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BENCHMARKING AND TOTAL FACTOR PRODUCTIVITY: A LUENBERGER DECOMPOSITION WITHIN THE BANKING SECTOR

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Abstract: This paper has a dual aim. First, it analyses the total factor productivity of the Spanish banking sub-sectors throughout an eight-year time span. Second, derived from the Färe et al. (1994) Malmquist decomposition, it proposes a Luenberger indicator adapted to benchmarking purposes. Hence, by means of an application where the base period is an established reference unit, the indicator offers two types of measures: (1) benchmarking (total factor productivity and frontier indicators), and (2) static efficiency (technical efficiency as the sum of pure technical efficiency, scale economies and input congestion). Results show that benchmarks for private and savings banks have inferior scores than the mean sample level, while the ones for credit cooperatives are roughly equal to the sample mean. Moreover, new technologies are important in the sector as changes over time are all-significant for frontier shifts. Statically, the technical efficiency components demonstrate good organisational practices together with consistency over time.

Key words: Benchmarking, Luenberger decomposition, total factor productivity, banking sector

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1. Introduction

The purpose of the subsequent paper is twofold. First, we aim to analyse in an economically meaningful way the productivity and efficiency of the Spanish banking sector. Second, following the decomposition of the Malmquist indices suggested by Färe, et al. (1994), we propose a Luenberger indicator decomposition adapted to benchmarking purposes. Thus, the article presents the evolution of the total factor productivity (henceforth *TFP*) results together with the outcome of comparisons between banks and established points of reference.

There is more than one reason for why to employ this type of indicator. Recently, the academic literature on efficiency and productivity experienced a growth in the use of primal *TFP* indices. These have become increasingly popular since they do not require the specification of prices (information which is not always available), but they rather rely on physical inputs and outputs solely.

Numerous empirical applications exist of the ratio-based Malmquist productivity index (see the survey in Färe et al. 1998). Fewer applications exist of the Luenberger productivity indicator (Chambers 2002), which determines productivity in terms of differences rather than ratios. Moreover, there are differences between ratio- and difference-based productivity measures. Malmquist indices are known to overestimate the productivity change as opposed to the Luenberger indicators (Boussemart et al. 2003, Managi 2003).

Additionally, there is another consideration for utilising the Luenberger indicator. Even if economics' academia is familiar with the interpretation of ratios, the issues treated here also pertain to the business and accounting community, which is evidently more accustomed to evaluating cost, revenue, or profit differences (Boussemart et al. 2003) in terms of money.

Therefore, we make use of a basic Luenberger indicator (see *e.g.* Chambers 1996; Boussemart et al. 2003; Managi 2003) and further adapt it for our benchmarking intentions. Generally, in the above mentioned studies, the Luenberger indicator is additively decomposed into technical efficiency and frontier (technological) change. Furthermore, similarly to the Malmquist index decomposition in Färe et al. (1994), we express the technical efficiency component as the sum of pure efficiency, scale economies and congestion.

Consequently, the indicators are computed for different periods independently for the analysed units, as well as against an established benchmark within the sample. This is possible due to the dynamic approach of the Luenberger indicator. Normally, the differences are calculated between two time periods. In our decomposition case, the application is static. Thus, the comparison is done between all the banking units against the selected reference unit, all having the inputs and outputs in the same time-period. Hence, the results from different years show differences in scores dispersion, rankings and, if present, catch-up events.

As above stated, this research is conducted within the Spanish banking sector, which experienced consistent growth. This occurred on the background of the disappearance of the regulatory constrains and the intensive adaptation of the Spanish banking legislation to the European banking rules (Grifell-Tatjé and Lovell 1997b; Cuesta and Orea 2002; Zúñiga-Vicente et al. 2004). In consequence, a vast array of research analyses the productivity and efficiency of Spanish banks (*e.g.* Grifell-Tatjé and Lovell 1996, 1997a, b; Lozano-Vivas 1997; Prior 2003; Tortosa-Ausina 2003, 2004; Crespí et al. 2004; Zúñiga-Vicente et al. 2004; Más-Ruiz et al. 2005; García-Cestona and Surroca 2006; Prior and Surroca 2006, to name just a few).

However, albeit previous research treats efficiency issues, the use of *TFP* measures continues to be quite scarce. In addition, the use of a decomposed Luenberger indicator and benchmarking approaches are – to the best of our knowledge – non-existent. Accordingly, the next section introduces the indicator we make use of. Section 3 provides sample-related information together with the description of the variables and the methods of analysis. Section 4 presents results and their interpretation, whereas the final section formulates key conclusions and suggests directions of extending this research.

2. The Luenberger indicator and its decomposition for benchmarking

Based upon the shortage function established by Luenberger (1992a, b), Chambers et al. (1996) introduce the Luenberger productivity indicator as a difference of directional distance functions. The advantage of the Luenberger indicator is that instead of specialising in either input- or output-orientation (as the Shephardian distance function underlying the Malmquist indexes do), it addresses input contractions and output expansions simultaneously and is therefore compatible with the economic goal of profit maximisation (Boussemart et al. 2003; Managi 2003).

According to Chambers (2002:751) "these Luenberger indicators are novel because they are based on a translation (non radial) representation of the technology and, thus, are all specified in difference (non ratio) form". Therefore, the Luenberger productivity indicator is a generalisation of the Malmquist index (Managi 2003). Additionally, Boussemart et al. (2003) approximate that, under constant returns to scale (henceforth *CRS*), the logarithm of the Malmquist index is roughly twice the Luenberger indicator.

Let: $\mathbf{x} = (x_1, ...x_N) \in R_+^N$ and $\mathbf{y} = (y_1, ...y_M) \in R_+^M$ be the vectors of inputs, and outputs, respectively, and define the technology by the set T^t, which represents the set of all output vectors, **y**, that can be produced using the input vector **x** in the time period *t*:

$$T^t = \left\{ \left(\mathbf{x^t}, \mathbf{y^t} \right) : \mathbf{x^t} \text{ can produce } \mathbf{y^t} \right\} \tag{1}$$

According to Chambers (1998), the proportional distance function is as follows:

$$D^t \left(\mathbf{x^t}, \mathbf{y^t} \right) = \max \left\{ \delta : ((1-\delta)\mathbf{x^t}, (1+\delta)\mathbf{y^t}) \in P(\mathbf{x^t}) \right\} \tag{2}$$

Thus, the Luenberger indicator specified by Chambers et al. (1996) and Chambers (2002) is given by:

$$\begin{aligned} L^{t,t+1}\left(\mathbf{x^t}, \mathbf{y^t}, \mathbf{x^{t+1}}, \mathbf{y^{t+1}}\right) = \frac{1}{2} \Big[\Big(D^t \left(\mathbf{x^t}, \mathbf{y^t}\right) - D^t \left(\mathbf{x^{t+1}}, \mathbf{y^{t+1}}\right) \Big) + \\ + \Big(D^{t+1} \left(\mathbf{x^t}, \mathbf{y^t}\right) - D^{t+1} \left(\mathbf{x^{t+1}}, \mathbf{y^{t+1}}\right) \Big) \Big] \end{aligned} \tag{3}$$

This formulation represents an arithmetic mean between the period *t* (the first difference) and the period *t+1* (the second difference) Luenberger indicators. Hence, arbitrary selection among base years is avoided (Balk 1998). Equation 3 is interpreted as one would normally interpret difference-based indicators. Improvements are denoted by positive results, while negative values represent a decline from the period *t* to period *t+1*.

In general applications, the above equation is decomposed into two components:

$$L^{t,t+1}\left(\mathbf{x}^{t},\mathbf{y}^{t},\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)=D^{t}\left(\mathbf{x}^{t},\mathbf{y}^{t}\right)-D^{t+1}\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)+ \\ +\frac{1}{2}\left[\left(D^{t+1}\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)-D^{t}\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)\right)+\left(D^{t+1}\left(\mathbf{x}^{t},\mathbf{y}^{t}\right)-D^{t}\left(\mathbf{x}^{t},\mathbf{y}^{t}\right)\right)\right] \quad (4)$$

where the first difference expresses the efficiency changes and the arithmetic mean of the two last differences represents the technological change. This decomposition is similar to the basic ones of the Mamquist index (see *e.g.* Färe et al. 1994), and has been applied empirically by several authors (*e.g.* Managi 2003; Mussard and Peypoch 2006; Barros et al. 2007). More elaborate empirical applications of decompositions of the Luenberger indicator are – to the best of our knowledge – non-existent.

However, in our case this decomposition is not economically meaningful. As mentioned before, the purpose of the analysis is to benchmark all banking units against a fixed base. This, within the Luenberger formulation, means that, when constructing the data, the base period (*t*) will keep the values corresponding to the benchmark in period *t+1* throughout the whole sample. Thus, the real units will appear in the second period. Accordingly, the indicators compare the movements from the benchmark (period *t*) to the analysed bank (period *t+1*).

The shortcomings when interpreting the above equations are due to the fact that the $D^{t}\left(\mathbf{x}^{t},\mathbf{y}^{t}\right)$ component will always be equal to 0. Therefore, through simple mathematical manipulation we put forth the following decomposition of the Luenberger indicator (see equation 3) applied to this particular scenario. This consists of the sum of three components. First, the technical efficiency indicator is given by:

$$TE=D^{t}\left(\mathbf{x}^{t},\mathbf{y}^{t}\right)-D^{t+1}\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)=-D^{t+1}\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right) \quad (5)$$

This indicator is similar to the one of technical efficiency change from equation 4. Nonetheless, since the first term is 0 independently of the iteration, equation 5 shows static technical efficiency (henceforth *TE*) in period *t+1*. In this case the results can show values smaller or equal to 0. When the value is 0, the unit is technically efficient, and thus in the efficiency frontier. Accordingly, the negative values indicate the inefficiency scores.

Second, the frontier (technological) comparison indicator is also a static indicator for period *t+1*:

$$FR = \frac{1}{2}[D^{t+1}\left(\mathbf{x^{t+1}}, \mathbf{y^{t+1}}\right) - D^{t}\left(\mathbf{x^{t+1}}, \mathbf{y^{t+1}}\right)] \quad (6)$$

In this case the inputs and outputs in period *t+1* are evaluated against the two frontiers (one given by the sample in the second period and one given by the benchmark in the first period). The frontier component (henceforth *FR*) can produce results smaller, greater or equal to 0 showing decline, improvement or stagnation. Furthermore, the division by two is necessary due to mathematical issues linked to the decomposition of the two-period Luenberger indicator.

The third indicator is the period *t* Luenberger technological component. Yet, owing to the null second indicator it is expressed by a constant representing half the inverse of the technical efficiency of the benchmark. Therefore, this distance function does not have an eloquent interpretation.

$$Cons = \frac{1}{2}[D^{t+1}\left(\mathbf{x^{t}}, \mathbf{y^{t}}\right) - D^{t}\left(\mathbf{x^{t}}, \mathbf{y^{t}}\right)] = \frac{1}{2}D^{t+1}\left(\mathbf{x^{t}}, \mathbf{y^{t}}\right) \quad (7)$$

All the above equations are defined in *CRS* and strong disposability of inputs and outputs (henceforth *SD*). Moreover, Figure 1, assuming a simple technology with only one output and one input, illustrates the *TE* and the *FR*. On the one hand, *TE* represents the distance from the analysed unit in period *t+1* ((x^{t+1},y^{t+1}) in the figure) to the frontier in *t+1*. On the other hand, *FR* can be observed graphically and, as represented in equation 6 it embodies the shift of the frontier. The frontier in period *t* is defined only by the established benchmark, while the frontier in period *t+1* is the actual one. Hence, *FR* shows the difference between the distance to the frontier in *t+1* and the distance to the frontier in *t*, maintaining the inputs and outputs in *t+1*.

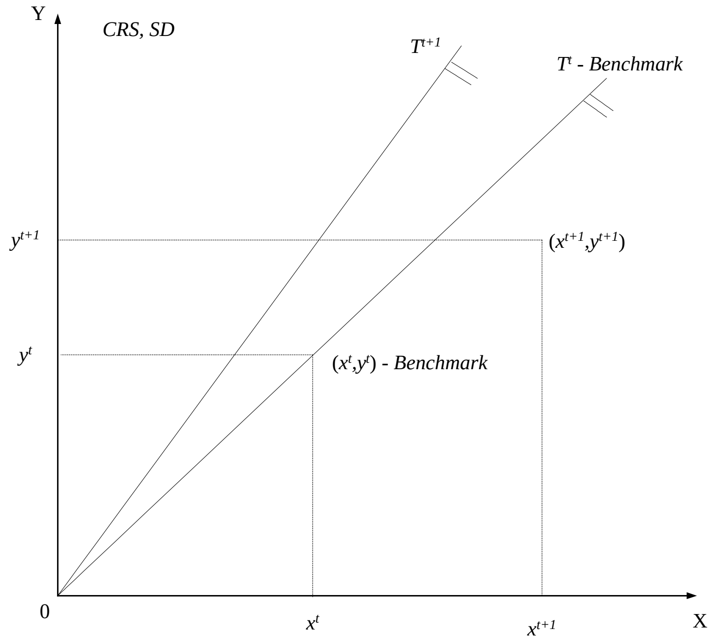

Figure 1. Technical Efficiency and Frontier Change

Consequently, we propose a decomposition of the Luenberger indicator similar to the one applied to the Malmquist index by Färe et al. (1994: 227-235). The basis of this specification is the above formulation. While the frontier components remain untouched, the initial efficiency change component (*i.e.* the first part of equation 4) is decomposed as the sum of pure technical efficiency (henceforth *PTE*), scale economies (henceforth *SE*) and congestion (henceforth *CG*).

Also, apart from the above defined *CRS* and *SD*, the new indicators employ variable returns to scale (henceforth *VRS*) and assume weak disposability of inputs (henceforth *WDI*), while maintaining the strong disposability assumption for the outputs.

The *PTE* is analogous in interpretation to the *TE*. The pure inefficiency is shown through negative results, whereas the purely efficient units attain the 0 value.

$$\begin{aligned} PTE &= D^t\left(\mathbf{x^t},\mathbf{y^t} \mid VRS, WDI\right) - D^{t+1}\left(\mathbf{x^{t+1}},\mathbf{y^{t+1}} \mid VRS, WDI\right) \\ &= -D^{t+1}\left(\mathbf{x^{t+1}},\mathbf{y^{t+1}} \mid VRS, WDI\right) \end{aligned} \quad (8)$$

The scale inefficiencies are given by the difference between the *CRS* frontier and the *VRS* frontier. In the benchmarking context, these can be observed only for the period *t+1*, and the interpretation of the results is similar to the one of *TE* and *PTE*.

$$SE = \left[D^t\left(\mathbf{x^t}, \mathbf{y^t} \mid CRS, SD\right) - D^t\left(\mathbf{x^t}, \mathbf{y^t} \mid VRS, SD\right)\right] + \\ + \left[D^{t+1}\left(\mathbf{x^{t+1}}, \mathbf{y^{t+1}} \mid VRS, SD\right) - D^{t+1}\left(\mathbf{x^{t+1}}, \mathbf{y^{t+1}} \mid CRS, SD\right)\right] = \\ = \left[D^{t+1}\left(\mathbf{x^{t+1}}, \mathbf{y^{t+1}} \mid VRS, SD\right) - D^{t+1}\left(\mathbf{x^{t+1}}, \mathbf{y^{t+1}} \mid CRS, SD\right)\right] \tag{11}$$

In order to explain the *SE* concept, let us take one arbitrary period as exemplification together with two units (see Figure 2). Both (x_k,y_k) and (x_l,y_l) show input scale inefficiencies. In the case of unit (x_k,y_k) the source is the production of an inefficiently small output vector in the presence of increasing returns to scale. Correspondingly, unit (x_l,y_l) produces an inefficiently large output while decreasing returns to scale are present.

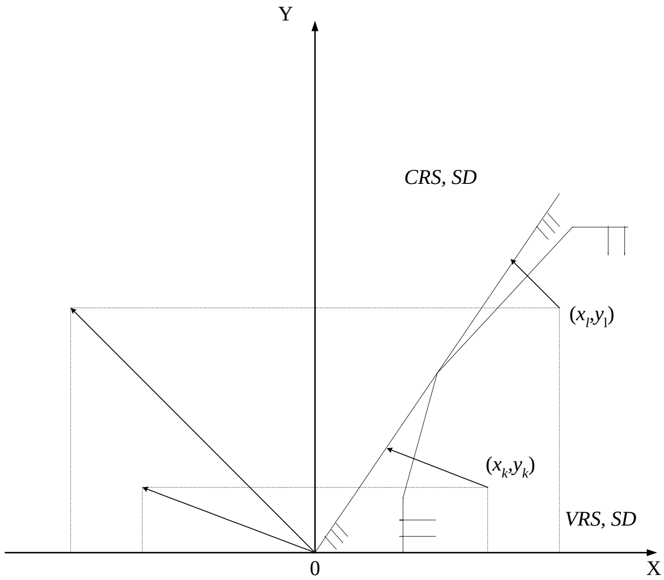

Figure 2. Scale Inefficiency (adapted from Färe et al. 1994: 75)

Progressing, "the input congestion measure provides a comparison of the feasible proportionate reduction in inputs required to maintain output when technology satisfies weak versus strong input disposability" (Färe et al. 1994: 75).

$$CG = \left[D^t\left(\mathbf{x^t}, \mathbf{y^t} \mid VRS, SD\right) - D^t\left(\mathbf{x^t}, \mathbf{y^t} \mid VRS, WDI\right)\right] + \\ + \left[D^{t+1}\left(\mathbf{x^{t+1}}, \mathbf{y^{t+1}} \mid VRS, WDI\right) - D^{t+1}\left(\mathbf{x^{t+1}}, \mathbf{y^{t+1}} \mid VRS, SD\right)\right] \\ = \left[D^{t+1}\left(\mathbf{x^{t+1}}, \mathbf{y^{t+1}} \mid VRS, WDI\right) - D^{t+1}\left(\mathbf{x^{t+1}}, \mathbf{y^{t+1}} \mid VRS, SD\right)\right] \tag{11}$$

Results show no congestion of inputs when the value is 0, while the amount of congestion is seen in negative values. Figure 3, assuming a technology with two inputs needed to produce one output, shows that input vector x_j congests output vector y_j as the inefficiency in SD is smaller than in WD. Consequently, input vector x_k is not congested for output vector $y_k = y_j$ since the inefficiency in SD is equal to the one in WD.

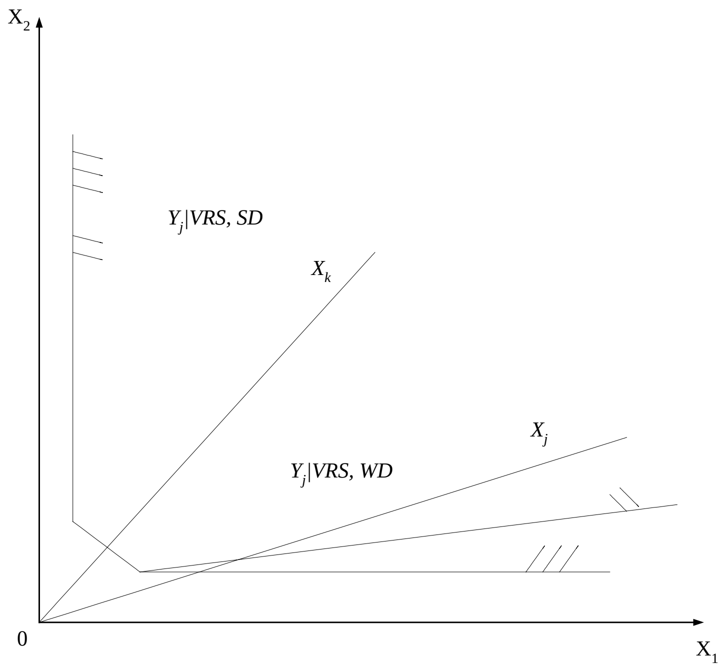

Figure 3. Input Congestion (Färe et al. 1994: 76)

Accordingly, the above decomposition of the Luenberger indicator is applied to the Spanish banking sector. The description of the process of analysis follows within the methodology section.

3. Data, variables and method of analysis

3.1. Sample

The competitive pressure in the Spanish banking increased due to the disappearance of the regulatory constrains (Grifell-Tatjé and Lovell 1997b; Cuesta and Orea 2002; Zúñiga-Vicente et al. 2004). Consequently, inside the liberalised market structure, emergent financial intermediaries were allowed to carry out activities normally linked with banks, and new information technologies were introduced (Cuesta and Orea 2002).

Therefore, according to the legal status, the Spanish banking sector is composed of: private banks, savings banks and credit cooperatives. The main difference between the three types of institutions is given by the ownership structure. On the one hand, the private banks are classical profit-seeking firms. On the other hand, the savings banks are public (in some cases owned by public institutions), while and the credit cooperatives are mostly held by customers.

The last two are the beneficiaries of the deregulation process. Not only that they are now allowed to perform general banking operations, but they can expand throughout all the provinces. Moreover, by studying annual reports we noticed that expansion was at the turn of the century, and still is, one of the priorities of savings banks, fact that enhances the assumption of high competition.

Accordingly, all three sub-sectors represent attractive objects of analysis. Therefore we created three samples corresponding to the type of banking units for the years 1998, 2002, and 2006 respectively. The only restriction in this first selection was the availability of information. The removed units were the foreign private banks which did not have assets-related reliable information.

First, we tested for the eventual presence of outliers. It is common knowledge that outliers, as extreme points, may well determine the production frontier and can create bias in the efficiency and productivity change estimated in any given sample. Andersen and Petersen’s (1993) super-efficiency measure together with the Wilson (1993) study are the seminal studies on outliers in a frontier context. Consequently, when possibly influential units are encountered, these are removed from the sample and the super-efficiency measures are recalculated and compared with the previous ones. Furthermore, as suggested by Prior and Surroca (2006), this process is repeated until the null hypotheses of equality between successive efficiency scores cannot be rejected.

At the end of the assessment, the private banks sample presents the highest fluctuation and consists of 87, 66 and 90 units in 1998, 2002 and 2006 respectively. Matching the same time periods the savings banks samples are 51, 47 and 47, whereas the credit cooperatives are 92, 84 and 80.

3.2. Variables and Method of Analysis

Banking activity can be defined through different methods (see the surveys of Berger and Humphrey (1997) or Goddard, Molyneux and Wilson (2001) for more details). At first glance, the situation seems a bit chaotic due to the diversity of approaches. Nonetheless, the reviewed research evaluates dissimilar dimensions of banking efficiency. As pointed out by Favero and Papi (1995) and Berger and Humphrey (1997) there exist five approaches to banking efficiency.

On the one hand, the production and intermediation approaches are the main choices for measuring the flow of services provided by financial institutions (Berger and Humphrey 1997). Under the production approach banks are generally considered producers of deposit accounts and loan services, while employing as inputs capital and labour. The intermediation approach views banks as mediators that turn deposits and purchased funds into loans and financial investments (Favero and Papi 1995). On the other hand, the rest of three approaches (asset, user cost, and value added) concur that loans and other major assets of financial institutions should be treated as outputs (Berger and Humphrey 1997). Even so, there is debate whether deposits should be included as inputs or outputs.

Therefore, the dissimilar pursued objectives determine the lack of homogeneity. Subsequent to the literature review we have chosen a classical definition of the variables to match the characteristics of the Spanish banking sector. A production approach is utilised comprising the following features. Inputs are (1) operative assets (defined as total assets – financial assets), (2) labour (number of employees), and (3) other administrative expenses, whereas outputs are (1) deposits, (2) loans, and (3) fee-generated income (non-traditional output).

As it can be noticed, the variables are with one exception in monetary terms. First, the rationale for this specification is relatively simple. Let us consider two banks that have the same number of deposits, but one of them holds twice as much money-wise. The physical deposits would be equal, whereas the monetary deposits would show the real situation. Second, labour is expressed in absolute numbers as the values showed higher consistency throughout the sample, thus producing less bias.

Hence, using this production approach the analysis is developed in the following fashion. First, the benchmarks are established for each sub-sector. The identification of benchmarks is done as a function of the selected input-output mix. Thus, the units are ranked by the levels of each input and output. Subsequently, the most consistent leader over the eight-year period is chosen as the reference bank.

Table 1 provides the selected points of reference per each sub-sector together with the mean values of the input output variables. By looking upon average mean values related with each sub-sector one can observe the differences in size, another reason for having separate benchmarks. Hence, the units are evaluated against Banco Bilbao Vizcaya Argentaria, La Caixa, and Caja Laboral Popular for private banks, savings banks and credit cooperatives respectively. Still, these are also maintained in the whole sample as they also form part of the efficiency frontier.

Table 1. Benchmarks per Sub-Sector. Associated Mean Values of Input-Output Variables.

PRIVATE BANKS	Year	Operative Assets	Labour No. Empl.	Other Adm. Exp.	Deposits	Loans	Fee-Gener. Income
Banco Bilbao Vizcaya Argentaria,S.A.	**1998**	5.932.068	20.212	329.601	49.697.691	35.257.065	665.645
Average Private Banks		418.893	1.502	32.260	2.818.085	2.602.863	52.812
Banco Bilbao Vizcaya Argentaria,S.A.	**2002**	16.459.324	30.971	721.030	98.472.990	100.687.471	1.532.072
Average Private Banks		773.109	1.674	45.417	5.075.727	4.920.313	84.974
Banco Bilbao Vizcaya Argentaria,S.A.	**2006**	11.904.268	28.680	849.074	146.891.740	183.852.896	2.062.234
Average Private Banks		526.453	1.233	49.732	6.167.555	7.641.640	92.274
SAVINGS BANKS	**Year**	**Operative Assets**	**Labour No. Empl.**	**Other Adm. Exp.**	**Deposits**	**Loans**	**Fee-Gener. Income**
La Caixa	**1998**	4.001.340	16.328	382.154	39.175.111	31.649.850	616.837
Average Savings Banks		408.588	1.860	40.566	4.446.878	3.381.501	43.610
La Caixa	**2002**	8.607.443	21.124	539.176	61.751.169	57.775.478	931.678
Average Savings Banks		750.736	2.308	56.466	7.495.035	6.743.751	72.746
La Caixa	**2006**	11.079.165	23.674	636.980	120.422.696	138.128.963	1.312.807
Average Savings Banks		897.977	2.641	69.957	13.704.761	15.490.617	110.519
CREDIT COOPERATIVES	**Year**	**Operative Assets**	**Labour No. Empl.**	**Other Adm. Exp.**	**Deposits**	**Loans**	**Fee-Gener. Income**
Caja Laboral Popular	**1998**	381.541	1.668	34.113	4.190.731	3.084.226	65.480
Average Credit Cooperatives		20.102	144	2.705	273.497	200.863	2.400
Caja Laboral Popular	**2002**	549.781	1.990	41.250	7.362.912	5.973.830	79.424
Average Credit Cooperatives		32.619	195	4.211	489.998	420.763	4.345
Caja Laboral Popular	**2006**	586.393	2.188	49.510	14.061.586	12.972.717	103.674
Average Credit Cooperatives		44.020	233	5.426	962.030	942.989	6.411

The second step in the analysis is the Luenberger indicator decomposition computed for each one of the three periods. This shows the movements of the analysed unit against the benchmark, as well as the static productivity and efficiency scores for the former. Consequently, descriptive statistics present the outcome of the study, and statistical ranking tests (*i.e.* Mann-Whitney) show the significant differences throughout the results.

At this point a further explanation is necessary. With the exception of congestion all the decomposition components are calculated with respect to all inputs and outputs. However, as the weak disposability assumption (see Färe et al., 1994) is associated with an undesirable large amount of one specific input or output, a different specification was required. While the weak disposability assumption in outputs is dealt with in the efficiency literature (*i.e.* in the case of eco-efficiency residuals represent an undesirable output), in our specific case this is not called for. By reviewing the input-output mix, it is quite obvious that all outputs are desirable at the highest levels possible.

Conversely, the situation in the inputs side is rather different. Despite the fact that in accordance with the declared expansion plans we acknowledge that all the inputs will increase, there still remain problems of controlling their quantity. New branches (and/or *ATMs*) lead to increases in all specified input dimensions, especially in operative assets and administrative expenses. Nonetheless, the personnel aspect should be cautiously treated, especially taking into account the technological development. Therefore, congestion is measured with respect to the labour input.

4. Discussion of results

The Luenberger decomposition endows us with the results for each sample in the three time-periods. These are discussed gradually in our analysis. To begin with, Table 2 presents the descriptive statistics associated with the private banks. It has to be mentioned that in 2006 the sample has been reduced from 90 to 88 units due to infeasible solutions. However, these are the only infeasibilities to be reported throughout the analysis.

The positive Luenberger *TFP* scores point to the fact that most of the units perform better than the benchmark in all three periods under examination. Moreover, these results are extended to more than 75% of the private banks (see percentiles in Table 2). Likewise, the *FR* is also showing uniformity with these values and it is probably the source of this outcome. Again, the interpretation is that the actual frontier is better than the one established only by the benchmark. Therefore, the technological development of the whole sample is superior to the one of the bank that is leading in terms of inputs and outputs levels.

Table 2. Private Banks Descriptive Statistics

		No. Units	Mean	Std. Dev.	Min.	Max.	Percentiles		
							25	50, Med.	75
LUENB	**1998**	87	0,1261	0,2166	-0,5926	0,4320	0,0162	0,1472	0,2937
	2002	66	0,1566	0,2305	-0,5302	0,4728	0,0587	0,2059	0,3150
	2006	88	0,2017	0,2337	-0,7695	0,5711	0,0668	0,2305	0,3990
TE	**1998**	87	-0,2168	0,1979	-0,8295	0,0000	-0,3091	-0,1778	-0,0701
	2002	66	-0,2024	0,2276	-0,8697	0,0000	-0,2608	-0,1301	0,0000
	2006	88	-0,2425	0,2328	-0,8958	0,0000	-0,3771	-0,2177	-0,0004
FR	**1998**	87	0,3022	0,0821	0,0407	0,4609	0,2614	0,3086	0,3593
	2002	66	0,3285	0,0984	0,0306	0,5175	0,2740	0,3357	0,3912
	2006	88	0,3633	0,1338	0,0455	0,7427	0,2843	0,3680	0,4440
PTE	**1998**	87	-0,1352	0,1673	-0,6812	0,0000	-0,2253	-0,0692	0,0000
	2002	66	-0,1160	0,1964	-0,7054	0,0000	-0,1193	0,0000	0,0000
	2006	88	-0,1284	0,1829	-0,7983	0,0000	-0,2035	-0,0064	0,0000
CG	**1998**	87	-0,0154	0,0517	-0,3567	0,0000	0,0000	0,0000	0,0000
	2002	66	-0,0076	0,0265	-0,1714	0,0000	0,0000	0,0000	0,0000
	2006	88	-0,0176	0,0536	-0,3155	0,0000	0,0000	0,0000	0,0000
SE	**1998**	87	-0,0662	0,1004	-0,6548	0,0000	-0,0827	-0,0306	-0,0034
	2002	66	-0,0789	0,1332	-0,5990	0,0000	-0,1101	-0,0180	0,0000
	2006	88	-0,0965	0,1461	-0,7736	0,0000	-0,1632	-0,0388	0,0000

Next, the static components first point to the fact that about 25% of the units are technically efficient. Yet, when looking upon *PTE* we notice that almost 50% of the private banks are in the frontier. While this is consistent with the *SE*, there seem to be no *CG* problems at the sample level.

Furthermore, ranking tests show that significant differences are present only in the case of the benchmarking indicators. Table 3 contains the Mann-Whitney hypotheses tests between the three time-periods. Whereas for all the static factors the null hypothesis of equality of the efficiency scores cannot be rejected, there are four cases in which the Luenberger and the *FR* are dissimilar among the years. First, there is a significant increase in the mean *TFP* distance between the point of reference and the analysed unit from 1998 to 2006. Second, each step between periods is accompanied by an evident frontier shift, signalling that new technologies are rather important in the sector.

Table 3. Private Banks Mann-Whitney Test

	LUENB	TECH	FRSTATIC	PTECH	CG	SC
1998-2002	0,262	0,298	0,077*	0,179	0,407	0,480
1998-2006	0,012*	0,631	0,000***	0,431	0,947	0,710
2002-2006	0,254	0,247	0,069*	0,526	0,371	0,407

*, **, ***: Significant at 0.1, 0.05 and 0.01 respectively.

Interpretations are quite similar in the case of savings banks (see Table 4). The Luenberger indicator shows that the benchmark keeps itself in the first 25%. Hence the *TFP* at general sample level is quite superior, fact also noticed in the second benchmark component. The *FR* within the savings banks sector does not show such a high difference with respect to the benchmark as in the case of the private banks. Nonetheless, the technology is still better than the base frontier. Therefore, the enhancement of the competition is probably attributable to expansion which is importantly accompanied by novel technologies.

Table 4. Savings Banks Descriptive Statistics

		No. Units	Mean	Std. Dev.	Min.	Max.	Percentiles		
							25	**50, Med.**	**75**
LUENB	**1998**	51	0,0311	0,0704	-0,1193	0,1895	-0,0141	0,0202	0,0838
	2002	47	0,1124	0,0669	-0,0422	0,2530	0,0703	0,1096	0,1643
	2006	47	0,0986	0,0842	-0,1019	0,3021	0,0558	0,1000	0,1519
TE	**1998**	51	-0,0898	0,0691	-0,2661	0,0000	-0,1337	-0,0820	-0,0409
	2002	47	-0,0815	0,0728	-0,2690	0,0000	-0,1142	-0,0731	-0,0119
	2006	47	-0,0910	0,0822	-0,3185	0,0000	-0,1464	-0,0759	-0,0227
FR	**1998**	51	0,1209	0,0380	0,0000	0,1895	0,0979	0,1180	0,1481
	2002	47	0,1940	0,0494	0,0000	0,2702	0,1754	0,2018	0,2292
	2006	47	0,1647	0,0477	0,0249	0,2772	0,1391	0,1693	0,1964
PTE	**1998**	51	-0,0647	0,0660	-0,2557	0,0000	-0,1067	-0,0542	0,0000
	2002	47	-0,0307	0,0537	-0,2050	0,0000	-0,0430	0,0000	0,0000
	2006	47	-0,0497	0,0666	-0,2415	0,0000	-0,0775	-0,0163	0,0000
CG	**1998**	51	-0,0042	0,0100	-0,0493	0,0000	-0,0006	0,0000	0,0000
	2002	47	-0,0200	0,0358	-0,1807	0,0000	-0,0319	0,0000	0,0000
	2006	47	-0,0154	0,0335	-0,1297	0,0000	-0,0072	0,0000	0,0000
SE	**1998**	51	-0,0209	0,0362	-0,1766	0,0000	-0,0248	-0,0072	-0,0024
	2002	47	-0,0309	0,0521	-0,2690	0,0000	-0,0328	-0,0080	-0,0004
	2006	47	-0,0259	0,0528	-0,3185	0,0000	-0,0289	-0,0070	0,0000

Statically, the *TE* provides the expected results for all three periods. The frontier is formed by less than 25% of the units, but with quite low inefficiency values. This is easily noticed when decomposed. *CG* and *SE* show no notable issues (even if at the same time there are no considerable economies of scale at a general level). Moreover, the *PTE* demonstrates the good organisational practices.

Statistically, it is important to notice that in the case of the savings banks the significant differences are more present (see Table 5). Both for of the Luenberger indicator as well as for the *FR*, the distance of the benchmark to the sample increases at first and then manifests a decrease between the last two periods (the later change is significant only for the *FR*). The null hypothesis of equality is also rejected for the improvement of the *PTE* between 1998 and 2002.

Table 5. Savings Banks Mann-Whitney Test

	LUENB	TECH	FRSTATIC	PTECH	CG	SC
1998-2002	0,000***	0,484	0,000***	0,002***	0,032**	0,764
1998-2006	0,000***	0,792	0,000***	0,150	0,291	0,770
2002-2006	0,463	0,670	0,001***	0,126	0,358	0,615

*, **, ***: Significant at 0.1, 0.05 and 0.01 respectively.

Conversely to the above sectors, the benchmark of the credit cooperatives performs better than the sample at mean level both for 1998 and 2006. Still, the values are fairly close to 0, situation also present in 2002. The distances diminish between the benchmark and the technology progressively between the three periods. Yet, the frontier of the reference point remains below the actual one (see Table 6).

Table 6. Credit Cooperatives Descriptive Statistics

		No. Units	Mean	Std. Dev.	Min.	Max.	Percentiles		
							25	50, Med.	75
LUENB	**1998**	92	-0,0184	0,1076	-0,2832	0,2934	-0,0899	-0,0180	0,0503
	2002	84	0,0155	0,1101	-0,2349	0,2825	-0,0580	0,0152	0,0897
	2006	80	-0,0605	0,1364	-0,3168	0,2601	-0,1576	-0,0725	0,0445
TE	**1998**	92	-0,2087	0,1057	-0,4534	0,0000	-0,2804	-0,2153	-0,1417
	2002	84	-0,1205	0,0908	-0,3076	0,0000	-0,1880	-0,1013	-0,0549
	2006	80	-0,1551	0,1006	-0,3553	0,0000	-0,2350	-0,1644	-0,0842
FR	**1998**	92	0,1902	0,0541	0,0000	0,3126	0,1580	0,1937	0,2215
	2002	84	0,1360	0,0536	0,0000	0,2825	0,1038	0,1355	0,1689
	2006	80	0,0946	0,0633	0,0000	0,2601	0,0386	0,0867	0,1448
PTE	**1998**	92	-0,1301	0,1051	-0,3950	0,0000	-0,2039	-0,1363	-0,0288
	2002	84	-0,0808	0,0856	-0,3008	0,0000	-0,1485	-0,0569	0,0000
	2006	80	-0,1045	0,0931	-0,3442	0,0000	-0,1729	-0,1136	0,0000

CG	**1998**	92	-0,0115	0,0297	-0,1732	0,0000	-0,0065	0,0000	0,0000
	2002	84	-0,0039	0,0143	-0,0712	0,0000	0,0000	0,0000	0,0000
	2006	80	-0,0178	0,0495	-0,3133	0,0000	-0,0086	0,0000	0,0000
SE	**1998**	92	-0,0671	0,0590	-0,2560	0,0000	-0,1033	-0,0564	-0,0118
	2002	84	-0,0358	0,0486	-0,2481	0,0000	-0,0492	-0,0197	-0,0021
	2006	80	-0,0327	0,0437	-0,2120	0,0000	-0,0472	-0,0144	-0,0031

The credit cooperatives are different at the static level as well. The *TE* scores first show increases and then decreases, and together with the *PTE* ones show us that the frontiers are formed by less units than in the other two cases. However, the *CG* and *SE* elements have rather similar levels as for private and savings banks.

Table 7. Credit Cooperatives Mann-Whitney Test

	LUENB	TECH	FRSTATIC	PTECH	CG	SC
1998-2002	0,034**	0,000***	0,000***	0,002***	0,004***	0,000***
1998-2006	0,022**	0,001***	0,000***	0,125	0,952	0,000***
2002-2006	0,000***	0,020**	0,000***	0,134	0,015**	1,000

*, **, ***: Significant at 0.1, 0.05 and 0.01 respectively.

All the reported changes in the benchmarking components are statistically significant (see Table 7). Additionally, the null hypothesis is rejected for all *TE* comparisons. Thus, the credit cooperatives manifest important dissimilarities form one period of analysis to another with respect to the employment of the input-output mix. Furthermore, all three indicators that form *TE* point to significant advances between 1998 and 2002.

5. Conclusions, Limitations and Future Lines of Research

This paper has empirically analysed the *TFP* of the Spanish banks with respect to the years 1998, 2002 and 2006. Although this sector attracted vast amounts of interest in past research, the present study puts forward a new understanding of the phenomena.
The proposed Luenberger indicator decomposition adapted to benchmarking purposes leads to *TFP*- and organisational-wise interpretations. By comparing the real units' performance against selected reference points, we observe both benchmark's and the analysed bank's behaviours. Besides, the indicators provide the traditional static productivity and efficiency measures.

In our specific case we established as reference units the leaders with respect to market share. However, within the proposed methodology this can be done in accordance with the analysed unit's interest. While this specification is proper for large banks, the situation can be different when dealing with local competitors. As a function of the bank's position and behaviour, the benchmark can be established at local or global level and/or at strategic level.

Thus, within the presented scenario, with respect to *TFP*, the benchmarks of private and savings banks are significantly inferior to the mean sample level, while the credit cooperative reference point is fairly equal to the sample mean. Most important, and all-significant, are the changes in the *FR* component. These demonstrate the weight of the introduction of new technologies in a period of continuous expansion and increases of competition in all three Spanish banking sub-sectors. Next, the *TE* components show developments with respect to the organisational practices. On the one hand, *CG* and *SE* show no issues to be dealt with. On the other hand, the *PTE* frontier puts forth good input-output mix employment together with consistency of results over time.

The aim of the analysis was to present an economically meaningful explanation. Nonetheless, we acknowledge that there might be limitations due to our sample and method. Sample-wise there can be extensions to more time periods, as well as analyses of more than one sub-sector all together. This would be possible in the case of establishing common criteria for the benchmark selection. Method-wise, in the case of sample stability over time, convergence ranking tests might be employed so as to evaluate the movements of certain banks and possible catch-up events.

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