European Doctoral Programme in Entrepreneurship and Small Business Management

AN ANALYSIS OF STRATEGIC PATHS THROUGH THE DECOMPOSITION OF TOTAL FACTOR PRODUCTIVITY: THE CASE OF SPANISH SAVINGS BANKS

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JANUARY 2007

ABSTRACT

The Spanish savings banks attracted quite a considerable amount of interest within the scientific arena, especially subsequent to the disappearance of the regulatory constraints during the second decade of the 1980s. Nonetheless, a lack of research is identified with respect to mainstream paths given by strategic groups, and the analysis of the total factor productivity. Therefore, on the basis of the resource-based view of the firm and cluster analysis, we make use of changes in structure and performance ratios in order to identify the strategic groups extant in the sector. We attain a three-ways division, which we link with different input-output specifications defining strategic paths. Consequently, on the basis of these three dissimilar approaches we compute and decompose a Hicks-Moorsteen total factor productivity index. Obtained results put forward an interesting interpretation under a multi-strategic approach, together with the setbacks of employing cluster analysis within a complex strategic environment. Moreover, we also propose an ex-post method of analysing the outcomes of the decomposed total factor productivity index that could be merged with non-traditional techniques of forming strategic groups, such as cognitive approaches.

KEYWORDS:
Hicks-Moorsteen total factor productivity index, cluster analysis, strategic groups, structure and performance ratios, Spanish savings banks.

JEL Classification: D24, L1, G21.

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1. INTRODUCTION

The savings banks embody an essential Spanish banking sector. The changes within this area could be noticed at the time of the integration within the Single European Market, when the banks had to adapt their strategies and behaviours to the new rules of the game (Pastor et al. 1997).

Banking institutions in Spain are divided into three groups: commercial banks (nearly 60% of the banking activity), savings banks (40% of the banking activity), and cooperatives (about 2% of the banking activity) (Grifell-Tatjé & Lovell 1997a). Furthermore, according to the same study, the growth of the savings banks sector was due to the gradual disappearance of the regulatory constraints which existed prior to the mid-1980s (Grifell-Tatjé & Lovell 1997a) (see Appendix 1 for the fundamental changes in the Spanish banking system).

Up to date insights are presented by the financial Spanish newspaper “Cinco Días”, which, from an efficiency orientated perspective, points out that in spite of the improvements since the past year, only seven of the savings banks satisfy their goals (Cinco Días 19.04.2006). Nonetheless, efficiency here is given by operational expense divided by operational income (*i.e.* operational margin), which is not quite expressing efficiency from the activity analysis perspective, but only an excessively aggregated performance ratio.

However, not only journalists manifest their interest towards the Spanish savings banks. Recent academic literature is regarding the sector as an interesting topic. Studies by Grifell-Tatjé & Lovell (1996, 1997a, b), Lozano-Vivas (1997), Prior (2003), Tortosa-Ausina (2003), Crespí, García-Cestona & Salas (2004), García-Cestona & Surroca (2006), and Prior & Surroca (2006), to name just a few, are looking at the savings banks and studying their productivity and efficiency from different perspectives.

For example, Grifell-Tatjé & Lovell (1997b) are comparing the differences in performance between commercial banks and savings banks in Spain. This is done on the background of the freedom offered by the deregulation, a time when the savings banks have rapidly developed and grown, through mergers and branch expansion. More recently, Fuentelsaz & Gomez (2001) analyse the factors influencing the geographical expansion and diversification. Savings banks here are found as preferring closer locations, fact considered by the authors as detrimental for the potential benefit of the consumers.

Another study is that of Prior (2003), who investigates the non-parametric cost frontier efficiency in the same sector, and distinguishes between long- and short-run cost frontier efficiency. Among other results, the essential factor explaining the inefficiency in the Spanish financial sector is the inadequate capacity utilisation (defined as the short-run inefficiency caused by a non-optimal dimension of the fixed inputs).

At the same time, Tortosa-Ausina (2003) is studying the banking sector in Spain by looking upon the impact of the non-traditional activities (*e.g.* fee-based activities). The article is contributing to the creation of a comprehensible post-deregulation image of the sector, enhancing information given by studies such as the one of Kumbhakar et al. (2001). Also, it is observed that average cost efficiency increases when considering an alternative model which includes the banks' non-traditional activities. Nonetheless, time, size, and type (commercial/savings banks) variations have been detected.

Moving on, the topic of ownership structure is reflected by Crespí, García-Cestona & Salas (2004), who discover that savings banks have weak internal mechanisms of control, and are governed by several stakeholder groups with no clear allocation of property rights. However, these issues do not appear to affect the economic performance.

Our review could continue, but regardless the high amount of research in the sector, we encounter a relative lack of attention paid to what are our main interests: mainstream paths given by strategic groups, and the analysis of the total factor productivity of the savings banks. Therefore, the aim of this paper is *to identify the strategic groups existent in the sector, and to analyse their behaviour through the decomposition of their total factor productivity.* Also, as an extension, we will investigate whether the traditional methodology is appropriate for answering this type of research problems.

In order to attain our above-stated objective, we first turn to the resource-based view of the firm. We acquire structure and performance ratios based on the key resources of the savings banks, which are used as input variables for cluster analysis. Once identified the extant strategic groups, we move to the decomposition of the Hicks-Moorsteen total factor productivity index first specified by Bjurek (1996), and then developed by Lovell (2003).

There is more than one reason for why we choose to work with this family of indexes. First, as opposed to the traditional quantity index proposed by Malmquist (1953), these are total factor productivity indexes. Grifell-Tatjé & Lovell (1995) demonstrate that when confronted with non-constant returns to scale in both periods, Malmquist productivity indexes show biased measures of productivity change.

Moreover, even if other authors, such as Färe et al. (1997), provided decompositions of the Malmquist productivity index, they did not refer to total factor productivity indexes. In addition, in this case, the authors begin by presenting the index broken up in the product of a technical change index and a technical efficiency change index, and continue by expressing it as a product of a magnitude index, an output bias index, and an input bias index.

On the other hand, the proposition of Bjurek (1996), further developed by Lovell (2003), is able to provide the scale effect together with five other components (*i.e.* the total factor productivity decomposed into technical efficiency change, technical change, scale effect, and output and input mix effects). Hence, instead of a relative simulation, even without knowing exactly the production function, the Hicks-Moorsteen total factor productivity index offers us a real prevision, containing accurate movements in the technology.

Following the decomposition, non-parametric tests illustrate the significant differences which emerge as a result of the analysis. The ending commentaries are bound to put forward a response to our research objectives, and offer future investigation lines together with alternative ways of examining the data jointly with the results.

Therefore, section 2 refers to the resource-based view of the firm, section 3 defines the concept of strategic groups, and section 4 that of cluster analysis. The 5th chapter describes the employed methodology, and is followed by chapter 6 containing the description of the results. The last two sections provide our conclusions, limitations and the future lines of research.

2. THE RESOURCE-BASED VIEW AND STRATEGIC PATHS

The resource-based view of the firm (hereafter *RBV*) theory was first pointed out in the book of Penrose (1959), which brought up that "the firm is more than an administrative unit; it is also a collection of productive resources, the disposal of which between different users and over time is determined by administrative decisions." (1959: 24).

More recently, the seminal works in the research stream of the *RBV* are given by Wernerfelt (1984) and Barney (1991). Wernerfelt (1984) sees resources and products as two sides of the same coin, and suggests looking upon resources as important antecedents for products. His work fits well together with the statement of Dierickx & Cool (1989) that managers often have problems when recognising that the bundle of assets, instead of a particular product-market combination, stands at the basis of the competitive advantage.

Continuing, for Barney (1991) the *RBV* theory is based on two critical issues: (1) firms are heterogeneous, as they are characterised by different resources, and (2) resources are not necessarily mobile, therefore heterogeneity can be durable. Therefore, having one of the most influential frameworks of advantage-creating resource characteristics, Barney (1991) puts forth that the firm's assets, in order to be a source of competitive advantage, have to be valuable, rare, imperfectly imitable, and they cannot have a strategically equivalent substitute.

Hence, according to Barney (1991) not all resources are equally important for the firm's performance. Galbreath & Galvin (2004) remind the classical configuration of the firm's resources, that includes tangible resources and intangible resources. Tangible resources can be encountered in the balance sheet. On the other hand, the intangible ones can be rarely physically or financially expressed, if at all. Therefore, the latter category can be identified as either assets or capabilities (Galbreath & Galvin 2004).

Nonetheless, perspectives evolve within the *RBV* framework, and consequently the strategic views, and attaining and maintaining the competitive advantage have been observed to experience a change from "external positioning" and the balance of the competitive forces, to "internal awareness" of one's own resources. Thus, the consciousness towards the firm's resources is now viewed as fundamental for sustainable efficiency (Wright et. al 2001). Furthermore, Luneborg & Nielsen (2003) argues that overall efficiency and productivity depend on internal resources and knowledge, but not without an adaptive capacity to strategic change.

Focusing on the sector under investigation (*i.e.* the Spanish savings banks), and our productivity analysis approach, the emphasis is put on the tangible variables. Although the intangibles are given a growing importance within the *RBV*, our motivation for not employing them is twofold. First, due to our orientation towards productivity decomposition, we act within a methodology where most of the employed inputs and outputs are extracted from balance sheets and income statements.

Second, as a result of researching the savings banks, we encounter a lack of information with regard to intangibles. In private banking the value of intangibles can be obtained by comparing the market price with the balance sheet. Nonetheless, this type of information is not accessible if the units do not participate in the stock market, which, for the moment, is the case of the Spanish savings banks.

Even so, this is but one aspect of the sector. Nowadays, this segment of the banking industry is characterised as being a dynamic and complex environment. Hence, the units performing here have to be ready at all times to adapt to the strategic changes that emerge. The outcome of this way of thinking is a “sustainable multi-strategic positioning” (Yee-kwong & Wong 1999).

The above mentioned authors state that banks adopting a multi-strategic approach outperform single-strategically oriented rivals. Keeping in mind this assertion, units under the *RBV* can combine key resources in a synergetic manner so as to attain flexibility, and thus a sustainable multi-strategic position (Yee-kwong & Wong 1999). Moreover, while the *RBV* points towards the feasibility of adopting this kind of approaches, it is also important to have it adapted to certain industries.

Progressing, the same authors advance the importance of pursuing integrated flexibility through seeking elasticity at the level of the key resources. Accordingly with the fact that resourceful players top the less-endowed ones, within the savings banks sector we add that the units have to perform competitively not only at the level of their major strategic orientation, but also to be capable of shifting to the other mainstream strategic paths present in the market.

As a consequence of the above discussion, we make use of key resources in an attempt to identify the extant strategic groups in the Spanish savings banks’ sector, and furthermore to perform the productivity analysis. The next chapter aims at defining our approach with relation to the s concept of strategic groups.

3. STRATEGIC GROUPS

The initial concept of strategic groups was proposed by Hunt (1972), who was aiming at identifying similar configurations of the firms’ strategic behaviours within a certain industry.

A strategic group is described by Porter (1979) as a group of firms that share similar strategic orientations, which are different from the strategies followed by the other firms pertaining to the same sector. Also, Caves and Porter (1977) state that firms coming from the same strategic group are not only similar, but also work together to raise movement barriers. Absence of such barriers could result in quick imitation of successful strategies (Porter 1979).

Nevertheless, a condition for mobility barriers to exist is the heterogeneity of resources (González-Fidalgo & Ventura-Victoria 2002). Even more, for the existence of performance differences between the groups, besides the mobility barriers, inimitable resources should also be encountered. Failure of such elements to manifest would bring about a lack of group-specific competitive advantages (González-Fidalgo & Ventura-Victoria 2002).

On the same topic, Prior & Surroca (2006) argue that there is a price to pay for changing strategies, and therefore firms in one strategic group will encounter less difficult to act as the other group members. Consequently, those who do not belong to the group have to undertake high costs when attempting to copy strategies.

Evolutions of the literature on this topic produced insights into the rivalry between companies and the interactions of firms and their performance (Mas-Ruiz et al. 2005). Here, important factors are represented by issues such as the number and size of the strategic groups, and the distance between them.

Day et al. (1995), brings about the idea that the conflicting results obtained by the existing studies when talking about the differences in performance between the strategic groups may appear due to the lack of the use of multiple criteria, and the employment of inappropriate methods of selection. What is to be noted is that no matter which the way of selecting, two firms within a group, even with the same objective, may have different levels of success (Day et al. 1995). The same author takes a step further, and states that more firms with one strategic orientation do not necessarily have similar objectives.

On one hand, the present study adopts the definition of Porter (1979), and intents to group the Spanish savings banks according to the performance-related strategic paths. On the other hand, our perspective is quite similar with the one of Day et al. (1995), for due to differences in size and power among the savings banks, it is probable to have dispersion in the total factor productivity measures correlated with the different strategic orientations.

In addition, taking into account the multi-strategic approach discussed in the previous section, we will obtain divisions that provide us the productive, and at the same time flexible units. Keeping in mind the statement of Prior & Surroca (2006), the most flexible units will be the ones that pay the lowest price when having to shift from one strategic path to another.

Consequently, we aim to find out the leading group not only in terms of total factor productivity, but also which are the units defining the frontier, their followers, and also good performers under criteria such as technical efficiency and scale effect.

Summing up, we define the strategic groups on the basis of our *RBV* framework, through the structure and performance indicators of the employed key resources. The subsequent total factor productivity analysis is carried out using as a foundation the same division of the banking units. Therefore, this latter evaluation of each group's productivity per components will be the basis of our concluding remarks.

Moreover, we opt for a traditional method of forming the strategic groups – the cluster analysis. This method represents the mainstream in the literature of strategic groups, and involves different ways it can be applied in. The next chapter aims at clarifying the most important aspects of this technique.

4. CLUSTER ANALYSIS

The cluster analysis is a widely known method for separating units under investigation into different groups. This descriptive technique categorises observations as a function of one or more input variables. Consequently, these variables offer the main characteristics of each of the obtained groups.

There exist two main methods of applying cluster analysis: (1) the hierarchical method, and (2) the mutually exclusive method (non-hierarchical). Moreover, discriminant analyses are often carried out as a second step in order to verify whether the units were correctly situated within the newly formed division.

Examples of cluster division are easily encountered in the literature. For instance, Amel & Rhoades (1988) are making use of the second clustering method in order to look upon strategies in banking. The input variables are given by balance sheet items. Also, the technique proves itself useful for comparisons between regions. From another perspective, the research of Flavian et al. (1999) marks the dissimilarities between the food industry of Spain and the UK. Marketing related variables are utilised to run a hierarchical cluster analysis.

In addition, this technique goes together well with the *RBV*. Studies by Oliveira & Fensterseifer (2003), and Zuniga-Vicente et al. (2004) mix the concept with the method. The second mentioned study is carried out in the Spanish private banking sector, and has as variables performance indicators related with the resources of the firm. The important issue brought up by this research is the testing of the stability over time of the strategic groups. Moreover, the applied clustering method (*MCLUST*), method which does not identify itself with the two classic techniques, is considered innovative by the authors.

Continuing, clustering was used in internationalisation studies by Maitland et al. (2005) and by Narasimhan et al. (2005) who looked upon the manufacturing performance of plants positioned in different strategic groups. The latter study goes through a two-stage process of cluster analysis. First, a hierarchical technique is used with manufacturing variables, and second a non-hierarchical cluster analysis and discriminant analysis prove the validity of the formed division.

Furthermore, cluster analysis is also present in efficiency related studies, as Prior & Surroca (2006) investigate the Spanish banking industry. Here we encounter a contrast between the cluster analysis having as input variables marginal rates obtained through Data Envelopment Analysis, and cluster analysis with the original variables. Attained results show the advantages of utilising marginal rates.

In the present paper our intention is to employ cluster analysis within the Spanish savings banks sector, with the aim of achieving insights into the strategic paths of different strategic groups present within this area. Additionally, we verify if the method is adequate for answering strategy-related research questions.

Our dilemma is whether this technique is appropriate for identifying the strategic conduit of each group so as to provide a way for the researcher to accurately detect differences between the performance and the productivity of different orientations. This latter doubt is given by the emergence of novel forms of investigating strategic behaviours that challenge the traditional methods, such as the cognitive approaches.

5. METHODOLOGY

5.1. Strategic Groups, Performance Indicators, and Input-Output Mixes

In order to identify the strategic groups we have chosen to employ as input variables a series of banking-related structure and performance indicators. Moreover, utilising performance ratios for identifying strategic groups seems to be consistent with the cluster analysis literature (Zuniga-Vicente et al. 2004).

Our review included proxies for different financial indicators, but the main aim was given by the identification of ratios related with the multiple strategies/input-output mixes that we came upon within the banking sector. Therefore, we opt to utilise structure and performance ratios as in D’Souza & Megginson (1999), Verbrugge et al. (1999), and Dewenter & Malatesta (2001). Hence, we came across the following ratios:

$$\frac{\text{Operational margin}}{\text{Performing assets}} = \text{Proxy for ROA}^{1} \quad (1)$$

$$\frac{\text{Total assets}}{\text{Deposits}} = \text{Proxy 1 for intermediation} \quad (2)$$

$$\frac{\text{Investment portfolio}}{\text{Total assets}} = \text{Assets' structure in direct investments} \quad (3)$$

$$\frac{\text{Loans}}{\text{Total assets}} = \text{Proxy 2 for intermediation} \quad (4)$$

Keeping in mind our connection with the multi-strategic orientation already presented, we made a review of the strategic paths present in the sector. Authors such as Favero

[1] Return on assets

& Papi (1995), Grifell-Tatjé & Lovell (1996, 1997a, b), Lozano-Vivas (1997), Tortosa-Ausina (2003), Prior (2003), Crespí, García-Cestona & Salas (2004), García-Cestona & Surroca (2006), and Prior & Surroca (2006) offer diverse strategic views.

The main encountered strategies that aim at dissimilar ways of development were (1) *the strategy of attraction*, (2) *the strategy of intermediation*, and (3) *the strategy dedicated to diversification and/or geographical expansion*. First, the attraction (production) approach targets at attaining growth through enhancing the quantity of deposits from the bank's clients. Second, the intermediation of resources views the banking unit as a mediator between the collection of funds, and the granting of loans. Finally, long-term progress can be looked for through the employment of resources for diversifying and expanding the activities.

Consequently, our ratios express the three major strategies. On the basis of the fact that by attracting capital, business is generated, and therefore superior turnover over the assets is produced, we link the proxy we used for *ROA* with a strategy of attraction. Moving on, the second and last ratios are proxies towards a strategy of intermediation of resources, as they are showing the share of deposits and loans in the total assets structure. Similarly, the assets' structure in direct investments is representing diversification and/or geographical expansion. This comes as a result of the idea that the investments are employed for the foundation of new branches and/or for carrying out new activities.

Productivity- and efficiency-wise, the extant literature is revealing different possibilities for the specification of inputs and outputs, with regard to the above stated strategic paths. Table 1 is presenting some of the used mixes. At a first glance the presented situation seems a bit chaotic due to the diversity of approaches. Nonetheless, the reviewed studies evaluate different dimensions of the efficiency, and have dissimilar objectives, facts that account for the lack of homogeneity.

Considering the review in the presented table, we should also mention that we decided not to specifically define a value added approach on account of the fact that it somehow identifies itself with the attraction (production) approach, since it treats both deposits and loans as outputs.

Table 1 Input-Output Mixes (further developed from Favero & Papi 1995)

Author	Inputs	Outputs	Appr.
Rangan et al. (1988)	Labour (employees) Capital Purchased funds	Loans Deposits (demand and time)	IA[2]
Aly et al. (1990)	Labour (employees) Capital Loan funds	Loans (real estate comm. ind., consumer, others) Demand deposits	IA
Berger & Humphrey (1991)	Labour Purchased funds Capital	Deposits Loans	IA
Ferrier & Lovell (1990)	Labour (employees) Expenditures on materials Occupancy costs and expenditure on furniture and equipments	Number of deposit accounts (demand, time) Number of loans	PA[3]
Olivei (1992)	Labour (employees) Non-interest expense Depreciations (fixed assets and premise) Interest expenses	Loans Deposits Non-interest income	VAA[4]
English et al. (1993)	Deposits Labour Purchased funds	Loans Investments	IA
Favero & Papi (1995)	Labour Fixed assets Financial capital available for investment	Loans Investments in bonds Non-interest income	IA
Grifell-Tatjé & Lovell (1997a)	Number of employees Expenditures on materials Direct expenditure on buildings plus accounting depreciation	Number of loans Number of checking accounts Number of savings accounts	PA
Lozano-Vivas (1997)	Labour Materials Deposits (interest cost) Physical capital	Loans Interbank loans Produced deposits	VAA
Prior (2003)	Material consumption (variable) Staff (variable) Labour cost (variable) Number of branches Depreciation and operating expenses	Number of loans Number of savings accounts Service charges applied	PA
Tortosa-Ausina (2003)	Labour (no. of employees) Funding (savings, other and interbank) Physical capital (fixed assets) *prices = expenses of input / quantity	Loans Other earning assets Fee-generated income* * non-traditional output	IA

In order to define our established strategic orientations, we have to associate each of them with a specific input-output mix. Moreover, so as to thoroughly differentiate

[2] Intermediation approach
[3] Production (attraction) approach
[4] Value added approach

between the paths, we had to maintain some fixed (basic) inputs and outputs, and shift or introduce other variable ones (Table 2).

Table 2 Employed Input-Output Mixes

Intermediation		Attraction		Geographical expansion	
Inputs	**Outputs**	**Inputs**	**Outputs**	**Inputs**	**Outputs**
Fixed assets	Loans	Fixed assets	Loans	Fixed assets	Loans
Labour costs	Inv portfolio	Labour costs	Inv portfolio	Labour costs	Inv portfolio
Other admin. expenses		Other admin. expenses	Deposits	Other admin. expenses	Fee-based activities
Deposits				Deposits	No. of Branches

Subsequent to our review presented in Table 1, the fixed inputs are: (1) fixed assets, (2) labour costs, and (3) other administrative expenses, whereas the fixed outputs are: (1) loans, and (2) investment portfolio. The variable inputs/outputs are: (1) deposits – encountered as input for the intermediation and geographical expansion specifications, and as output for the attraction related one, (2) fee-based activities – encountered as an output linked with the geographical expansion approach, and (3) number of braches – an output of the geographical expansion mix.

The deposits mark the difference between the two strategic approaches. First, they point towards the short-term growth, by representing practically the final objective when dealing with an approach of attraction. Second, they stand for the first part of the intermediation process, as a resource for the provision of funding through loaning.

In the last input-output mix, we first put the basis of an intermediation orientation, with the purpose to geographically (physically) expand. Deposits are attracted with the purpose of funding (loaning), but at the same time the units seek new non-traditional activities (fee-generated), and also expansion. Therefore, the number of branches (*i.e.* the absolute total number of branches a savings bank has in all the regions where it develops its activity) appears as an output.

Hence, with the exception of the number of branches (which is an absolute value), all the other inputs and outputs are expressed in monetary terms. The dilemma of whether to use physical or monetary inputs and outputs is present in the literature. Our rationale for expressing the variables in mostly monetary terms is relatively simple.

For example, if two banks have the same number of deposits, but one of them holds twice as much money-wise as the other, the physical "deposits" would be equal, whereas the monetary "deposits" would show the real situation. Consequently, the same underlying principle was followed for all the defined input or output variables.

5.2. The Hicks-Moorsteen Total Factor Productivity Index

Suggestions such as the one of Grifell-Tatjé & Lovell (1995) pointing towards the necessity of a new productivity index, one which is able to account for variable returns to scale, made way for the conception of the Hicks-Moorsteen total factor productivity index.

The Hicks-Moorsteen index was introduced as a "Malmquist total factor productivity index" by Bjurek (1996). In accordance with the above stated, the rationale offered by Bjurek (1996) for computing this index was that the classic Malmquist productivity index does not measure properly the changes in productivity at the time of changes in returns to scale.

Hence, Bjurek (1996) puts forth a new definition of the Malmquist productivity index for the production unit between *t* and *t + 1*, given the technologies at times *k*, *k = 1* and *k = t + 1*. Furthermore, the index is a ratio between an output index and an input index:

$$MTFP = \frac{MO_k(y_t,\ y_{t+1},\ x_k)}{MI_k(y_k,\ x_t,\ x_{t+1})} = \frac{E_k^o(y_{t+1},\ x_k)/(E_k^o(y_t,\ x_k)}{E_k^i(y_k,\ x_t)/(E_k^i(y_k,\ x_{t+1})},\qquad k = t,\ t+1 \qquad (5)$$

Where, *MO* and *MI* stand for Malmquist output and input quantity index respectively, and $E^o\ and\ E^i$ stand for output and input efficiency measure respectively. Continuing, **y** = $(y_1, , . . ., y_m)$, and **x** = $(x_1, , . . ., x_n)$ represent vectors of output and input quantities.

The above mentioned author is pointing to the important fact that instead of defining an output or input oriented index, this specification measures the change in output quantities in output direction, and the change in input quantities in input direction, a detail of considerable meaning when employing variable returns to scale (Bjurek 1996).

Nevertheless, this simultaneously oriented index had the disadvantage of not being able to show isolated the various sources of productivity change. Therefore, the breakthrough was offered by Lovell (2003), who brings about a novel decomposition of the total factor productivity index.

According to Lovell (2003), Bjurek's (1996) proposal of a simultaneous oriented index (*i.e.* a ratio of an output quantity index to an input quantity index) decomposes the following way:

$$\begin{aligned} M^t\left(\mathbf{x^t},\mathbf{y^t},\mathbf{x^{t+1}},\mathbf{y^{t+1}}\right) = {} & TE\Delta_o\left(\mathbf{x^t},\mathbf{y^t},\mathbf{x^{t+1}},\mathbf{y^{t+1}}\right)\times T\Delta_o\left(\mathbf{x^{t+1}},\mathbf{y^{t+1}}\right)\times \\ & \times S\Delta^t\left(\mathbf{x^t},\mathbf{y^t},\lambda\mathbf{x^t},\mu\mathbf{y^t}\right)\times OM\Delta^t\left(\mathbf{x^t},\mathbf{y^{t+1}},\mu\mathbf{y^t}\right)\times \\ & \times IM\Delta^t\left(\mathbf{y^t},\mathbf{x^{t+1}},\lambda\mathbf{x^t}\right), \end{aligned} \tag{6}$$

where,

$$M^t\left(\mathbf{x^t},\mathbf{y^t},\mathbf{x^{t+1}},\mathbf{y^{t+1}}\right)=\frac{D_o^t\left(\mathbf{x^t},\mathbf{y^{t+1}}\right)/D_o^t\left(\mathbf{x^t},\mathbf{y^t}\right)}{D_i^t\left(\mathbf{x^{t+1}},\mathbf{y^t}\right)/D_i^t\left(\mathbf{x^t},\mathbf{y^t}\right)} \text{ – the total factor productivity index,} \tag{7}$$

$$D_o\left(\mathbf{x},\mathbf{y},t\right)=\inf_{\phi}\left\{\phi>0:\left(\mathbf{x},\mathbf{y}/\phi,t\right)\in T\right\} \text{ – output distance function,} \tag{8}$$

$$D_i\left(\mathbf{x},\mathbf{y},t\right)=\sup_{\theta}\left\{\theta>0:\left(\mathbf{x}/\theta,\mathbf{y},t\right)\in T\right\} \text{ – input distance function,} \tag{9}$$

$$\mathbf{x}\in R_+^N \text{ – input vector,} \tag{10}$$

$$\mathbf{y}\in R_+^M \text{ – output vector,} \tag{11}$$

$$TE\Delta_o\left(\mathbf{x^t},\mathbf{y^t},\mathbf{x^{t+1}},\mathbf{y^{t+1}}\right)=\frac{D_o^{t+1}\left(\mathbf{x^{t+1}},\mathbf{y^{t+1}}\right)}{D_o^t\left(\mathbf{x^t},\mathbf{y^t}\right)} \text{ – output-oriented measure of technical efficiency change,} \tag{12}$$

$$T\Delta_o\left(\mathbf{x^{t+1}},\mathbf{y^{t+1}}\right)=\frac{D_o^t\left(\mathbf{x^{t+1}},\mathbf{y^{t+1}}\right)}{D_o^{t+1}\left(\mathbf{x^{t+1}},\mathbf{y^{t+1}}\right)} \text{ – output-oriented measure of technical change,} \tag{13}$$

$$S\Delta^{t}\left(\mathbf{x^t},\mathbf{y^t},\lambda\mathbf{x^t},\mu\mathbf{y^t}\right)=\frac{D_o^t\left(\mathbf{x^t},\mu\mathbf{y^t}\right)\Big/D_o^t\left(\mathbf{x^{t+1}},\mathbf{y^{t+1}}\right)}{D_i^t\left(\lambda\mathbf{x^t},\mathbf{y^t}\right)\Big/D_i^t\left(\mathbf{x^t},\mathbf{y^t}\right)}$$ - index identifying the scale effect, [5] (14)

$$\mu=\left[D_o^t\left(\mathbf{x^{t+1}}\Big/D_o^t\left(\mathbf{x^{t+1}},\mathbf{y^{t+1}}\right),\mathbf{y^t}\right)\right]^{-1}, \quad (15)$$

$$\lambda=\left[D_i^t\left(\mathbf{x^t},\mathbf{y^{t+1}}\Big/D_i^t\left(\mathbf{x^{t+1}},\mathbf{y^{t+1}}\right)\right)\right]^{-1}, \quad (16)$$

$$OM\Delta^{t}\left(\mathbf{x^t},\mathbf{y^{t+1}},\mu\mathbf{y^t}\right)=\frac{D_o^t\left(\mathbf{x^t},\mathbf{y^{t+1}}\right)}{D_o^t\left(\mathbf{x^t},\mu\mathbf{y^t}\right)}$$ - index identifying the output mix effect on TFP change, (17)

$$IM\Delta^{t}\left(\mathbf{x^{t+1}},\lambda\mathbf{x^t},\mathbf{y^t}\right)=\frac{D_i^t\left(\lambda\mathbf{x^t},\mathbf{y^t}\right)}{D_i^t\left(\mathbf{x^{t+1}},\mathbf{y^t}\right)}$$ - index identifying the input mix effect on TFP change. (18)

The distance functions employed in the above formulation are defined in non-parametric technology, and variable returns to scale conditions. The direct input distance function "treats (multiple) outputs as given and contracts input vectors as much as possible consistent with the technological feasibility of the contracted input vector" (Färe et al. 1994:10).

Continuing, the authors state that this function presents a whole description of the structure of multi-input, multi-output efficient production technology, and furthermore it offers a two-ways assessment of the distance from a producer to the efficient technology. Similarly, the direct output distance function has alike characteristics, and can be employed to exemplify structures of efficient production technologies in multiproduct cases (Färe et al. 1994).

Figure 1 describes the technical efficiency change, the technical change, and the scale effect components. The last two can be easily observed by looking upon the graph. Technical change (according to the above presented formula and to our exemplified unit) is the movement of the frontier in period *t+1* with respect to period *t* (while we keep input and output quantities in *t+1*).

[5] $S\Delta^t$, $OM\Delta^t$ and $IM\Delta^t$ have been redefined in order to correctly express the present movements. The correction was done in accordance with the proposal discussed by Prior (2006).

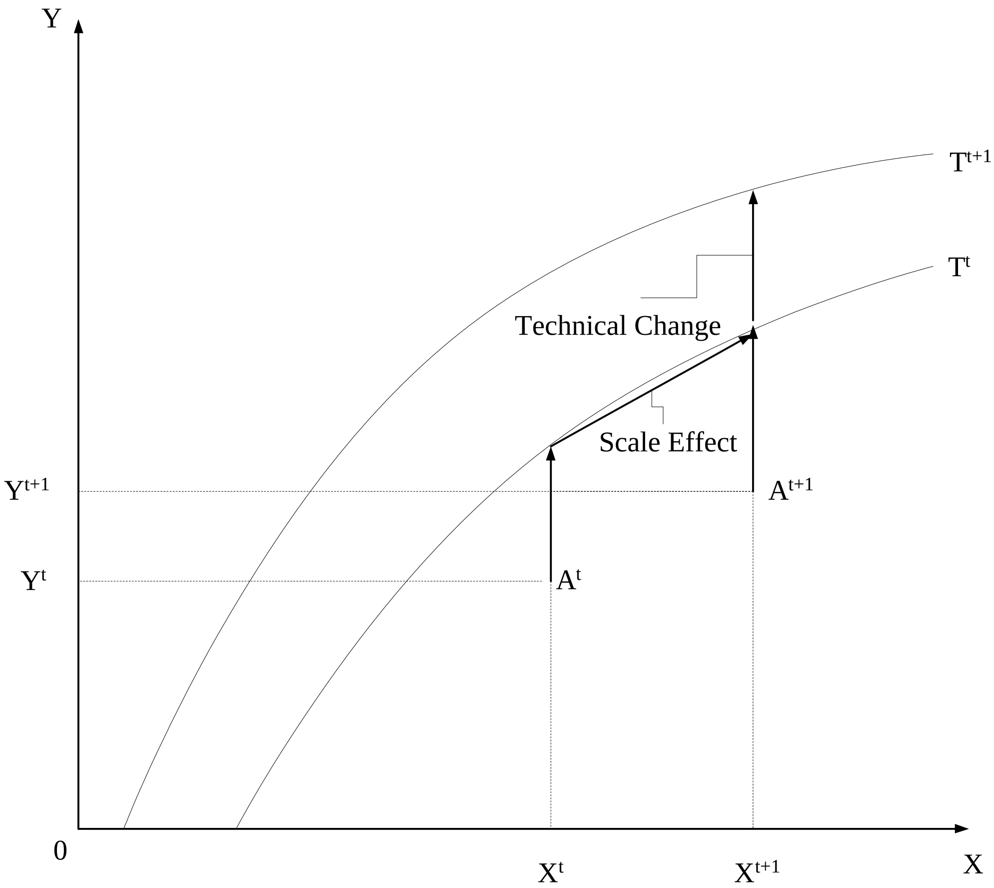

Figure 1 Technical Efficiency Change, Technical Change, and Scale Effect

Also noticeable in the figure, the scale change effect is influenced by the radial scaling of inputs and outputs. Moving on to the technical efficiency change, we take *Unit A* as an example. Therefore, the technical efficiency change is given by the distance from where the unit is situated in period *t+1* (A^{t+1} in the figure) to the frontier in *t+1*, divided by the distance from the unit in period *t* (A^t in the figure) to the frontier in period *t*.

What has to be mentioned is that the output and input mix effects cannot be represented on this graph due to the one input one output situation. Nonetheless, their interpretation is as follows. The output mix effect holds technology and inputs at their period *t* values, and compares them with outputs in the periods *t* and *t+1*. Similarly, the input mix effect holds technology and outputs as they were in the period *t*, and evaluates them against inputs in *t* and *t+1*.

Additionally to all of the above, Lovell (2003) identifies the activity effect as a product of the scale change effect, the output mix effect, and the input mix effect.

$$AE^{t}\left(\mathbf{x^{t}},\mathbf{y^{t}},\mathbf{x^{t+1}},\mathbf{y^{t+1}}\right)=S\Delta^{t}\left(\mathbf{x^{t}},\mathbf{y^{t}},\lambda\mathbf{x^{t}},\mu\mathbf{y^{t}}\right)\times OM\Delta^{t}\left(\mathbf{x^{t}},\mathbf{y^{t+1}},\mu\mathbf{y^{t}}\right)\times IM\Delta^{t}\left(\mathbf{x^{t+1}},\lambda\mathbf{x^{t}},\mathbf{y^{t}}\right) \quad (19)$$

Consequently, we find ourselves in the situation of having to interpret seven components. Considering that we are dealing with productivity indexes, given their definition, values higher than 1 show us a positive change, values equal to 1 indicate no change, whereas results lower than 1 point towards negative movements.

5.3. Methods of Analysis

The analysis begins with the measurement of the above presented structure and performance ratios. Results from the two periods under evaluation are utilised to provide us with temporal ratios describing the changes from 1998 to 2002 for each of the indicators (*e.g.* ROA_{2002} / ROA_{1998}). The rationale for making use of temporal rations is given by our desire of being consistent throughout the analysis. Since we compute the Hicks-Moorsteen total factor productivity index between the two above mentioned periods, we also need a unique cluster division that links the two years.

Following, obtained ratios are used as input variables in the cluster analysis. We chose to run a “non-hierarchical” cluster analysis using SPSS[6] 12.0, asking for a three-ways division (in order to later match it with our above stated specifications). Next, we also test the stability over time of the formed strategic groups, by running the analysis for each of the two years under investigation. Furthermore, the validity of the cluster analysis is tested through a discriminant analysis.

It is widely known that the analysis of efficiency and productivity is sensitive to the presence of outliers. The reason for this is that the extreme points determine the efficiency frontier and can affect the scores of the other *DMUs*[7]. Wilson (1995) points out that in output-oriented *DEA*[8] programs the exclusion of units with low values of the super-efficiency coefficient produces the most important movement of the frontier.

[6] Statistical Package for the Social Sciences
[7] Decision Making Units
[8] Data Envelopment Analysis

Hence, extremely super-efficient units will be removed from the sample in order for us to notice if any important movements occurred. We take as a limit for super-efficiency a level of less than 60% in output-oriented *VRS*[9] technology. Thus, if a *DMU* is found as influential to the rest of the analysed savings banks, it is removed from the sample and the test is rerun so as to observe the presence of new outliers.

Furthermore, according to Prior & Surroca (2006), the process is repeated until there is no more bias in the sample. At the same time, if no important changes take place, the unit is put back into the total population, and considered as not influential.

When running the test, possibly alarming super-efficiency was attained under some of the approaches by savings banks such as “Caja Madrid”, “La Caixa” or “Bancaja”. Nonetheless, the final decision was made in the direction of not interfering in the total sample, since no important differences were detected when examining the scores of the remaining population.

The next step is the computation of the Hicks-Moorsteen total factor productivity index. This will be done in accordance with the methodology presented in the latter chapter. The described mathematical formulation will be calculated by making use of the GAMS software[10].

Once all the results are obtained, one more stage is necessary in order for the results to be thoroughly interpreted: the non-parametric tests. These are also provided by SPSS 12.0. Hence, for our non-related samples (*i.e.* different strategic groups under the same specification) we employ the Mann-Whitney U test. The test provides us with Z-values which we associate with significance levels at a median height, in order to shed light upon the existing dissimilarities.

[9] Variable returns to scale
[10] See Appendix 7 for the GAMS routine

6. SAMPLE, DATA, AND RESULTS

The investigation was carried out within the Spanish banking sector, and the *DMUs* were the savings banks. A complete list was obtained by looking at the "Confederación Española de Cajas de Ahorros[11]". The total number of listed units is 46, but after studying the available information we were able to use 45 of them (due to mergers between the two studied periods).

For the analysis we used the balance sheets and income statements corresponding the years 1998 and 2002. Therefore, all the data used for the study is secondary data. Furthermore, information was also extracted from the annual reports offered by the savings banks, and from the "Anuario Estadístico de las Cajas de Ahorros Confederadas[12]" published by "Confederación Española de Cajas de Ahorros".

Following, this section provides, in a descriptive manner, the obtained results and the consequent discussion. We commence the depiction of the encountered outcome with the presentation of the structure and performance ratios together with the strategic groups division. Second, the description of the Hicks-Moorsteen total factor productivity index jointly with the decomposition is carried out, and finally the significant differences are illustrated by the non-parametric tests.

Table 3 is showing the results of the changes in the ratios per total, as well as for each of the three obtained strategic groups. It should be mentioned that the stability of the groups was tested by running correspondent cluster analyses for each of the two years under analysis. The results showed little movement across the formed distribution, hence we moved forward into our investigation.

Moreover, the results of the discriminant analysis demonstrated that the division was accurate, since the predicted positioning is correct at 100% for groups 1 and 3, and at more than 93% for group 2 (see Appendixes 2 and 3 for the strategic groups division and the discriminant analysis prediction).

[11] The Spanish Confederation of Savings Banks
[12] Annual. Statistical Report of the Confederation of Savings Banks

Table 3 Changes in Structure and Performance Ratios (2002 / 1998)

	Ratios	ROA	TA / DEP	INV / TA	LOAN / TA
Group 1 (21)	Mean	0.7015	1.0082	0.7047	1.2285
	Std. Dev	0.1699	0.0939	0.2295	0.1225
	Median	0.7358	0.9926	0.7433	1.1980
Group 2 (15)	Mean	0.8677	0.9915	1.2712	1.1959
	Std. Dev	0.2432	0.0911	0.1622	0.1646
	Median	0.8225	0.9843	1.2890	1.1740
Group 3 (9)	Mean	0.8015	1.0261	1.9971	1.1140
	Std. Dev	0.1830	0.0644	0.3820	0.1191
	Median	0.7381	1.0153	1.7784	1.0988
Total (45)	Mean	0.7769	1.0062	1.1520	1.1947
	Std. Dev	0.2090	0.0870	0.5525	0.1411
	Median	0.7559	0.9929	1.0649	1.1740

When reviewing the obtained results, it is easily noticeable that each of the groups has one variable that makes it stand out. Therefore, taking into account our previous description of the strategies, and their link with our variables, speculations can be made with regard to the strategic paths followed by the savings banks under analysis.

Consequently, it can be observed that group 1 is characterised by the high positive level of the change in loans per total assets, fact that can point towards the intermediation of resources. Continuing, group 2 has the lower decrease in *ROA*, and it is possibly dedicated to attraction, whereas group 3 is experiencing a considerable increase of the investments per total assets area, a sign of geographical expansion.

Table 4 Z-values for the Structure and Performance Ratios (2002/1998)

Group	1				2			
	ROA	TA / DEP	INV / TA	LOAN / TA	ROA	TA / DEP	INV / TA	LOAN / TA
1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø
2	-1.717*	-0.722	-4.925***	-0.337	Ø	Ø	Ø	Ø
3	-0.928	-0.747	-4.277***	-2.014**	-0.626	-1.163	-4.025***	-1.222

*, **, ***: significant at 0.1, 0.05, and 0.01 respectively

Significant changes between the shifts in ratios through the three-ways formed division can be observed in Table 4, and as expected they are manifested by *ROA*, investments by total assets, and loans by total assets.

Following, we computed the Hicks-Moorsteen total factor productivity index (hereafter *HMTFP*) decomposition in accordance with the three specified approaches (see Table 5 for the groups-related descriptive statistics associated with the *HMTFP*).

Table 5 HMTFP decomposition – descriptive statistics

	Group 1			Group 2			Group 3			Total		
Intermediation	**Mean**	**Std. Dev**	**Median**	**Mean**	**Std. Dev**	**Median**	**Mean**	**Std. Dev**	**Median**	**Mean**	**Std. Dev**	**Median**
HMTFP	1.4797	0.2099	1.4336	1.3784	0.1531	1.3392	1.3840	0.2500	1.3109	1.4268	0.2034	1.4090
EC	0.9882	0.0509	1.0000	0.9734	0.0805	0.9600	0.9836	0.1000	0.9985	0.9824	0.0714	0.9945
TC	1.4606	0.2191	1.4422	1.4178	0.1150	1.3886	1.5061	0.2456	1.5018	1.4554	0.1950	1.4281
AE	1.0314	0.0811	1.0092	0.9994	0.0232	1.0042	0.9401	0.0835	0.9691	1.0025	0.0750	1.0014
SC	0.9611	0.0729	0.9701	1.0271	0.1043	0.9993	1.0808	0.1353	1.0196	1.0070	0.1071	0.9957
OME	1.0350	0.0649	1.0067	1.0023	0.0115	1.0000	0.9438	0.0867	0.9949	1.0059	0.0672	1.0000
IME	1.0425	0.0929	1.0138	0.9789	0.0882	1.0125	0.9328	0.0982	0.9789	0.9994	0.1004	1.0036
Attraction	**Mean**	**Std. Dev**	**Median**	**Mean**	**Std. Dev**	**Median**	**Mean**	**Std. Dev**	**Median**	**Mean**	**Std. Dev**	**Median**
HMTFP	1.4988	0.2204	1.4911	1.4457	0.0889	1.4313	1.4366	0.2208	1.4138	1.4686	0.1852	1.4423
EC	0.9950	0.0667	1.0000	1.0181	0.0732	1.0000	0.9896	0.1235	0.9659	1.0016	0.0815	1.0000
TC	1.4586	0.2167	1.4133	1.3991	0.1181	1.3832	1.5394	0.2060	1.4407	1.4550	0.1898	1.4272
AE	1.0388	0.0840	1.0279	1.0196	0.0382	1.0076	0.9502	0.0808	0.9529	1.0147	0.0774	1.0076
SC	0.9485	0.0885	0.9471	0.9928	0.0855	0.9965	1.0696	0.1340	1.0354	0.9875	0.1061	0.9788
OME	1.0543	0.0736	1.0264	1.0277	0.0360	1.0080	0.9524	0.0791	0.9743	1.0250	0.0742	1.0105
IME	1.0461	0.0934	1.0247	1.0062	0.0850	1.0112	0.9443	0.1033	0.9739	1.0124	0.0986	1.0118
Geographical Expansion	**Mean**	**Std. Dev**	**Median**	**Mean**	**Std. Dev**	**Median**	**Mean**	**Std. Dev**	**Median**	**Mean**	**Std. Dev**	**Median**
HMTFP	1.4631	0.2257	1.4213	1.3963	0.2301	1.3805	1.4010	0.2481	1.4103	1.4284	0.2286	1.4143
EC	0.9888	0.0358	1.0000	0.9937	0.0210	1.0000	1.0324	0.0528	1.0000	0.9991	0.0390	1.0000
TC	1.4200	0.2408	1.3955	1.2785	0.1686	1.2240	1.3743	0.3215	1.2525	1.3637	0.2413	1.3642
AE	1.0490	0.0858	1.0433	1.1008	0.1228	1.0862	1.0046	0.1246	1.0093	1.0574	0.1105	1.0321
SC	0.9259	0.0701	0.9287	0.9232	0.0997	0.8951	1.0075	0.1568	0.9832	0.9413	0.1048	0.9287
OME	1.0752	0.0846	1.0577	1.1196	0.1190	1.0964	1.0145	0.1248	1.0094	1.0779	0.1096	1.0577
IME	1.0598	0.0891	1.0429	1.0757	0.1100	1.0616	1.0012	0.1344	1.0113	1.0534	0.1072	1.0429

As it can be noticed, seven components emerge from the decomposition. Therefore, *HMTFP* represents the total factor productivity's index overall value. *EC* is the change in technical efficiency, and *TC* is the technical change between the two evaluated periods. The activity variance is showed by *AE*, which is the product of *SC* (scale effect), *OME* (output mix effect on *HMTFP*), and *IME* (input mix effect on *HMTFP*).

A first look at the *HMTFP* decomposition denotes the superiority of group 1 at the level of the overall value, in all three specifications. Nonetheless, evaluating changes in the frontier, and shifts in the positioning of the *DMUs* as compared to it, we encounter a different situation.

When looking upon the movements of the frontier (technical change), we notice that these are shown mostly by group 3 when studying the first two approaches. However, the third specification points out group 1 once more, while group 3 still manifests quite a high score. Following, high scores at a mean level in efficiency change are manifested by all groups; even so, if we look upon the median level, the only all efficient group from this point of view, under all three specifications, is group 1.

Further insights are given by the activity variance and the correlated factors. While we found once again group 1 holding a general leading status as the total impact of activity variance upon the *HMTFP*, the scale economies seem to be dominated by group 3. Both situations manifest themselves across all the evaluated input-output mixes. Finally, the *OME* and *IME* also put forth group 1 as being generally productive; nonetheless under the third specification, group 2 is attracting the attention.

Nevertheless, to perform better when taking into account *SC*, *OME* or *IME* does not necessarily mean that the unit positions itself on the efficiency frontier, or even more that it experiences a larger growth of the total factor productivity. In order to shed light upon the differences between the three groups, we present the statistically significant differences (see Table 5).

Table 6 HMTFP decomposition – Mann-Whitney Z-values and Significant Differences

Group	1							2						
INTERM	**HMTFP**	**EC**	**TC**	**AE**	**SC**	**OME**	**IME**	**HMTFP**	**EC**	**TC**	**AE**	**SC**	**OME**	**IME**
1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø
2	-1.620	-1.741*	-0.786	-1.620	-2.326**	-1.286	-1.268	Ø	Ø	Ø	Ø	Ø	Ø	Ø
3	-1.335	-0.138	-0.656	-2.964***	-2.919	-3.723***	-2.925***	-0.328	-0.746	-0.984	-2.236**	-1.580	-3.290***	-1.878*
Group	**1**							**2**						
ATTR	**HMTFP**	**EC**	**TC**	**AE**	**SC**	**OME**	**IME**	**HMTFP**	**EC**	**TC**	**AE**	**SC**	**OME**	**IME**
1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø
2	-0.690	-0.279	-0.786	-1.011	-1.588	-0.915	-0.786	Ø	Ø	Ø	Ø	Ø	Ø	Ø
3	-1.154	-0.685	-1.516	-2.466**	-2.330**	-3.237***	-2.195**	-0.805	-0.835	-1.818*	-2.534**	-1.699*	-2.775***	-1.580
Group	**1**							**2**						
GEO. EXP.	**HMTFP**	**EC**	**TC**	**AE**	**SC**	**OME**	**IME**	**HMTFP**	**EC**	**TC**	**AE**	**SC**	**OME**	**IME**
1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø
2	-1.107	-0.456	-1,845*	-0.947	-0.209	-0.979	-0.433	Ø	Ø	Ø	Ø	Ø	Ø	Ø
3	-0.882	-2,235**	-1.018	-1.109	-1.290	-1.380	-1.064	-0.030	-2,031**	-0.268	-1,699**	-1,461	-1,878**	-1,282

*,**,*** sig. at 0.1, 0.05, 0.01 respectively

Therefore, with respect to the intermediation approach, the first noticeable difference is of efficiency change between groups 1 and 2 (at 90% of confidence), with group 1 having a better score. The dominance of group 1 in activity variance is materialised in a highly significant dissimilarity as compared to group 3, which is also significantly worse than group 2.

Group 2, is also better at a 95% confidence level than group 1 when looking upon the scale effect, a factor where the best performers at a mean level are in group 3. Furthermore, group 1 is also controlling the input and output mixes, being significantly superior to group 3, which is also notably inferior to group 2.

The attraction specification brings forth a somewhat interesting significant difference of the technical change factor between groups 2 and 3 (the third group has the best score under this approach when referring to technical change). Once more the activity variance belongs to group 1, having group 3 as the substandard, by experiencing significant lower results than both groups 1 and 2.

Moreover, the scale effect is yet again under the dominion of group 3, better at 95% and 90% levels of confidence than groups 1 and 2 respectively. Following, group 1 is better at 99% of confidence than group 3 at output mix effect, group which is worse at the same level than group 2. The same group 1 is also showing the way as to the input mix positive effect, but the significant difference is only with respect to group 3.

The last approach together with its division comes up with an out of the ordinary significant superiority manifested by group 3 in terms of efficiency change. However, between the first two groups no obvious distinction can be noticed in most of the components. The exception is offered by the technical change which puts the first group ahead of the second one.

Additionally, the activity variance brings about the inferiority of group 3, this time as compared to the second group when looking upon activity variance. An explanation for this could be the displayed weakness with regard to the output mix, one of the components of activity variance (both dissimilarities are encountered at a 95% level of confidence).

7. CONCLUSIONS

Our research is, to our knowledge, the first empirical application (in a non-parametric context) of the Hicks-Moorsteen total factor productivity index, proposed by Bjurek (1996), and decomposed by Lovell (2003). Bjurek's (1996) proposal was nonetheless utilised in a parametrical specification by Nemoto & Goto (2005) within their analysis of the Japanese economy.

Consequently, looking at the Spanish savings banks sector between the years 1998 and 2002, we observed three strategic groups from the point of view of changes in structure and performance ratios. We associated these groups with three input-output mixes related to strategies of intermediation, attraction, and geographical expansion.

On the basis of the three approaches and the division in strategic groups, the total factor productivity decomposition indicates improvements in the sector, not only from the point of view of the *HMTFP*, but also in technical change and efficiency change, activity variance, scale effect, and effects of input and output mixes.

With regard to the created strategic groups, we are inclined to believe that the criteria used by the cluster analysis points towards an interpretation through the presented multi-strategic approach. When looking upon the *HMTFP* decomposition, units are not separated in accordance with the scores they present under each of the specifications, but in conformity with the results shown in the three of them altogether.

Therefore, considering a holistic view that includes the main strategic paths, we put forth the units included in group 1 as being the "good performers", and shaping the productivity frontier. These units achieve better outcomes in the overall total factor productivity score, efficiency change and total activity variance. Nonetheless, group 2 seems to represent close followers of the units in the first division. Although group 3 may appear to embody the "bad performers", the savings banks here dominate the scale effect. This fact points towards a tendency of growth and innovation.

At the same time, the above discussion points towards a series of considerations with respect to the cluster analysis. As it was already known, this technique is quite demanding, as one unit belongs to only a certain group. However, from a strategy related perspective, and moreover a multi-strategic approach, a savings bank could be directed towards more than a single strategic path. For example “La Caixa” performs in almost the same manner under all the specified input-output mixes, hence it represents a flexible unit.

Consequently, cluster analysis applied to complex strategic environments is too deterministic, making strategy identification in cases such as the one of our study fairly unattainable. This method of creating strategic groups is good for very specialised units, that follow a certain path without interfering with others. But when dealing with global players aiming at achieving a leading position in a flexible holistic manner, the analysis proves itself unfeasible.

Finally, after attempting an ex-ante investigation through the clustering method, we propose an ex-post exploration of the decomposed Hicks-Moorsteen total factor productivity index. Thus, strategy identification could be performed in accordance with the scores of the *HMTFP* components. For instance, “Caja Duero” shows an overall value of the index of 1.31 under the intermediation approach, 1.23 linked to the attraction strategy, whereas for the geographical expansion orientation the score is 1.10.

As a product of those results, one could conclude that this unit is conducting its activity by following a path of intermediation. Nonetheless, this method cannot be applied either to units such as “La Caixa”, units which perform in fairly the same productive way under all specifications. Even so, this can be used as a test with the purpose of verifying if the savings banks really behave in the identified or the declared way. Therefore, dissimilarities in strategic behaviour can be observed by looking upon the complete results of the *HMTFP* decomposition shown in Appendixes 4, 5 and 6.

8. LIMITATIONS AND FUTURE LINES OF RESEARCH

One limitation to begin with is represented by the data included in the study. Since we utilise only two time periods, the changes might not be revealed to their total extent.

Therefore, the first main suggestion for future research is the inclusion of more time periods, updating as much as possible the data.

Second, we find that it is necessary to create a more exact link between the strategic groups and the employed input-output specifications. This should help in the direction of eliminating as much as possible the situations where we encounter units that attain roughly the same results under different approaches.

Continuing, the setbacks of the cluster analysis should be dealt with. In this case we vote in favour of putting aside the traditional methods and follow novel trends of forming strategic groups. One of these methods could be the implementation of a cognitive approach. In this kind of analyses, one maps the ways of acting of the units under investigation. Practically, what is important is to be aware of what the researched entities desire to do from a strategic point of view. Accordingly, strategic paths can be discovered by studying the declared intentions of each of the savings banks, and those can subsequently be categorised into strategic divisions.

This can be done in more than one way; however a quite straightforward manner of accomplishing the above mentioned cognitive division is to revise the available annual reports of the units under analysis, and extract information related with the strategic orientation. Moreover, this modus operandi could be merged with our proposition of ex-post analysis in conformity with the *HTMFP* scores.

Thus, a joint analysis of a social approach, such as the cognitive one, together with a very specific productivity and efficiency analysis, such as the *HMTFP* decomposition, will surely put forth quite interesting outcomes of the strategic paths followed within the sector.

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APPENDIX 1. Fundamental Environmental Changes in the Spanish Banking System from 1983 to 1997

Years	Main Events
1983– 1984	A severe crisis experienced by the Spanish banking system that started in 1978 comes to an end. This crisis led to the extinction of a very high proportion of banks in Spain.
1985	Freedom of branching is complete except for foreign banks and for the geographical limits imposed on savings banks which would be removed later. The Spanish government takes several measures in economic policy, such as a restrictive monetary policy, which continues until the late 1980s and early 1990s.
1986	Spain joins the European Community (EC). From this moment, the Spanish government is forced to adapt the Spanish banking legislation to European banking rules. In this context, it establishes a gradual adjustment schedule for the period 1986–1992 to deregulate the number of branch offices that an EC bank can open and the composition of its liabilities.
1987	All interest rates and service charges are liberalised.
1988	The Spanish savings banks are allowed to expand their number of branch offices outside their own geographic region. This possibility of expansion induces a process of mergers and takeovers between savings banks which increases concentration in the sector and competitiveness in the Spanish banking system. Spanish private banks and savings banks are also required to keep 18% of a subset of their liabilities as deposits in the Bank of Spain. An 11.5% share of these deposits receives a rate return of 7.75%. The level of the coefficient as well as its return is changed quite frequently by the Bank of Spain. The Spanish government instigates a major reform of the stock market, reflected in the 1988 Reform Bill. As a direct result of this reform banking starts to play an essential role in the stock market.
1989	The Spanish credit cooperatives and Spanish private banks and savings banks start to compete under similar conditions. In January, the Spanish government commits itself to a gradual phasing out of the investment coefficients, with them disappearing completely by January 1993. The Spanish currency (peseta) enters into the exchange mechanism of the EMS. An open price war breaks out between the major firms in the Spanish banking system. The period 1989–1992 also witnesses several important mergers among the major Spanish private banks, as well as some minor operations involving a large number of small savings banks. In addition, important changes in the behaviour of the clientele start to occur.
1990	The Spanish government drastically lowers the reserve coefficient.
1991	The complete liberalisation of capital flows across EC countries occurs this year. As a consequence of the public bank reorganisation, a public conglomerate of a very

	significant size appears. The impact of this public bank reorganisation in the loan market is considerable.
1992	The Treaty of the European Union (EU) comes into effect. This Treaty represents an important impetus for the constitution of the European Currency Unit from January 2002.
1993	This year the European Single Market comes into effect. From 1993, Spanish authorities have to authorize any bank, Spanish or EU, as long as the candidate satisfies the given legal conditions, and their discretionary power is abolished. This event implies an important increase in the degree of competitive rivalry in this industry.
1994	Spanish legislation regarding credit entities is adapted to the Second Community Directive of Bank Coordination, which fits Spanish legislation to the community conception of right of establishment.
1995	A new legal regime for the creation of banks is passed. This unleashes a real battle within the sector to massively incorporate the new information technologies to all kinds of financial products and services. This technological revolution entails a continuation of the one commenced in the 1960s and the 1970s, which was intensified during the 1980s.
1996	The economic crisis period that began in 1992 finishes. This crisis, just as previous economic crises, has very important consequences on the Spanish banking system because a very significant number of financial entities disappear during this time interval (1993– 1996).
1997	A strong economic growth in the Spanish economy starts to occur.

Source: Zuniga-Vicente et al. (2004:1382)

APPENDIX 2. Strategic Groups from the Application of Cluster Analysis

No / Group	1	2	3
1	Burgos C.C.O.	Badajoz	Guadalajara
2	Burgos Mpal.	Catalunya	Manresa
3	Cajasur	Girona	Asturias
4	Madrid	Granada	General Canarias
5	Layetana	Rioja	San Fernando
6	Ontinyent	Manlleu	Tarragona
7	Baleares	Murcia	Terrassa
8	Navarra	Insular Canarias	La Caixa
9	Pollensa	Segovia	Castilla-Mancha
10	Sabadell	Penedés	
11	Santander-Cantabria	Ibercaja	
12	Bancaja	Galicia	
13	Inmaculada	Huelva-Sevilla	
14	Mediterráneo	Extremadura	
15	Jaén	Unicaja	
16	Ávila		
17	Bilbao Bizkaia		
18	Caja España		
19	Vital		
20	Gipuzkoa Y S.S.		
21	Duero		

APPENDIX 3. Discriminant Analysis

Group		1	2	3	
Prediction	1	21	0	0	21
	2	0	14	1	15
	3	0	0	9	9
	1	100%	0	0	100
	2	0	93.33%	6.66%	100
	3	0	0	100%	100

APPENDIX 4. The Intermediation Approach – Total Results

SAVINGS BANK	HMTFP	EC	TC	AE	SC	OME	IME
BADAJOZ	1.1706	0.9525	1.2142	1.0122	0.9914	0.9996	1.0214
CATALUNYA	1.4797	0.9732	1.6147	0.9416	1.1331	1.0043	0.8274
BURGOS C.C.O.	1.3844	1.0000	1.1021	1.2561	0.8083	1.2681	1.2253
BURGOS MPAL.	1.6129	1.0000	1.6398	0.9836	0.9443	1.0416	1.0000
CAJASUR	1.3900	0.9251	1.5088	0.9958	0.9952	0.9989	1.0018
GIRONA	1.3229	0.9006	1.4296	1.0275	0.9864	1.0114	1.0299
GRANADA	1.2320	0.8927	1.3698	1.0075	0.9948	1.0000	1.0128
GUADALAJARA	1.2852	1.0711	1.2382	0.9691	1.0196	0.9980	0.9524
RIOJA	1.4921	1.0000	1.4647	1.0187	0.9883	1.0015	1.0292
MADRID	2.2311	1.0000	2.0538	1.0863	0.8346	1.0798	1.2054
MANLLEU	1.6870	1.2012	1.3589	1.0335	1.0198	1.0000	1.0134
MANRESA	1.3109	0.9080	1.4060	1.0268	1.0016	0.9987	1.0265
LAYETANA	1.4336	1.0244	1.3636	1.0263	1.0265	0.9998	1.0000
MURCIA	1.4367	0.9600	1.5032	0.9956	1.0017	1.0000	0.9939
ONTINYENT	1.2397	1.0000	1.1963	1.0363	0.9362	1.0067	1.0995
ASTURIAS	1.4525	1.1350	1.6593	0.7713	1.3536	0.7681	0.7418
BALEARES	1.4150	0.9506	1.4422	1.0321	0.9700	1.0221	1.0411
INSULAR CANARIAS	1.2508	0.9091	1.3634	1.0091	0.9966	1.0000	1.0125
NAVARRA	1.6511	1.0000	1.5774	1.0467	0.8980	1.1149	1.0455
POLLENSA	1.4911	1.0000	1.2627	1.1809	0.9585	1.0000	1.2321
SABADELL	1.3389	0.9112	1.4673	1.0014	0.9878	1.0000	1.0138
GENERAL CANARIAS	1.4808	0.9985	1.5018	0.9875	1.0282	0.9811	0.9789
SANTANDER-CANTABRIA	1.2949	0.9003	1.4252	1.0092	0.9967	0.9980	1.0146
SEGOVIA	1.2720	0.9625	1.3061	1.0118	0.9993	1.0001	1.0123
SAN FERNANDO	1.1080	0.9179	1.2190	0.9903	1.0008	0.9949	0.9946
TARRAGONA	1.2068	0.7970	1.5127	1.0010	1.0008	1.0000	1.0002
TERRASSA	1.5040	1.0472	1.5483	0.9277	1.1314	0.9220	0.8893
BANCAJA	1.6003	1.0000	1.8539	0.8632	0.8627	1.0005	1.0000
PENEDÉS	1.2325	0.9304	1.3191	1.0042	1.0006	1.0000	1.0036
IBERCAJA	1.5167	0.9885	1.5586	0.9844	1.3709	1.0000	0.7181
INMACULADA	1.4574	0.9926	1.4666	1.0011	0.9950	1.0000	1.0062
MEDITERRÁNEO	1.5660	1.0000	1.6800	0.9321	1.1268	1.0105	0.8186
GALICIA	1.5996	1.0000	1.6106	0.9932	0.9204	1.0353	1.0423
JAÉN	1.2730	1.0447	1.1638	1.0471	1.0561	1.0000	0.9914
ÁVILA	1.4377	1.0000	1.3781	1.0433	0.9415	1.0412	1.0643
BILBAO BIZKAIA	1.4090	0.9945	1.4199	0.9978	0.9957	1.0000	1.0022
CAJA ESPAÑA	1.3813	0.9928	1.3987	0.9947	0.9701	1.0269	0.9985
VITAL	1.6130	1.0027	1.4427	1.1151	0.9012	1.1162	1.1085
HUELVA-SEVILLA	1.2396	0.8967	1.3886	0.9955	0.9792	1.0016	1.0150
EXTREMADURA	1.3392	0.9498	1.4272	0.9880	1.0232	0.9770	0.9884
LA CAIXA	1.9354	1.0000	2.0418	0.9479	0.9479	1.0000	1.0000
GIPUZKOA Y S.S.	1.5477	1.1211	1.3732	1.0053	1.0053	1.0000	1.0000
UNICAJA	1.4043	1.0834	1.3385	0.9684	1.0011	1.0041	0.9634
DUERO	1.3056	0.8928	1.4556	1.0047	0.9722	1.0096	1.0237
CASTILLA-MANCHA	1.1722	0.9781	1.4281	0.8392	1.2430	0.8318	0.8117

APPENDIX 5. The Attraction Approach – Total Results

SAVINGS BANK	HMTFP	EC	TC	AE	SC	OME	IME
BADAJOZ	1.4206	1.0441	1.2546	1.0845	0.9474	1.0615	1.0784
CATALUNYA	1.4427	0.9287	1.5695	0.9898	1.1097	1.0255	0.8698
BURGOS C.C.O.	1.3438	1.0000	1.0866	1.2368	0.8173	1.2404	1.2200
BURGOS MPAL.	1.6129	1.0000	1.6398	0.9836	0.9256	1.0627	1.0000
CAJASUR	1.5730	1.0200	1.5431	0.9994	0.9962	1.0023	1.0010
GIRONA	1.3792	0.9854	1.2464	1.1229	0.8982	1.1110	1.1253
GRANADA	1.3487	0.9293	1.4481	1.0023	1.0101	1.0012	0.9911
GUADALAJARA	1.3030	0.9571	1.4287	0.9529	1.0734	0.9691	0.9160
RIOJA	1.5584	1.0466	1.4647	1.0167	1.0008	1.0000	1.0159
MADRID	2.2311	1.0000	2.0538	1.0863	0.8346	1.0798	1.2054
MANLLEU	1.4674	1.0575	1.3554	1.0238	1.0158	1.0039	1.0040
MANRESA	1.2035	0.8323	1.3776	1.0496	0.9723	1.0288	1.0493
LAYETANA	1.3994	1.0000	1.3636	1.0263	1.0231	1.0031	1.0000
MURCIA	1.4239	0.9742	1.4749	0.9910	1.0032	0.9984	0.9894
ONTINYENT	1.2953	0.8650	1.4272	1.0493	1.0475	1.0011	1.0006
ASTURIAS	1.4423	1.1081	1.6593	0.7844	1.3527	0.7824	0.7412
BALEARES	1.5793	1.0778	1.4187	1.0329	0.9711	1.0264	1.0362
INSULAR CANARIAS	1.3716	0.9668	1.4037	1.0107	0.9965	1.0030	1.0112
NAVARRA	1.6792	1.0000	1.5776	1.0644	0.8135	1.2305	1.0632
POLLENSA	1.4911	1.0000	1.2627	1.1809	0.9471	1.0120	1.2321
SABADELL	1.3389	0.8984	1.4881	1.0014	0.9898	1.0000	1.0118
GENERAL CANARIAS	1.4138	0.9659	1.4900	0.9824	1.0354	0.9743	0.9739
SANTANDER-CANTABRIA	1.6136	1.1298	1.3896	1.0279	0.9788	1.0189	1.0307
SEGOVIA	1.4675	1.0621	1.3832	0.9989	1.0076	1.0020	0.9894
SAN FERNANDO	1.3209	0.9403	1.4312	0.9815	1.0259	0.9779	0.9784
TARRAGONA	1.2452	0.8376	1.4375	1.0342	0.9760	1.0254	1.0334
TERRASSA	1.5294	1.0457	1.5483	0.9446	1.1106	0.9394	0.9054
BANCAJA	1.6003	1.0000	1.8539	0.8632	0.8627	1.0005	1.0000
PENEDÉS	1.2940	0.9742	1.3039	1.0187	0.9689	1.0080	1.0430
IBERCAJA	1.5469	1.1372	1.3642	0.9971	1.2205	1.0450	0.7817
INMACULADA	1.4659	0.9834	1.4870	1.0025	0.9907	1.0000	1.0118
MEDITERRÁNEO	1.5660	1.0000	1.6800	0.9321	1.1268	1.0105	0.8186
GALICIA	1.6428	1.0000	1.6303	1.0076	0.8650	1.0927	1.0660
JAÉN	1.2212	0.8253	1.3679	1.0818	1.1184	0.9883	0.9787
ÁVILA	1.4343	1.0000	1.3781	1.0408	0.9779	1.0387	1.0247
BILBAO BIZKAIA	1.2762	1.0000	1.2605	1.0124	0.9154	1.0439	1.0595
CAJA ESPAÑA	1.3387	1.0820	1.2517	0.9884	0.9384	1.0505	1.0028
VITAL	1.5808	1.0133	1.4133	1.1038	0.9103	1.1050	1.0973
HUELVA-SEVILLA	1.3988	0.9219	1.5242	0.9955	0.9856	1.0000	1.0100
EXTREMADURA	1.4921	1.0955	1.3013	1.0467	0.9276	1.0404	1.0845
LA CAIXA	1.9354	1.0000	2.0418	0.9479	0.9008	1.0000	1.0523
GIPUZKOA Y S.S.	1.6050	1.0000	1.3973	1.1486	0.8641	1.1632	1.1428
UNICAJA	1.4313	1.1476	1.2629	0.9876	0.9348	1.0224	1.0334
DUERO	1.2281	1.0000	1.2900	0.9520	0.8681	1.0630	1.0317
CASTILLA-MANCHA	1.5358	1.2194	1.4407	0.8742	1.1789	0.8740	0.8485

APPENDIX 6. The Geographical Expansion Approach – Total Results

SAVINGS BANK	HMTFP	EC	TC	AE	SC	OME	IME
BADAJOZ	1.0379	1.0000	0.9453	1.0979	0.8939	1.0964	1.1203
CATALUNYA	1.4828	1.0297	1.5014	0.9591	1.1290	1.0079	0.8428
BURGOS C.C.O.	1.4397	1.0000	1.1073	1.3002	0.7829	1.3272	1.2514
BURGOS MPAL.	1.6129	1.0000	1.6398	0.9836	0.9443	1.0416	1.0000
CAJASUR	1.4071	1.0063	1.3652	1.0243	0.9461	1.0507	1.0304
GIRONA	1.4175	1.0000	1.2240	1.1581	0.8537	1.1686	1.1609
GRANADA	1.4589	1.0000	1.1652	1.2520	0.7872	1.2632	1.2591
GUADALAJARA	1.0914	1.0000	1.0629	1.0267	0.9832	1.0326	1.0113
RIOJA	1.7283	1.0000	1.4647	1.1800	0.8391	1.1796	1.1921
MADRID	2.2311	1.0000	2.0538	1.0863	0.8341	1.0804	1.2054
MANLLEU	1.2558	1.0000	1.2197	1.0296	0.9973	1.0181	1.0140
MANRESA	1.2523	0.9958	1.1708	1.0740	0.9125	1.0921	1.0777
LAYETANA	1.4213	1.0000	1.3843	1.0268	0.9026	1.1376	1.0000
MURCIA	1.3805	1.0000	1.3755	1.0037	0.9670	1.0370	1.0009
ONTINYENT	1.2636	1.0000	1.1963	1.0562	0.9224	1.0218	1.1207
ASTURIAS	1.4525	1.1350	1.6593	0.7713	1.3536	0.7681	0.7418
BALEARES	1.4150	0.9506	1.4422	1.0321	0.9700	1.0221	1.0411
INSULAR CANARIAS	1.0901	0.9969	1.1306	0.9672	1.0446	0.9613	0.9632
NAVARRA	1.6901	1.0000	1.5774	1.0714	0.8032	1.2464	1.0701
POLLENSA	1.4911	1.0000	1.2627	1.1809	0.9249	1.0363	1.2321
SABADELL	1.3619	0.9581	1.3955	1.0186	0.9674	1.0211	1.0312
GENERAL CANARIAS	1.4103	1.0594	1.3630	0.9768	1.0300	0.9794	0.9682
SANTANDER-CANTABRIA	1.2949	0.9012	1.4238	1.0092	0.9967	0.9980	1.0146
SEGOVIA	1.2720	0.9637	1.3045	1.0118	0.9993	1.0001	1.0123
SAN FERNANDO	1.1928	1.0000	1.1024	1.0820	0.9165	1.0880	1.0851
TARRAGONA	1.4305	1.0000	1.1677	1.2250	0.8211	1.2255	1.2175
TERRASSA	1.5650	1.0015	1.5483	1.0093	1.0339	1.0094	0.9671
BANCAJA	1.6003	1.0000	1.8539	0.8632	0.8627	1.0005	1.0000
PENEDÉS	1.4143	1.0000	1.2117	1.1672	0.7918	1.2575	1.1724
IBERCAJA	1.9107	1.0000	1.3642	1.4007	0.9957	1.3768	1.0217
INMACULADA	1.3680	0.9558	1.4494	0.9875	1.0143	0.9809	0.9925
MEDITERRÁNEO	1.6559	1.0000	1.6800	0.9857	1.0598	1.0744	0.8656
GALICIA	1.6291	1.0000	1.6106	1.0115	0.8831	1.0790	1.0616
JAÉN	1.2715	1.0000	1.1314	1.1238	0.9499	1.1005	1.0751
ÁVILA	1.4377	1.0000	1.3781	1.0433	0.9077	1.0800	1.0643
BILBAO BIZKAIA	1.2916	0.9557	1.3984	0.9664	1.0168	0.9792	0.9706
CAJA ESPAÑA	1.4052	1.0916	1.2024	1.0706	0.8934	1.1150	1.0747
VITAL	1.5203	0.9871	1.4221	1.0830	0.9287	1.0832	1.0766
HUELVA-SEVILLA	1.2522	0.9353	1.3313	1.0057	0.9563	1.0256	1.0253
EXTREMADURA	1.3605	1.0000	1.1509	1.1822	0.8154	1.1998	1.2084
LA CAIXA	1.9354	1.0000	2.0418	0.9479	0.9008	1.0000	1.0523
GIPUZKOA Y S.S.	1.4429	1.0000	1.3760	1.0486	0.9506	1.0577	1.0429
UNICAJA	1.2539	0.9805	1.1774	1.0862	0.8951	1.1231	1.0805
DUERO	1.1029	0.9575	1.0800	1.0666	0.8652	1.1247	1.0961
CASTILLA-MANCHA	1.2790	1.0999	1.2525	0.9284	1.1155	0.9356	0.8895

APPENDIX 7. GAMS Routine for the Geographical Expansion Approach

```
$ONINLINE
OPTION ITERLIM = 5000;

SETS
R    Results / MALM,MALMLHS,TC,EC,SC,OME,IME,SCOMEIME,ZIT1T1T1VRS,ZIT1T1T2VRS,
            ZIT1T2T2VRS,ZIT1T2T1VRS,ZOT1T1T1VRS,ZOT1T1T2VRS,ZOT1T2T2VRS,
            ZOT1T2T1VRS,ZOT2T2T2VRS,
            MLO111VRS,SLO111VRS,MLO112VRS,SLO112VRS,MLO122VRS,SLO122VRS,
            MLO121VRS,SLO121VRS,MLO222VRS,SLO222VRS,
            MLI111VRS,SLI111VRS,MLI112VRS,SLI112VRS,MLI122VRS,SLI122VRS,
            MLI121VRS,SLI121VRS,MLI222VRS /
D      Data        / Dim1*Dim8 /
D1(D)  Outputs     / Dim1*Dim4 /
D2(D)  Inputs      / Dim5*Dim8 /
Y      Years       /1*2    /
K      Units       / 1*45   /
ITY(Y) Iterations   /1*2     /
IT(K)  Iterations   / 1*45   /                              ;

PARAMETERS
TEST
EOUT1(K,D1) Vector outputs in T1
EOUT2(K,D1) Vector outputs in T2
EINP1(K,D2) Vector inputs  in T1
EINP2(K,D2) Vector inputs  in T2
DAT(Y,K,D)  Table in Excel file with data
RES(Y,K,R)  Table in Excel file with results
EOT1(D1)    Vector outputs evaluated unit in T1
EOT2(D1)    Vector outputs evaluated unit in T2
EIT1(D2)    Vector inputs evaluated unit  in T1
EIT2(D2)    Vector inputs evaluated unit  in T2                ;

SCALAR
MALM     Scalar to compute input Malmquist index (compute by the decomposition form)
MALMLHS  Scalar to compute input Malmquist index (original formula)
TC       Scalar to compute Techn.Effic. change
EC       Scalar to compute Efficiency change
SCOMEIME
SC       Scalar to compute scale efficiency change
OME      Scalar to compute output mix effect change
IME      Scalar to compute input mix effect change                 ;

$LIBINCLUDE XLIMPORT DAT c:\tesina\hmtfp.xls Data!A2:J92

VARIABLES
ZIT1T1T1VRS     Objective function T1T1T1 VRS TECHNOLOGY
ZIT1T1T2VRS     Objective function T1T1T2 VRS TECHNOLOGY
ZIT1T2T2VRS     Objective function T1T2T2 VRS TECHNOLOGY
ZIT1T2T1VRS     Objective function T1T2T1 VRS TECHNOLOGY

ZOT1T1T1VRS     Objective function T1T1T1 VRS TECHNOLOGY
ZOT1T1T2VRS     Objective function T1T1T2 VRS TECHNOLOGY
ZOT1T2T2VRS     Objective function T1T2T2 VRS TECHNOLOGY
ZOT1T2T1VRS     Objective function T1T2T1 VRS TECHNOLOGY
ZOT2T2T2VRS     Objective function T2T2T2 VRS TECHNOLOGY

HIT1T1T1      efficiency coefficient measure T1T1T1 VRS TECHNOLOGY
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HIT1T1T2     efficiency coefficient measure T1T1T2 VRS TECHNOLOGY
HIT1T2T2     efficiency coefficient measure T1T2T2 VRS TECHNOLOGY
HIT1T2T1     efficiency coefficient measure T1T2T1 VRS TECHNOLOGY

HOT1T1T1     efficiency coefficient measure T1T1T1 VRS TECHNOLOGY
HOT1T1T2     efficiency coefficient measure T1T1T2 VRS TECHNOLOGY
HOT1T2T2     efficiency coefficient measure T1T2T2 VRS TECHNOLOGY
HOT1T2T1     efficiency coefficient measure T1T2T1 VRS TECHNOLOGY
HOT2T2T2     efficiency coefficient measure T2T2T2 VRS TECHNOLOGY

SOT1T1T1(D1) Slacks outputs
SIT1T1T1(D2) Slacks inputs
SOT1T1T2(D1) Slacks outputs
SIT1T1T2(D2) Slacks inputs
SOT1T2T2(D1) Slacks outputs
SIT1T2T2(D2) Slacks inputs
SOT1T2T1(D1) Slacks outputs
SIT1T2T1(D2) Slacks inputs
SOT2T2T2(D1) Slacks outputs
SIT2T2T2(D2) Slacks outputs


MT1T1T1(K)   Activity T1T1T1
MT1T1T2(K)   Activity T1T1T2
MT1T2T2(K)   Activity T1T2T2
MT1T2T1(K)   Activity T1T2T1
MT2T2T2(K)   Activity T2T2T2                                   ;

POSITIVE VARIABLE HIT1T1T1, HIT1T1T2, HIT1T2T2, HIT1T2T1,
            HOT1T1T1, HOT1T1T2, HOT1T2T2, HOT1T2T1, HOT2T2T2,
            SOT1T1T1(D1), SIT1T1T1(D2), SOT1T1T2(D1), SIT1T1T2(D2),
            SOT1T2T2(D1), SIT1T2T2(D2), SOT1T2T1(D1), SIT1T2T1(D2),
            SOT2T2T2(D1), SIT2T2T2(D2),
            MT1T1T1(K), MT1T1T2(K), MT1T2T2(K), MT1T2T1(K),
            MT2T2T2(K)                                 ;

TEST = 0    ;

EQUATIONS
OBJOT1T1T1VRS      objective function T1T1T1 VRS TECHNOLOGY
OBJIT1T1T1VRS      objective function T2T2T1 VRS TECHNOLOGY
OBJOT1T1T2VRS      objective function T1T1T2 VRS TECHNOLOGY
OBJIT1T1T2VRS      objective function T1T1T2 VRS TECHNOLOGY
OBJOT1T2T2VRS      objective function T1T2T2 VRS TECHNOLOGY
OBJIT1T2T2VRS      objective function T1T2T2 VRS TECHNOLOGY
OBJOT1T2T1VRS      objective function T1T2T2 VRS TECHNOLOGY
OBJIT1T2T1VRS      objective function T1T2T1 VRS TECHNOLOGY
OBJOT2T2T2VRS      objective function T2T2T2 VRS TECHNOLOGY
COT1T1T1(D1)    constraints on the output dimensions in T1T1T1
CIT1T1T1(D2)    constraints on the inputs dimensions in T1T1T1
COT1T1T2(D1)    constraints on the output dimensions in T1T1T2
CIT1T1T2(D2)    constraints on the inputs dimensions in T1T1T2
COT1T2T2(D1)    constraints on the output dimensions in T1T2T2
CIT1T2T2(D2)    constraints on the inputs dimensions in T1T2T2
COT1T2T1(D1)    constraints on the output dimensions in T1T2T1
CIT1T2T1(D2)    constraints on the inputs dimensions in T1T2T1
COT2T2T2(D1)    constraints on the output dimensions in T2T2T2
CIT2T2T2(D2)    constraints on the output dimensions in T2T2T2
CIOT1T1T1(D1)
CIOT1T1T2(D1)
```

```
CIOT1T2T2(D1)
CIOT1T2T1(D1)
CIIT1T1T1(D2)
CIIT1T1T2(D2)
CIIT1T2T2(D2)
CIIT1T2T1(D2)
CIMUST1T1T1      sum of activity in T1T1
CIMUST1T1T2      sum of activity in T2T2
CIMUST1T2T2      sum of activity in T1T2
CIMUST1T2T1      sum of activity in T2T1
COMUST1T1T1      sum of activity in T1T1
COMUST1T1T2      sum of activity in T2T2
COMUST1T2T2      sum of activity in T1T2
COMUST1T2T1      sum of activity in T2T1
COMUST2T2T2    sum of activity in T1T1T2                              ;

OBJOT1T1T1VRS ..    ZOT1T1T1VRS =E= HOT1T1T1                         ;
COT1T1T1(D1)                          ..                        SUM(K,MT1T1T1(K)*EOUT1(K,D1))-
SOT1T1T1(D1)=E=HOT1T1T1*EOT1(D1) ;
CIT1T1T1(D2) .. SUM(K,MT1T1T1(K)*EINP1(K,D2))+SIT1T1T1(D2)=E=EIT1(D2)         ;
COMUST1T1T1 ..   SUM(K,MT1T1T1(K)) =E= 1                              ;

OBJOT1T1T2VRS ..    ZOT1T1T2VRS =E= HOT1T1T2                         ;
COT1T1T2(D1)                          ..                        SUM(K,MT1T1T2(K)*EOUT1(K,D1))-
SOT1T1T2(D1)=E=HOT1T1T2*EOT2(D1) ;
CIT1T1T2(D2) .. SUM(K,MT1T1T2(K)*EINP1(K,D2))+SIT1T1T2(D2)=E=EIT1(D2)         ;
COMUST1T1T2 ..   SUM(K,MT1T1T2(K)) =E= 1                              ;

OBJOT2T2T2VRS ..    ZOT2T2T2VRS =E= HOT2T2T2                         ;
COT2T2T2(D1)                          ..                        SUM(K,MT2T2T2(K)*EOUT2(K,D1))-
SOT2T2T2(D1)=E=HOT2T2T2*EOT2(D1) ;
CIT2T2T2(D2) .. SUM(K,MT2T2T2(K)*EINP2(K,D2))+SIT2T2T2(D2)=E=EIT2(D2)         ;
COMUST2T2T2 ..   SUM(K,MT2T2T2(K)) =E= 1                              ;

OBJOT1T2T2VRS ..    ZOT1T2T2VRS =E= HOT1T2T2                         ;
COT1T2T2(D1)                          ..                        SUM(K,MT1T2T2(K)*EOUT1(K,D1))-
SOT1T2T2(D1)=E=HOT1T2T2*EOT2(D1) ;
CIT1T2T2(D2) .. SUM(K,MT1T2T2(K)*EINP1(K,D2))+SIT1T2T2(D2)=E=EIT2(D2)         ;
COMUST1T2T2 ..   SUM(K,MT1T2T2(K)) =E= 1                              ;

OBJOT1T2T1VRS ..    ZOT1T2T1VRS =E= HOT1T2T1                         ;
COT1T2T1(D1)                          ..                        SUM(K,MT1T2T1(K)*EOUT1(K,D1))-
SOT1T2T1(D1)=E=HOT1T2T1*EOT1(D1) ;
CIT1T2T1(D2) .. SUM(K,MT1T2T1(K)*EINP1(K,D2))+SIT1T2T1(D2)=E=EIT2(D2)         ;
COMUST1T2T1 ..   SUM(K,MT1T2T1(K)) =E= 1                              ;

OBJIT1T1T1VRS ..    ZIT1T1T1VRS =E= HIT1T1T1                         ;
CIOT1T1T1(D1) .. SUM(K,MT1T1T1(K)*EOUT1(K,D1))-SOT1T1T1(D1)=E=EOT1(D1)        ;
CIIT1T1T1(D2) .. SUM(K,MT1T1T1(K)*EINP1(K,D2))+SIT1T1T1(D2)=E=HIT1T1T1*EIT1(D2);
CIMUST1T1T1 ..   SUM(K,MT1T1T1(K)) =E= 1                              ;

OBJIT1T1T2VRS ..    ZIT1T1T2VRS =E= HIT1T1T2                         ;
CIOT1T1T2(D1) .. SUM(K,MT1T1T2(K)*EOUT1(K,D1))-SOT1T1T2(D1)=E=EOT2(D1)        ;
CIIT1T1T2(D2) .. SUM(K,MT1T1T2(K)*EINP1(K,D2))+SIT1T1T2(D2)=E=HIT1T1T2*EIT1(D2);
CIMUST1T1T2 ..   SUM(K,MT1T1T2(K)) =E= 1                              ;

OBJIT1T2T2VRS ..    ZIT1T2T2VRS =E= HIT1T2T2                         ;
CIOT1T2T2(D1) .. SUM(K,MT1T2T2(K)*EOUT1(K,D1))-SOT1T2T2(D1)=E=EOT2(D1)        ;
CIIT1T2T2(D2) .. SUM(K,MT1T2T2(K)*EINP1(K,D2))+SIT1T2T2(D2)=E=HIT1T2T2*EIT2(D2);
CIMUST1T2T2 ..   SUM(K,MT1T2T2(K)) =E= 1                              ;
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OBJIT1T2T1VRS ..    ZIT1T2T1VRS =E= HIT1T2T1                              ;
CIOT1T2T1(D1) .. SUM(K,MT1T2T1(K)*EOUT1(K,D1))-SOT1T2T1(D1)=E=EOT1(D1)        ;
CIIT1T2T1(D2) .. SUM(K,MT1T2T1(K)*EINP1(K,D2))+SIT1T2T1(D2)=E=HIT1T2T1*EIT2(D2);
CIMUST1T2T1 ..   SUM(K,MT1T2T1(K)) =E= 1                                ;

MODEL DCIT1T1T1VRS /OBJIT1T1T1VRS,CIIT1T1T1,CIOT1T1T1,CIMUST1T1T1/ ;
MODEL DCIT1T1T2VRS /OBJIT1T1T2VRS,CIIT1T1T2,CIOT1T1T2,CIMUST1T1T2/ ;
MODEL DCIT1T2T2VRS /OBJIT1T2T2VRS,CIIT1T2T2,CIOT1T2T2,CIMUST1T2T2/ ;
MODEL DCIT1T2T1VRS /OBJIT1T2T1VRS,CIIT1T2T1,CIOT1T2T1,CIMUST1T2T1/ ;
MODEL DCOT1T1T1VRS /OBJOT1T1T1VRS,CIT1T1T1,COT1T1T1,COMUST1T1T1/ ;
MODEL DCOT1T1T2VRS /OBJOT1T1T2VRS,CIT1T1T2,COT1T1T2,COMUST1T1T2/ ;
MODEL DCOT1T2T2VRS /OBJOT1T2T2VRS,CIT1T2T2,COT1T2T2,COMUST1T2T2/ ;
MODEL DCOT1T2T1VRS /OBJOT1T2T1VRS,CIT1T2T1,COT1T2T1,COMUST1T2T1/ ;
MODEL DCOT2T2T2VRS /OBJOT2T2T2VRS,CIT2T2T2,COT2T2T2,COMUST2T2T2/ ;

LOOP(ITY,
TEST=TEST+1;
LOOP(IT,
HIT1T1T1.L=0;
MT1T1T1.L(K)=0;
MT1T1T1.L(IT)=1;
HIT1T1T2.L=0;
MT1T1T2.L(K)=0;
MT1T1T2.L(IT)=1;
HIT1T2T2.L=0;
MT1T2T2.L(K)=0;
MT1T2T2.L(IT)=1;
HIT1T2T1.L=0;
MT1T2T1.L(K)=0;
MT1T2T1.L(IT)=1;
HOT1T1T1.L=1;
HOT1T1T2.L=0;
HOT1T2T2.L=0;
HOT1T2T1.L=0;
HOT2T2T2.L=1;
EOT1(D1)    = DAT(ITY,IT,D1);
EIT1(D2)    = DAT(ITY,IT,D2);
EOT2(D1)    = DAT(ITY+1,IT,D1);
EIT2(D2)    = DAT(ITY+1,IT,D2);
EOUT1(K,D1) = DAT(ITY,K,D1);
EINP1(K,D2) = DAT(ITY,K,D2);
EOUT2(K,D1) = DAT(ITY+1,K,D1);
EINP2(K,D2) = DAT(ITY+1,K,D2);

IF(TEST LT CARD(ITY),

DCIT1T1T1VRS.SCALEOPT = 1 ; DCIT1T1T2VRS.SCALEOPT = 1 ;
DCIT1T2T2VRS.SCALEOPT = 1 ; DCIT1T2T1VRS.SCALEOPT = 1 ;
DCOT1T1T1VRS.SCALEOPT = 1 ; DCOT1T1T2VRS.SCALEOPT = 1 ;
DCOT1T2T2VRS.SCALEOPT = 1 ; DCOT1T2T1VRS.SCALEOPT = 1 ;
DCOT2T2T2VRS.SCALEOPT = 1 ;

OPTION LP=CPLEX;
SOLVE DCIT1T1T1VRS USING LP MINIMIZING ZIT1T1T1VRS ;
SOLVE DCIT1T1T2VRS USING LP MINIMIZING ZIT1T1T2VRS ;
SOLVE DCIT1T2T2VRS USING LP MINIMIZING ZIT1T2T2VRS ;
SOLVE DCIT1T2T1VRS USING LP MINIMIZING ZIT1T2T1VRS ;

SOLVE DCOT1T1T1VRS USING LP MAXIMIZING ZOT1T1T1VRS ;
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SOLVE DCOT1T1T2VRS USING LP MAXIMIZING ZOT1T1T2VRS ;
SOLVE DCOT1T2T2VRS USING LP MAXIMIZING ZOT1T2T2VRS ;
SOLVE DCOT1T2T1VRS USING LP MAXIMIZING ZOT1T2T1VRS ;
SOLVE DCOT2T2T2VRS USING LP MAXIMIZING ZOT2T2T2VRS ;

EC = ZOT1T1T1VRS.L/ZOT2T2T2VRS.L                    ;
TC = ZOT2T2T2VRS.L/ZOT1T2T2VRS.L                    ;
SC =  (ZOT1T2T1VRS.L*ZIT1T2T2VRS.L)/(ZOT1T1T1VRS.L*ZIT1T1T2VRS.L)          ;
OME = (ZOT1T1T1VRS.L*ZOT1T2T2VRS.L)/(ZOT1T1T2VRS.L*ZOT1T2T1VRS.L)          ;
IME = (ZIT1T2T1VRS.L*ZIT1T1T2VRS.L)/(ZIT1T1T1VRS.L*ZIT1T2T2VRS.L)          ;
SCOMEIME = (ZOT1T2T2VRS.L/ZOT1T1T2VRS.L)*(ZIT1T2T1VRS.L/ZIT1T1T1VRS.L)     ;
MALMLHS = (ZOT1T1T1VRS.L/ZOT1T1T2VRS.L)*(ZIT1T2T1VRS.L/ZIT1T1T1VRS.L)      ;
MALM = EC*TC*SC*OME*IME                    ;

RES(ITY,IT,'MALMLHS') = MALMLHS;
RES(ITY,IT,'MALM') = MALM;
RES(ITY,IT,'EC') = EC;
RES(ITY,IT,'TC') = TC;
RES(ITY,IT,'SCOMEIME') = SCOMEIME;
RES(ITY,IT,'SC') = SC;
RES(ITY,IT,'OME') = OME;
RES(ITY,IT,'IME') = IME;
RES(ITY,IT,'ZOT1T1T1VRS') = ZOT1T1T1VRS.L;
RES(ITY,IT,'ZOT1T1T2VRS') = ZOT1T1T2VRS.L;
RES(ITY,IT,'ZOT1T2T2VRS') = ZOT1T2T2VRS.L;
RES(ITY,IT,'ZOT1T2T1VRS') = ZOT1T2T1VRS.L;
RES(ITY,IT,'ZOT2T2T2VRS') = ZOT2T2T2VRS.L;
RES(ITY,IT,'ZIT1T1T1VRS') = ZIT1T1T1VRS.L;
RES(ITY,IT,'ZIT1T1T2VRS') = ZIT1T1T2VRS.L;
RES(ITY,IT,'ZIT1T2T2VRS') = ZIT1T2T2VRS.L;
RES(ITY,IT,'ZIT1T2T1VRS') = ZIT1T2T1VRS.L;
RES(ITY,IT,'MLO111VRS') = DCOT1T1T1VRS.MODELSTAT;
RES(ITY,IT,'SLO111VRS') = DCOT1T1T1VRS.SOLVESTAT;
RES(ITY,IT,'MLO112VRS') = DCOT1T1T2VRS.MODELSTAT;
RES(ITY,IT,'SLO112VRS') = DCOT1T1T2VRS.SOLVESTAT;
RES(ITY,IT,'MLO122VRS') = DCOT1T2T2VRS.MODELSTAT;
RES(ITY,IT,'SLO122VRS') = DCOT1T2T2VRS.SOLVESTAT;
RES(ITY,IT,'MLO121VRS') = DCOT1T2T1VRS.MODELSTAT;
RES(ITY,IT,'SLO121VRS') = DCOT1T2T1VRS.SOLVESTAT;
RES(ITY,IT,'MLO222VRS') = DCOT2T2T2VRS.MODELSTAT;
RES(ITY,IT,'SLO222VRS') = DCOT2T2T2VRS.SOLVESTAT;
RES(ITY,IT,'MLI111VRS') = DCIT1T1T1VRS.MODELSTAT;
RES(ITY,IT,'SLI111VRS') = DCIT1T1T1VRS.SOLVESTAT;
RES(ITY,IT,'MLI112VRS') = DCIT1T1T2VRS.MODELSTAT;
RES(ITY,IT,'SLI112VRS') = DCIT1T1T2VRS.SOLVESTAT;
RES(ITY,IT,'MLI122VRS') = DCIT1T2T2VRS.MODELSTAT;
RES(ITY,IT,'SLI122VRS') = DCIT1T2T2VRS.SOLVESTAT;
RES(ITY,IT,'MLI121VRS') = DCIT1T2T1VRS.MODELSTAT;
RES(ITY,IT,'SLI121VRS') = DCIT1T2T1VRS.SOLVESTAT;

* Model status: 1 Optimal (for LP) Solver status: 1 Normal completion
);
* closes test statement
);
* closes iteration over units
);
* closes iteration over years

RES(Y,K,R)$(NOT RES(Y,K,R))=EPS;
$LIBINCLUDE XLEXPORT RES c:\tesina\hmtfp.xls RESULTS!A1:AK91
```