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Productivity Growth, Technical Progress, and Efficiency Change in Spanish retail trade (1995-2004): a disaggregated sectorial analysis

Abstract:
This paper analyses productivity growth in Spanish retail stores during the period 1995-2004. We are also interested in analysing the influence of regulation/deregulation processes in this period of analysis on the efficiency and productivity of the firms. The analysis is carried out from a disaggregated sectorial perspective at the 4-digit NACE code level. The non-parametric Data Envelopment Analysis approach is used to compute Malmquist productivity indexes. These are decomposed into efficiency change and technical change. We find big differences in the productivity growth for each sector. First, six retail sectors experienced positive productivity growth, while six saw productivity growth decrease. Second, most sectors experienced technical progress. Third, some sectors improved their efficiency, while others became less efficient. Fourth, the TFP improvements were almost entirely due to technical progress, and only four sectors improved their efficiency. The findings obtained from this analysis of Spanish retail stores confirm the importance of a sectorial approach compared to a global analysis.

Keywords: Retail stores, Productivity growth, efficiency changes, technical progress, regulation, retail sector, stochastic kernels.

JEL Classification: C61, L51, L81, F10

1. Introduction

In recent decades, the Spanish retail trade sector has undergone profound changes, to some extent similar to those occurring throughout the rest of Europe. This sector is becoming more concentrated, and important changes are occurring in the market shares of the different commercial formats.

For example, in the period 1995-2004 the market share of large outlets and traditional stores dropped from 33% to 25%, and from 21% to 11%, respectively. Meanwhile, supermarkets' market share rose from 46% to 64% Nielssen (2005). There have also been some important legislative changes in the sector, with the Retail Trade Regulation Act (1996), and the Shop Opening Hours Decree-Law (2000), which have had an impact on retailers' strategies.

In this respect, this paper analyses productivity growth in Spanish retail stores during the period 1995-2004. We are also interested in analysing the influence of the regulation/deregulation processes taking place in this period of analysis on the efficiency and productivity of retail stores. The analysis is carried out from a disaggregated sectorial perspective at the 4-digit NACE code level.

Productivity and efficiency are two concepts that require clarification. The concept of productivity usually refers to the concept of mean factor productivity, i.e., the number of output units produced per unit of factor employed. On the other hand, the concept of efficiency refers to a judgement about the relation between the resources used (inputs) and a measure of the results obtained (outputs). The idea of opportunity costs underlies both concepts Bosch *et al*. (1998).

Retail productivity provides vital information for a number of tactical, strategic, and policy-related decisions in the retail industry. At the tactical level, for a multi-unit firm, a manager's control and expansion strategies begin with an assessment of the stores' relative productivity level Bubelaar *et al*.(2002). Strategically, retail productivity can be used to differentiate firms and provides the foundations for developing strategies for growth and diversification Walters and Laffy (1996). As Färe *et al.* (2001) mention, productivity is of interest to economists and policymakers, because productivity growth is a major source of economic growth and welfare improvement.

The literature on productivity in commercial distribution has centred on estimating the mean productivity of the work factor (Walford, 1966; Goldman, 1992), as well as on its determinant factors (Hall et al., 1961; Good, 1984). On the other hand, the literature on efficiency in distribution[1] has mainly examined efficiency levels rather than the causes of the levels (Athanassopoulos, 1995; Thomas et al., 1998; Donthu and Yoo, 1998; Keh and Chu, 2003; Ratchford, 2003; Barros and Alves, 2004).

For information about Spanish retail trade, some relevant works include those by Sellers and Más (2004), who analyse economic efficiency in a sample of supermarkets in the Spanish market in the period 1994-2001, comparing this with market concentration and firm size, and De Jorge (2006), who associates differences in efficiency with the regulation processes carried out in the sector and with firm size.

This paper is organised as follows. In Section 2, we begin by describing the Malmquist productivity index, the distance functions from which it is constructed, and how we propose to calculate them. In Section 3, we describe the database used here. In Section 4, we calculate the productivity growth and its components: first, we conduct an aggregate analysis, considering all the firms in the same frontier regardless of the sector. Second, the productivity is analysed considering a frontier for each sector. Section 5 analyses the efficiency by examining features of the retail stores' kernel densities from the static and dynamic perspectives. In Section 6, we present our summary and conclusions, consider the managerial implications of the study, and put forward the limitations and possible extensions

2. Methodology

In this study, we adopt the efficient frontier approach using the Malmquist index Malmquist (1953), based on DEA. The Malmquist productivity index allows changes in productivity to be broken down into changes in efficiency and technical change. Efficiency change (movement towards or away from the production frontier) and technical change (shift in the production frontier) are two key factors to productivity growth. Like Barros and Alves (2004), for our productivity measurement we adopt the framework set down in the papers by Färe *et al*. (1990), Hjalmarsson and Veiderpass (1992) and Price and Weyman-Jones (1996). Figure 1 shows two observations of the input (x) and output (y) bundles of a retail store at times t and $t+1$. The objective is to measure the productivity growth between t and $t+1$ in terms of the change from input-output bundle $z(t)$ to input-output bundle $z(t+1)$.

This productivity is measured through the potential production frontier that is imposed on the production bundle in Figure 1. The production frontier represents the efficient levels of output (y) that can be produced from a given level of input. If the store is technically efficient at t, it produces along the frontier the maximum output attainable. Point $z(t)$ corresponds to a technically inefficient store, which uses more than the minimal amount of input to produce a given level of output. The bundle $z(t)$ can be reduced by the horizontal distance ratio= *ON/OS* in order to make the production technically efficient.

Insert Figure 1

The frontier can shift over time. By analogy, the bundle *z(t+1)* should be multiplied by the horizontal distance ratio=*OR/OQ* to achieve comparable technical efficiency. Since the frontier has shifted in the meantime, *z(t+1)* is technically inefficient in *t+1*, it must be reduced by the horizontal distance=*OP/OQ*. The relative movement of a production observation over time may be because stores are catching up with their own frontier, or because the frontier is shifting up over time.

The Malmquist index of productivity growth (*M*) is the ratio of the two distances at *t* and *t+1*. To break down the index into catching up (*MC*) and shifting up (*MF*) effects, we rescale M by multiplying it top and bottom by *OP/OQ*:

$$M = \frac{OR \cdot ON}{OQ \cdot OS} = \left[\frac{OP \cdot ON}{OQ \cdot OS} \right] * \frac{OR}{OP} = MC * MF \qquad [1]$$

Formally, the Malmquist index is based on the output distance function defined as:

$S^t = \{(x^t, y^t) : x^t \text{ can produce } y^t\}$

where x^t and y^t are the vectors of inputs and outputs, respectively.

Following Shephard (1970), the distance function at *t* is defined as:

$$d^T(x^t, y^t) = \min\{\theta : (x^t, y^t/\theta) \in S^t\} \qquad [2]$$

where *x* denotes a vector of inputs, y are outputs, *S* is the technology set, and superscript *T* denotes the technology reference period, usually *T=t* or *T=t+1*, and *1/θ* defines the amount by which outputs in year t could have been increased, given the inputs used, if the technology for year *T* had been fully utilised.

Färe *et al.* (1994) proposed to measure the Malmquist index as the geometric mean of two such indexes calculated both for year t and t+1 reference technologies as:

$$\mathrm{M_i}(y^{t+1}, x^{t+1}, y^{t}, x^{t}) = \left[\frac{d_i^{t}(x^{t+1}, y^{t+1})}{d_i^{t}(x^{t}, y^{t})} \times \frac{d_i^{t+1}(x^{t+1}, y^{t+1})}{d_i^{t+1}(x^{t}, y^{t})}\right]^{1/2} \qquad [3]$$

where $\mathrm{M_i}$ (•) is the composed geometric mean of two Malmquist productivity indices: the first evaluated with respect to the technology at time *t*, and the second with respect to the technology at time *t+1*. Färe et al. (1994) factor this expression into the product of technical change and efficiency change as follows:

$$\mathrm{M_i}(y^{t+1}, x^{t+1}, y^{t}, x^{t}) = \frac{d_i^{t+1}(x^{t+1}, y^{t+1})}{d_i^{t}(x^{t}, y^{t})}\left[\frac{d_i^{t}(x^{t+1}, y^{t+1})}{d_i^{t+1}(x^{t+1}, y^{t+1})} \times \frac{d_i^{t}(x^{t}, y^{t})}{d_i^{t+1}(x^{t}, y^{t})}\right]^{1/2} \qquad [4]$$

where the first ratio represents the change in relative efficiency between *t* and *t+1*, and the geometric mean of the two ratios in the brackets measures the change or movement of technology between *t* and *t+1*.

In order to estimate the component distance functions of the Malmquist index, we use the non-parametric data envelopment analysis (DEA) [2] technique, based on linear programming. By assuming variable returns to scale and exploiting the fact that the distance functions can be estimated as reciprocals of Farrell efficiency measures, the specific problem to calculate $d^T(y^t,x^t)$ can be expressed as:

$$[d_0^{\,t}(x_i^{\,t}, y_i^t)]^{-1} = \max_\lambda \Phi_i^{t,t} \qquad [6]$$

$$\text{s.t.} \quad \sum_{k=1}^{K} \lambda_k^t y_{sk}^t \geq \Phi_i^{t,t} y_{si}^t \qquad s=1,\dots,S$$

$$\sum_{k=1}^{K} \lambda_k^t x_{mk}^t \leq x_{mi}^t \qquad m=1,\dots,M$$

$$\lambda_k^t = 1 \qquad k,i=1,\dots,K$$

where K represents the number of cross-sectional units for each time period within the panel data, S and M indicate outputs and inputs respectively, and λ_k^t measures the weight of each cross-sectional unit within the peer group with which any particular observation is compared to determine the distance to the efficient frontier.

3. Data

To estimate the production frontier, panel data are used for the years 1995 to 2004, obtained from the SABI database. This database collects data on more than 180,000 firms inscribed in the Mercantile Register (BORME), covering all sectors of business activity in Spain. It is highly representative of firms from the 18 Spanish autonomous "communities" (i.e., regions).

The sample of firms analysed was extracted starting from the year 1995 and ending in 2004. In the years previous to 1995 most of the database variables suffer from missing values. As final year we consider the information from the last available year, 2004. Firms are included in the SABI database under the condition that their turnovers exceed €6m or their workforces are over 20 employees. Our objective in building the sample was that the companies analysed be present every year, so that a complete panel would be obtained.

The sectors of commercial distribution are distinguished according to their 4-digit NACE codes. Table 1 shows descriptive statistics for the main variables.

Insert Table 1

For the efficiency analysis that we will shortly outline, it would have been desirable for both consumption of materials and flow of services to be expressed in physical units. However, the limitations of the available information have obliged us to use accounting variables, expressed in constant monetary units (using the GDP deflator from INE, the Spanish National Institute of Statistics). The choice of output and input type follows Donthu and Yoo's (1998) recommendations. We measured inputs by three variables. We followed the DEA convention that the minimum number of DMUs should be greater than three times the number of inputs plus output. For example, in the case of retail sale of textiles NACE 5241 (14>3(1+3)). We measured labour by personnel costs. The variable employees is more problematic, because this value is missing in many companies. We measured capital by fixes assets, and the other input is intermediate consumption. Finally, we measured output by sales.

4. Total factor productivity (TFP) results:

In this section we calculate productivity growth and its components for a sample of 12 retail trade sectors at the 4-digit NACE code level over the period 1995-2004 in two ways Färe *et al*. (2001). First, in an aggregate way considering all the firms in the same frontier regardless of the sector. Second, the productivity is analysed considering a frontier for each sector.

4.1 Total factor productivities of sector as a whole

Malmquist productivity indexes were calculated, as well as the efficiency change, technical change and scale components for each sector in the sample. Instead of presenting the disaggregated results for each sector and year, a summary description of the average performance of all sectors over the entire period was utilised. Note that if the value of the Malmquist index or any of its components is less than 1, this denotes regress or deterioration in performance between any two adjacent years, whereas values greater than 1 denote improvements in the relevant performance[3]. Also note that these measures capture performance relative to the best practice in the sample. Looking first at the bottom of Table 2, we find that TFP decreased at an average rate of -0.5% per annum over the entire 1995-2004 period for the service sectors as a whole. On average, that deterioration can be ascribed to a catching up, i.e., a severe efficiency worsening (-2.5%). The technical efficiency improved at an average rate of 1.9%.

Insert Table 2

Decomposing the efficiency change shows that the distancing from the efficient frontier is largely due to the decrease in the pure technical efficiency (-1.9%), and to a lesser extent to the fall in the scale efficiency (-0.7%).

4.2 Total factor productivities of individual industries

The analysis carried out in the previous section considering all the sectors as one sample is only complementary. Authors often carry out an additional analysis at the sectorial level, probably to increase the size of the sample. But the inconveniences of this method are important. For example, it is difficult to assume that when the additional analysis is being carried out, a homogeneous technology is being used. An example is the case of sector 5211 (non-specialised shops, with predominance of foods) compared to sector 5248 (specialised shops). Thus, firms with different business models are being analysed. This diversity incorporates biases into the calculations, which will likely lead to an incorrect interpretation.

Analysing the productivity growth for each sector, Table 2 shows some important stylised facts. First, six retail sectors had positive productivity growth and six saw declines in productivity. Second, most of the sectors experienced technical progress. Third, some sectors gained in efficiency, but most became less efficient. Fourth, the TFP improvements were almost entirely due to technical progress, and only four sectors improved their efficiency.

More specifically, the productivity growth and its components do not have the same behaviour patterns. On the one hand, in the retail sectors bread and bakery products (5224), textiles (5241), electrical appliances (5245), books (5247) and furniture, lighting and other household goods (5244) TFP increased at an average rate of 1.5 %, 1.4%, 0.7%, 0.6% and 0.4% per annum, respectively, over the entire period 1995-2004. On average, these improvements were due to technical progress (1%, 1.1%, 0.9%, 1.7% and 0.5%), and to a slight improvement in efficiency (0.5%, 0.3%) in the case of retail sectors bread and bakery products and textiles. But the retail sectors electrical appliances, books and furniture became slightly less efficient (-0.2%, -1%, -0.1%, respectively). On the other hand, the retail sectors furniture, fuel (5200), clothing (5242), ironmongery (5246), other specialised shops (5248), repairs (5274) and foods

(5211) all saw negative productivity growth, at an average rate of -0.8%, -0.4%, -0.2%, -0.1%, -1%, and -0.5%, respectively.

This worsening of the productivity growth in the case of sectors 5200 and 5246 is attributable as much to technical change as to efficiency change. For the retail sectors with predominance of foods (5211) and repairs (5274) the worsening in productivity growth is due to technical change (-1.5%, -1.3%), there being a slight improvement in efficiency (1.0%, 0.3%).

Given the decline in the mean efficiency of the firms analysed in most of the sectors, it is useful to decompose this value into pure technical efficiency and scale efficiency. It is then possible to analyse the causes of the fall in efficiency experienced during the period studied in more depth. Table 2 columns 6 and 7 present the results of the pure technical efficiency and scale efficiency. It is worthwhile commenting on some important findings. For example in the sectors other products (5212), clothing (5242) and other specialised shops (5248) the average change in productive efficiency is -0.3%, -2.4% and -1%. In the case of this last sector, for example, its decline in efficiency of -1% is attributable to a -1% fall in the pure technical efficiency, added to a -0.1% fall in the scale efficiency. Thus, we can deduce that the scale of operations does not appear to be particularly relevant in the sample firms. Both firms that are operating at the optimal scale and those that are not hardly differ in terms of efficiency. Hence, all the loss of efficiency can be attributed to technical questions rather than to deficiencies in the size of the companies.

With respect to the sectors showing improvements in efficiency, the improvement attributable to the scale efficiency is important. For example, the foods sector (5211) shows an improvement of 1%, with the pure technical efficiency responsible for 0.2% of this, and the scale efficiency responsible for 0.8%.

Finally, Figure 2 shows the evolution in the Malmquist productivity index (tfpch), efficiency change (effch) and technical change (techch) over the period every two years. Recall that if the value of the Malmquist index or any of its components is less than 1, this denotes regress or deterioration in the relevant performance, whereas values greater than 1 denote improvements in performance.

Insert Figure 2

As we mentioned in the introduction, important legislation affecting the sector has been enacted during the period under analysis: the Retail Trade Regulation Act (1996), and the Shop Opening Hours Decree-Law (2000). Both have had an impact on retailers' strategies.

Centring on the evolution of productivity growth (tfpch), different behaviour patterns can be seen throughout the period. Considering the years 1999/00 as an intermediate point, we find that in the sectors r.s. of bread and bakery products (5224) and r.s. of ironmongery, paint and glass (5246) productivity growth improves between that year and the end of the period. Less evidently, improvements also take place in the sectors r.s. of books, newspapers and stationary (5247) and r.s. in other specialised shops (5248). On the other hand, in r.s. of other products in non-specialised shops (5212), r.s. of clothing (5242) and r.s. of textiles (5241), productivity growth falls. Productivity growth does not follow a clear pattern of behaviour in sectors r.s. furniture, fuel (5200), r.s. of furniture, lighting and other household goods (5244) or r.s. repairs (5274). Finally, in sector 5211 r.s. with predominance of foods, in non-specialised shops the tendency seems stable.

5. Efficiency analysis: static and dynamic perspective

The results obtained in the previous section demonstrate that efficiency deteriorated in most of the sectors analysed. Hence it is useful to examine this aspect in more depth. In this section we will analyse the efficiency by means of features of kernel density of the retail stores from the static and dynamic perspectives. To simplify the analyses we use two sectors: with predominance of foods, in non-specialised shops (5211); and retail sector in other specialised shops (5248).

These sectors present important differences. On the one hand, sector 5211 experiences the biggest growth in efficiency, attributable to improvements in the pure efficiency and scale efficiency. On the other hand, the pattern in sector 5248 is very different (see Table 2).

5.1 Static Perspective of the distribution of the efficiency: cross-sectional analysis

The first step in evaluating how the entire distribution of efficiency scores evolves over time is to estimate non-parametrically their corresponding density functions in each sample year. The implications of this analysis are clear: if the probability mass tends to be more markedly concentrated around a certain value, for example close to unity, the outcome would be a convergence process to a high efficiency value. Although the opposite outcome (divergence) would imply that the probability mass is increasingly spread across a wider range, there is a broad spectrum of additional outcomes, such as different modes emerging or vanishing, phenomena with strong economic implications.

A variety of techniques to estimate density functions non-parametrically exists. We use kernel smoothing (Silverman, 1986; Wand and Jones, 1995), a technique that provides a way of uncovering the data structure without imposing any parametric structure. Kernel smoothing[4] has been applied to the efficiency scores computed in Section 2, Equation 6.

The results appear in Figure 3. The graphs on the top left show the density functions for the foods sector (5211), while those on the right correspond to the retail sector other specialised shops (5248). Both sectors show the time evolution of the cross-sectional efficiency scores distribution for the years 1995-2000-2004. The efficiency distributions show two different patterns. On the one hand, in the foods sector there is a convergence process towards a high level of efficiency over time. But for the other specialised shops, the convergence process is to low to medium-level efficiency.

Insert figure 3

The graphs in the middle of Figure 3 show the time evolution of the cross-sectional distribution of efficiency scores for all sample years. Finally, the contour charts at the bottom of the figure show in a clear way the patterns of the distribution of the efficiency.

5.2 Dynamic Perspective of the distribution of the efficiency

The analysis up to this point only sheds light on the external form of the distribution of efficiency and its variation in time, it does not say anything about the changes that may have occurred within the distribution itself. These intradistributional movements can be as relevant or even more so than the changes observed in the external form of the distribution.

In order to capture this dynamism we use stochastic kernel estimations that inform about the probability of moving between any two levels in the range of values. A stochastic kernel is therefore conceptually equivalent to a transition matrix with the number of intervals tending to infinity (Quah, 1996a, 1997). The stochastic kernel can be approximated by estimating the density function of the distribution at a particular time $t + k$, conditioned by the values corresponding to a previous time t. For this, we carry out a nonparametric estimation of the joint density function of the distribution at times t and $t + k$. Figure 4 shows the stochastic kernels estimated from the efficiency for time periods of six years (t = 1995 and t + k = 2000), five years (t = 2000 and t + k = 2004) and ten years (t = 1995 and t + k = 2004) for the foods sector (5211), while Figure 5 shows the corresponding data for the sector other specialised shops (5248).

Insert Figure 4 and 5 about here

The interpretation is straightforward: in the 3D part of these graphs on the left, the X-axis represents the efficiency values in 1995 for the top graph of Figure 4, the Y-axis represents the efficiency values six years later (in 2000), while the Z-axis represents the density (or conditioned probability) of each point in the X-Y plane. Lines parallel to the year 2000 show the probability of moving from the point considered on the X-axis to any other point on the Y-axis. Given that the probability mass for the two sectors concentrates around the positive diagonal (particularly sector 5248 in Figure 5) we can conclude that the distribution is characterised by a high degree of persistence. Nevertheless, comparing sectors 5211 and 5248 in the period 1995-2004 (bottom figs. 4 and 5), sector 5211 presents some mobility. In other words, there is a certain distancing of the probabilistic mass from the diagonal.

An easier way of analysing this phenomenon is shown on the right-hand side of figures 4 and 5, which shows the contour plots, representing cuts parallel to the base of the kernel (X-Y plane) at equidistant heights. Thus, the points are at an equal height and density. According to the contour plots in Figure 4 and 5 the probability mass largely concentrates around the main diagonal for sector 5248, so we can confirm the conclusion that the firms' degree of mobility in terms of efficiency within the distribution is limited. But important differences exist between the two sectors. As Figure 4 shows for sector 5211, the central nucleus is located above the diagonal for the three periods considered, indicating that these retail stores become more efficient during the period under analysis. For other specialised shops (5248) in Figure 5, the central nuclei are all below the diagonal, indicating a worsening of the efficiency.

For the two sectors a layering process takes place due to the retail stores that were in the frontier in the initial year of every period and that remain there in the final year, upper nucleus (efficiency = 1). The remaining firms at lower efficiency levels are located in the nucleus (nuclei) in the middle or below. On the other hand, we can appreciate that a concentration process takes place in the two sectors in the period 2000-2004 compared to the period 1995-2000. In the case of sector 5211 (Figure 6 shows, in a complementary way, the transitions realised between the periods considered), a general enhancement of the efficiency levels takes place.

Insert Figure 6

This could be justified by the improved conditions brought about by the deregulation in commercial opening hours after the year 2000.

6. Summary and conclusions

The estimation of the productivity growth of retail-sector firms has been carried out using a non-parametric focus. This measurement has been interesting in three aspects. First, it has allowed us to analyse the relative efficiency of the retail stores for 12 sectors at the 4-digit NACE code level. Although it is possible to find some references in this respect (at the international level), they use other focuses or shorter time periods. Second, using the Malmquist TFP index has not only allowed us to analyse the productivity growth of the retail stores, but also to decompose this change into changes in the efficiency (*catching up*) and technical change experienced by the frontier. Finally, decomposing the efficiency indexes has allowed us to attribute the efficiency changes to changes in the scale efficiency and to changes in the pure technical efficiency.

We find big differences analysing the productivity growth for each sector (average annual changes). First, six retail sectors saw positive productivity growth, while in the remaining six sectors productivity growth decreased. Second, most of the sectors experienced technical progress. Third, some sectors improved their efficiency, while others did worse. Fourth, the TFP improvements were almost entirely due to technical progress, and only four sectors improved their efficiency. Only five sectors have scale inefficiencies.

The period analysed has seen some important legislative changes – the Retail Trade Regulation Act (1996), and the Shop Opening Hours Decree-Law (2000). This legislation has had some impact on retailers' strategies. Concentrating on the evolution of productivity growth, different behaviour patterns can be seen throughout the period. Observing particularly the period from 1999/2000 to 2003/2004, four sectors experience growing trends of the productivity growth, although in only two is this clear. Three sectors suffer falls in productivity in that period. For the remaining sectors the behaviour is either stable or alternating, with rises and falls in the productivity. On the other hand, detailed analysis of the efficiency in sectors 5211 r.s. with predominance of foods, in non-specialised shops and 5248 r.s. in other specialised shops reveals the convergence and divergence processes, respectively, that have taken place there.

All of this leads us to conclude that the retail industry is composed of very unequal sectors that must be analysed separately. Thus, when a firm opts for a retail activity it must take into account that the type of product it plans to commercialise will to a large extent condition the sales threshold that will guarantee minimum efficient scale, profit margins, and the strategic decisions it should take.

Finally, we should indicate some limitations and possible extensions to this study. Despite working with a data panel in an extensive period and at an important level of sectorial desegregation, it would have been desirable to work with larger samples that could back up the results more robustly. In some sectors, and in order to observe the retail stores over time, the sample decreased considerably.

The choice of the non-parametric DEA methodology imposes certain constraints. The DEA model does not impose any functional form on the data, or make distributional assumptions for the inefficient term. This efficiency measurement assumes that the production function of the fully efficient outlet is known. In practice, this is not the case and the efficient isoquant must be estimated from the sample data. In these conditions, the frontier is relative to the sample considered in the analysis. Moreover, without statistical distribution hypotheses, DEA does not allow for random errors in the data, assuming away measurement error and chance as factors affecting outcomes. Nevertheless, DEA estimators have been applied in more than 1,800 articles published in more than 490 refereed journals Gattoufi *et al*. (2004).

A variety of extensions to this paper could be undertaken. First, non-parametric, or alternatively, parametric, free-disposal hull analysis could be used to assess the efficiency scores. A second possibility would be to use an environmental variable such as store location and analyse differences in productivity growth. In this sense, it would be useful to analyse productivity growth and efficiency from the creation of the retail store onwards, by means of a data panel.

Notes

1.- An interesting review of the literature can be found in Barros (2005).

2.- A method developed by Charnes *et al*. (1978), based on Farrell (1957) technical efficiency measures.

3.- Subtracting 1 from the figure reported in Table 2 gives the mean increase or decrease per annum for the relevant time period and relevant performance measure.

4.- The kernel estimator of the value of the density function of that variable at point *x*, *f(x)*, is given by: $\hat{f}(x) = \frac{1}{nh}\sum_{i=1}^{n} K(\frac{x_i - x}{h})$, where K(·) is the so-called kernel function, and h is the bandwidth (or smoothing parameter) that controls the regularity of the estimated curve. Technical details for the smoothing parameter (h) can be found in the works of Sheather and Jones (1991) and Park and Marron (1990). Steve Marron's website offers the Matlab routines for obtaining these parameters (http:\\www.stat.unc.edu/faculty/marron.html).

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Figure 1. Production frontier in period *t* and *t+1*

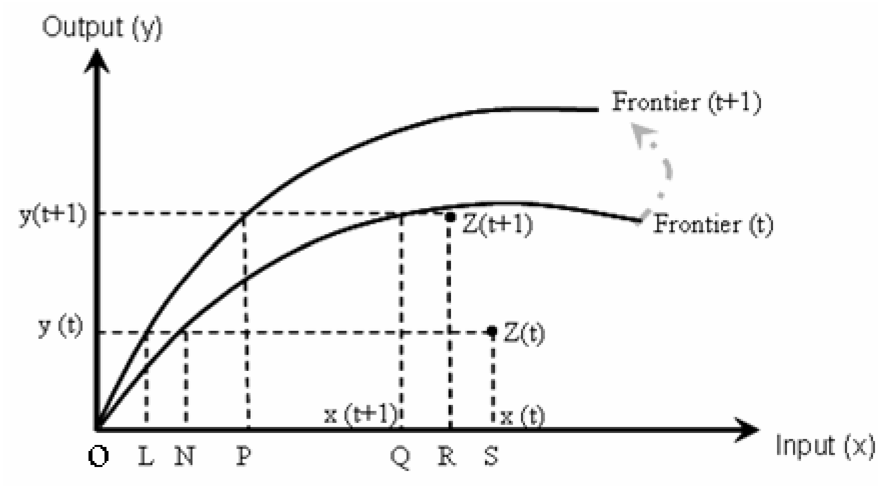


Table 1.

Characteristics of the inputs and outputs

Sector of retail activity (defined by four digits according to NACE)		No. obs.	Sales	Fixed Assets	Personnel cost (expenses)	Intermediate consumption
5200	r.s. furniture, fuel	21	1191.2	185.3	172.5	810.6
			964.3	264.0	142.3	701.0
5224	r.s. of bread and bakery products,	16	720.8	161.1	262.0	328.5
	sweets and cakes		471.3	146.9	251.3	202.6
5212	r.s. of other products in non-specialised shops	19	549563.5	216476.1	95273.4	380698.1
			2391846.0	943179.5	414751.6	1656888.9
5241	r.s. of textiles	14	907.2	179.6	197.8	574.6
			865.5	262.1	155.0	623.1
5242	r.s. of clothing	68	1314.5	259.6	245.1	917.1
			1263.1	571.9	266.7	806.5
5244	r.s. of furniture, lighting and other household	55	1006.9	110.4	158.8	745.1
	goods		865.7	188.3	139.4	605.6
5245	r.s. of electrical appliances, radio, TV and	33	752.6	153.6	116.3	592.5
	sound systems		883.0	373.8	134.9	690.3
5246	r.s. of ironmongery, paint and glass	36	1832.2	195.6	247.7	1450.5
			2707.3	309.4	387.7	2041.4
5247	r.s. of books, newspapers and stationary	29	1302.4	119.3	238.7	943.7
			3044.1	263.0	703.9	2059.6
5248	r.s. in other specialised shops	107	2667.1	245.6	317.7	1989.1
			9162.5	615.7	988.7	6567.2
5274	r.s. repairs	16	1170.6	121.3	270.2	735.9
			2531.6	154.8	350.4	1915.9
5211	r.s. with predominance of foods, in	92	35676.3	14649.2	4207.3	28151.9
	non-specialised shops		244626.1	134861.8	30555.0	169797.5

r.s. retail sale

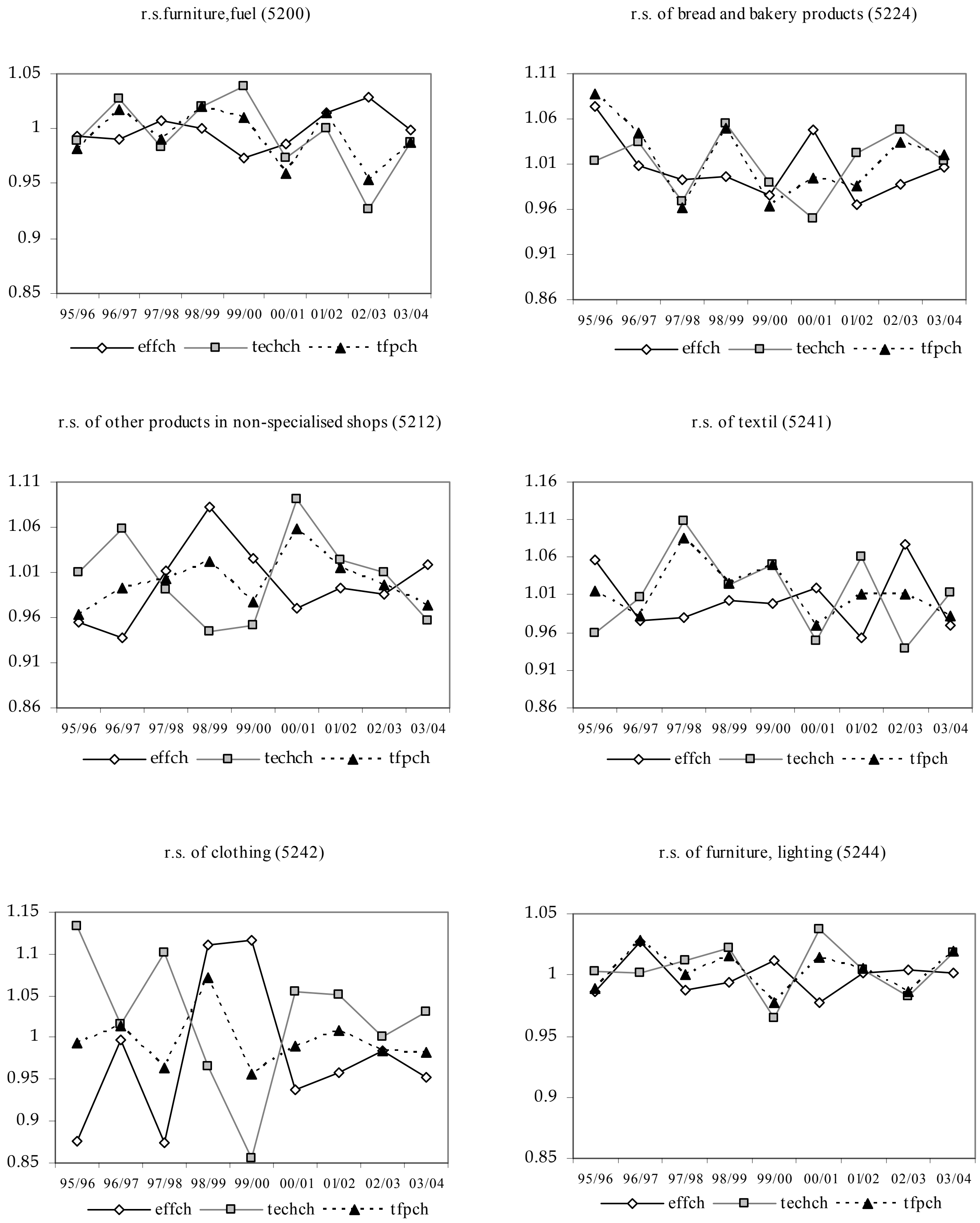
Table 2.

Decomposition of TFP with scale effects: average annual changes

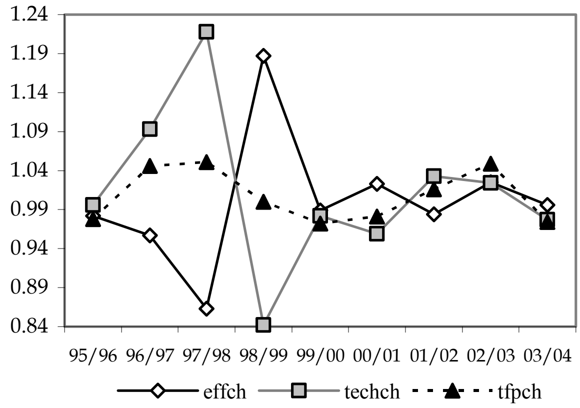
Sector of retail activity (defined by four digits according to NACE)		MALM	EFFCH	TECH	PECH	SECH
5200	r.s. furniture, fuel	0.992	0.999	0.994	0.999	1.000
5224	r.s. of bread and bakery products, sweets etc.	1.015	1.005	1.010	0.998	1.007
5212	r.s. of other products in non-specialised shops	1.000	0.997	1.003	0.998	0.999
5241	r.s. of textiles	1.014	1.003	1.011	0.997	1.007
5242	r.s. of clothing	0.996	0.976	1.021	0.988	0.987
5244	r.s. of furniture, lighting and other household goods	1.004	0.999	1.005	1.000	0.999
5245	r.s. of electrical appliances, radio, TV etc.	1.007	0.998	1.009	0.996	1.001
5246	r.s. of ironmongery, paint and glass	0.998	0.999	0.999	0.999	1.000
5247	r.s. of books, newspapers and stationary	1.006	0.990	1.017	0.993	1.000
5248	r.s. in other specialised shops	0.999	0.990	1.010	0.990	0.999
5274	r.s. repairs	0.990	1.003	0.987	1.001	1.001
5211	r.s. with predominance of foods, in non	0.995	1.010	0.985	1.002	1.008
Global	Mean	0.995	0.975	1.019	0.981	0.993

MALM= Malmquist index

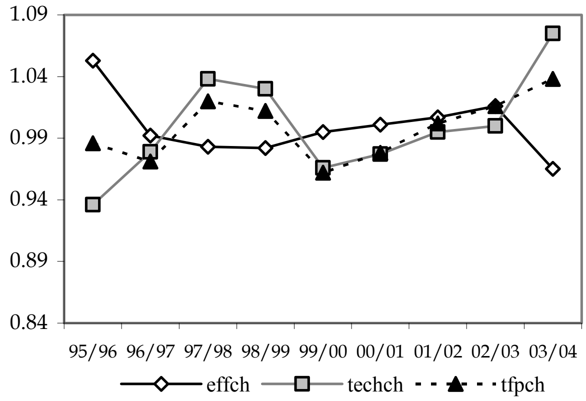
Figure 2


r.s.furniture,fuel (5200)
1.05
1
0.95
0.9
0.85
95/96 96/97 97/98 98/99 99/00 00/01 01/02 02/03 03/04
effch techch tfpch
r.s. of bread and bakery products (5224)
1.11
1.06
1.01
0.96
0.91
0.86
95/96 96/97 97/98 98/99 99/00 00/01 01/02 02/03 03/04
effch techch tfpch
r.s. of other products in non-specialised shops (5212)
1.11
1.06
1.01
0.96
0.91
0.86
95/96 96/97 97/98 98/99 99/00 00/01 01/02 02/03 03/04
effch techch tfpch
r.s. of textil (5241)
1.16
1.11
1.06
1.01
0.96
0.91
0.86
95/96 96/97 97/98 98/99 99/00 00/01 01/02 02/03 03/04
effch techch tfpch
r.s. of clothing (5242)
1.15
1.1
1.05
1
0.95
0.9
0.85
95/96 96/97 97/98 98/99 99/00 00/01 01/02 02/03 03/04
effch techch tfpch
r.s. of furniture, lighting (5244)
1.05
1
0.95
0.9
0.85
95/96 96/97 97/98 98/99 99/00 00/01 01/02 02/03 03/04
effch techch tfpch

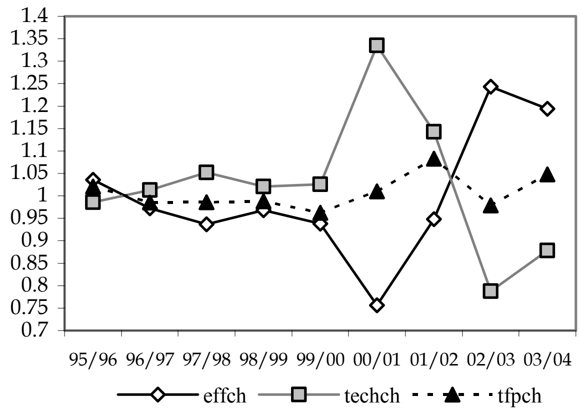
r.s. of electrical appliances, radio, TV (5245)



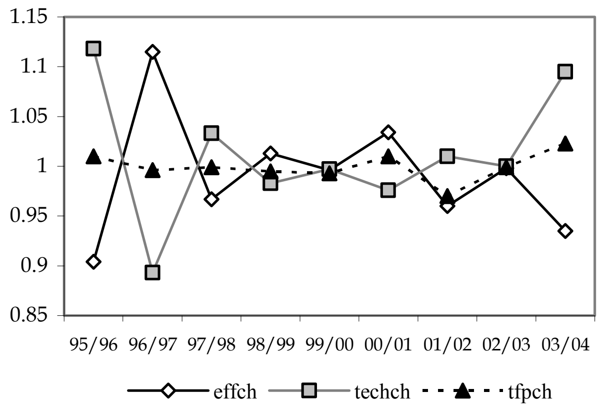
r.s. of ironmongery, paint and glass (5246)



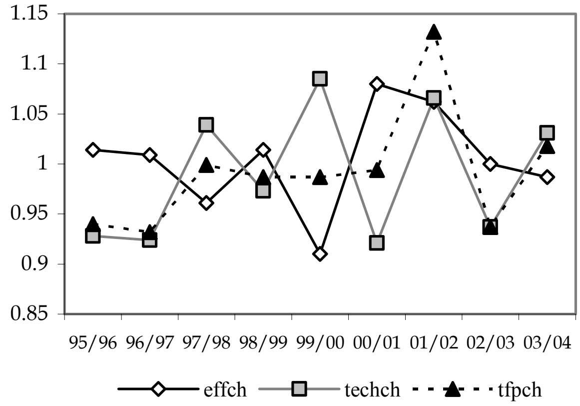
r.s. of books, newspapers and stationary (5247)



r.s. in other specialised shops (5248)



r.s. repairs (5274)



r.s. with predominance of foods (5211)

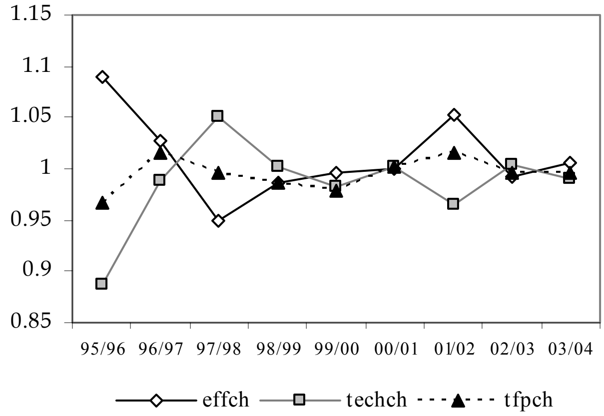
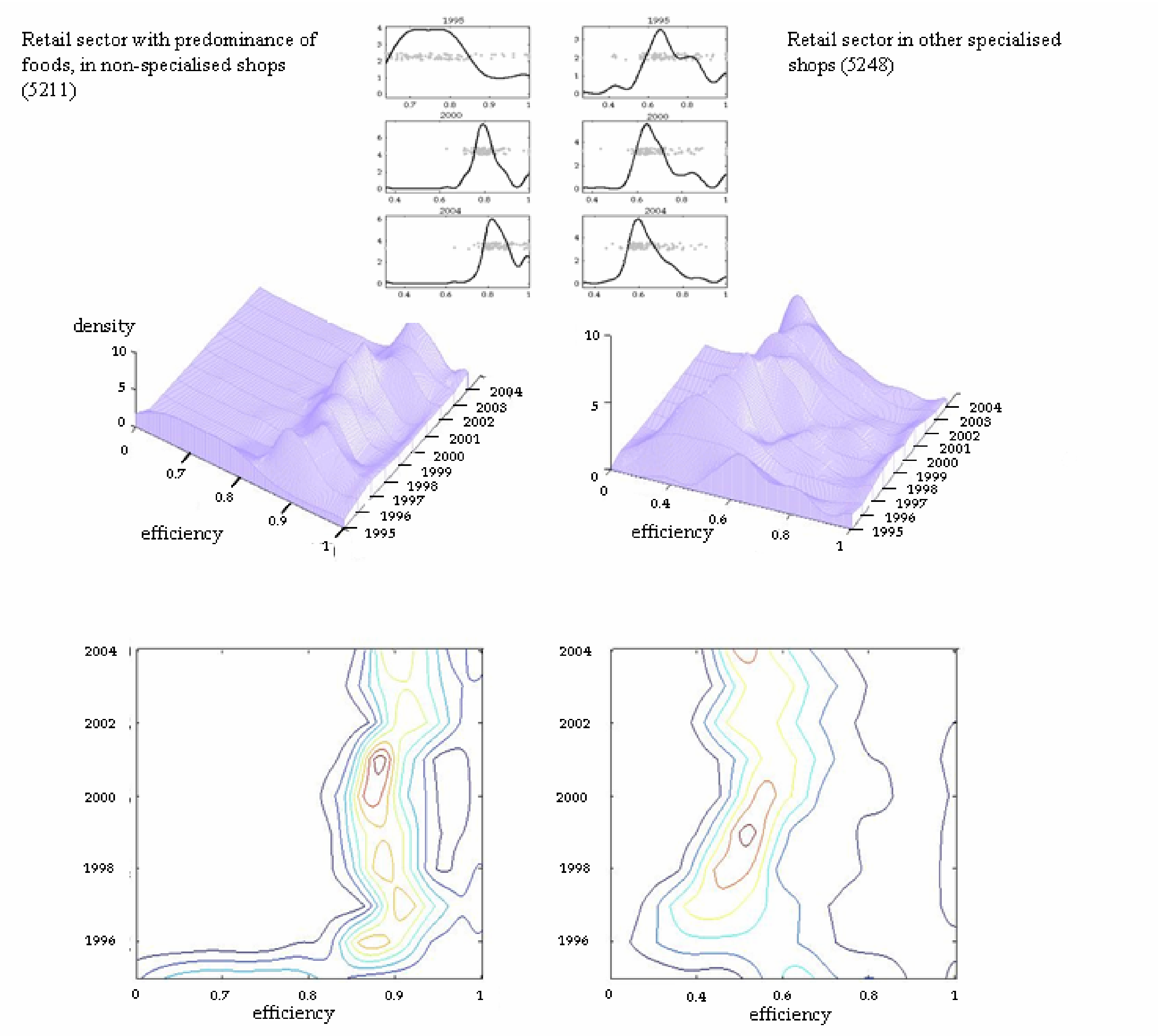


Figure 3



Retail sector with predominance of foods, in non-specialised shops (5211)
Retail sector in other specialised shops (5248)
1995
2000
2004
density
efficiency
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
efficiency

Figure 4

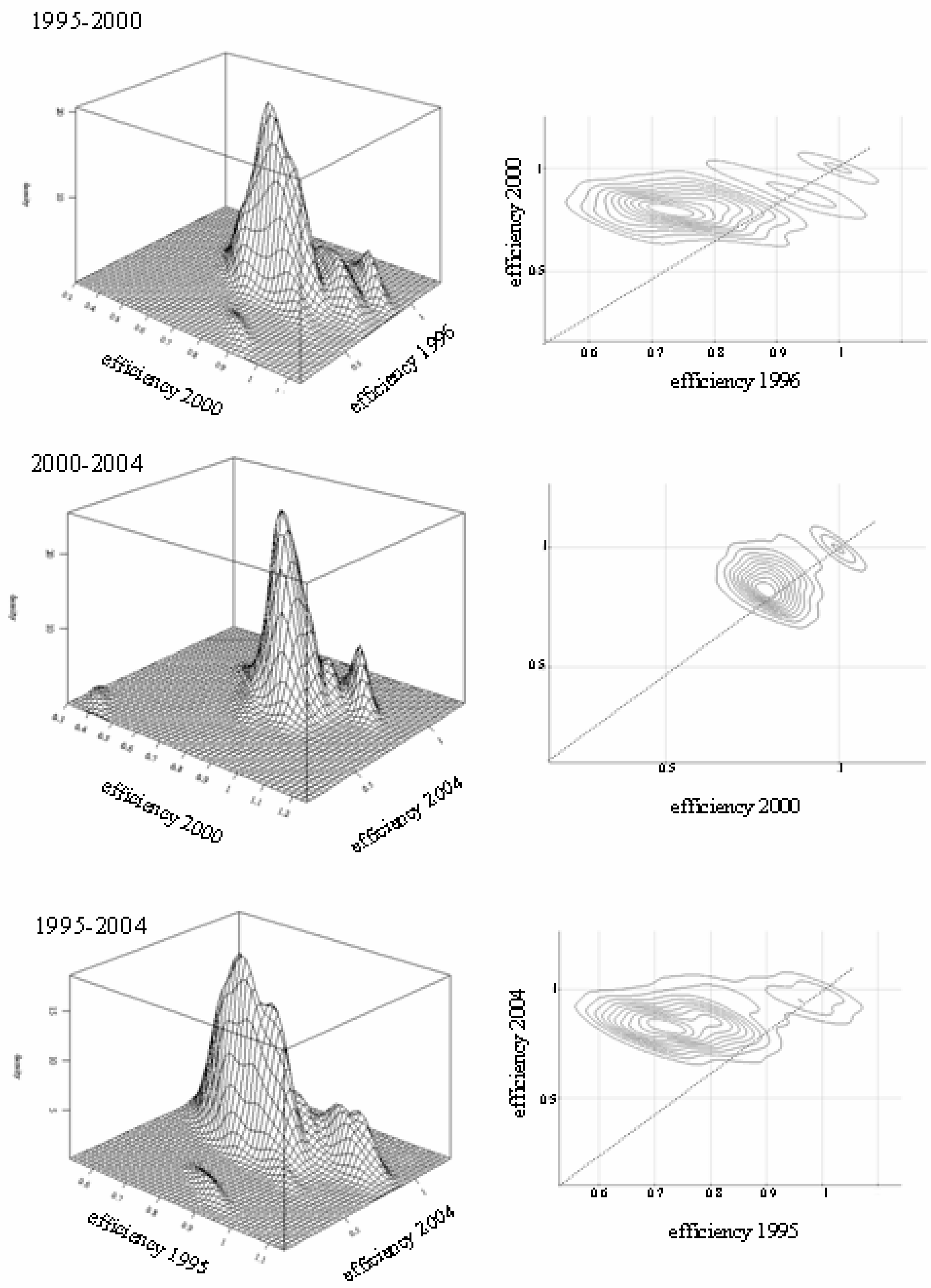
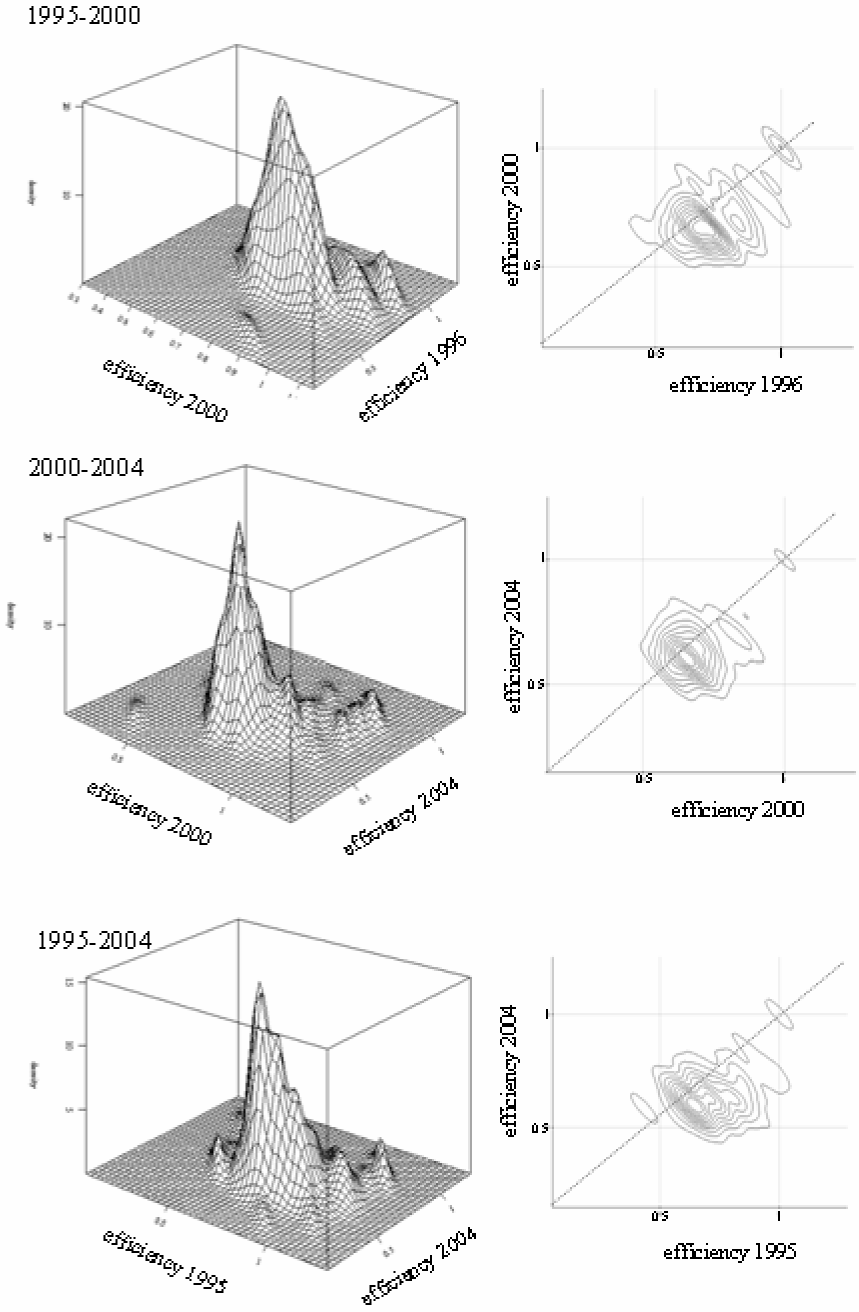
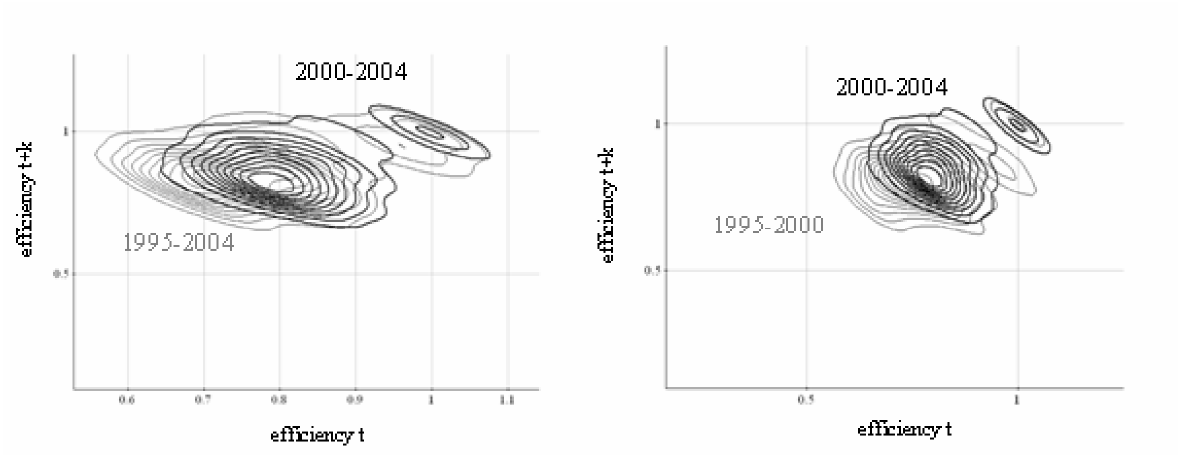

1995-2000
efficiency 2000
efficiency 1996
efficiency 2000
efficiency 1996
2000-2004
efficiency 2000
efficiency 2004
efficiency 2000
1995-2004
efficiency 1995
efficiency 2004
efficiency 2004
efficiency 1995

Figure 5



1995-2000
efficiency 2000
efficiency 1996
efficiency 2000
efficiency 1996
2000-2004
efficiency 2000
efficiency 2004
efficiency 2004
efficiency 2000
1995-2004
efficiency 1995
efficiency 2004
efficiency 2004
efficiency 1995

Figure 6


2000-2004
1995-2004
efficiency t+k
efficiency t
2000-2004
1995-2000
efficiency t+k
efficiency t