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Sources of productivity growth in the Spanish pharmaceutical industry (1994-2000)

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Abstract

The Spanish pharmaceutical industry underwent an important transformation during the 1990s. To survive under the new market conditions, labs had to refocus their competitive strategies towards increasing productive efficiency or reinforcing R&D activities. This paper analyzes the evolution of the productive patterns in a sample of 80 pharmaceutical laboratories that operated in Spain from 1994 to 2000. We estimate Malmquist productivity indexes and decompose them into four sources of productivity change. The results suggest that pure technical efficiency change and the scale change of the technology explain most of the productivity growth observed during the period. The contribution of technical change to productivity growth is negligible, indicating a poor result from R&D activities at least in the group of small and medium sized labs.

Keywords: Productivity, Malmquist index decomposition, pharmaceutical labs, DEA.

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1. Introduction

Several important regulatory changes shaped the evolution of the Spanish pharmaceutical industry during the 1990s. First, the 1990 Drugs Act introduced new safety, quality, and effectiveness requirements for the registration of new drugs. Second, the 1986 reform in the patents system, adopted as a consequence of Spain's entry into the European Union, allowed for product patents to be registered in Spain from 1992 on. Third, the method employed to regulate the price of drugs was also changed in 1990. Despite the fact that since 1998 the Government can only regulate the prices of the drugs financed by the Health Administration, in practice, price controls on drugs intensified due to the pressure to comply with the strict budgetary requirements to enter the European Monetary Union.

The objective of this paper is to assess how these changes have affected the productive activity of the Spanish pharmaceutical laboratories. Pharmaceutical activity is complex, and can be divided into three principal tasks: production, distribution, and research and development (R&D). In the early evolution of the Spanish pharmaceutical industry, a protectionist regulatory environment fostered the proliferation of local labs whose main activity consisted of copying and manufacturing foreign products that were unprotected by product patents in Spain or other European countries. This situation also led multinationals to locate production plants in every European country. The landscape changed dramatically after the consolidation of the European Common Market. Frontiers within the Euro-zone virtually disappeared and multinationals concentrated production in order to achieve economies of scale (Rodríguez and Miravitlles, 1999).

With respect to R&D activities, the primary inputs are the skills of scientists and the ability to maintain an extensive flow of information within firm boundaries and also between the firm and the scientific community. Firms wishing to take advantage of

research conducted beyond the organizational boundaries need to invest in “absorptive capacity” (Cohen and Levinthal, 1989). In other words, they need to accumulate the knowledge, skills, and organizational routines needed to identify and use the knowledge that has been generated elsewhere (Cockburn & Henderson, 1998). Pharmaceutical research activities are subjected to significant economies of scale and scope[1] (Henderson and Cockburn, 1996).

The third task undertaken by pharmaceutical labs is commercialization. Labs commercialize two types of pharmaceutical products: own products (developed in-house) and licensed products (developed by other labs). The highest margins and sales come from own products. In general, labs concentrate their research efforts on a narrow range of pharmaceutical products, although sales may spread over a wide variety of products (licensed and generics). In order to gain access to a license the most important aspect is the sales force under the control of the lab. Competition to obtain licenses induces a decline in commercial margins. The environmental changes mentioned above have tended to increase the weight given to drugs commercialization in the activity of international companies present in Spain, thereby reducing investment in R&D and production facilities.

To assess the impact of these regulatory changes in the Spanish pharmaceutical industry, this paper estimates the sources of productivity change during the period 1994-2000 in a sample of 80 Spanish labs. We first describe the recent evolution of the Spanish pharmaceutical industry. Then, we present a non-parametric

[1] Achilladelis and Antonakis (2001) provide an excellent and exhaustive historical assessment of the driving forces of technological innovation in the pharmaceutical industry. While many of these can be considered environmental (government legislation, competition, scientific and technological advances, etc.), company specific forces exert a very strong influence on the patterns of innovation within this industry.

model that permits the measurement of pharmaceutical productivity change and its decomposition into two indexes related to efficiency gains and two indexes related to technical change. The subsequent sections describe the data and discuss the results. Concluding remarks are presented in a final section.

2. The Pharmaceutical Industry in Spain

The European pharmaceutical industry is heavily regulated. Within the European Union, about 63% of the global expenditure on drugs is financed by the Administration, with this figure increasing to 72% in Spain. It is therefore unsurprising that the growth in the pharmaceutical bill is an issue of maximum concern to all European governments. These concerns increased during the second half of the 1990s due to the need to control public expenditure in order to meet the requirements for entry into the Monetary Union. In recent years, the Spanish Government has tried to achieve an exact balance between public income and public expenditure, a policy which has been labelled *déficit cero*. This objective has affected the pharmaceutical industry in the form of a stricter price regulation that has had the overall effect of decreasing the margins in the industry. The first price revision of the decade (undertaken in 1991) allowed an increase of 3.2%. The following revisions (in 1993 and 1999) forced reductions of 3%, although other revisions in the lists of drugs (in 1996 and 1997) may have had a favorable impact on the prices of 0.8% each year (estimates of Farmaindustria, 2001). In summary, while the price index of pharmaceutical products increased by 8.5% from 1992 to 2000, the general price index increased 30.4% during the same period (Farmaindustria, 2000). The margins of wholesalers and pharmacies were also significantly reduced during the decade. Additionally, the number of products reimbursable by the Health Administration has

also decreased from 8210 in 1990 to 7350 in 2000, a 10.5% reduction[2]. However, the reduction in the list of reimbursable drugs does not seem to have had a significant impact on the pharmaceutical bill, because patients are able to switch to other products with similar therapeutic effects (Nonell and Borrell, 1998).

The pharmaceutical industry is intensive in R&D. Of the 336 labs that operated in Spain in 1998, 41.1% had investments in R&D. The global expenditure on R&D represented 7.7% of drugs sales. Even though this sector leads in R&D activity in Spanish industry in relative terms[3], a deceleration can be appreciated over recent years, probably due to the uncertainties introduced by the price reductions enforced by the regulators in those years (Farmaindustria, 2000). Between 1992 and 2000—the period in which product patents become available—3788 prescription medicines and 406 over-the-counter (OTC) products were registered. Before 1992, activity in the Spanish industry consisted of producing and selling copies of products developed by foreign firms (Rovira, 1998). Given the new constraints imposed by the regulatory environment, the ability to introduce new products will be the only way to raise margins in the future. This, of course, requires more intensive investment in R&D and also the possession of a substantial pool of knowledge and absorptive capacity within the labs (Henderson and Cockburn, 1994). This new situation places non-innovative labs at a serious competitive disadvantage that threatens their survival. The cost of developing a new product has also increased as a consequence of the new requirements imposed on safety and effectiveness, which in turn contributes to increasing the degree of market concentration (Puig, 1998)

[2] Prescription sales account for 94.5% of the market and the co-payment percentage (7%) is one of the smallest in the EU, with only the Netherlands (0.6%) and the United Kingdom (4.9%) having lower figures.

[3] The automobile industry spends more on R&D activities, but its weight in the GNP is also much more significant.

The pharmaceutical labs that operate in Spain confront the threats posed by the new regulatory environment in different ways. Multinational labs are largely diversified over a wide range of therapeutic products and geographical areas. This diversification and globalization strategy comes from the need to obtain a stable stream of returns during the life of the products' patents to cover the massive investments in R&D. Given the large economies of scale and scope that exist in pharmaceutical R&D activities, some labs have tried to increase their size. During the 1990s some of the leading multinational pharmaceutical companies have engaged in merger processes (Glaxo/Wellcome, Upjohn/Pharmacia, Ciba-Geigy/Sandoz, Pfizer/Warner-Lambert). These mergers may reduce the total level of R&D through a rationalization that eliminates unproductive overlapping in R&D activities, but also may reduce beneficial R&D activities due to anticompetitive practices (Morgan, 2001). In the Spanish context, multinational companies have never undertaken important research activity but instead have limited themselves to production and distribution. Even though some firms carry out R&D in Spain (GlaxoSmithKline, Beecham, and Novartis) the magnitude of these activities is insignificant in terms of the global R&D effort of these companies. In fact there is an important geographical concentration of R&D activities in the pharmaceutical industry. Achilladelis and Antonakis (2001) report that about 80% of R&D activities are concentrated in five countries: the USA, Germany, Switzerland, the UK and France.

National labs, on the other hand, target the Spanish geographical market and some of them export their own products. These labs are usually family-owned and their small size prevents them from operating at a global level, except for some very specific niche products. Large Spanish labs follow strategies that are similar to multinational labs in terms of R&D, although at a smaller scale. They also concentrate in fewer therapeutic groups, although sales are spread over a wider range of products. Their competitive disadvantage in comparison to multinationals is that they lack critical mass

in R&D. This limits the number of own products and forces Spanish labs to rely on licenses, which provide lower margins, or on commercial activities. Today just a few Spanish labs carry out R&D (Ferrer, Admirall-Prodesfarma, and Esteve)[4]. The representatives of the pharmaceutical industry complain that an excessive control on prices discourages R&D activities. The evidence shows that the leading countries in pharmaceutical R&D also charge higher prices. In light of the disappointing R&D results in the Spanish pharmaceutical industry, some authors call for a more active role of the Administration in promoting these activities, including patent protection, higher prices and public financing of innovative products, initiatives that should be undertaken at the EU level (Rovira, 1998).

Spanish small and medium-sized labs are the most affected by the changes in the regulatory environment. They came into business because of the absence of strong patent protection and they never really engaged in R&D activities. Thus, they lack own products with high margins. Maintaining themselves up to date is also difficult and expensive because of the rapid technological changes of the pharmaceutical sector. These firms will tend to disappear unless they specialize in niche products or produce small lots of licensed products for multinationals (Rodríguez and Miravitlles, 1999). Rodríguez (2000) explored the characteristics of the labs that were experiencing decline. They found Spanish ownership in all the declining firms, while the capital in non-declining firms was both Spanish and foreign. Most of the declining firms were also small labs. He identified three basic factors influencing the decline of Spanish labs: 1) the lack of new products is the major source of decline, 2) the price reduction in old products, and 3) an excessive dispersion in sales and R&D efforts, instead of concentrating in a narrow range of therapeutic groups.

[4] National labs are considerably larger than the small Spanish labs, but they are small by international standards (Rodríguez and Miravitlles, 1999).

3. Data

The data used in this study comes from the CABSA database. It contains accounting data for a large number of firms classified according to the Spanish National Code of Economic Activities (CNAE)[5]. The firms listed in the CABSA database are included in seven different CNAE codes. To delimit the scope of the study to pharmaceutical labs we considered the 5-digit CNAE code 24421, which contains firms that produce and sell pharmaceutical products both for human and veterinary use[6]. After filtering out some firms that did not provide all the information that was necessary for the estimation of the model presented in this paper, the final sample contains aggregated annual firm-level data on 80 labs that operated in Spain from 1994 to 2000. This sample accounts for approximately 25% of the population of labs in Spain according to Farmaindustria (2000).

To compute the indexes of efficiency and productivity, we have selected the net sales as the output variable and labor costs, fixed assets depreciation (capital) and other costs as the three inputs utilized. These data were deflated using the Spanish Consumer Price Index, base 1994. Table 1 provides the basic descriptive statistics of these variables in 2000 (expressed in billions of pesetas).

<<<<<<<<<<<<<<<TAKE IN TABLE 1>>>>>>>>>>>>>>>>>

4. Methodology

[5] This classification scheme is similar to the SIC codes.

[6] We use the term lab and firm indistinctly. Even though some of the labs included in the sample belong to multinational corporations, they are *strategic business units* that operate in Spain as an independent firm.

This section briefly explains the foundations of the computation of Malmquist productivity indexes and their decomposition with non-parametric techniques. In order to estimate efficiency and productivity growth in the labs included in the sample, we will follow a non-parametric approach to the computation and decomposition of the Malmquist productivity index. Several different decompositions of the Malmquist index have been proposed in the literature. The most commonly used are those proposed by Färe et al (1994), which assumes a constant returns to scale technology, and Ray and Desli (1997), which does not require that assumption. A third decomposition has been suggested by Simar and Wilson (1998) and Zofio and Lovell (1998), which extends the Ray and Desli (1997) decomposition. More concretely, the technical change component in Ray and Desli (1997) is further decomposed into a "pure" technical change of the frontier plus a residual measure of the scale change of the technology. This residual measure evaluates the separation between the constant returns to scale and the variable returns to scale technologies. In this paper, we will follow this extended decomposition because it adds more information about the sources of productivity change.

The Malmquist productivity index was introduced by Caves, Christensen, and Diewert (1982) as the ratio of two distance functions pertaining to distinct time periods[7]. The productivity level of a firm may be measured by the relationship between the inputs employed and the outputs attained. In the case of a technology with just one input and one output, a productivity index can be computed, using only quantity data, as the ratio y_i^t / x_i^t, where y_i^t is the quantity of output produced by firm i at period t and x_i^t the quantity of input employed by that firm during the same period.

[7] The index took its name from Sten Malmquist, who had proposed the construction of quantity indexes based on distance functions (Malmquist, 1953). See also Moorsten (1961).

A difficulty arises with multidimensional production technologies, which involve comparing vectors of inputs and outputs. In these cases it is necessary to use some criterion to aggregate inputs and outputs. The resulting productivity index can be defined as $g^t(\mathbf{y}_i^t)/h^t(\mathbf{x}_i^t)$, where $g^t(\mathbf{y}_i^t)=\mathbf{u}^t\mathbf{y}^{t\prime}$ is an output aggregating function where $\mathbf{u}^t$ is the weighting vector, and $h^t(\mathbf{x}_i^t)=\mathbf{v}^t\mathbf{x}^{t\prime}$ is an input aggregating function with weighting vector $\mathbf{v}^t$. The question then arises as to how these weights should be chosen. While an obvious possibility is to use the prices of inputs and outputs, the Malmquist approach allows the above index to be computed using only data on quantities. It is defined as a ratio between distance functions and the computation of these distance functions implicitly generates appropriate weights for inputs and outputs.

Given that distance functions are computed by comparing a given firm with another firm that acts as referent or benchmark, the relative productivity index has to be defined as the ratio between the absolute productivity index of the firm in question (defined above) and the absolute productivity index of the benchmark firm. This relative productivity index (*RP*) can be defined as:

$$(1) \qquad RP_i^t = \frac{g^t(\mathbf{y}_i^t)/h^t(\mathbf{x}_i^t)}{g^t(\mathbf{y}_*^t)/h^t(\mathbf{x}_*^t)}$$

where the symbol * represents the benchmark firm, i.e. the firm that attains the highest ratio of absolute productivity. Note that the relative productivity index of the benchmark firm must take a value of one, while remaining firms will have relative productivities of less than one.

It is possible to compute the *RP* index using distance functions, but certain assumptions must first be made regarding the production technology, namely constant returns to scale (i.e. homogeneity of degree one) and separability of inputs and outputs. The output distance function is defined with respect to that technology as[8]:

$$(2) \qquad DC_i^t(\mathbf{x}_i^t, \mathbf{y}_i^t) = \min\left\{\theta : (\mathbf{x}_i^t, \theta^{-1}\mathbf{y}_i^t) \in T_{CCR}^t\right\}$$

where T_{CCR}^t represents the CCR technology, which satisfies the assumptions in Charnes, Cooper, and Rhodes (1978) of constant returns to scale (CRS) and free disposability of inputs and outputs. The distance function indicates the maximum proportion by which the output vector can be expanded, holding the input vector constant, in order to obtain the productivity level of the benchmark firm. Thus, it is a measure of relative productivity. The value of the distance function for a firm can be computed by solving the following linear program:

$$(3) \qquad \begin{aligned} DC_i^t(\mathbf{x}_i^t, \mathbf{y}_i^t) = \max \quad & \theta = \frac{\mathbf{u}^t \mathbf{y}_i^{t\,\prime}}{\mathbf{v}^t \mathbf{x}_i^{t\,\prime}} \\ s.a \quad & \frac{\mathbf{u}^t \mathbf{y}_j^{t\,\prime}}{\mathbf{v}^t \mathbf{x}_j^{t\,\prime}} \le 1 \quad , \quad j \in J \\ & \mathbf{u}^t, \mathbf{v}^t \ge 0 \end{aligned}$$

where J represents the set of firms used to construct the empirical reference technology, which are generically denoted by the subindex j to distinguish them from

[8] Distance functions can be defined with an input or output orientation. Given that in our empirical application we have chosen an output orientation, the methodology is explained for an output orientation. It is very easy to extend these results to an input orientation using the appropriate input distance functions instead of output distance functions. In the particular case of the constant returns to scale technology, the value of the distance function is the same in both orientations (Färe and Lovell, 1978).

the firm that is being evaluated, i. The program finds the weights that maximize the relative productivity of firm i. The objective function measures the distance that separates this firm from the benchmark firm in terms of productivity. Thus,

(4) $$RP_i^t = DC_i^t(\mathbf{x}_i^t, \mathbf{y}_i^t)$$

The Malmquist index introduced by Caves *et al.* (1982) measures the variation in the relative productivity of a firm between two time periods with respect to the reference production technology—i.e., the benchmark firm—, which we hold fixed:

(5) $$M_{CCD}^t = \frac{DC_i^t(\mathbf{x}_i^{t+1}, \mathbf{y}_i^{t+1})}{DC_i^t(\mathbf{x}_i^t, \mathbf{y}_i^t)}$$

Note that the only difference between the distance functions in the numerator and the denominator are the activity vectors of the firm evaluated. The benchmark technology is constructed in both periods from the data of period t. The same effect could be measured using the period $t+1$ technology as the benchmark technology,

(6) $$M_{CCD}^{t+1} = \frac{DC_i^{t+1}(\mathbf{x}_i^{t+1}, \mathbf{y}_i^{t+1})}{DC_i^{t+1}(\mathbf{x}_i^t, \mathbf{y}_i^t)}$$

To avoid choosing arbitrarily between taking period t or period $t+1$ technology as the reference to compute the Malmquist productivity index, the usual way to proceed is to take the geometric mean of these indexes,

(7) $$M_{CCD}(\mathbf{x}_i^{t+1}, \mathbf{y}_i^{t+1}, \mathbf{x}_i^t, \mathbf{y}_i^t) = \left[\frac{DC_i^t(\mathbf{x}_i^{t+1}, \mathbf{y}_i^{t+1})}{DC_i^t(\mathbf{x}_i^t, \mathbf{y}_i^t)} \frac{DC_i^{t+1}(\mathbf{x}_i^{t+1}, \mathbf{y}_i^{t+1})}{DC_i^{t+1}(\mathbf{x}_i^t, \mathbf{y}_i^t)} \right]^{1/2}$$

If $M_{CCD}(\mathbf{x}_i^{t+1}, \mathbf{y}_i^{t+1}, \mathbf{x}_i^t, \mathbf{y}_i^t) > 1$, the index reflects a productivity growth that may come from different sources. First, it is possible that the firm improved its level of efficiency relative to the benchmark firm, i.e., the firm performed relatively better than the benchmark firm. This effect is commonly referred to as *catching up*. Second, the available technology may have also improved (recall that we have fixed the technology). Färe, Groskopf, Norris, and Zhang (1994) were the first to propose a decomposition of the Malmquist index that separates both sources of productivity variation,

$$(8) \qquad M_{CCD}(\mathbf{x}_i^{t+1}, \mathbf{y}_i^{t+1}, \mathbf{x}_i^t, \mathbf{y}_i^t) = \frac{DC_i^{t+1}(\mathbf{x}_i^{t+1}, \mathbf{y}_i^{t+1})}{DC_i^t(\mathbf{x}_i^t, \mathbf{y}_i^t)} \left[\frac{DC_i^t(\mathbf{x}_i^{t+1}, \mathbf{y}_i^{t+1})}{DC_i^{t+1}(\mathbf{x}_i^{t+1}, \mathbf{y}_i^{t+1})} \frac{DC_i^t(\mathbf{x}_i^t, \mathbf{y}_i^t)}{DC_i^{t+1}(\mathbf{x}_i^t, \mathbf{y}_i^t)} \right]^{1/2} =$$

$$= \text{efficiency change} \cdot [\text{technical change}] = \Delta EF_i^{t,t+1} \cdot \Delta T_{CCR,i}^{t,t+1}$$

The first ratio in (8) reflects the relative efficiency change of the firm evaluated—variation in the distance towards its contemporaneous frontier—, while the second ratio (in brackets) shows the productivity change that can be attributed to a movement in the CCR frontier—benchmark firm—between t and $t+1$. Notice that, even though this last component refers to technical change, it incorporates the subindex of firm *i* because it is computed from the activity vectors of firm *i*. Thus, the technical change index measures the movement of the frontier at the output level of the firm that is being evaluated, and is defined as a geometric mean in order to avoid choosing between periods.

The efficiency change index may in turn be decomposed into two indexes. One of them measures the change in pure technical efficiency and must be computed with respect to the variable returns to scale (VRS) technology, while the other one measures scale efficiency change. The VRS frontier has the advantage of providing a

more appropriate treatment of firm heterogeneity associated with firm size. In the pharmaceutical industry there are important differences between small, medium, and large labs. The VRS frontier provides, for each lab, the best possible production vector that a lab of that size can achieve. The index is computed as,

$$(9) \qquad DV_i^t(\mathbf{x}_i^t, \mathbf{y}_i^t) = \min\left\{\theta : (\mathbf{x}_i^t, \theta^{-1}\mathbf{y}_i^t) \in T_{BCC}^t\right\}$$

which is the output distance function defined with respect to the T_{BCC}^t technology that satisfies the assumptions in Banker, Charnes, and Cooper (1984)[9]. The BCC technology drops the CRS assumption, and imposes only the assumption of convexity. The BCC production set is said to satisfy variable returns to scale (VRS). We can compute a residual scale efficiency index comparing the two distance functions defined above:

$$(10) \qquad SE_i^t(\mathbf{x}_i^t, \mathbf{y}_i^t) = \frac{DC_i^t(\mathbf{x}_i^t, \mathbf{y}_i^t)}{DV_i^t(\mathbf{x}_i^t, \mathbf{y}_i^t)}$$

Therefore,

$$(11) \quad \Delta EF_i^{t,t+1} = \frac{DC_i^{t+1}(\mathbf{x}_i^{t+1}, \mathbf{y}_i^{t+1})}{DC_i^t(\mathbf{x}_i^t, \mathbf{y}_i^t)} = \frac{DV_i^{t+1}(\mathbf{x}_i^{t+1}, \mathbf{y}_i^{t+1}) \cdot SE_i^{t+1}(\mathbf{x}_i^{t+1}, \mathbf{y}_i^{t+1})}{DV_i^t(\mathbf{x}_i^t, \mathbf{y}_i^t) \cdot SE_i^t(\mathbf{x}_i^t, \mathbf{y}_i^t)} = \Delta PE_i^{t,t+1} \cdot \Delta SE_i^{t,t+1}$$

[9] The linear programs used to compute this index can be found in Banker, Charnes, and Cooper (1984). Basically, the BCC program introduces an additional constraint to (3) that forces each lab to be compared with other labs, or a composite unit, of a similar size. A more exhaustive treatment of the non-parametric approach to efficiency measurement and the properties of the different distance functions employed can be found in Färe, Grosskopf, and Lovell (1994).

The Malmquist index is finally decomposed into three indexes that measure pure efficiency change (relative to the VRS frontier), scale efficiency change (comparing the VRS benchmark with the CRS benchmark) and an index of technical change (that reflects the movement of the CRS frontier).

The Färe et al. (1994) decomposition can be pushed a step further by identifying two components in the index of technical change. Ray and Desli (1997) proposed the computation of technical change using the VRS instead of the CRS production set as the reference technology. The difference between the Färe et al. (1994) and Ray and Desli (1997) indexes of technical change can be interpreted as a residual measure of the scale change of the technology. This latter index indicates whether the projection of the firm on the VRS frontier is now closer or farther from the projection on the CRS frontier (i.e. the optimal scale), that is, whether the VRS is closer or farther from the CRS technology than it previously was. The four-component decomposition of the Malmquist index was developed by Simar and Wilson (1998) and Zofío and Lovell (1998):

$$M_{CCD}(\mathbf{x}_i^{t+1},\mathbf{y}_i^{t+1},\mathbf{x}_i^{t},\mathbf{y}_i^{t}) = \frac{DC_i^{t+1}(\mathbf{x}_i^{t+1},\mathbf{y}_i^{t+1})}{DC_i^{t}(\mathbf{x}_i^{t},\mathbf{y}_i^{t})}\left[\frac{DC_i^{t}(\mathbf{x}_i^{t+1},\mathbf{y}_i^{t+1})}{DC_i^{t+1}(\mathbf{x}_i^{t+1},\mathbf{y}_i^{t+1})}\frac{DC_i^{t}(\mathbf{x}_i^{t},\mathbf{y}_i^{t})}{DC_i^{t+1}(\mathbf{x}_i^{t},\mathbf{y}_i^{t})}\right]^{1/2} =$$

$$\frac{DV_i^{t+1}(\mathbf{x}_i^{t+1},\mathbf{y}_i^{t+1})}{DV_i^{t}(\mathbf{x}_i^{t},\mathbf{y}_i^{t})}\frac{SE_i^{t+1}(\mathbf{x}_i^{t+1},\mathbf{y}_i^{t+1})}{SE_i^{t}(\mathbf{x}_i^{t},\mathbf{y}_i^{t})}\left[\frac{DV_i^{t}(\mathbf{x}_i^{t+1},\mathbf{y}_i^{t+1})}{DV_i^{t+1}(\mathbf{x}_i^{t+1},\mathbf{y}_i^{t+1})}\frac{DV_i^{t}(\mathbf{x}_i^{t},\mathbf{y}_i^{t})}{DV_i^{t+1}(\mathbf{x}_i^{t},\mathbf{y}_i^{t})}\right]^{1/2} \cdot \tag{12}$$

$$\left[\frac{SE_i^{t}(\mathbf{x}_i^{t+1},\mathbf{y}_i^{t+1})}{SE_i^{t+1}(\mathbf{x}_i^{t+1},\mathbf{y}_i^{t+1})}\frac{SE_i^{t}(\mathbf{x}_i^{t},\mathbf{y}_i^{t})}{SE_i^{t+1}(\mathbf{x}_i^{t},\mathbf{y}_i^{t})}\right]^{1/2} = \Delta PE_i^{t,t+1}\cdot\Delta SE_i^{t,t+1}\cdot\Delta T_{BCC,i}^{t,t+1}\cdot\Delta S_i^{t,t+1}$$

where the original index of technical change—in brackets— has been decomposed into an index measuring the technical change of the BCC frontier, $\Delta T_{CCB,i}^{t,t+1}$, and a second residual index reflecting the scale change of the BCC frontier, $\Delta S_i^{t,t+1}$, where

$\Delta T_{CCR,i}^{t,t+1} = \Delta T_{BCC,i}^{t,t+1} \cdot \Delta S_i^{t,t+1}$. Zofio and Lovell (1998) interpret this fourth component as a bias of technical change with respect to scale, as it reflects a change in the optimal scale of the technology[10].

It should be noted that the distance functions that are used to compute the indexes of technical change with respect to the BCC technology do not necessarily have a bounded solution. This happens because the radial projection of the firm's input-output vector towards the BCC frontier of another period—$DV_i^t(\mathbf{x}_i^{t+1}, \mathbf{y}_i^{t+1})$, for instance—does not necessarily belong to that frontier. In the cases where this happened in our empirical application, for unbounded output oriented solutions we changed the orientation of the distance function to an input distance function to get a bounded solution that approximates the real movement of the technology. This solution seems appropriate because the problem with the unbounded solution in the computation of the output distance function reflects the fact that the movement of the technology was an input reducing or augmenting movement relative to the previous period[11].

5. Results

Table 2 summarizes the evolution of technical and scale efficiency scores during the period 1994-2000. The table shows the yearly average of the technical efficiency scores computed under constant returns to scale (DC) and variable returns to scale (DV), and the residual scale efficiency score (SE), with standard deviations in

[10] See Ray (2001) for a discussion of alternative interpretations of this component.

[11] We checked other ways around the unboundedness problem, such as substituting the unbounded value by 1 or omitting the observation that presented the problem in the computation of averages. We found that the average results reported did not vary significantly regardless of the treatment given to unbounded values.

brackets. The table reveals a decrease in the level of global efficiency (DC) that is due to a dramatic reduction in scale efficiency (SE). Global technical efficiency (DC) decreased from a mean value of 0.691 in 1994 to 0.673 in 2000. This result reflects an increase in the distances separating the best practices from the rest of the labs in the sample, and thus an increase in the heterogeneity of production practices. The value of the DC index in 2000 indicates that the labs in the sample could produce 33% more output without increasing any of the inputs.

The decomposition of the DC index provides some insights into how the overall reduction in technical efficiency occurred. Table 2 shows that the reduction was largely due to an enormous decrease in scale efficiency (SE), from a value of 0.854 in 1994 to 0.788 in 2000. The labs are now positioned farther from the optimal scale[12]. This effect has been partially offset by the moderate improvement in pure technical efficiency (DV). While the main source of inefficiency in 1994 was pure inefficiency, scale inefficiencies were the dominant effect on global inefficiency in 2000.

<<<<<<<<<TAKE IN TABLE 2>>>>>>>>>>>

These indexes do not separate the effect of labs moving towards the benchmark technology (frontier) from the effect of the intertemporal movements of the frontier. To separate both sources of productivity change, we must use the decomposition of the Malmquist productivity index, as shown in Table 3. On average, productivity grew some 8.5% from 1994 to 2000, with 63.7% of the labs in the sample benefited from this. The period 1995-1996 shows the largest productivity growth, 4.8%, followed by 1997-1998 with 1.3%. The decomposition of the Malmquist productivity index helps explain the manner in which this 8.5% productivity growth was attained.

[12] The smaller labs suffered the most severe reductions in the index of scale efficiency.

Focusing on relative efficiency, the decomposition shows a moderate contribution of efficiency to productivity growth. However, while 52.5% labs increased their scores of pure technical efficiency over the period, only 21.2% increased their scale efficiency indexes. Pure efficiency increased by an average of 7.9%. This increase in technical efficiency coincided temporarily with a period characterized by strong public control over the prices of pharmaceutical products. The increase in technical efficiency may reflect the natural survival reaction of labs to the new regulatory environment. However, this positive effect was offset by a reduction of 6.9% in scale efficiency. These two indexes (pure efficiency change and scale efficiency change) constitute the efficiency part of the Malmquist productivity index, and reflect a modest movement of inefficient labs towards the CRS best practice frontier.

<<<<<<<<<<<<TAKE IN TABLE 3>>>>>>>>>>>>

The technological part of the Malmquist index is composed of the indexes of technical change and scale change of the technology. These components reflect movements of the best practice frontier rather than movements of the labs towards the frontier, and thus show the evolution of the production possibilities permitted by the technology. The period has been characterized by a moderate level of pure technical regress, although 56.2% of the labs seem to have benefited from technical progress[13]. This situation reflects a non-neutral shift of the technology over the period. However,

[13] In the context of our analysis, technical regress means that there are productive options that are not available anymore for labs to exploit. This can happen for reasons related to the regulatory context in which production takes place. For example, if legal pollution standards are raised, some production practices that were possible before cannot be undertaken after the new regulation. In the pharmaceutical industry, the introduction of product patents and alterations in the list of reimbursable drugs can produce such situations of technical regress.

the scores are near to 1, reflecting that the shifts have been relatively small (and probably due to measurement errors). This reflects the modest results of the R&D undertaken by the Spanish labs. Under the new regulatory environment, technical change principally occurs when innovations take place and result in the introduction of new, high-margin patented own-products. On the opposite side, the index that measures the scale change of the technology is the only one that shows significant progress, with an average of 17%. This result means that the technology offers much more to be gained now by adopting a more appropriate scale than it did in 1994. In other words, it reflects a movement of the production technology that makes firms farther from the efficient scale than they were with the technology of 1994. In other words, he separation between the constant returns to scale technology and the variable returns to scale technology has increased.

Given that differences in the indexes of technology change for each lab in the sample may only be due to differences in their relative sizes, we have compared the Malmquist index and its components across three size intervals based on assets (Small, Medium, Large). The results are presented in Table 4, where standard deviations are shown in brackets[14]. The three groups were constructed so as to contain approximately the same number of labs. The group of Small labs has an average of 1 billion pesetas in assets, Medium sized labs 3.6 billion, and Large labs 17.4 billion. The group of Large labs experienced the greatest productivity growth, with an average Malmquist index of around 1.14 between 1994 and 2000. In contrast, Medium and

[14] To test the statistical significance of the mean differences across size intervals, we use the Kruskal-Wallis test instead of conventional Analysis of Variance because DEA scores are not normally distributed. Furthermore, even though our sample size is large, we cannot apply central limit properties because DEA scores are not iid (independence is violated). For further discussion about the application of non-parametric rank-based statistics to efficiency scores see Brockett and Golany (1996) and Sueyoshi and Aoki (2001).

Small sized labs show Malmquist productivity indexes of 1.07 and 1.04, respectively. However, due to the great dispersion that exists within groups, the differences across groups in productivity growth are not statistically significant at conventional levels.

<<<<<<<<<<<TAKE IN TABLE 4>>>>>>>>>>>>

There are no significant differences across groups with regard to the index of pure efficiency change. This result reflects the fact that the catching-up effect did not depend on lab size, although Small labs show the highest index of catching-up with 1.12. The opposite pattern is observed with respect to the change in scale efficiency. All the groups experience a deterioration in their scale efficiency indexes (on average), but the proportion is significantly larger for Small labs. The average index shows that in 2000 they were 12% farther from the efficient size than in 1994.

Technical change differs markedly across size groups, reflecting a non-neutral shift in the production technology. Technical regress is observed in the group of Small sized labs and a notable degree of technical progress is observed in Medium and especially in Large labs. This result means that the technology has generated more production possibilities that can be enjoyed by Medium and Large labs and has eliminated some productive options that were previously available for smaller labs. In particular, after the introduction of product patents small labs cannot continue copying the innovations of others. The differences between the three groups with respect to technical change are statistically significant at conventional levels. The result reflects that most innovations are being introduced by Large firms, while Small firms should look for new sources of competitive advantage in the future. Significant differences also arise regarding the scale change of the technology. The efficient scale for small labs in 2000 has moved away from the standard in 1994, as reflected by the scale change index of 1.43. Thus, Small labs that have not increased their sizes are today more

scale inefficient than they were before, implying that there is more to gain today by scale adjustments (some 43%). This result is consistent with a technological change that has shifted the efficient scale of the technology upwards. The groups of Medium and Large labs show much more moderate averages. This means that the separation between the VRS and the CRS technologies has concentrated in the low output segments of the technology.

6. Concluding remarks

This paper has estimated the sources of productivity change in the Spanish pharmaceutical industry during the second half of the 1990s. The results show a notable contribution of technical efficiency to productivity growth, whereas the impact of technical change was, on average, negligible. During the 1990s, many changes in the regulation environment affected the Spanish pharmaceutical industry. First, the introduction of the product patent in 1992 imposed a serious constraint on labs whose main activity was to copy an existing product to produce it and commercialize it in Spain. Second, the need to meet the criteria for entry into the European Monetary Union made the Spanish Government a tougher negotiator in this regulated sector. These pressures have materialized in an intensification of the regulation of drugs prices. While the consumer price index increased by a 30.4% during the period, the pharmaceutical price index increased just an 8.5%.

Given this situation, Spanish pharmaceutical labs have three strategic options with which to face the future. They can intensify their R&D efforts, expanding their production possibilities and thereby enabling themselves to develop high margin and patented own-products. They can also concentrate in the market for generic drugs not protected by product patents. Finally, they can concentrate on the production and/or commercialization of licensed products. The latter options involve a fundamental change in the competitive strategy that the firm should follow (Rovira, 1998). The

source of competitive advantage for the firms that follow this reorientation towards generics or licensed products will change from differentiation (marketing, promotion) to cost leadership (static productive efficiency).

The important impact of technical efficiency change on productivity growth may reflect that some labs have already begun to refocus their competitive strategies along the lines indicated above. The contribution of technical efficiency change to productivity growth is more important in the group of Small labs, precisely the group that may be most affected by the new situation. In contrast, technical change has been the main source of productivity growth in the group of Large labs, reflecting their ability to expand their production possibilities through innovation. Within the group of Medium sized labs, both factors have contributed to productivity growth in more or less the same proportion.

The empirical study presented here has some limitations. First, we only had access to aggregated accounting magnitudes. Thus, we cannot provide a more exhaustive analysis of the strategic options followed by different groups of labs and relate these strategies to the outcomes obtained. Moreover, given the long time period that the development of new drugs involves, the impact of the product patent introduced in 1992 would reasonably intensify from 2000 on. Third, we have interpreted the results obtained as a consequence of the profound regulatory changes that affected the industry during the 1990s. While we are confident that our estimates reflect the main trends in the reorganization of the industry after the regulation changes that occurred during that decade, other forces may have contributed to generate the results[15]. For example, technical progress is always expected in an R&D-intensive industry such as the pharmaceutical industry, regardless of regulation concerns.

Multinationals have introduced an increasing number of new high-margin drugs in Spain in the last years that have been generated from research efforts that foster technical progress. However, it is not clear that these innovations would have reached the Spanish industry without the protection of product patents that was granted after 1992. Thus, regulation changes may directly affect productivity change and also interact with other driving forces to generate the patterns finally observed.

References

Achilladelis, B., Antonakis, N., 2001. The dynamics of technological innovation: the case of the pharmaceutical industry. Research Policy 30, 535-588.

Banker, R.D, Charnes, A., Cooper, W.W., 1984. Some models for estimating technical and scale inefficiencies. Management Science 39, 1261-1264.

Brockett, P.L., Golany, B., 1996. Using rank statistics for determining programmatic efficiency differences in data envelopment analysis. Management Science 42(3), 466-472.

Caves, D., Christensen, L., Diewert, E., 1982. The economic theory of index numbers and the measurement of input, output, and productivity. Econometrica 50(6), 1393-1414.

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

[15] In fact, our analysis relates just two observed facts that occurred in the same period of time: 1) profound regulatory changes in one of the most heavily regulated Spanish industries, and 2) the patterns of productivity changes reported in the results section.

Cockburn, I., Henderson, R., 1998. Absorptive capacity, coauthoring behavior and the organization of research in drug discovery. Journal of Industrial Economics 46(2), 157-182.

Cohen, W.M., Levinthal, D.A., 1989. Innovation and learning: the two faces of R&D. Economic Journal 99, 569-596.

Farmaindustria, 2000. Memoria anual 2000. Asociación de Empresarios de la Industria Farmacéutica, Madrid.

Farmaindustria, 2001. The Pharmaceutical Industry in Figures. Asociación de Empresarios de la Industria Farmacéutica, Madrid.

Färe, R., Grosskopf, S., Lovell, C.A.K., 1994. Production Frontiers. Cambridge University Press, London.

Färe, R., Grosskopf, S., Norris, M., Zhang, Z., 1994. Productivity growth, technical progress, and efficiency change in industrialized countries. American Economic Review 84 (1), 66-83.

Färe, R., Lovell, C.A.K., 1978. Measuring the technical efficiency of production. Journal of Economic Theory 19, 150-162.

Henderson, R., Cockburn, I., 1994. Measuring competence? exploring firm effects in pharmaceutical research. Strategic Management Journal 15(s.i.), 63-84.

Henderson, R., Cockburn, I., 1996. Scale, scope and spillovers: the determinants of research productivity in drug discovery. Rand Journal of Economics 27(1), 32-59.

Lopez-Bastida, J., Mossialos, E., 1997. Pharmaceutical expenditure in Spain: cost and control. London School of Economics and Political Science.

Malmquist, S., 1953. Index numbers and indifference curves. Trabajos de Estadística 4(1), 209-242.

Moorsten, R.H., 1961. On measuring productivity potential and relative efficiency. Quarterly Journal of Economics 75, 451-467.

Morgan, E.J., 2001. Innovation and merger decisions in the pharmaceutical industry. Review of Industrial Organization 19, 181-191.

Mossialos, E., 1998. Pharmaceutical pricing, financing and cost containment in the European Union member states. In Leidl, R. (Ed.), Health care and its financing in the single European market, IOS Press, Amsterdam, 85-115.

Nonell, R., Borrell, J.R., 1998. Mercado de medicamentos en España: diseño institucional de la regulación y de la provisión pública. Papeles de Economía Española 76, 113-131.

Puig, J., 1998. Regulación y competencia de precios en el mercado farmacéutico. Papeles de Economía Española 76, 96-111.

Ray, S., 2001. On an extended decomposition of the Malmquist productivity index. 7th European Workshop on Efficiency and Productivity Analysis, Oviedo, Spain.

Ray, S., Desli, E., 1997. Productivity growth, technical progress, and efficiency change in industrialized countries: comment. American Economic Review 87(5), 1033-1039.

Rodríguez, G., 2000. Posición competitiva y estrategia empresarial asociadas al declive en las empresas del sector farmacéutico español. X ACEDE Meeting, Oviedo, Spain.

Rodríguez, G., Miravitlles, P., 1999. Estrategias de especialización y diversificación de las empresas del sector farmacéutico español: variables definitorias. Working paper, Universidad Autónoma de Barcelona.

Rovira, J., 1998. Impacto del mercado único sobre el sector farmacéutico en España. Papeles de Economía Española 27, 132-140.

Simar, L., Wilson, P., 1998. Productivity growth in industrialized countries. Discussion paper 9810, Institut de Statistique, Université Catholique de Louvain, Belgium.

Simar, L., Wilson, P., 1999. Estimating and bootstrapping Malmquist indices. European Journal of Operational Research 115(3), 459-471.

Sueyoshi, T., Aoki, S., 2001. A use of a nonparametric statistic for DEA frontier shift: the Kruskal and Wallis rank test. Omega 29(1), 1-18.

Zofío, J.L., Lovell, C.A.K., 1998. Yet another Malmquist productivity index decomposition. Mimeo, Departamento de Economía, Universidad Autónoma de Madrid.

Table1.- Descriptive statistics of the data (year 2000)

	Average	S. Deviation	Min	Max
OUTPUT				
Net sales	8.50	12.76	0.44	83.22
INPUTS				
Labor costs	1.56	1.78	0.03	8.70
Capital	0.29	0.39	0.0008	1.58
Other costs	4.33	7.63	0.24	52.5

Table 2.- Temporal Evolution of Technical and Scale Efficiency

Years	DC		DV		SE	
1994	0.691	(0.14)	0.815	(0.15)	0.854	(0.12)
1995	0.663	(0.16)	0.824	(0.15)	0.810	(0.15)
1996	0.674	(0.14)	0.852	(0.14)	0.797	(0.13)
1997	0.651	(0.14)	0.845	(0.15)	0.782	(0.15)
1998	0.732	(0.13)	0.854	(0.14)	0.864	(0.11)
1999	0.691	(0.13)	0.857	(0.14)	0.816	(0.13)
2000	0.673	(0.14)	0.865	(0.14)	0.788	(0.14)
Average	0.682	(0.14)	0.845	(0.14)	0.816	(0.14)

Table 3.- Decomposition of the Malmquist index

Period	M_{CCD}	$\Delta PE^{t,t+1}$	$\Delta SE^{t,t+1}$	$\Delta T_{BCC}{}^{t,t+1}$	$\Delta S^{t,t+1}$
1994-1995	0.999	1.014	0.948	1.015	1.059
1995-1996	1.048	1.045	0.994	1.009	1.018
1996-1997	1.007	0.994	0.980	1.010	1.070
1997-1998	1.013	1.021	1.123	0.982	0.914
1998-1999	1.009	1.008	0.943	1.015	1.063
1999-2000	1.004	1.012	0.964	0.997	1.041
1994-2000	1.085	1.079	0.931	0.991	1.170
s.d.	(0.35)	(0.20)	(0.17)	(0.25)	(0.38)
%>1	63.7	52.5	21.2	56.2	72.2

Table 4.- Decomposition of the Malmquist Index by Sizes (1994-2000)

	N	***Assets***	M_{CCD}	$\Delta PE^{t,t+1}$	$\Delta SE^{t,t+1}$	$\Delta T_{BCC}{}^{t,t+1}$	$\Delta S^{t,t+1}$
Small	26	0.98	1.042	1.124	0.883	0.835	1.435
		(0.52)	(0.19)	(0.25)	(0.19)	(0.25)	(0.55)
Medium	27	3.62	1.074	1.054	0.968	1.048	1.022
		(1.03)	(0.20)	(0.21)	(0.09)	(0.10)	(0.10)
Large	27	17.41	1.138	1.061	0.941	1.085	1.063
		(13.3)	(0.55)	(0.12)	(0.22)	(0.28)	(0.21)
Kruskal-Wallis χ^2 test			1.46	0.26	6.59**	13.2***	15.0***

* Significance level 0.1 ** Significance level 0.05 *** Significance level 0.01