Economic Efficiency and Value Maximization in Banking Firms

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Abstract

The objective of this paper is to study economic efficiency in 142 financial intermediaries of eighteen countries over the 1989-1998 period and the relationship between efficiency, productivity change and shareholders wealth maximization. A non-parametric frontier analysis (DEA) is applied to estimate the relative efficiency of commercial banks of different geographical areas. Then, a Malmquist decomposition is carried out in order to separate efficiency change from technical change. We evaluate the relationship between economic efficiency and wealth maximization and we identify the characteristics of financial intermediaries that lead to an optimal use of resources. Results show different productivity patterns among the three geographical areas (North America, Japan and Europe) over the sample period. The estimates of economic efficiency and productivity changes are consistent with the wealth maximization criterion in financial intermediaries.

Key words: Bank Efficiency, Malmquist index, DEA, Value Maximization

1. INTRODUCTION

The banking industry is constantly and rapidly evolving. The last two decades, in particular, represent a substantial metamorphosis for banking sectors in countries around the world. On the one hand, the rapid advances achieved in information technology have notably altered the way banks do business. On the other hand, deregulation and re-regulation have been a common denominator in banking industries across the world, although their effects are likely to differ across countries[1]. The study of the effects of technological transformations and regulations on the banks' production practices and, hence, on bank production frontiers has give rise to a growing body of empirical literature.

Although regulation constraints the expansion of banking activity, both geographically and across banking product lines, financial innovation bypasses regulatory processes. These changes in regulation reinforce the competitiveness among different financial institutions. After an adjustment process, the raise in competition induces a raise in banking productivity.

In this paper we explore the changes in banking productivity of a group of banks that belong to different competitive environments and also different regulatory environments in the period 1989-1998. In order to measure banking productivity it is possible to use both parametric and non-parametric methods. We adopt a non-parametric DEA-like methodology to estimate and decompose Malmquist productivity index, with the aim of identifying those banks which shift the frontier and the effect of these shifts on the rest of banks. We complete our analysis with the estimation of the relationship between the banks' market returns and the components of productivity change.

We measure productivity change using Malmquist productivity indexes which are computed using linear programs. Using total assets as a proxy for size, we make three groups and study productivity changes in each of them. Finally, we have studied the relationship between the components of productivity change and bank stock performance with the objective of determining how cumulative market returns may be explained in terms of productivity growth.

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[1] See Berger et al. (1995) for a more detail description of the technological and regulatory changes in US banking. See Altunbas et al. (2000) and Molyneux et al. (1996) for a study of Japanese banks and Altunbas and Molyneux (1996) for a study of EU banking.

The next section describes the previous literature, then we introduce the database and the variables selected to define the bank production function. In fourth section we introduce the methodology used to estimate efficiency and productivity change. In the fifth section we present efficiency and productivity changes results. In the sixth section we explore the relationship between productivity changes and bank stock returns and in the final section we conclude.

2.REVIEW OF THE RELEVANT LITERATURE

The analysis of productivity change and its sources in financial intermediaries has drown the attention of the scholars resulting in a wide and diverse literature on the subject along the last two decades. This line of research approaches the efficiency and productivity of banking firms considering how productivity changes are motivated and driven by changes in regulation, differences across countries and the effect of innovation and technological processes.

These works show a disperse evidence which precludes a direct comparison of productivity changes in different geographical areas over the same time interval due to differences in the chosen methodology to estimate efficiency and productivity, not only because of the classical distinction between parametric and non-parametric methods but also due to differences in the chosen productivity decomposition. Also, the existence in the previous literature of alternative time intervals and other differences such as the size of the banks included in the sample preclude an international comparison of the evolution of the productivity in areas with different legal and institutional frameworks.

Elyasiani and Mehdian (1995) working with U.S. data selected 1979 and 1986 as rough proxies for the pre and post-deregulation periods. Using DEA they calculated efficiency scores for samples of US banks from these two years. They found that ,for large banks, technical efficiency declined by 3% and using a time dependent ratio analysis, technology regressed by 2% over this eight years period.

Recent studies of productivity changes focus on US banks in the post-deregulation period, they consider either total factor productivity growth or technological progress in the US commercial banking industry during the 1980s. Mukherjee et al. (2001) explore productivity growth for a group of large commercial banks over the period from 1984 to 1990. They find overall productivity growth at the rate of 4.5% per year on average[2]. They also find that larger banks and higher specialization of product mix are associated with higher productivity. Alam (2001) studies bank productivity over the period 1980 to 1989 and find that productivity movements are mainly attributable to technological change rather than scale changes or convergence to the frontier.

Whelock and Wilson (1999) study productivity change of US banks over the period from 1984 to 1993. They find that banks of all sizes experienced declines in technical efficiency and productivity also decline on average. They claim that this decline is attributable to a minority of banks in each size category pushing forward the frontier, while the rest do not follow within the time interval that was considered. They do find technological progress over the period.

Grifell-Tatjé and Lovell (1997) found that commercial banks had lower productivity growth than saving banks during the period 1986-1993. In a subsequent paper, Grifell-Tatjé and Lovell (1999) analyze the sources of profit growth in Spanish commercial banks during the period 1987-1994, finding a large increase in bank productivity. This effect was offset by a large negative price effect due to increasing competition. The increase in productivity is entirely attributed to technological progress, and is partially offset by negative catching up. The same result—technological progress, negative catching up, and an overall increase in productivity—is also found in Kumbhakar et al. (2001) and Maudos (1996).

Productivity growth in Asian banking has received little attention in the literature. In the case of Japanese banks, Fukuyama (1995) reports large indexes of technological progress and moderate negative indexes of catching up in a sample of 155 banks during 1989-1991. Leightner and Lovell (1998) also report increases in production and total factor productivity in a sample of Thai banks during 1989-994. Thus, the increases in productivity and technological progress during the late 80s and early 90s conform a consistent finding across the world, with the exception of Portuguese banks (Mendes and Rebelo, 1999).

Some studies also analyze productivity variation not along time but across countries. For example, Dietsch et al. (2001) have used a Malmquist decomposition to

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[2] They claim that, after an initial adjustment period to deregulation, banks would be expected to increase their productivity. However they comment that the majority of prior commercial bank total factor productivity studies find either little, no or even negative productivity growth. See Humphrey (1991,1993); Hunter and Timme (1991) and Bauer et al. (1993) for parametric methods used to estimate productivity growth and Wheelock and Wilson (1999) for a non-parametric approach.

explain the productivity gaps of banking industries across four major countries in Europe, being able to separate productivity differences into pure technological differences and differences due to environmental or external factors. Berg et al. (1994) made cross-country comparisons using cross-section data of banks from three Nordic countries, finding important differences between them.

All the papers cited above refer to productivity growth during the 80s and early 90s, and few of them make inter-country productivity comparisons. This paper aims to extend previous literature by analyzing the evolution of bank productivity during the 90s in a wide variety of countries. To accomplish this task, we use a complete panel of 142 banks from eighteen different countries covering the period 1989-1998. In particular, we will analyze productivity change in banks located at three different geographical areas (Europe, Japan, and North America) computing Malmquist productivity indexes. The decomposition of the Malmquist index will allow to explain the manner in which productivity growth or regress was attained. We also study the relationship between the components of productivity growth and bank stock performance. The objective is to evaluate whether our estimates of productivity changes are consistent with the wealth maximization criterion in financial intermediaries. Thus, our paper complements and extends the previous literature.

Contrary to most of previous literature we will use the decomposition of the Malmquist productivity index proposed by Simar and Wilson (1998) and Zofio and Lovell (1998), which adds more information than the classical decompositions of Färe, Grosskopf, Norris, and Zhang (1994) and Ray and Desli (1997).

3. DATABASE AND VARIABLES

An output efficient firm is one which cannot increase its output unless it also increases one or more of its inputs. We use DEA to define the boundary of the technology and obtain efficiency score for each bank in each time period. We have obtained the data for this study from Worldscope which covers public company financial data of firms that quote. The final database contains 142 commercial banks from 18 countries (see table I) from 1989 to 1998[3]. We have created three groups according to geographical proximity: Europe, Japan and North America. Europe

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[3] We did have complete data sets for European and North American banks for 1999 but there were missing values in the Japanese banks data set for 1999.

includes the first 15 countries in Table I and North America includes US and Canada. Japan is a geographical group in itself.

Germany (6)	France (4)	Sweden (3)
Austria(3)	Ireland (1)	Switzerland (3)
Belgium (1)	Italy (12)	UK (7)
Denmark (3)	Luxemburg (1)	USA (45)
Spain (11)	Norway (1)	Canada (8)
Finland (1)	Portugal (2)	Japan (30)

Table 1 – number of banks and country of origin
In brackets the number of commercial banks per country

The availability of data is a key determining factor when choosing a production function. Taking this factor into account is more important when the database includes firms from different countries. When defining the bank function we considered that although all the selected banks fall into the same category (commercial banks), this classification refers to the main business line of the bank and does not consider other business lines. Thus, there may be differences in terms of the bank production function in different geographical areas. Depending on the country of origin, banks are (were) not allowed to perform simultaneously various activities (e.g. private and investment banking versus retail banking) or were limited geographically in their activities.

We have chosen a mix of stock and flow variables to account for the differences in business activities of commercial banks in the three geographical regions[4].The selected variables that define the bank production function are shown in Table 2.

Class	***Description***	***Variable type***
Output 1	INVESTMENTS - TOTAL	Level
Output 2	LOANS - TOTAL	Level
Output 3	NON-INTEREST INCOME Plus OTHER OPERATING INCOME	Flow
Input 1	PROPERTY, PLANT AND EQUIPMENT - NET	Level
Input 2	SALARIES AND BENEFITS EXPENSES	Flow
Input 3	OTHER OPERATING EXPENSES	Flow

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[4] It is possible to choose among stock (Balance Sheet) and flow (Profit & Loss Account) variables. The choice of stock values instead of flow variables (Resti, 1997) is justified by the argument that flow variables would be biased by market power because different banks charge different rates. Within this line of argument, it is assumed that the differences in rates have nothing to do with efficiency or input consumption. However, the differences in rates may be attributed to differences in the creation of value to customers. Efficiency measures, either based on economic or production costs, should be defined so that there is a complete set of inputs and outputs which result in a meaningful production function to estimate efficiency.

Input 4	DEPOSITS - TOTAL	Level

Table 2 – Bank production function: selected inputs and outputs

Regarding outputs we have considered three outputs: a) total investments, b) total loans and c) non-interest plus other operating income. Although there may be some overlapping regarding "non-interest plus other operating income" and the previous two outputs we try to capture possible differences in the asset side of commercial banks activities in the three geographical regions. Also, even if this third output were to be superfluous it would have a reduced impact on our results given that we are estimating efficiency and productivity using DEA like linear programs.

When considering loans we have chosen total loans instead of net loans due to problems with Japanese banks and with some European banks. Net loans in these commercial banks were zero. Thus, including net loans would penalize mainly North American banks were reserve for loan losses are properly accounted for. Basically, we have many missing data values in European and Japanese commercial banks when trying to desegregate total loans, thus we have selected the aggregated values.

Regarding inputs we have considered four inputs: a) property, plant and equipment net, b) Salaries and benefit expenses, c) other operating income and d) total deposits. There is some disagreement concerning the role of core deposits as an input or output (Sealey and Lindley, 1977). It is argued that they are an input to the production of loans or alternatively they are considered an output, because they involve the creation of added value (Berger and Humphrey, 1993) and customers are willing to bear an opportunity cost through lower interest rates on their deposits. We decided to consider deposits as inputs[5] and we have included only a single input "aggregate total deposits" due to lack of quality of disaggregated data[6].

Mester (1996) includes *financial capital* as and input to the bank and adjusts efficiency measures for the quality and riskiness of its output. Also accounting for risk, Clark (1996) tested a broader concept of cost, *economic cost*, which is constructed by adding production costs to the opportunity cost of capital. It is claimed that this new

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[5] The following studies choose the specification of deposits as inputs: Humphrey (1991), English et al. (1993), Lang and Welzel (1996) and Adams, Berger and Sickles (1999) and Alam (2001). Adams, Berger and Sickles (1999) present preliminary results indicating that this specification is favored based on statistical grounds.

[6] More specifically, the field "unspecified deposits" was empty for North American banks but it represented an important proportion of total deposits for Japanese and European banks.

measure of cost should be considered as an improved measure of efficiency. It is argued that the assessment of the competitive viability of banking firms should consider the effects of resource allocation decisions on risk and return as well as on the explicit costs of production. Alam (2001) and Mukherjee et al. (2001) include bank equity capital as input. Given that we consider commercial banks from different geographical areas, we face a dilemma: how to measure equity capital. If we measure equity capital using accounting data we find problems with Japanese banks which do not account properly for reserves for loan losses and thus accounting equity capital is not a reliable input. Alternatively, if we measure equity capital using market data, then we have a more reliable measure of equity capital, but, as shown in Graph I, we would penalize those banks that are performing better. That is to say, if we consider a market measure of equity capital then North American banks and to a lesser extend European banks would have a higher input because the value of their shares has risen dramatically while the market value of equity of Japanese banks has diminished. Thus we decided not to include any measure of equity capital.

We compare simultaneously commercial banks from the three geographical areas and thus we have chosen broad categories when faced with the decision to choose the inputs and outputs that define the bank production function. Although we have no desegregation of deposits and loans, although we have not included equity capital for the reasons given above and although we did not have the number of employees and use salaries and benefits expenses as a proxy we believe the bank function is an adequate one. Thus, our variables, in particular deposits and loans, are aggregates the reason being that with these aggregates it is possible to have same variables for banks in different countries and regions and with somewhat different accounting standards. We may not be able to study the effect of specialization of product mix on productivity as in Mukherjee et al. (2001) however, we are able to study overall efficiency and productivity change components of banks. Also, our bank production function definition is similar to model 4 of Alam (2001)[7].

In Table 3 we show descriptive statistics of inputs, outputs and total assets of banks in the three geographical areas that we consider in our study: Europe, Japan and

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[7] In model 4, the more aggregated model, Alam (2001) considers two outputs (securities and Total loans) and four inputs (Bank Equity capital, physical capital, full time employees and total loanable funds). We include an additional output which considers the inflows via non-interest income and other operating income and regarding inputs we do not include bank equity capital but we include other operating expenses.

North America. As it can be observed, European commercial banks in our sample are larger than North American banks and North American banks are larger than Japanese banks. This may be due to the fact that some large North American and Japanese banks may have been excluded from the sample when we required complete data for the period 1989 to 1998. In terms of standard deviation European and North American banks in our sample are much more heterogeneous than Japanese banks.

All values in Table 3 are in billion USD. Values have been converted into dollars using the corresponding exchange rates as at 1/1/90. We have converted all values using one conversion rate per country so that fluctuations in exchange rates do not affect the Malmquist growth results. Due to our type of analysis, using different conversion rates into dollars (one conversion rate per year per country) would lead to misleading results. That is to say, if a conversion rate per year were chosen, then the measurement of productivity change would be biased due to the fluctuations of exchange rates. We do have deflated values using CPI of the relevant country and year and using 1989 as the base year[8].

(Billion USD)	Europe		Japan		North America	
	Mean	SD	Mean	SD	Mean	SD
Outputs						
Output 1	11.26	(22.84)	2.55	(1.39)	7.20	(14.03)
Output 2	38.65	(57.28)	9.72	(4.47)	20.15	(29.83)
Output 3	1.18	(2.97)	0.05	(0.05)	0.74	(1.36)
Inputs						
Input 1	0.72	(1.01)	0.16	(0.08)	0.41	(0.61)
Input 2	0.63	(0.93)	0.10	(0.03)	0.48	(0.73)
Input 3	0.54	(1.33)	0.07	(0.03)	0.29	(0.45)
Input 4	25.81	(36.56)	11.93	(5.60)	21.37	(30.67)
Total assets						
Total assets	55.48	(82.81)	13.60	(6.31)	30.74	(48.35)

Table 3 – Summary of descriptive statistics

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[8] Data for exchange rates and CPIs come from Datastream series.

4. METHOD

This section briefly explains the foundations of the computation of Malmquist productivity indexes and their decomposition with non-parametric estimators. In order to estimate efficiency and productivity growth in the banks that conform the sample, we will follow a non-parametric approach to the computation and decomposition of the Malmquist productivity index. Several different decompositions of the Malmquist index have been proposed. The most commonly used are Färe et al (1994) which assumes a constant returns to scale technology and Ray and Desli (1997) which does not require that assumption. Previous literature on the analysis of bank productivity has used both of these approaches. For instance, Alam (2001) used the Malmquist productivity decomposition suggested by Färe et al. (1994), while Mukherjee et al. (2001) followed the decomposition proposed by Ray and Desli (1997). A third decomposition has been recently suggested by Simar and Wilson (1998) and Zofio and Lovell (1998), which extends Ray and Desli (1997) decomposition. In particular, the technical change component in Ray and Desli (1997) is further decomposed into "pure" technical change of the frontier plus a residual measure of scale change of the technology. Wheelock and Wilson (1999) has been the first paper that applies this enhanced decomposition to the study of productivity change in banking. In this paper, we will also follow this decomposition because it adds more information about the sources of productivity change.

The Malmquist productivity index was introduced by Caves, Christensen, and Diewert (1982) as the ratio of two distance functions pertaining distinct time periods[9]. The productivity level of a firm may be measured by the relationship between the inputs employed and the outputs attained. In the case of a technology with just one input and one output, a productivity index can be computed using just quantity data as the ratio y_i^t / x_i^t, being y_i^t the quantity of output produced by firm *i* at period *t* and x_i^t the quantity of input employed by that firm during the same period.

A difficulty arises with multidimensional production technologies, which involve comparing vectors of inputs and outputs. In those cases it is necessary to use a criterion to aggregate inputs and outputs. The resulting productivity index can be defined as $g^t(\mathbf{y}_i^t)/h^t(\mathbf{x}_i^t)$, where $g^t(\mathbf{y}_i^t) = \mathbf{u}^t \mathbf{y}^{t\,\prime}$ is an output aggregating function,

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

being $\mathbf{u}^t$ the weighting vector, and $h^t(\mathbf{x}_i^t) = \mathbf{v}^t \mathbf{x}^{t\,\prime}$ is an input aggregating function, being $\mathbf{v}^t$ the weighting vector. But how must those weights be chosen? An obvious possibility is to use the prices of inputs and outputs. The Malmquist index allows computing the former index using just data on quantities. It is computed as a ratio of distance functions and the computation of those distance functions implicitly generate appropriate weights for inputs and outputs.

Given that distance functions are computed by comparison between a firm and another firm that acts as referent or benchmark, because it is considered to be optimal, we must define a relative productivity index as the ratio between the absolute productivity index of the firm (defined above) and the absolute productivity index of the benchmark firm. This relative productivity index (*RP*) can be defined as:

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

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

It is possible to compute the *RP* index using distance functions, but we must first formulate some assumptions about the production technology —constant returns to scale (i.e. first degree homogeneity) and separability of inputs and outputs—. The output distance function is defined with respect to that technology as[10]:

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

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

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

$$DC_i^t(\mathbf{x}_i^t, \mathbf{y}_i^t) = \max \quad \theta = \frac{\mathbf{u}^t \mathbf{y}_i^{t\,\prime}}{\mathbf{v}^t \mathbf{x}_i^{t\,\prime}}$$

$$(3) \qquad s.a \quad \frac{\mathbf{u}^t \mathbf{y}_j^{t\,\prime}}{\mathbf{v}^t \mathbf{x}_j^{t\,\prime}} \leq 1 \quad , \quad j \in J$$

$$\mathbf{u}^t, \mathbf{v}^t \geq 0$$

where *J* represents the set of firms used to construct the empirical reference technology, which are generically denoted with the subindex *j* to distinguish them from the firm that is being evaluated, *i*. The program finds the weights that maximize the relative productivity of firm *i*. The objective function measures the distance that separates this firm from the benchmark firm in terms of productivity. Thus,

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

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

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

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

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

To avoid choosing arbitrarily among taking period t or period t+1 technology as the reference to compute the Malmquist index, a usual way to proceed is to take the geometric mean of both extreme indexes,

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

If $M_{CCD}(\mathbf{x}_i^{t+1}, \mathbf{y}_i^{t+1}, \mathbf{x}_i^t, \mathbf{y}_i^t) > 1$, the index reflects a productivity growth that may come from different sources. First, it is possible that the firm did improve its level of efficiency relative to the benchmark firm—i.e., the firm did improve more than the benchmark firm—. Second, the available technology may have also improved—recall that we have fixed the technology—. Färe, Groskopf, Norris, and Zhang (1994) proposed a first decomposition of the Malmquist index that separates both sources of productivity variation,

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

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

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

The efficiency change index may in turn be decomposed in two indexes. One of them measures the change in pure technical efficiency—and must be computed with respect to the variable returns to scale technology—and the other one measures scale efficiency change. Let

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

be the output distance function defined with respect to the T_{BCC}^{t} technology, that satisfies the assumptions in Banker, Charnes, and Cooper (1984)[11]. The BCC technology drops the CRS assumption and imposes only the convexity assumption. The BCC production set is said to satisfy variable returns to scale (VRS). We can compute a residual scale efficiency index comparing the two distance functions defined above,

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

and, therefore,

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

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[11] The linear programs used to compute this index can be found in Banker, Charnes, and Cooper (1984). A more exhaustive treatment of the non parametric approach to efficiency measurement and the properties of the different distance functions employed can be found in Färe, Grosskopf, and Lovell (1994).

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

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

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

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

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

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

It must be noted that the distance functions that are used to compute the indexes of technical change with respect to the BCC technology do not necessarily have a bounded solution. This happens because the radial projection of the firm's input-output vector towards the BCC frontier of other period—$DV_i^{t}(\mathbf{x}_i^{t+1},\mathbf{y}_i^{t+1})$, for instance—does not necessarily belong to that frontier. In the cases that this happened in our empirical application, for output oriented unbounded solutions, we changed the orientation of the distance function to an input distance function to get a bounded solution that approximates the real movement of the technology. This solution seems appropriate because the problem with the unbounded solution in the computation of the output distance function reflects that the movement of the technology was an input reducing or augmenting movement relative to the previous period[12].

5. RESULTS

5.1. Technical and scale efficiency

Table 4 summarizes the evolution of technical and scale efficiency scores during the period 1989-1998. The table shows the year average of the technical efficiency scores computed under constant returns to scale (DC) and under variable returns to scale (DV), the residual scale efficiency score (SE), and standard deviations in brackets. The table reveals that a significant improvement has occurred during the period as reflected by the three indexes. Technical efficiency (DC) increased from a mean value of 0.579 in 1989 to 0.717 in 1998. This result reflects a reduction in the distances separating the best practices from the rest and, thus, a reduction in the heterogeneity in the production practices. The standard deviations shown in brackets confirm this reduction in heterogeneity. Despite this notable improvement, the value of the DC index in 1998 indicates that the banks in the sample could still produce a 28% more output without increasing any of the inputs.

Table 4.- Temporal Evolution of Technical and Scale Efficiency

Years	**DC**		**DV**		**SE**	
1989	0.579	(0.21)	0.653	(0.21)	0.897	(0.15)
1990	0.621	(0.20)	0.693	(0.20)	0.902	(0.14)
1991	0.619	(0.21)	0.685	(0.21)	0.911	(0.14)
1992	0.655	(0.20)	0.718	(0.20)	0.917	(0.12)
1993	0.725	(0.19)	0.785	(0.19)	0.927	(0.10)
1994	0.677	(0.19)	0.745	(0.20)	0.915	(0.09)

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[12] In our empirical application we found 9 problems of unbounded values out of 142 observations. We checked out other possibilities to the unboundedness problem as substituting the unbounded value by 1 or omitting the observation that presented the problem in the computation of averages. We found that the average results reported did not vary significantly regardless of the treatment given to unbounded values.

1995	0.707	(0.19)	0.760	(0.20)	0.933	(0.09)
1996	0.742	(0.19)	0.777	(0.18)	0.956	(0.07)
1997	0.725	(0.18)	0.761	(0.18)	0.954	(0.07)
1998	0.717	(0.18)	0.754	(0.19)	0.954	(0.07)
Average	0.677	(0.20)	0.733	(0.20)	0.927	(0.11)

The decomposition of the DC index provides some insights about how the overall improvement in technical efficiency has been achieved. Table 4 shows that the improvement has been largely due to an enormous increase in pure technical efficiency (DV), from a value of 0.653 in 1989 to 0.754 in 1998. Scale efficiency has also contributed to the improvement in technical efficiency. The banks are now positioned nearer to the optimal scale, as reflected by the increase observed in SE indexes, from 0.897 in 1989 to 0.954 in 1998. Although pure technical efficiency has experimented the largest increase it is still the main source of inefficiency.

Table 5 offers a comparison between the average efficiency levels of the banks operating at each of the three geographic zones present in the sample: Europe, Japan and North America. Mean technical efficiency in European and Japanese banks is significantly larger than in North American banks, as confirmed by the Kruskal-Wallis means test[13]15. If we just look at the means we would not be able to appreciate the enormous difference that exists between European and Japanese banks. The great majority of banks leading the production frontier are European. In other words, 23% of European banks are completely efficient, while only a 5.7% of Japanese and 6% of North American banks get DC scores of 1. Still average efficiency is the same in Europe and Japan due to the great dispersion that exists in European DC scores, as evidenced by the large value of the standard deviation.

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

Differences between geographic zones concerning pure technical efficiency and scale efficiency are more pronounced. On average, the best managed banks are the European banks, with a DV score of 0.78 and 38.8% units being completely pure-efficient, followed by Japanese banks, with a 0.73 average score. On the opposite hand, Japanese banks are the most scale-efficient, with an average SE score of 0.97, quite close to the absolute efficient scale. The Kruskal-Wallis test shows that these differences across zones are statistically significant at conventional levels. It is also noticeable that there is quite less within group variation regarding scale efficiency than pure efficiency. This result suggests that there is more variation in managerial practices than in sizes.

Table 5.- Efficiency Scores by Geographic Zones

	DC			**DV**			**SE**		
	mean	**s.d.**	**DC=1**	**mean**	**s.d.**	**DV=1**	**mean**	**s.d**	**SE=1**
Europe	0.71	(0.23)	23.1%	0.78	(0.23)	38.8%	0.91	(0.13)	23.1%
Japan	0.71	(0.13)	5.7%	0.73	(0.13)	7.0%	0.97	(0.03)	5.7%
North America	0.62	(0.18)	6.0%	0.68	(0.19)	13.4%	0.92	(0.11)	6.0%
K-W test : χ^2	69.9***			73.5***			35.9***		

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

5.2. Decomposition of the Malmquist productivity index

The temporal evolution of the Malmquist productivity index is shown in Table 6. On average, bank productivity has grown a 19.6% from 1989 to 1998. The period 1992-1993 shows the largest productivity growth with a 7.9%, followed by 1997-1998 with a 7.7%. The decomposition of the Malmquist productivity index helps explain the manner in which productivity growth was attained. Focusing on relative efficiency, the decomposition shows an extremely large improvement in pure technical efficiency during the period 1989-1998, with an average increase above 25%. This improvement was achieved mainly during the first 4 years of the period, from 1989 till 1993. Again, 1992-1993 was the period with the largest improvement in pure efficiency, with an average increase of 14%, followed by 1989-1990 with an 8.6% and 1991-1992 with a 7.5%. Changes in scale efficiency have been more moderated and more evenly distributed throughout the period. The average gain in scale efficiency from 1989 to

1998 was near 10% and may be a visible consequence of the merging processes that have occurred during the period, that have resulted in new entities with a more productive scale. These two indexes (pure efficiency change and scale efficiency change) conform the efficiency part of the Malmquist productivity index, and reflect a notable movement of inefficient banks towards the best practice frontier.

Table 6.- Decomposition of the Malmquist index

Period	M_{CCD}	$\Delta PE^{t,t+1}$	$\Delta SE^{t,t+1}$	$\Delta T_{BCC}^{t,t+1}$	$\Delta S^{t,t+1}$
1989-1990	1.013	1.086	1.012	0.972	1.009
1990-1991	1.028	0.990	1.012	1.079	0.995
1991-1992	0.977	1.075	1.016	0.949	1.029
1992-1993	1.079	1.140	1.022	0.977	1.006
1993-1994	0.985	0.951	0.991	1.031	1.018
1994-1995	1.031	1.033	1.024	1.007	0.981
1995-1996	1.041	1.033	1.030	1.003	0.984
1996-1997	1.039	0.986	1.000	1.053	1.003
1997-1998	1.077	0.994	1.001	1.094	0.999
1989-1998	1.196	1.254	1.105	1.023	0.944

The technological part of the Malmquist index is composed by the indexes of technical change and scale change. These components reflect movements of the best practice frontier, rather than movements of the banks towards the frontier. Thus, they show the evolution of the production possibilities. The period has been characterized by a moderated technical progress that has increased the production possibilities of the banks a 2.3% on average. Although the net effect of technical change during the period is positive, technical regress was also observed in three years: 1989-1990, 1991-1992 and 1992-1993. The index that measures the scale change of the technology (SC) is the only one that shows an average value below 1. However, this result may have a positive interpretation, because it indicates an approximation of the optimal scale to the projection of the bank on the VRS frontier. In other words, there is less to be gained by adopting a better scale. This means that scale efficiency scores would be larger even if the banks have not done anything[14].

Table 7 compares the Malmquist index and its components across the three geographic zones represented in the sample[15]. The table shows for each zone the mean and standard deviation of each index and the percentage of banks with a score above 1. On average, productivity has increased in Europe and North America, with a 24% and 27% respectively. Even though Japanese banks are on average 2% less productive, 53.3% of them show a Malmquist productivity index above 1, a larger proportion than in Europe (52.5%). The dispersion around the mean is very large in Europe, reflecting again the great heterogeneity of the European banks included in the sample. Japanese banks have productivity profiles that are much more homogeneous, with a standard deviation of just 0.18. The Kruskal Wallis means test confirms the significance of the differences observed on average productivity.

Table 7.- Decomposition of the Malmquist Index by Zones (1989-1998)

		M_{CCD}	$\Delta PE^{t,t+1}$	$\Delta SE^{t,t+1}$	$\Delta T_{BCC}^{t,t+1}$	$\Delta S^{t,t+1}$
Europe	**mean**	1.24	1.34	1.14	1.01	0.90
	s.d.	(0.66)	(0.56)	(0.38)	(0.49)	(0.26)
	%>1	52.5%	54.2%	50.8%	45.8%	35.6%
Japan	**mean**	0.98	1.04	0.99	0.95	1.02
	s.d.	(0.18)	(0.20)	(0.05)	(0.20)	(0.06)
	%>1	53.3%	50.0%	33.3%	40.0%	66.7%
North America	**mean**	1.27	1.28	1.13	1.08	0.95
	s.d.	(0.37)	(0.46)	(0.21)	(0.39)	(0.31)
	%>1	77.4%	67.9%	73.6%	54.7%	47.2%

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[14] Of course, a negative interpretation of this result is also possible. The result implies that there is less to be gained by scale adjustments and thus fewer directions for improvement through, for example, mergers or downsizing processes.

[15] The figures in the table were computed using data of 1989 and 1998. Thus, they reflect the net variations observed throughout the whole period.

K-W test : χ^2	9.75***	5.93**	14.8***	3.12	8.58**

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

European and North American banks also show large increases in pure technical efficiency, a 34% and a 28% respectively, with a quite large dispersion around the mean value. Although the average efficiency improvement was larger in Europe, only 54% of European banks increased pure efficiency during the period, which contrast with the 68% of North America. The profile is again different in Japan. Japanese banks have only increased pure efficiency a 4% and the dispersion around the mean is relatively small. The differences between Europe and North America and Japan are significant as shown by the value of the Kruskal Wallis test. The same pattern is observed regarding the changes in scale efficiency. There are not appreciable changes in Japanese banks. Recall that most Japanese banks were already completely scale efficient. In contrast, scale efficiency has increased around a 14% in Europe and North America.

There are not significant differences across geographic zones regarding technical change. This result could be expected because, in a globalized world, changes in the technology (in the best practice frontier) should affect all the banks regardless of the geographic zone in which they operate. Only differences in bank size across countries could explain differences in technical change, because the zones could then be confounded with scale intervals in the frontier. This may be the source of the differences observed, because the European banks in the sample are larger on average than North American banks, which in turn are significantly larger than Japanese banks. The index of scale change reflects a movement of the efficient scale towards European and North American banks. There is not an appreciable scale change for Japanese banks, which were already operating near the efficient scale in 1989.

Given that differences in technology change across countries can only be due to differences in bank size, we have compared the Malmquist index and its components across three size intervals based on assets (Small, Medium, Large). Standard deviations are shown in brackets. Note that all our banks are per se large banks. For Mukherjee et al. (2001) large banks are those were assets exceed $1 billion and for Alam (2001) large banks are those were assets exceed $0.5 billion. In our sample, although there exist a significant dispersion between bank sizes, the size of the smallest bank is $0.76 billion while average total assets are $40 billion.

The groups were constructed as to contain approximately the same number of banks. The group of Small banks averages $4.5 billion dollars in assets, Medium sized banks $14.3, and Large banks $100 billion dollars. The group of Large banks experimented the greatest productivity growth with an average Malmquist index of 1.30 between 1989 and 1998. In contrast, Small and Medium sized banks show Malmquist productivity indexes of 1.17 and 1.11. However, due to the great dispersion that exists within groups, the differences across groups in productivity growth are not statistically significant at conventional levels.

Table 8.- Decomposition of the Malmquist Index by Sizes (1989-1998)

	N	*Assets*	M_{CCD}	$\Delta PE^{t,t+1}$	$\Delta SE^{t,t+1}$	$\Delta T_{BCC}{}^{t,t+1}$	$\Delta S^{t,t+1}$
Small	47	4.5	1.174	1.221	1.022	0.873	1.143
		(2.24)	(0.54)	(0.53)	(0.16)	(0.27)	(0.23)
Medium	47	14.3	1.110	1.251	1.006	0.925	1.003
		(4.82)	(0.36)	(0.47)	(0.03)	(0.25)	(0.09)
Large	48	100.0	1.301	1.290	1.282	1.267	0.691
		(80.9)	(0.56)	(0.44)	(0.41)	(0.53)	(0.17)
K-W test : χ^2			3.40	0.31	27.6***	18.1***	102.0***

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

There are not significant differences across groups regarding the index of pure efficiency change. This result reflects that the catching up effect did not depend on bank size. The results show a very different pattern with respect to the index of scale efficiency change. Large banks show a large improvement of 28.2% in scale efficiency, while the Small and Medium sized banks did not experiment important changes. Thus, the efforts of large banks to get a more scale-efficient through mergers and/or acquisitions seem to have had positive results.

Technical change also differs markedly across size groups, reflecting a non-neutral shift in the production technology. Technical regress is observed in the groups of Small and Medium sized banks and a large index of technical progress is achieved by Large banks. This result means that the technology has generated more production possibilities that can be enjoyed by Large banks and has eliminated some productive options for smaller banks. It could be because small efficient banks have increased their sizes more than inefficient small banks. There are also significant differences regarding the scale change of the technology. The efficient scale for small banks in 1998 has moved away from the standard in 1989, as reflected by the scale change index of 14%. Thus Small banks that have not increased their sizes are today more scale inefficient than they were before. There is more to gain today by scale adjustments. The opposite profile is observed in the part of the technology populated by Large banks. Large banks do have now less to be gained by scale adjustments than they had in 1989. This means that even if they have not changed their scales, they are more scale efficient now. These results are consistent with a technological change that has shifted the efficient scale upwards.

6. LINKING PRODUCTIVITY CHANGE AND MARKET RETURNS OF BANKS

Once we have analyzed efficiency and productivity change in the sample, we turn in this section to the study of the relationship between the components of productivity growth and the changes in the market value of the banks. The objective is to test whether bank stock performance may be partially explained by the different components of productivity change.

6.1 Productivity growth and market returns framework

It is common to rank firms according to productivity change and/or stock performance. Both rankings try to evidence the differences between firms that perform better and firms that perform poorly. In a semi-strong efficient market where most of the information available is incorporated into stock prices, stock value performance is, as it is widely accepted (Brealey and Myers, 1991, p. 915), the best estimate of value creation for shareholders. As productivity growth has an unambiguous effect on value creation, it is reasonable to expect that firms with higher productivity growth will have a better performance in the stock exchange market.[16].

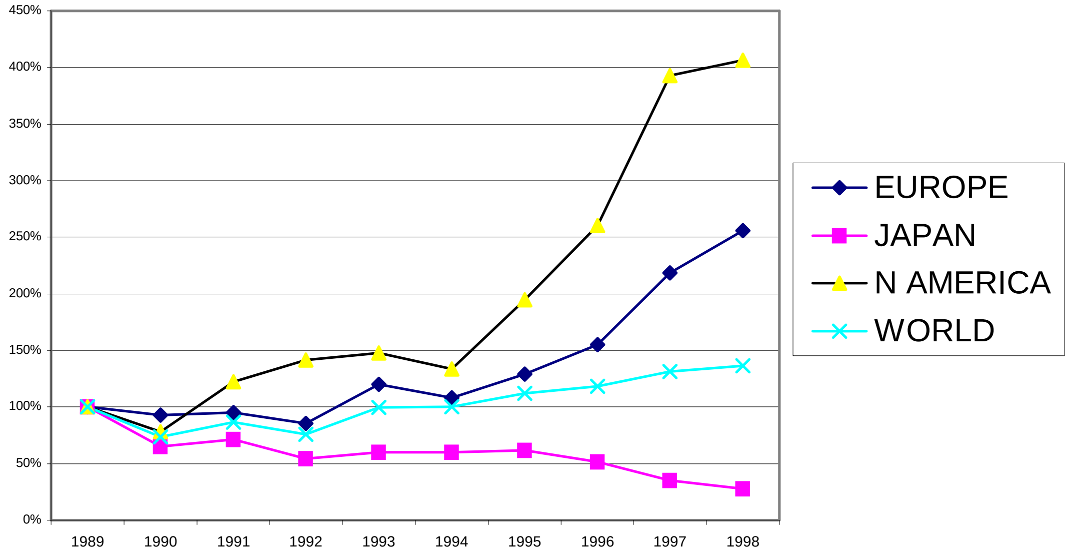

Figure 1.- Evolution of DataStream Bank price indexes

Figure 1 depicts the temporal evolution of commercial banks price indexes from December 1989 to December 1998 in the three geographic areas considered in this study and a fourth world-average index[17]. The figure shows that, during the period considered, the North American index has grown faster than the European and the World indexes. Unlike the trends observed in the Europe and America, the Japanese index at the end of the period was lower than at the beginning of the period. Thus, we see important differences in terms of value creation for shareholders that invested in the same sector (commercial banks) but in different geographical areas. Part of these differences may be explained by environmental factors that have affected different geographical areas unevenly. Another part of the differences could have an explanation in terms of the differences in productivity growth across geographic areas that we have reported in the previous section.

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[16] Alternative business performance measures such as the Tobin Q (Tobin, 1969) could have been considered. However, we lack information to calculate Tobin Q. Also, accounting profit may be a more stable measure of business performance. However, it is fully related to past performance instead of expected future performance. In the case of Tobin Q, it is expected that, even after accounting for assets replacement costs, the ranking of banks would have been the same according to stock performance and according to Tobin Q.

[17] These are Datastream indexes: BANKSER(PI) for European commercial banks, BANKSJP(PI) for Japanese commercial banks, BANKSNA(PI) for North American banks, and BANKSWD(PI) for World commercial banks.

In order to determine the relationship between the components of productivity growth and stock prices, we use our 1989-1998 panel. Given that productivity growth indexes refer to pairs of years, we will have a panel of 142 banks and 9 time periods, from 1989-90 to 1997-98. There are 81 missing values corresponding to banks which market returns could not be determined for some of the years of the panel. We also excluded an outlier bank that had a market return in one of the years of the panel of 727%, when the average variation is 14.6%[18]. The final number of observations in the sample is 1196.

The availability of panel data allows to control the effect of unobserved heterogeneity, i.e. unobserved variables that may affect the dependent variable but do not vary across units (time effects) or along time (individual effects). A generic panel data regression model can be expressed as:

$$y_{it} = \alpha_i + \delta_t + \beta \mathbf{x}'_{\mathbf{it}} + u_{it} \qquad (13)$$

where *y* is the dependent variable, **x** the vector of explanatory variables, and *u* is the random error term. Subindexes *i* and *t* refer to the individual and the time period, respectively. Coefficients α_i are the individual effects that capture the time invariant effect of unobserved characteristics of each individual on the dependent variable (unobserved heterogeneity). Similarly, coefficients δ_t are time effects that capture the effect of period *t* which is common across individuals.

Individual and time effects can be considered fixed parameters or random variables. The appropriate model depends on the specific setting of the analysis. When the specific value of the effect of a bank is of interest, then the fixed model is more appropriate[19]. Also, the Hausman (1978) test can be run to test the hypothesis of no correlation between the effects and the explanatory variables. Unlike in a fixed effects model, consistency in a random effects model rests on the assumption that there is no correlation between the effects and the explanatory variables. In this study, the

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[18] We run various regressions with and without this observation and found that it had an influential effect on some of the estimated coefficients. This fact reinforced the decision of excluding the observation.

[19] See Greene (1993: pp. 479-480) for a deeper discussion about the differences between the fixed and random effects models.

Hausman test rejected the hypothesis in all the models that we have estimated, reinforcing the choice of a fixed effects model[20].

The explanatory variables in our model are the four components of the Malmquist productivity index. We expect a positive effect of pure efficiency change and scale efficiency change on bank market returns. It is more difficult to establish the relationship between the technological components of the Malmquist index (technical change and scale change of the technology) and changes in market value. There may be technical progress that is not enjoyed is not enjoyed by an important number of observations. Technical progress is common to all the banks in a given size interval, but some of them may improve their results while others may not, as we have seen in the previous section. There is another problem with the technological components. Given that technical change (and the scale change of the technology) is common for all the banks of similar size, its effect might be highly correlated with the time effects. For this reason, Table 9 shows the results of the model with and without the time effects.

Table 9. Components of productivity as drivers of market value

	Individual effects only		Individual and time effects	
	Coefficient	t-test	Coefficient	t-test
Intercept	-	-	-0.019	-0.08
$\Delta PE^{t,t+1}$	0.264	4.08***	0.291	5.01***
$\Delta SE^{t,t+1}$	-0.063	-0.44	-0.152	-1.23
$\Delta T_{BCC}^{t,t+1}$	0.181	2.13**	0.051	0.68
$\Delta S^{t,t+1}$	0.035	0.37	-0.040	-0.48
R^2	0.19		0.40	

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

The results show a strong relationship between pure efficiency change and changes in market value, as it was expected. However, there is no relationship between

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[20] The fixed effects model can be estimated using the Ordinary Least Squares Dummy variables estimator or using the WITHIN estimator.

scale efficiency change and changes in market value. A possible explanation for this result may be that changes in scale efficiency are discounted in the stock price far before the scale efficiency improvements are actually achieved. Such may be the case with most announcements of bank mergers, which (positive or negative expected effects) are rapidly discounted by the market. Alternatively, it may be due to an inadequate treatment of merger processes in our sample due to a lack of data.

Technical change has a positive and statistically significant effect on bank market value when time effects are not included in the model. As it was expected, technical change is strongly correlated with time effects and its coefficient is not significantly different from zero when we include the time effects in the model. These results suggest that most banks benefit from the technical change leaded by the banks on the frontier, as reflected in their stock prices. In contrast, there is no significant effect associated with the scale change of the technology. The reason may be the same as for the effect of scale efficiency changes. It seems that the market is able to discount the effects of technological changes that affect the optimal scale before the banks can actually enjoy them.

7. CONCLUSIONS

In this paper we have studied the evolution of productivity in a complete panel of 142 banks operating in eighteen different countries over the period 1989-1998. Our objective was to extend the results from previous research, covering the 1990s decade in three different geographic areas as North America, Europe, and Japan. Our results have evidenced that commercial bank productivity across the world has grown significantly during the 1990s and that this effect has been principally due to relative efficiency improvement or catching up, with a very moderate effect of technological progress.

Our estimates of efficiency scores show large gains over the period considered, which were primarily due to growth in pure technical efficiency, which increased from an average of 0.65 in 1989 to 0.75 in 1998. Scale efficiency has improved less on quantitative terms, although the average score in 1998 (0.95) comes close 1, i.e. to absolute scale efficiency. Our results have also evidenced pronounced differences between geographical areas. Mean technical efficiency in European and Japanese banks during the 90s has been significantly larger than in North American banks. The great majority of banks leading the production function were European banks (23% of European banks are completely efficient) while only 5.7% of Japanese banks and 6% of North American banks were also leading the production function. Differences between geographical zones concerning pure technical efficiency and scale efficiency are even more pronounced. According to our results, on average, the best managed commercial banks were the European banks, while Japanese banks were the most scale efficient.

We also computed Malmquist productivity indexes using linear programming DEA techniques. Unlike most of previous research, we used the enhanced decomposition of the Malmquist index proposed contemporaneously by Simar and Wilson (1998) and Zofío and Lovell (1998). Overall bank productivity has grown a 19.6% from 1989 to 1998. Productivity growth was mainly due to the large improvement of pure technical efficiency, above 25% on average. The scale efficiency gain along the period 1989-1998 was of 10%. Regarding the technological part of the Malmquist index, the period has been characterized by a moderate technical progress of 2.3%. The residual index that measures the scale change of the technology presented a less than one value, indicating that there is less to be gained by adopting a better scale.

Results show markedly different productivity patterns among the three geographical zones represented in the sample. On average, productivity has increased significantly in Europe (24%) and North America (27%), due principally to large increases in pure technical efficiency. On the opposite hand, Japanese banks experienced a productivity decline of 2%, due to technological regress. The dispersion of productivity indexes was found to be extremely large in Europe, reflecting the great heterogeneity of the European commercial banks included in the sample. The profiles of Japanese banks are instead much more homogenous. Unlike the case of Japan, technological progress is found in Europe and, especially, in North America. However, the differences across countries regarding technological progress are not statistically significant.

The insignificant variation in technological change across countries appears to be due to differences in bank size across countries. Using total assets as a proxy for bank size, we constructed three groups of Small, Medium, and Large size banks, with approximately the same number of observations within each group. We do not find statistically significant differences in productivity growth, although the Large banks present the highest Malmquist productivity indexes. However, the results show statistically significant differences with respect to scale efficiency, technical change and the scale change of the technology. Large banks show a large improvement of 28.2% in scale efficiency while Small and Medium sized banks did not experiment appreciable changes. Thus, the efforts of large banks to get a more efficient scale through mergers and/or acquisitions seem to have had positive results. Technical change also differs across size groups, indicating a non-neutral shift in the production technology. Technical regress is observed in the groups of Small and Medium sized banks, while a large index of technical progress is achieved by Large banks. This result indicates that the technology has generated new production possibilities that can be enjoyed by large banks. The efficient scale in the frontier has moved away from Small banks. This result means that Small banks that have not increased their sizes yet are today more scale inefficient than they were ten years ago and, thus, there is more to gain today by scale adjustments. The opposite profile is observed in the part of the frontier populated by Large banks. Large banks do have now less to be gained by scale adjustments than they had in 1989.

Finally, we have studied the relationship between the components of productivity change and bank stock performance, with the objective of determining how cumulative market returns may be explained in terms of productivity growth. The estimates are consistent with the wealth maximization criterion in financial intermediaries. Our results show a strong positive relationship between pure efficiency change and market returns. As it was expected, an increase in pure efficiency is associated with an increase in the bank's market value. However, no relationship was found between variations in scale efficiency and changes in market value. This result may be due to the possibility of discounting the effect of scale adjustments in the market value of the bank long before the effects of the adjustment translate into efficiency gains. Technical change was found to exert a positive and statistically significant effect on the banks' market returns when time effects are not included in the model. This result suggests that the majority of the banks benefit from the technical change leaded by the banks on the frontier.

Our results seem to be in consonance with the main findings reported in previous literature. However, there are three factors that limit the comparability of our results.

First, our sample refers to the period 1989-1998, while previous research has focused on the period 1980-1994. Second, we have constructed a common frontier for North American, European and Japanese banks. In our sample, the frontier is primarily populated by European banks. This means that a large part of the efficiency changes reported for North American and Japanese banks would have been "named" as technological change if the study was centered in just one geographic area. As that has been the case in previous studies, the comparison must be done carefully. A third concern that limits the comparability of our results with previous research is that we have extended the decomposition of the Malmquist index along the lines suggested by Simar and Wilson (1998) and Zofio and Lovell (1998). Our estimator of technological change thus differs from that employed in previous research, with the exception of Wheelock and Wilson (1999).

In the case of North American banks, our results are consistent with the trend reported by Mukherjee et al. (2001) for U.S. banks along the period 1984-1990, although our sample also includes Canadian banks. However, contrary to Wheelock and Wilson (1999) and Alam (2001), we find that catching up is the main source of the large productivity increase experimented by North American banks, appreciating a moderate effect of technological progress. With respect to Europe, it is more difficult to make a comparison, because there exist a large degree of heterogeneity across countries. Our results show significant productivity increase due to catching up and almost no average effect of technological progress. This result is in consonance to that reported by Berg, Førsund, and Jansen (1992) for Norwegian banks, but not with Lang and Welzel (1996), Grifell-Tatje and Lovell (1999), Kumbhakar et al. (2001) and Maudos (1996) who found productivity growth due to technological progress with moderate or even negative catching up in German and Spanish banks, or Mendes and Rebelo (1999) who reported negative catching up and technological regress in Portuguese banks. Our results for Japanese banks contradict those obtained by Fukuyama (1995) who found negative catching up and technological progress for 1989-1991, a result that is exactly the opposite of that reported here for the period 1989-1998. As we have pointed out above these differences may be due to differences in the methodology, in the composition of the database and in the time period covered.

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Appendix I – Database details

We have included only those banks present in Datastream lists for commercial banks in the countries we have studied. We have selected commercial banks from those Datastream lists (DS lists) included in Table I. The list does not include all the commercial banks in the country but it is expected that the criteria for inclusion in the list be the same for all lists/countries. We have just taken those commercial banks in each of the lists that fulfilled simultaneously the time interval 1989 to 1998 and that have all the inputs and outputs specified in the bank production function. From the initial 319 banks included in the Datastream commercial banks lists, we have finally selected 142 and from the original 21 countries. There were three countries (Greece, Netherlands and Poland) where no banks fulfilled simultaneously the time interval and inputs/outputs criteria.

NAME	DS lists	Initial number of banks (*)	Final number of banks (Our sample)
GERMANY-DS BANKS	LBANKSBD	7	6
BELGIUM-DS BANKS	LBANKSBG	6	1
DENMARK-DS BANKS	LBANKSDK	4	3
SPAIN-DS BANKS	LBANKSES	16	11
FINLAND-DS BANKS	LBANKSFN	3	1
FRANCE-DS BANKS	LBANKSFR	5	4
GREECE-DS BANKS	LBANKSGR	10	0
IRELAND-DS BANKS	LBANKSIR	4	1
ITALY-DS BANKS	LBANKSIT	35	12
LUXEMBURG-DS BANKS	LBANKSLX	6	1
NETHERLAND-DS BANKS	LBANKSNL	6	0
NORWAY-DS BANKS	LBANKSNW	4	1
AUSTRIA-DS BANKS	LBANKSOE	5	3
POLAND-DS BANKS	LBANKSPO	8	0
PORTUGAL-DS BANKS	LBANKSPT	6	2
SWEDEN-DS BANKS	LBANKSSD	4	3
SWITZ-DS BANKS	LBANKSSW	17	3
UK-DS BANKS	LBANKSUK	12	7
CANADA-DS BANKS	LBANKSCN	10	8
US-DS BANKS	LBANKSUS	65	45
JAPAN-DS BANKS	LBANKSJP	86	30
TOTAL		***319***	***142***

Table I – Datastream commercial banks lists

* Initial number of banks in the Datastream commercial bank list

Regarding the data source we have consider Worldscope account formats. Worldscope data takes into consideration the variety of accounting conventions in a global template designed to facilitate comparisons between companies and industries within and across national boundaries. Although, there are limitations to the comparability and thus utility of raw data as reported in company accounts, Worldscope is designed for the user who needs to compare the financial information of companies from different industries and countries throughout the world. Where differences arise due to disclosure or presentation, however, it is possible to improve the value of fundamental information.

Thus, differences in accounting terminology, presentation and language are minimized. However, there exist many other differences that may impede such comparisons.

Accounting practices under all major headings are described on a company-by-company and year-by-year basis, in order to allow users to identify the major valuation policies. Worldscope database providers claim that they do not “change” any figures reported by the company in its accounts. Although, if necessary, accounts are rebuilt using the same components the company originally used, to arrive at more uniform reporting templates. We also include in table II information on the 142 commercial banks in our sample. For more information on Worldscope visit the following website http://www.worldscope.com