of growth, so we can break down the labour productivity convergence into the contribution due to the change in each type of efficiency and that due to the effect of technical progress and of more inputs per worker[20].

In particular, we can estimate the relative contribution of each factor to convergence between the years 0 and T by taking logarithmic differences between them, and by the following regressions:

---

[18] We use Malmquist productivity index (Malmquist, 1953) to break down productivity change into technical progress and efficiency change. See appendix for technical details.

[19] This denomination was proposed by Barro and Sala-i-Martin (1992).

[20] For an application of this type of convergence accounting to the countries of the OECD see Serrano (1998b).

[8] $$\left(\frac{dy_i}{T}\right) = c + b \cdot \log y_{io} + u_i$$

[9] $$\left(\frac{dy_{E_i}}{T}\right) = c_E + b_E \cdot \log y_{io} + u_{E_i}$$

[10] $$\left(\frac{dy_{IE_i}}{T}\right) = c_{IE} + b_{IE} \cdot \log y_{io} + u_{IE_i}$$

[11] $$\left(\frac{dy_{CE_i}}{T}\right) = c_{CE} + b_{CE} \cdot \log y_{io} + u_{CE_i}$$

[12] $$\left(\frac{dy_{TCi}}{T}\right) = c_{TC} + b_{TC} \cdot \log y_{io} + u_{TCi}$$

[13] $$\left(\frac{dy_{Ii}}{T}\right) = c_I + b_I \cdot \log y_{io} + u_{Ii}$$

where log y_{i0}, the logarithm of the initial level of labour productivity, is always the only regressor. The left hand side variable is the annual growth rate of labour productivity in equation [8], the average contribution of efficiency gains (*E*) to that growth in equation [9], the average contribution of intra-sector efficiency gains (*IE*) in equation [10], the average contribution of composition efficiency gains (*CE*) in equation [11], the average contribution of technical change (TC) in equation [12], and the average contribution of the accumulation of inputs per worker in equation [13]. Furthermore, it can be seen that among the estimators of these parameters there are relationships such as:

[14] $$\hat{b} = \hat{b}_{IE} + \hat{b}_{CE} + \hat{b}_{TC} + \hat{b}_I = \hat{b}_E + \hat{b}_{TC} + \hat{b}_I$$

In table 5 we offer the results for the period 1964-1993 and for three differentiated sub-periods in the growth of the Spanish economy: a sub-period of intense growth (1964-1973), a sub-period of crisis (1973-1985) and a sub-period of recovery (1985-1993). Column 1 shows the existence of convergence in the levels of labour productivity during the period. Its cumulative magnitude (-2.35%) and its evolution over time, agrees with the results habitually offered by the literature[21]. Thus, there was convergence both in the period 1964-1973 (-2.22%) and during the crisis of 1973-1985 (-3.58%), intensifying in the last

[21] Dolado et al. (1994), Mas et al. (1994a, 1995 and 1998), De la Fuente (1996), Maudos et al. (1998) among others.

sub-period (-4.79%). Of greater interest is the analysis of the break-down of this process of convergence in terms of the different sources of growth.

Column 2 shows the induced effect on convergence of the change in total efficiency. As can be observed, the cumulative effect in the period as a whole (-1.12%) is statistically significant, contributing positively to convergence. In the sub-period 1964-1973 its effect, though divergent, was negligible (+0.25%) and not significant. In the period 1973-1985, on the other hand, the change in efficiency was a significant source of convergence (-2.46%). During the period of economic crisis, which affected especially certain industrial sectors, the regions with highest levels of labour productivity, more industrialized, experienced losses of efficiency in relative terms. Finally, during the period 1985-1993 efficiency was a significant source of convergence (-3.46%), due to the fact that the regions with lowest labour productivity improved their efficiency in relative terms. Altogether, the contribution of efficiency to labour productivity convergence is characterized by its variability, as in some periods it generates divergence and in others convergence, and by its ever-greater magnitude. However, this overall evolution masks the effect of the different sources of inefficiency.

The effect of gains in intra-sector efficiency can be seen in column 3. The results indicate that it has been a systematic and significant source of convergence, though increasingly weaker. In general, the regions with highest initial labour productivity have experienced lower gains in efficiency within each sector in relative terms. Thus the effect over the whole of the period was -0.88%, being somewhat greater in the initial sub-period of expansion, 1964-1973 (-2.07%), and rather less during the crisis 1973-1985 (-0.88%) and the sub-period 1985-1993 (-0.37%).

Column 4 shows the results corresponding to the gains in composition efficiency. The cumulative effect over the period was convergent (-0.24%) but not significant. In fact, composition efficiency was an important source of divergence in the sub-period 1964-1973 (+2.32%). However, during the sub-period 1973-1985 it became a major source of convergence (-1.58%). This trend was reinforced during the last sub-period, in which again the greater part of regional convergence could be attributed to this factor (-3.08%).

The effect of technical change is shown in column 5. The results indicate that technical change was a source of divergence, specially during the first sub-period; the regions with highest initial productivity experienced greater relative technical progress. Thus, the effect over the period as a whole was +2.22%. This result seems reasonable if it is considered that it is the most developed regions that make the innovations. This means that they are the first to adopt them, and also that technical change is adapted to the characteristics of this type of economy. For all these reasons technical change benefits in the short term especially the more developed regions[22].

Finally, the effect attributable to the accumulation of inputs per worker can be seen in column 6. This was a systematic and significant source of convergence in the period as a whole (-3.43%) as well as in each of the three sub-periods: 1964-73 (-7.03%); 1973-85 (-2.86%) and 1985-93 (-2.45%). Thus, the accumulation of factors of production was greater in the regions with lower initial levels of labour productivity, and as a result this tended to converge at regional level.

Having reached this point, it is possible to examine in depth the evolution of regional labour productivity in Spain. Thus, there is an appreciable qualitative difference between the convergence experienced in the sub-period 1964-1973 and that of the two following sub-periods. In the first case this is due to the intense convergence effect of the accumulation of factors added to intra-sector efficiency, which counteract the strong divergence induced by technical change and the gains in composition efficiency. However, the latter is a source of convergence –specially in the last sub-period- during the following sub-periods.

Altogether, gains in efficiency have contributed substantially to regional convergence in Spain. In particular, the gains in composition efficiency have changed from being an important source of divergence to being the main source of convergence, taking over from gains in intra-sector efficiency. The latter, on the other hand, after being an important source of convergence have ceased to contribute significantly to this process. Structural change in the regional economies appears as a key factor in economic convergence. However, this process has to a large extent reduced the magnitude of

[22] Taskin and Zaim (1997) and Maudos et al. (1999) obtain the same result in OECD countries. Maudos et al. (1998) also obtain the same result in the Spanish regions.

composition inefficiency as shown by graph 2. It is therefore not to be expected that, in a context of increasing competition in the European Union, future reductions in composition inefficiency will generate convergence with as much intensity as in the past. Future convergence will thus have to be based on the reduction of intra-sector inefficiency, accumulation of capital and/or technical progress.

5. Conclusions

This paper proposes a methodology for considering the importance of the composition of production when quantifying and evaluating technical efficiency and analyzes its importance as a source of convergence. For this purpose, using as the case for study the major productive sectors of the Spanish regions in the period 1964-1993, total inefficiency is broken down into one part that is attributable to the existence of inefficiencies within each sector – intra-sector inefficiency - and another part attributable to the choice of a productive specialisation that does not minimize inefficiency - composition inefficiency. The comparison of total inefficiency thus obtained with that resulting from working with aggregate data, which ignore the composition of production, shows that the latter underestimates the true inefficiency. Thus, for a proper evaluation of efficiency, productive specialisation must be considered.

Sector analysis reveals the existence of important differences in efficiency, the most inefficient sectors being agriculture and energy. The break-down of efficiency gains into an intra-sector component and a component associated with the variation in the composition of production shows that, although until the late 1970s the quantitative importance of both types of inefficiency was similar, from then onwards gains in composition efficiency are much more important, to the extent that in the last year analysed (1993), intra-sector inefficiency is four times higher than composition inefficiency. Thus, these results suggest that future efforts to reduce inefficiency -in the context of an increasing competition in the European Union - should be aimed at improving the efficiency of use of productive factors in each sector of activity, rather than reallocating resources among sectors.

The break-down of labour productivity convergence into its different components - intra-sector efficiency gains, composition efficiency gains, technical progress and a residual factor attributable to the accumulation of capital - shows that efficiency can act as a factor of convergence. Thus, for the whole of the period analysed (1964-1993), the regions that were initially poorest (with lowest labour productivity) reduced their levels of inefficiency at a faster rate that the richer regions, above all as a result of the reduction of intra-sector inefficiency. Nevertheless, the analysis by sub-periods indicates that this type of inefficiency ceases to be a significant source of convergence from the early 1970s, composition efficiency gains being from then onwards a source of convergence even more important than capital accumulation in the last years.

Appendix: The measurement of productivity growth by means of the Malmquist index

In this study the Malmquist productivity index (Malmquist, 1953) is used to measure the productivity growth of the Spanish regions. The basic idea of this method is to construct a best practice frontier for these regions and then compute the distance of individual regions from the frontier.

Following Shephard (1970) or Caves et al. (1982), the "distance function in outputs" of an individual in t relative to the technology of t (F^t) can be expressed as $D_0^t(x^t,y^t)=inf\{\vartheta^{t,t}:(x^t,y^t/\vartheta^{t,t})\in F^t\}$, where y^t is the vector of outputs, x^t the vector of inputs, and (F^t) the technology corresponding to period t. This function D_0^t is defined as the reciprocal of the maximum expansion to which it is necessary to subject the vector of outputs of period t (y^t), given the level of inputs (x^t), so that the observation stands at the frontier of period t. On the basis of the above concepts, the Malmquist productivity index based on outputs to analyze productive change between periods t and $t+1$, using the technology of period t as reference, is defined as

$$M_o^t\left(x^{t+1},y^{t+1},x^t,y^t\right)=\frac{D_o^t\left(x^{t+1},y^{t+1}\right)}{D_o^t\left(x^t,y^t\right)} \qquad \text{[A.1]}$$

$M_o^t>1$ indicates that the productivity of period $t+1$ is higher than that of period t, $M_o^t<1$ indicates that productivity has descended between periods t and $t+1$.

When we wish to analyze the productive change of a longer time series, the use of a fixed technology may cause problems the further we get from the base year. To attempt to solve these problems it is usual to calculate two indices based on pairs of consecutive years which take as base the technology of the two periods t and $t+1$, and to calculate the geometric mean of the two. Re-writing the geometric mean, it is possible to break down the Malmquist productivity index into the catching-up effect and technical change (Färe et al. ,1994) :

$$M_o\left(x^{t+1},y^{t+1},x^t,y^t\right)=\frac{D_o^{t+1}\left(x^{t+1},y^{t+1}\right)}{D_o^t\left(x^t,y^t\right)}\left[\left(\frac{D_o^t\left(x^{t+1},y^{t+1}\right)}{D_o^{t+1}\left(x^{t+1},y^{t+1}\right)}\right)\left(\frac{D_o^t\left(x^t,y^t\right)}{D_o^{t+1}\left(x^t,y^t\right)}\right)\right]^{1/2} \qquad \text{[A.2]}$$

The catching-up effect, or change in relative efficiency between periods t and $t+1$, is represented by the first ratio, which will be higher than unity if there has been an increase in efficiency. Similarly, the geometric mean of the two ratios between brackets measures the technical change, or movement of technology, between periods t and $t+1$[23].

[23] The Malmquist productivity index is obtained using distance functions calculated on the basis of problem [7].

References

Abramovitz, M. (1986): "Catching Up, Forgoing Ahead, and Falling Behind", *Journal of Economic History*, 46, 385-1406.

Abramovitz, M. (1994): "Catch-up and Convergence in the Postwar Growth Boom and After", in *Convergence of Productivity, Cross-National Studies and Historical Evidence*, 86-125, Baumol, W.J.; Nelson, R.R. and Wolff, E.N. (Eds.), Oxford University Press.

Barro, J. and Sala-i-Martin, X. (1991): "Convergence across states and regions ", *Brookings Papers on Economic Activity*, No. 1, 107-52.

Barro, J. and Sala-i-Martin, X. (1992): "Convergence", *Journal of Political Economy*, vol. 100, 223-51.

Barro, J. and Sala-i-Martin, X. (1995): *Economic Growth*, McGraw-Hill, NewYork.

Bernard, A. B. and Jones, C. I. (1996a). "Technology and Convergence", *The Economic Journal* 106*,* 1037-1044.

Bernard, A. B. and Jones, C. I. (1996b). "Productivity Across Industries and Countries: Time Series Theory and Evidence", *The Review of Economics and Statistics,* 135-146.

Caves, D.W., L.R. Christensen and W.E. Diewert, (1982). "The Economic Theory of Index Numbers and the Measurement of Input, Output and Productivity", *Econometrica* 50, 1393-1414.

Charnes, A., W.W. Cooper and E. Rhodes (1978): "Measuring the efficiency of decision making units", *European Journal of Operational Research 2,* 429-444.

De la Fuente, A. (1996): "Economía regional desde una perspectiva neoclásica. De convergencia y otras historias", *Revista de Economía Aplicada*, Vol. 4(10), 5-63.

Dolado, J., González-Páramo, J.M., and Roldán, J.M. (1994). "Convergencia entre las provincias españolas", *Moneda y Crédito* 198, 91-119.

Dollard, D. and Wolff, E.N. (1994): "Capital intensity and TFP convergence by industry in manufacturing, 1963-1985", *in Convergence of Productivity, Cross-National Studies and Historical Evidence, 197-224*, Baumol, W.L., Nelson, R R. and Wolff, E.N. (Ed.), Oxford University Press.

Dowrick, S. and Nguyen, D. (1989): "OECD comparative economic growth 1950-85: Catch-up and Convergence", *American Economic Review*, December, 79(5), 1010-30.

Färe, R., Grosskopf, S., Morris, M. and Zhang, Z. (1994). "Productivity Growth, Technical Progress, and Efficiency in Industrialized Countries", *American Economic Review* 84(1), 66-82.

Fecher, F. and Perelman S. (1992). "Productivity Growth and Technical Efficiency in OECD Industrial Activities", *Industrial Efficiency in Six Nations,* Richard Caves (Ed.), 459-488. MIT Press, Cambridge Massachusetts.

Fundación BBV/IVIE (1997): *El Stock de Capital en la Economía Española*, Mas, M.; Pérez, F. and E. Uriel (directores), 3ª edición revisada, Bilbao.

Grosskopf, S. (1993). "Efficiency and Productivity", in The *Measurement of Productive Efficiency: Techniques and Applications*, Harold O. Fried, C.A.K. Lovell and Shelton S. Schmidt (Eds.), Oxford: Oxford University Press, 160-194.

Gumbau, M. and Maudos, J. (1996). "Eficiencia productiva sectorial en la regiones españolas: una aproximación frontera", *Revista Española de Economía 13(2)*, 239-260 .

Malmquist, S. (1953). "Index Numbers and Indifference Surfaces", *Trabajos de Estadística* 4, 209-242.

Marimon, E. and Zibilotti, F. (1995): "Por qué hay menos empleo en España. Empleo "real" versus empleo "virtual" en Europa", in R. Marimon (Ed) *La economía española en una Europa diversa*, Universitat Pompeu Fabra, Barcelona.

Mas, M.; Maudos, J.; Pérez, F. and Uriel, E. (1994a): "Disparidades regionales y convergencia en las CC.AA", *Revista de Economía Aplicada*, Vol. II (4), 129-148.

Mas, M.; Maudos, J.; Pérez, F. and Uriel, E. (1994b): "Capital Público y productividad de las regiones Españolas", *Moneda y Crédito*, No. 198, 163-195.

Mas, M.; Maudos, J.; Pérez, F. and Uriel, E. (1995): "Public capital and convergence in the Spanish regions", *Entrepreneurship and Regional Development*, Vol. 7(4), 309-327.

Mas, M.; Maudos, J.; Pérez, F. and Uriel, E. (1998): "Public capital, productive efficiency and convergence in the Spanish regions. 1964-93", *The Review of Income and Wealth*, september, (forthcoming).

Maudos, J.; Pastor, J.M. and Serrano, L. (1998): "Convergencia en las regiones españolas: cambio técnico, eficiencia y productividad", *Revista Española de Economia*, vol. 15, No. 2, (forthcoming).

Maudos, J.; Pastor, J.M. and Serrano, L. (1999): "Convergence in OECD countries: technical change, efficiency and productivity", *Applied Econom*ics (forthcoming).

Perelman, S. (1995). "R&D, Technological Progress and Efficiency Change in Industrial Activities" *The Review of Income and Wealth 41(3),* 349-366.

Pérez, F.; Goerlich, F.J. and Mas, M. (1996): *Capitalización y crecimiento en España y sus regiones 1955-1996*, Fundación BBV.

Raymond, J.L. and García-Greciano, B. (1994): "Las disparidades en el PIBpc entre las CC.AA. y la hipótesis de convergencia", *Papeles de Economía Espa*ñola, No. 67, 185-201.

Sala-i-Martin, X. (1996): "Regional Cohesion: Evidence and Theories of Regional Growth and Convergence", *European Economic Review*, vol. 40.

Serrano, L. (1998a): "Capital humano y convergencia regional", Working Paper WP-EC 98-12, Instituto Valenciano de Investigaciones Económicas.

Serrano, L. (1998b): "On convergence accounting", *Applied Economic Letters* (forthcoming).

Shephard, R.W. (1970). *Theory of Cost and Production Function*, Princeton University Press. Princeton, NJ.

Taskin, F. and Zaim, O. (1997). "Catching-up and innovation in high- and low-income countries", *Economics Letters,* 54, 93-100.

Table 1: Efficiency scores by sectors ($\hat{\theta}_i^n$)

	Agriculture																	
	Andalusia	Aragon	Asturias	Balearic Isl.	Canary Isl.	Cantabria	C-León	C-La Mancha	Catalonia	Valencian C.	Extremadura	Galicia	La Rioja	Madrid	Murcia	Navarra	Basque C.	Spain(*)
1964	1,77	1,68	2,17	1,61	1,30	1,88	1,81	1,66	1,25	1,00	2,22	2,46	1,00	1,54	1,37	1,05	1,21	1,66
1973	1,26	1,21	2,39	1,41	1,36	2,01	1,48	1,07	1,01	1,00	1,64	2,68	1,15	1,17	1,22	1,00	1,00	1,39
1985	1,00	1,29	2,24	1,85	1,40	2,27	1,47	1,24	1,35	1,26	1,45	2,17	1,00	1,61	1,05	1,19	1,42	1,36
1993	1,00	1,25	2,48	1,25	1,00	1,71	1,09	1,00	1,19	1,61	1,33	2,03	1,06	1,60	1,14	1,02	1,09	1,25
1964-93(*)	1,22	1,37	2,10	1,54	1,28	1,81	1,47	1,29	1,19	1,10	1,68	2,19	1,05	1,33	1,13	1,05	1,10	1,37

	Industry																	
	Andalusia	Aragon	Asturias	Balearic Isl.	Canary Isl.	Cantabria	C-León	C-La Mancha	Catalonia	Valencian C.	Extremadura	Galicia	La Rioja	Madrid	Murcia	Navarra	Basque C.	Spain(*)
1964	1,21	1,26	1,06	1,00	1,26	1,00	1,17	1,31	1,01	1,27	1,14	1,31	1,41	1,00	1,53	1,20	1,05	1,46
1973	1,31	1,32	1,00	1,00	1,13	1,41	1,29	1,29	1,08	1,15	1,11	1,36	1,64	1,00	1,45	1,33	1,34	1,18
1985	1,14	1,00	1,00	1,00	1,11	1,15	1,05	1,19	1,03	1,09	1,35	1,17	1,18	1,00	1,20	1,09	1,02	1,06
1993	1,21	1,14	1,08	1,03	1,16	1,06	1,09	1,21	1,07	1,10	1,24	1,11	1,00	1,00	1,12	1,03	1,00	1,08
1964-93(*)	1,22	1,18	1,03	1,02	1,22	1,17	1,15	1,25	1,06	1,17	1,31	1,22	1,31	1,00	1,32	1,14	1,11	1,12

	Energy																	
	Andalusia	Aragon	Asturias	Balearic Isl.	Canary Isl.	Cantabria	C-León	C-La Mancha	Catalonia	Valencian C.	Extremadura	Galicia	La Rioja	Madrid	Murcia	Navarra	Basque C.	Spain(*)
1964	1,79	1,31	1,00	1,95	1,00	1,49	1,13	1,25	1,70	1,55	1,30	1,34	1,35	1,62	1,00	1,82	1,40	1,30
1973	1,24	1,08	1,00	1,54	1,18	1,24	1,12	1,34	1,48	1,30	1,24	1,23	1,26	1,50	1,00	1,25	1,00	1,21
1985	1,62	1,46	1,00	1,79	1,39	2,23	2,10	1,55	1,17	1,63	1,00	1,07	1,17	1,73	1,00	1,83	1,31	1,39
1993	1,27	1,62	1,10	1,40	1,52	2,52	1,57	1,00	1,33	1,09	1,00	1,46	1,00	1,21	1,00	1,64	1,09	1,28
1964-93(*)	1,43	1,42	1,08	1,71	1,32	2,10	1,62	1,35	1,38	1,46	1,22	1,24	1,26	1,66	1,01	1,64	1,30	1,35

	Construction																	
	Andalusia	Aragon	Asturias	Balearic Isl.	Canary Isl.	Cantabria	C-León	C-La Mancha	Catalonia	Valencian C.	Extremadura	Galicia	La Rioja	Madrid	Murcia	Navarra	Basque C.	Spain(*)
1964	1,60	1,45	1,50	1,20	1,42	1,23	1,46	1,70	1,00	1,11	1,78	1,49	1,02	1,17	1,43	1,31	1,04	1,28
1973	1,27	1,09	1,35	1,00	1,13	1,27	1,26	1,34	1,19	1,04	1,36	1,45	1,00	1,36	1,34	1,24	1,13	1,23
1985	1,25	1,24	1,72	1,13	1,00	1,45	1,32	1,27	1,33	1,04	1,22	1,33	1,11	1,26	1,00	1,21	1,58	1,25
1993	1,13	1,11	1,04	1,08	1,08	1,16	1,27	1,28	1,00	1,00	1,07	1,16	1,10	1,00	1,13	1,09	1,01	1,08
1964-93(*)	1,25	1,17	1,36	1,14	1,13	1,24	1,27	1,28	1,18	1,05	1,31	1,32	1,03	1,17	1,12	1,14	1,23	1,17

	Services																	
	Andalusia	Aragon	Asturias	Balearic Isl.	Canary Isl.	Cantabria	C-León	C-La Mancha	Catalonia	Valencian C.	Extremadura	Galicia	La Rioja	Madrid	Murcia	Navarra	Basque C.	Spain(*)
1964	1,38	1,24	1,18	1,08	1,23	1,16	1,35	1,48	1,02	1,25	1,42	1,47	1,26	1,00	1,18	1,14	1,01	1,17
1973	1,25	1,20	1,13	1,00	1,10	1,12	1,30	1,38	1,05	1,09	1,36	1,30	1,11	1,00	1,20	1,11	1,02	1,12
1985	1,31	1,18	1,20	1,11	1,17	1,14	1,27	1,36	1,06	1,10	1,38	1,27	1,12	1,00	1,28	1,15	1,13	1,14
1993	1,24	1,11	1,23	1,07	1,10	1,12	1,23	1,25	1,02	1,08	1,37	1,22	1,09	1,00	1,23	1,07	1,05	1,11
1964-93(*)	1,28	1,18	1,19	1,07	1,16	1,13	1,29	1,37	1,04	1,13	1,38	1,30	1,13	1,00	1,23	1,13	1,07	1,13

(*) Weighted average

Table 2: Intra-sector (🖹$_i^{IE}$) and Composition (🖹$_i^{CE}$) Efficiency

	Intra-sector efficiency (🖹$_i^{IE}$)					Composition efficiency (🖹$_i^{CE}$)				
	1964	1973	1985	1993	Average 1964-93(*)	1964	1973	1985	1993	Average 1964-93(*)
Andalusia	1,43	1,26	1,25	1,20	1,26	1,16	1,24	1,10	1,05	1,17
Aragon	1,32	1,21	1,16	1,15	1,20	1,35	1,19	1,07	1,00	1,15
Asturias	1,22	1,14	1,19	1,22	1,19	1,39	1,18	1,17	1,05	1,19
Balearic Islands	1,13	1,02	1,14	1,08	1,10	1,25	1,03	1,05	1,04	1,10
Canary Islands	1,24	1,13	1,16	1,11	1,17	1,29	1,14	1,05	1,00	1,11
Cantabria	1,20	1,28	1,25	1,17	1,22	1,35	1,17	1,12	1,04	1,17
C-León	1,40	1,30	1,31	1,21	1,31	1,41	1,32	1,10	1,00	1,22
C-La Mancha	1,50	1,30	1,31	1,19	1,32	1,26	1,39	1,16	1,03	1,24
Catalonia	1,04	1,08	1,08	1,05	1,06	1,20	1,10	1,05	1,00	1,08
Valencian Com.	1,22	1,10	1,12	1,10	1,13	1,24	1,18	1,14	1,06	1,16
Extremadura	1,59	1,37	1,35	1,28	1,40	1,16	1,44	1,20	1,08	1,28
Galicia	1,63	1,48	1,35	1,29	1,39	1,34	1,29	1,27	1,08	1,27
La Rioja	1,21	1,22	1,12	1,06	1,15	1,52	1,37	1,15	1,05	1,27
Madrid	1,03	1,03	1,02	1,01	1,02	1,00	1,00	1,00	1,00	1,00
Murcia	1,26	1,24	1,20	1,18	1,21	1,58	1,22	1,12	1,07	1,22
Navarra	1,16	1,18	1,15	1,06	1,13	1,38	1,20	1,10	1,01	1,17
Basque Country	1,04	1,15	1,12	1,03	1,10	1,22	1,00	1,02	1,00	1,04
Spain(*)	1,22	1,17	1,16	1,11	1,16	1,23	1,16	1,09	1,03	1,13

(*)Weighted average

Table 3: Output composition (%)

	1964																	
	Andalusia	Aragon	Asturias	Balearic Isl.	Canary Isl.	Cantabria	C-León	C-La Mancha	Catalonia	Valencian C.	Extremadura	Galicia	La Rioja	Madrid	Murcia	Navarra	Basque C.	Spain
Agriculture	12,27	12,40	7,54	6,50	13,18	9,37	16,82	22,36	4,03	11,39	20,48	18,80	24,39	0,95	11,68	15,85	4,25	9,18
Construction	9,80	9,70	9,45	9,64	9,01	7,63	8,31	6,93	9,48	9,03	10,69	9,33	7,27	9,23	7,48	7,91	8,33	9,09
Energy	1,99	6,68	22,79	1,40	7,06	3,24	8,92	4,80	2,10	2,02	2,53	3,62	1,73	1,11	9,41	1,78	2,37	3,75
Industry	14,87	15,48	15,15	10,69	7,99	27,58	12,51	13,91	24,61	19,30	9,90	14,29	17,85	13,92	14,94	19,29	31,32	18,02
Services	61,07	55,74	45,07	71,77	62,76	52,19	53,43	52,00	59,77	58,27	56,40	53,96	48,76	74,80	56,49	55,17	53,72	59,97
Total	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

	1993																	
	Andalusia	Aragon	Asturias	Balearic Isl.	Canary Isl.	Cantabria	C-León	C-La Mancha	Catalonia	Valencian C.	Extremadura	Galicia	La Rioja	Madrid	Murcia	Navarra	Basque C.	Spain
Agriculture	12,49	9,66	4,18	2,60	5,41	6,29	14,03	17,42	2,52	3,97	15,22	11,18	11,30	0,30	10,61	6,31	2,78	6,35
Construction	8,13	7,49	9,27	6,34	7,49	7,79	8,23	10,13	7,29	7,24	12,42	9,78	6,50	7,33	8,92	7,32	7,16	7,87
Energy	2,55	3,78	10,81	2,41	2,72	1,85	6,12	5,60	3,20	2,83	7,96	3,86	1,51	2,03	4,17	1,65	4,43	3,49
Industry	12,78	22,98	19,02	7,08	7,45	23,56	17,58	17,84	26,57	24,28	8,77	16,45	30,57	14,88	17,93	34,21	29,54	19,40
Services	64,05	56,08	56,72	81,56	76,93	60,51	54,04	49,02	60,42	61,68	55,62	58,73	50,12	75,46	58,36	50,52	56,09	62,88
Total	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

	1993 - 1964																	
	Andalusia	Aragon	Asturias	Balearic Isl.	Canary Isl.	Cantabria	C-León	C-La Mancha	Catalonia	Valencian C.	Extremadura	Galicia	La Rioja	Madrid	Murcia	Navarra	Basque C.	Spain
Agriculture	0,22	-2,74	-3,36	-3,90	-7,77	-3,08	-2,79	-4,94	-1,52	-7,41	-5,26	-7,62	-13,09	-0,64	-1,07	-9,55	-1,47	-2,83
Construction	-1,67	-2,20	-0,18	-3,29	-1,52	0,17	-0,09	3,20	-2,19	-1,79	1,73	0,45	-0,77	-1,90	1,44	-0,59	-1,17	-1,21
Energy	0,56	-2,90	-11,98	1,01	-4,35	-1,39	-2,80	0,80	1,10	0,81	5,44	0,24	-0,22	0,92	-5,24	-0,13	2,05	-0,26
Industry	-2,09	7,50	3,87	-3,61	-0,54	-4,02	5,06	3,93	1,96	4,98	-1,13	2,16	12,71	0,97	3,00	14,92	-1,78	1,38
Services	2,98	0,34	11,65	9,79	14,17	8,32	0,61	-2,98	0,65	3,42	-0,77	4,77	1,36	0,66	1,87	-4,66	2,37	2,92

	Average 1964-93																	
	Andalusia	Aragon	Asturias	Balearic Isl.	Canary Isl.	Cantabria	C-León	C-La Mancha	Catalonia	Valencian C.	Extremadura	Galicia	La Rioja	Madrid	Murcia	Navarra	Basque C.	Spain
Agriculture	10,99	8,79	4,79	3,54	6,29	6,96	12,55	16,38	2,67	6,11	15,70	12,13	13,75	0,49	9,51	8,85	2,83	6,34
Construction	9,11	7,73	6,85	8,31	10,61	6,68	8,07	10,12	6,85	8,04	10,37	9,22	7,32	6,83	8,72	7,19	5,96	7,81
Energy	2,72	6,01	16,17	1,94	4,32	2,58	7,38	5,15	3,38	2,32	5,83	5,15	1,56	1,35	6,85	1,90	3,70	3,84
Industry	15,31	22,09	23,32	9,32	7,54	27,86	17,63	17,45	28,68	23,75	9,71	16,81	24,78	17,17	17,47	30,72	35,89	21,26
Services	61,86	55,38	48,87	76,89	71,24	55,92	54,37	50,91	58,43	59,77	58,39	56,69	52,59	74,14	57,45	51,33	51,62	60,75

Table 4: Total Efficiency (🖹$_i$)

	1964	1973	1985	1993	Average 1964-93(*)
Andalusia	1,66	1,57	1,38	1,26	1,48
Aragon	1,79	1,44	1,25	1,15	1,38
Asturias	1,70	1,34	1,40	1,28	1,40
Balearic Islands	1,41	1,06	1,19	1,12	1,21
Canary Islands	1,60	1,28	1,23	1,11	1,30
Cantabria	1,61	1,50	1,40	1,22	1,43
C-León	1,97	1,72	1,44	1,21	1,59
C-La Mancha	1,88	1,81	1,53	1,23	1,64
Catalonia	1,24	1,19	1,13	1,05	1,15
Valencian Com.	1,50	1,30	1,27	1,16	1,32
Extremadura	1,85	1,98	1,62	1,39	1,79
Galicia	2,19	1,90	1,71	1,40	1,78
La Rioja	1,84	1,68	1,28	1,11	1,47
Madrid	1,03	1,03	1,02	1,01	1,02
Murcia	1,98	1,51	1,35	1,27	1,48
Navarra	1,60	1,41	1,26	1,08	1,33
Basque Country	1,27	1,15	1,14	1,03	1,15
Spain(*)	1,50	1,35	1,26	1,14	1,31

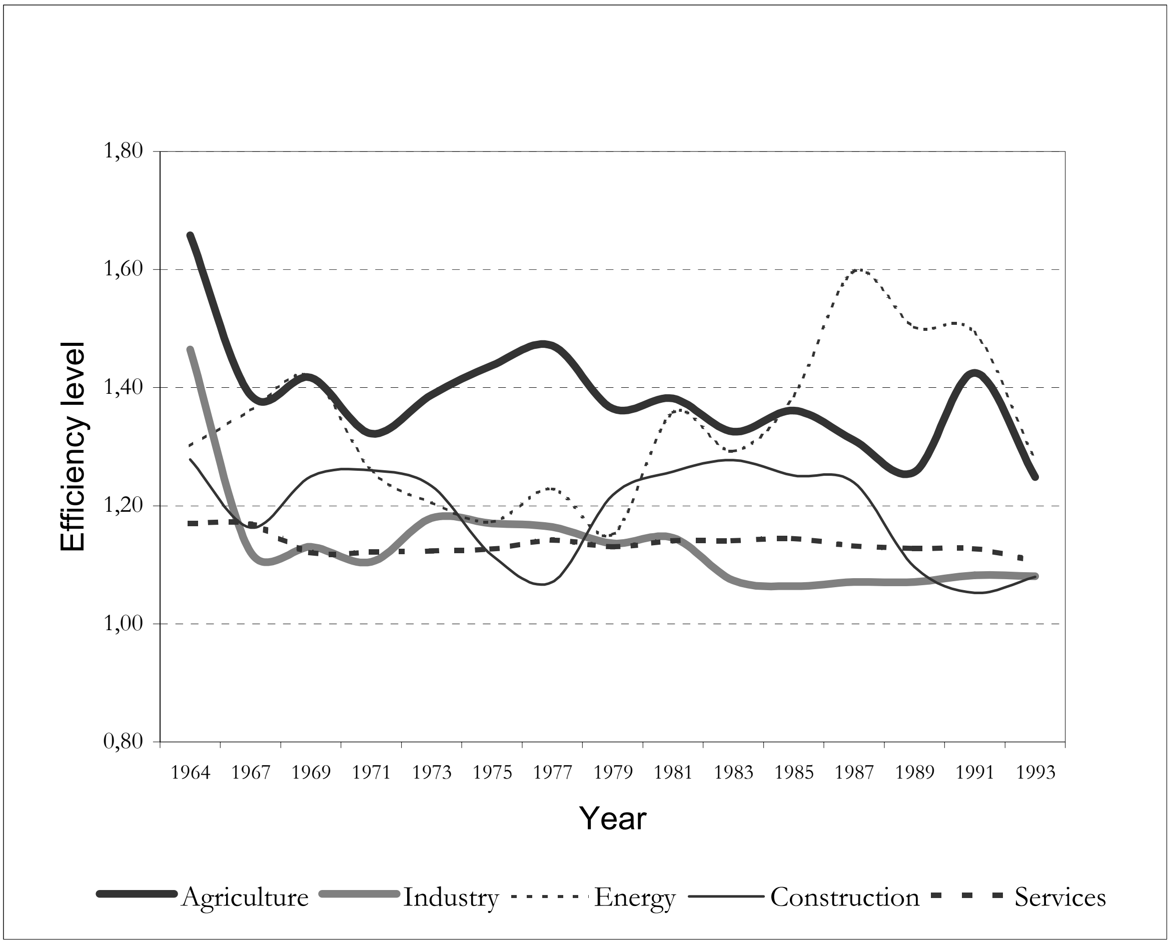
(*)Weighted average

Table 5: Sources of convergence in the Spanish regions

	(1)=(2)+(5)+(6) Labor Productivity (Y/L)	(2)=(3)+(4) Changes in total efficiency	(3) Changes in intra-sector efficiency	(4) Changes in composition efficiency	(5) Technical Change	(6) Residual: Input accumulation
1964-93	-0,0235 (-14.782) *R^2=0.94*	-0,0112 (-3.714) *R^2=0.48*	-0.0088 (-6.948) *R^2=0.76*	-0.0024 (-0.714) *R^2=0.03*	0,022 (2.315) *R^2=0.26*	-0,0343 (-3.116) *R^2=0.39*
1964-73	-0.0222 (-2.251) *R^2=0.29*	0,0025 (-0.246) *R^2=0.00*	-0.0207 (-3.584) *R^2=0.46*	0.0232 (2.142) *R^2=0.23*	0,0456 (3.314) *R^2=0.43*	-0,0703 (-3.685) *R^2=0.47*
1973-85	-0.0358 (-6.469) *R^2=0.74*	-0,0246 (-4.085) *R^2=0.53*	-0,0088 (-2.513) *R^2=0.30*	-0,0158 (-3.076) *R^2=0.39*	0,0175 (1.616) *R^2=0.15*	-0,0286 (-2.260) *R^2=0.25*
1985-93	-0.0479 (-5.142) *R^2=0.64*	-0,0346 (-4.678) *R^2=0.59*	-0,0037 (-0.570) *R^2=0.02*	-0,0308 (-7.243) *R^2=0.77*	0,0112 (0.637) *R^2=0.03*	-0,0245 (-1.286) *R^2=0.10*

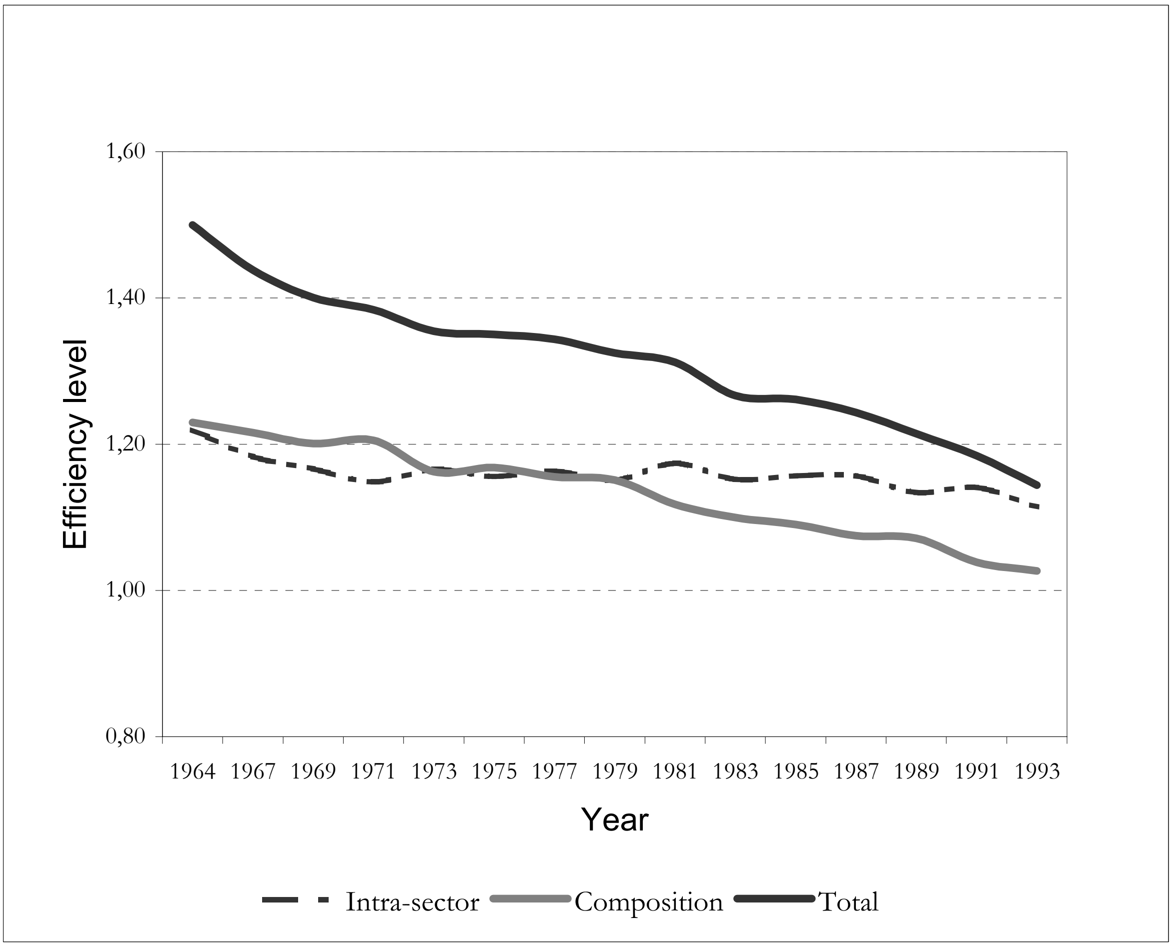
t-ratios between parentheses

Figure 1: Sector Efficiency (weighted average)



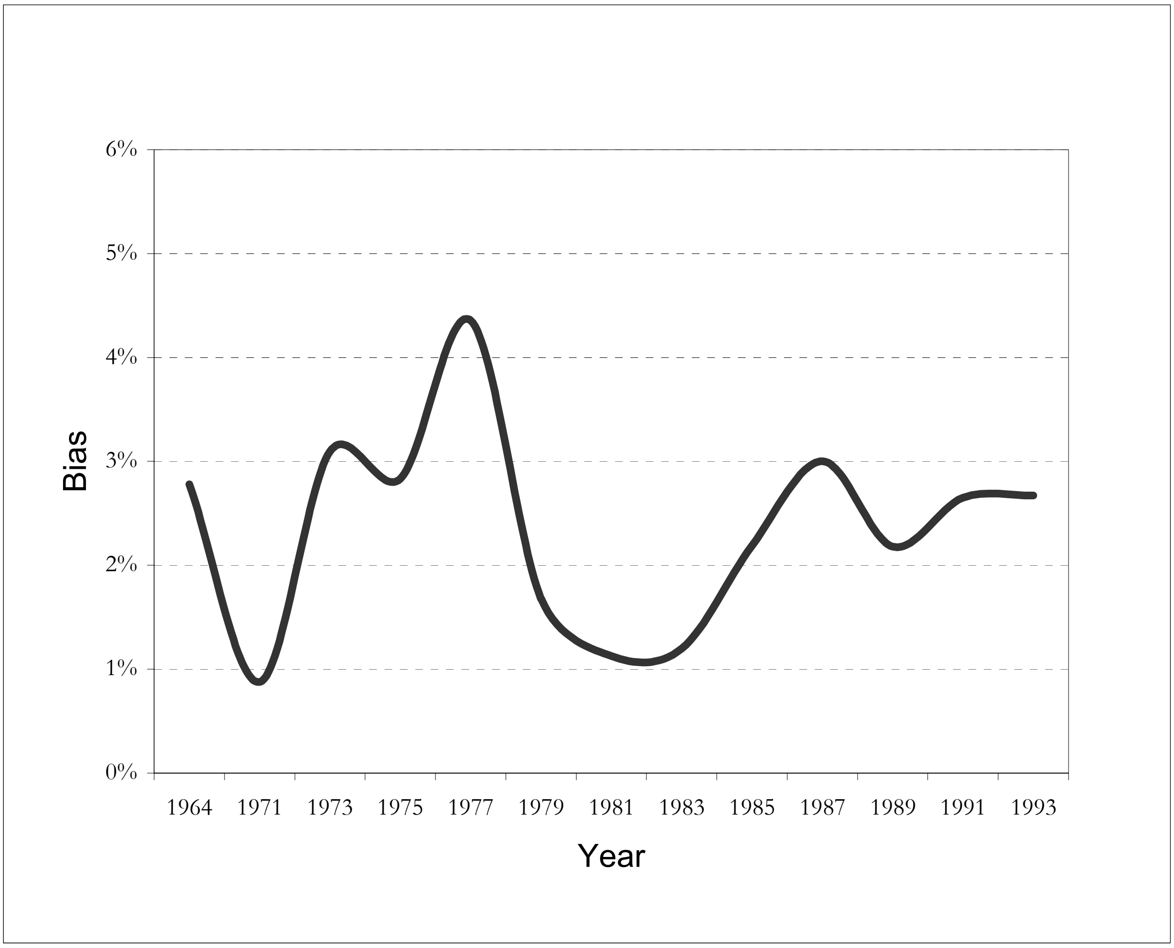
	Agriculture	Industry	Energy	Construction	Services
1964	1,658052143	1,464669613	1,301562968	1,278111856	1,170056914
1967	1,387371219	1,121004833	1,361813332	1,162771028	1,168811328
1969	1,416923502	1,130225939	1,419880828	1,249712471	1,12067008
1971	1,322237989	1,10522859	1,259352657	1,259658115	1,121900185
1973	1,387614338	1,179128895	1,205071208	1,233303009	1,123236977
1975	1,437774578	1,169730468	1,172497179	1,115878999	1,126602517
1977	1,471365287	1,164095677	1,22841493	1,071102435	1,141650333
1979	1,364514971	1,136141783	1,15173626	1,218135601	1,13050184
1981	1,382060403	1,145412649	1,357928136	1,257853267	1,14065489
1983	1,325391026	1,073718906	1,292588354	1,27702956	1,140945572
1985	1,361432358	1,063861359	1,385995009	1,25146442	1,144712114
1987	1,310770215	1,070798451	1,597008976	1,239193158	1,132115844
1989	1,257177163	1,070616223	1,502421758	1,096058664	1,127599777
1991	1,425015756	1,08208707	1,493445938	1,052602587	1,127043207
1993	1,248294167	1,080424435	1,27595058	1,07935501	1,106608395

Figure 2: Total, intra-sector and composition efficiency (Weighted average)



	Intra-sector	Composition	Total
1964	1,219521957	1,229868438	1,499851565
1967	1,182927492	1,215780408	1,438180069
1969	1,166264967	1,200704998	1,400340175
1971	1,148451369	1,205117065	1,384018343
1973	1,165626597	1,162170983	1,354657407
1975	1,155963593	1,168111931	1,350294864
1977	1,163064646	1,155145167	1,343508504
1979	1,151146426	1,150846625	1,324792978
1981	1,17360429	1,117940744	1,312020053
1983	1,151817173	1,099567965	1,266501264
1985	1,156589084	1,090346605	1,261082981
1987	1,156670053	1,075049855	1,243477973
1989	1,133866224	1,07117819	1,21457277
1991	1,140725911	1,038306538	1,184423171
1993	1,114291663	1,02660484	1,143937214

Figure 3: Bias evolution



1964	0,027804885
1971	0,008766409
1973	0,030940041
1975	0,028323414
1977	0,043576141
1979	0,0168072
1981	0,011269807
1983	0,011978534
1985	0,021901884
1987	0,03000041
1989	0,02178238
1991	0,026512263
1993	0,026729231