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ECONOMIC EFFICIENCY AND VALUE MAXIMIZATION IN BANKING FIRMS

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Abstract
We study economic efficiency in 142 financial intermediaries from eighteen countries over the period 1989-1998 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. A Malmquist decomposition is then carried out in order to separate efficiency change from technical change. We evaluate the relationship between economic efficiency and wealth maximization. Results show different productivity patterns among 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.

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

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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 regulation and technological transformations on banks' production practices, and hence on bank production frontiers, has given rise to a growing body of empirical literature.

Although regulation constrains 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 rise in competition induces a raise in banking productivity.

In this paper we explore the changes in banking productivity over the period 1989-1998 of a group of banks that belong to different competitive and regulatory environments. 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 a Malmquist productivity index, with the aim of identifying those banks which shift the frontier and the effect of these shifts on the remaining 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 via linear programs. Using total assets as a proxy for size, we divide the banks into three groups and study productivity changes in each of these. Finally, we study 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.

[1] Berger et al. (1995) give detailed 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.

We proceed as follows. The next section describes the previous literature, and then in section three we introduce the database and the variables selected to define the bank production function. In the fourth section we introduce the methodology used to estimate efficiency and productivity change. In section five we present results on efficiency and productivity changes. In the sixth section we explore the relationship between productivity changes and bank stock returns and section seven concludes.

2. Review of the literature

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

The diversity and disperse evidence of these studies precludes a direct comparison of productivity changes in different geographical areas over the same time interval due to differences in the methodology chosen to estimate efficiency and productivity, not only because of the traditional distinction between parametric and non-parametric methods but also due to differences in the choice of productivity decomposition. Also, the existence 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, for large banks, that technical efficiency declined by 3% and, using a time dependent ratio analysis, that technology regressed by 2% over this eight years period.

Recent studies of productivity changes focus on US banks in the post-deregulation period, focusing on 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 an overall productivity growth rate of 4.5% per year on average[2]. They also find that larger banks and a higher specialization of product mix are associated with higher productivity. Alam (2001) studies bank productivity over the period 1980 to 1989 and finds 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 that productivity also declines on average. They claim that this decline in productivity is attributable to a minority of banks in each size category pushing the frontier forward, while the rest remained behind during the time interval that was considered. However, they do find technological progress over the sample period.

Grifell-Tatjé and Lovell (1997) found that commercial banks had lower productivity growth than saving banks over the period 1986-1993. In a subsequent paper, Grifell-Tatjé and Lovell (1999) analyze the sources of profit growth in Spanish commercial banks over the period 1987-1994, finding a large increase in bank productivity. This 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 1989-94. Thus, increases in productivity and technological progress during the late 1980s and early 1990s are a

[2] They claim that bank productivity, after an initial period of adjustment to deregulation, would be expected to increase. However they comment that the majority of previous commercial bank total factor productivity studies find either little, zero, 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.

consistent finding across the world, with the exception of Portuguese banks (Mendes and Rebelo, 1999).

Instead of analyzing variations in productivity over time, some studies carry out analyses across countries. For example, Dietsch et al. (2001) have used a Malmquist decomposition to explain productivity gaps in banking industries across four major European countries, and have been able to separate productivity differences into purely technological differences and differences due to environmental or external factors. Berg et al. (1994) made cross-country comparisons using cross-section data on banks from three Nordic countries, finding important differences between them.

All the papers cited above refer to productivity growth during the 1980s and early 1990s, and few of them make inter-country productivity comparisons. This paper aims to extend the literature by analyzing the evolution of bank productivity over the 1990s across a wide range 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 analyze productivity change in banks located in three different geographical areas (Europe, Japan, and North America) by computing Malmquist productivity indexes. The decomposition of the Malmquist index will allow us to identify the components of productivity growth or regress. We also study the relationship between the components of productivity growth and bank stock performance, with the objective being to evaluate whether our estimates of productivity changes are consistent with the wealth maximization criterion of financial intermediaries. Thus, our paper complements and extends the previous literature.

Contrary to most of the 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 to obtain efficiency scores for each bank in each time period. We have obtained the data for this study from Worldscope, which provides financial data on public companies quoted on the corresponding stock exchange. The final database contains 142 commercial banks from 18 countries (see Table 1) from 1989 to 1998[3]. We have created three groups on the basis of geographical proximity: Europe, Japan, and North America. Europe includes the first 15 countries in Table 1 and North America includes the US and Canada. Japan is a geographical group in itself.

The availability of data is a key determining factor when choosing a production function and this is especially important when the database includes firms from different countries. . Although all the selected banks fall into the same category (commercial banks), when defining the bank production function we considered that 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 across different geographical areas as, depending on the country of origin, banks were not allowed to simultaneously perform various activities (e.g. private and investment banking versus retail banking) or were limited geographically in their activities.

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

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

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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 data set for that year.

[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 is justified by the argument that flow variables would be biased by market power because different banks charge different rates (Resti, 1997). With 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, based on either 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.

With regard to loans, 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, so including them would generally penalize North American banks where reserves for loan losses are properly accounted for. Basically, when trying to disaggregate total loans we have come across many missing data values in European and Japanese commercial banks, so we have selected the aggregated values.

Four inputs have been considered: 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 can be argued that they are an input to the production of loans but they can also be considered as an output in that 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 the lack of quality of the disaggregated data[6].

Mester (1996) includes *financial capital* as an 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 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 an input. Given that we are studying commercial banks from different geographical areas, we face the dilemma of 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, with the result that accounting equity capital is not

[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.

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 extent, 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.

As we are simultaneously comparing commercial banks from three geographical areas, we have opted to choose broad categories when deciding on the choice of inputs and outputs to define the bank production function. Despite the facts that we have no disaggregation of deposits and loans, that we have not included equity capital for the reasons given above, and that we did not have the number of employees and thus use salaries and benefits expenses as a proxy, we believe the bank production function is adequate. Our variables, in particular deposits and loans, are aggregates, the reason being that with these aggregates it is possible to have comparable variables for banks even though they come from different countries and regions and have somewhat different accounting standards. Although we may not be able to study the effect of specialization of the product mix on productivity as in Mukherjee et al. (2001), 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 for banks in the three geographical areas that we consider in our study: Europe, Japan and North America. As 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 due to our requirement of 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.

[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 with regard to inputs we do not include bank equity capital but we do include other operating expenses.

All values in Table 3 are in billions of US dollars. Values have been converted into dollars using the corresponding exchange rates at January 1st, 1990. 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 the type of analysis we are carrying out, 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 have deflated values using the CPI for the relevant country and year and using 1989 as the base year[8].

4. Method

This section briefly explains the background to 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 make up 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, which extends that of Ray and Desli (1997), has recently been suggested by Simar and Wilson (1998) and Zofio and Lovell (1998). . Under this method, the technical change component in Ray and Desli (1997) is further decomposed into a "pure" technical change of the frontier plus a residual measure of scale change in the technology. Wheelock and Wilson (1999) has been the first paper to apply this enhanced decomposition to the study of productivity change in banking. We will also follow this decomposition because it adds more information about the sources of productivity change.

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

The Malmquist productivity index was introduced by Caves, Christensen, and Diewert (1982) as the ratio of two distance functions pertaining to 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 using only quantity data can be computed as the ratio y_i^t / x_i^t, where y_i^t is the quantity of output produced by firm *i* at period *t* and x_i^t the quantity of input employed by that firm during the same period.

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

Distance functions are computed by comparing one firm with another that acts as reference or benchmark because it is considered to be optimal. Hence, we have to define a relative productivity index, which will be the ratio between the absolute productivity index of the firm under study and that of the benchmark firm. This relative productivity index (*RP*) can be defined as:

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

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 remaining firms will have relative productivities of less than one.

[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).

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

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

where T_{CCR}^t represents the CCR technology, which satisfies the assumptions in Charnes, Cooper, and Rhodes (1978) of constant returns to scale (CRS) and free disposability of inputs and outputs. The distance function indicates the proportion in 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:

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

with *J* representing the set of firms used to construct the empirical reference technology, where these are assigned 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* Where the objective function measures the distance that separates this firm from the benchmark firm in terms of productivity. Thus,

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

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

[10] Distance functions can be defined with an input or output orientation. Given that in our empirical application we have chosen an output orientation, this is the orientation in terms of which the methodology is explained. 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 under both orientations (Färe and Lovell, 1978).

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

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

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

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

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

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. For example, it is possible that the firm improved its level of efficiency relative to the benchmark firm i.e., the firm improved more than the benchmark firm. Alternatively, the available technology may have improved — recall that we have fixed the technology. Färe, Groskopf, Norris, and Zhang (1994) proposed the first decomposition of the Malmquist index that separates both sources of productivity variation,

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

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

The first ratio in (8) reflects the relative efficiency change of the firm evaluated, that is, the variation in the distance from its frontier 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*. In summary, the technical change index measures the movement of the frontier at the output level of the firm that is being evaluated and is defined as a geometric mean to avoid having to choose between the input-output vectors of one period or the other.

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

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

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 only imposes convexity, and the BCC production set satisfies variable returns to scale (VRS). We can compute a residual scale efficiency index by comparing the two distance functions defined above,

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

and, therefore,

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

The Malmquist index is finally decomposed into three indexes that measure pure efficiency change (relative to the VRS frontier), scale efficiency change (comparing the VRS benchmark with the CRS benchmark), and an index of technical change (which 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 computing technical change using the VRS instead of the CRS production set as the reference technology. The difference between the Färe et al. (1994) and the Ray and Desli (1997) indexes of technical change can be interpreted as a residual measure of

[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).

scale change of the technology. The latter index indicates whether the projection of the firm on the VRS frontier is now closer or farther from the projection on the CRS frontier (i.e. the optimal scale). The decomposition of the Malmquist index into these four components has been developed by Simar and Wilson (1998) and Zofío and Lovell (1998),

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

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

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

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

It should be noted that the distance functions 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 the 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 where these unbounded output-oriented solutions occurred our empirical application, we changed the distance function to an input-oriented distance function to get a bounded solution that approximates the real movement of the technology. This solution seems appropriate because the problem with the unbounded solution in the computation of the output distance function reflects the fact that the movement of the technology was an input reducing or augmenting movement relative to the previous period[12].

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

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 yearly averages of the technical efficiency scores computed under constant returns to scale (DC) and variable returns to scale (DV), and also the residual scale efficiency score (SE). The standard deviations are in brackets. The figures on display reveal that a significant improvement has occurred over 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 of 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 28% more output without increasing any of the inputs.

The decomposition of the DC index provides some insights as to 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), with the value of the index changing from 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 increases observed in the SE indexes, going from 0.897 in 1989 to 0.954 in 1998. Although pure technical efficiency has experienced the largest increase it is still the main source of inefficiency.

Table 5 offers a comparison between the average efficiency levels of the banks according to 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]. 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

[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).

majority of banks leading the production frontier are European. 23% of European banks are completely efficient, while only 5.7% of Japanese and 6% of North American banks get DC scores of 1. In spite of this, average efficiency is the same in Europe and Japan due to the great dispersion that exists in European DC scores, as shown by the large value of the standard deviation.

Differences between geographic zones with respect to pure technical efficiency and scale efficiency are more pronounced. On average, the best-managed banks are the European ones, with a DV score of 0.78 and with 38.8% units being completely pure-efficient, followed by Japanese banks, with an average score of 0.73. On the other 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 much less within-group variation in terms of scale efficiency than there is in terms of pure efficiency. This result suggests that there is more variation in managerial practices than in sizes.

Insert Table 5

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 some 19.6% from 1989 to 1998. The period 1992-1993 shows the largest productivity growth, 7.9%, followed by 1997-1998 with 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 over the period 1989-1998, with an average increase of over 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 8.6% and 1991-1992 with 7.5%. Changes in scale efficiency have been more moderate and more evenly distributed throughout the period. The average gain in scale efficiency from 1989 to 1998 was close to 10% and may be a visible consequence of the merger processes that occurred during the period, which have resulted in new entities with a more productive scale. These two indexes (pure efficiency change and scale efficiency change) constitute the efficiency part of the Malmquist productivity index, and reflect a notable movement of inefficient banks towards the best practice frontier.

The technological part of the Malmquist index is composed of the indexes of technical change and scale change[14]. 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 moderate technical progress that has increased the production possibilities of the banks by an average of 2.3%. Although the net effect of technical change over 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 in the sense that 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 have been larger even if the banks had not done anything[15].

Table 7 compares the Malmquist index and its components across the three geographic zones represented in the sample[16]. 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, 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, which a larger proportion than that for Europe (52.5%). The dispersion around the mean is very large in Europe, reflecting again the high degree of 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 in average productivity.

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[14] Regarding the scale change index, there are alternative interpretations of this component by Wheelock and Wilson (1999) and by Zofio and Lovell (1998). Ray (2001) argues that although the decomposition is algebraically correct the factor is reasonably interpreted as Zofio and Lovell proposed. Thus, it can be interpreted as the bias in the technical change in favor or against the current period scale. Nevertheless, a value of this factor equal to one is neither necessary nor sufficient for invariance of the technically optimal scale.

[15] 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.

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

European and North American banks also show large increases in pure technical efficiency (34% and a 28% respectively) with quite a 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, compared to 68% of North American ones. The profile is again different in Japan. Japanese banks have only increased pure efficiency by 4% and the dispersion around the mean is relatively small. The differences between the three zones are significant as shown by the value of the Kruskal-Wallis test. The same pattern is observed with regard to the changes in scale efficiency, where there are no appreciable changes in Japanese banks. Recall that most Japanese banks were already completely scale efficient. In contrast, scale efficiency has increased by around 14% in Europe and North America.

There are no significant differences across geographic zones in terms of technical change. This result is to be expected because, in a globalized world, changes in the technology (that is, in the best practice frontier) should affect all 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 become confused 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 the North American banks, which in turn are significantly larger than the Japanese banks. The index of scale change reflects a movement of the efficient scale towards European and North American banks. There is no 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). The results are presented in Table 8, where standard deviations are shown in brackets. Note that all our banks are large banks per se. For Mukherjee et al. (2001) large banks are those whose assets exceed $1 billion and for Alam (2001) they were those whose assets exceed $0.5 billion. Although a significant dispersion between bank sizes exists in our sample, the size of the smallest bank is $0.76 billion while average total assets are $40 billion.

The groups were constructed so as to contain approximately the same number of banks. The group of Small banks has an average of $4.5 billion dollars in assets, Medium sized banks $14.3, and Large banks $100 billion. The group of Large banks experienced 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.

There are no significant differences across groups with regard to the index of pure efficiency change. This result reflects the fact that the catching-up effect did not depend on 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 experience 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 found for 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. The reason for this could be that small efficient banks have increased their sizes more than small inefficient 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, implying that there is more to gain today by scale adjustments. The opposite profile is observed in the part of the technology occupied by Large banks. Large banks now have less to gain 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

Having analyzed efficiency and productivity change in the sample, we now turn to the study of the relationship between the components of productivity growth and the changes in the market values 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 provide evidence on the differences between firms that perform better and those 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 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 perfom better in the stock exchange market.[17].

Figure 1 depicts the temporal evolution of commercial bank price indexes from December 1989 to December 1998 in our three geographic areas considered in this study as well as a fourth world-average index[18]. The figure shows that, over the period considered, the North American index has grown faster than the European and the World indexes. Unlike the trends observed in 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. They may also be partly explained by the differences in

[17] Alternative business performance measures such as Tobin's Q (Tobin, 1969) could have been considered. However, we lack the information to calculate it. Also, accounting profit may be a more stable measure of business performance. However, this refers entirely to past performance instead of expected future performance. In the case of Tobin's 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's Q.

[18] 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.

productivity growth across geographic areas that we have reported in the previous section.

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 whose 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%, whereas the average variation is 14.6%[19]. The final number of observations in the sample is 1196.

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

$$y_{it} = \boldsymbol{a}_i + \boldsymbol{d}_t + \boldsymbol{b}\mathbf{x'_{it}} + u_{it} \tag{13}$$

where y is the dependent variable, $\mathbf{x}$ the vector of explanatory variables, and u is the random error term. Subindexes i and t refer to the individual firm and the time period respectively. The coefficients a_i are the individual effects that capture the time-invariant effect of the unobserved characteristics of each individual on the dependent variable (unobserved heterogeneity). Similarly, the coefficients d_t are time effects that capture the effect of period t which is common across individuals.

Individual and time effects can be considered as 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[20]. Moreover, 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,

[19] We ran various regressions with and without this observation and found that it had an influential effect on some of the estimated coefficients. This reinforced our resolve to excluding the observation.

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

the Hausman test rejected the hypothesis in all the models that we have estimated, reinforcing the choice of a fixed effects model[21].

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 by an important number of firms. 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 also 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.

The results show a strong relationship between pure efficiency change and changes in market value, as was expected. However, there is no relationship between 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, where the (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 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 led 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 that for the effect of scale efficiency changes. It seems that the market is able to discount the effects of

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

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 the three different geographic areas of North America, Europe, and Japan. Our results show 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 technological progress having a very moderate effect.

Our estimates of efficiency scores show large gains over the period considered, with these being due primarily 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 in quantitative terms, although the average score in 1998 (0.95) comes close 1, i.e. to absolute scale efficiency. Our results also provide evidence of pronounced differences across geographical areas. Mean technical efficiency in European and Japanese banks during the 1990s has been significantly larger than in North American banks. The great majority of banks leading the production function were European (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 across 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 previous research, we used the enhanced decomposition of the Malmquist index simultaneously proposed by Simar and Wilson (1998) and Zofío and Lovell (1998). Overall bank productivity has grown some 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 over the period 1989-1998 was 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 shows a value of a less than one, indicating that there is less to be gained by adopting a better scale.

Results show markedly different productivity patterns across 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 other 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 high degree of heterogeneity of the European commercial banks included in the sample. The profiles of Japanese banks are much more homogenous. Unlike the case of Japan, technological progress is found in Europe and in North America, and especially in the latter. 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. 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 big improvement of 28.2% in scale efficiency while Small and Medium sized banks did not experience appreciable changes. Thus, the efforts of large banks to attain 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 found for 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, a result which implies that Small banks that have not increased their sizes yet are more scale inefficient today than they were ten years ago and there is thus more to be gained today by scale adjustments. The opposite profile is observed in the part of the frontier occupied by Large banks. Large banks now have less to gain 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 of financial intermediaries. Our results show a strong positive relationship between pure efficiency change and market returns. As 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 that exists of discounting the effect of scale adjustments in the market value of the bank long before the effects of the adjustment are manifested in terms 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 suggests that the majority of banks benefit from the technical change led by the banks on the frontier.

Our results seem to be in concordance with the main findings reported in the 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, which means that a large part of the efficiency changes reported for North American and Japanese banks would have been labelled as technological change if the study had been centered on just one geographic area. As that has been the case in previous studies, the comparison must be made 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 over the period 1984-1990, although it should be kept in mind that 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 experienced by North American banks, with technological progress having a moderate effect. With respect to Europe, it is more difficult to make a comparison because a large degree of heterogeneity exists across countries. Our results show significant productivity increases due to catching up and almost no average effect of technological progress. This result is in line with that reported by Berg, Førsund, and Jansen (1992) for Norwegian banks, but not with Lang and Welzel (1996), Grifell-Tatjé 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 the composition of the database, differences in the methodology, and in the time period covered.

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Table 1 – number of banks and country of origin

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)

In brackets, the number of commercial banks per country

Table 2 – Bank production function: selected inputs and outputs

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
Input 4	DEPOSITS - TOTAL	Level

Table 3 – Summary of descriptive statistics

(Billion USD)	Europe		Japan		N.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 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)
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)

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

Table 6.- Decomposition of the Malmquist index

Period	M_{CCD}	$DPE^{t,t+1}$	$DSE^{t,t+1}$	$DT_{BCC}{}^{t,t+1}$	$DS^{t,t+1}$
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

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

		M_{CCD}	$DPE^{t,t+1}$	$DSE^{t,t+1}$	$DT_{BCC}{}^{t,t+1}$	$DS^{t,t+1}$
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%
K-W test : c^2		9.75***	5.93**	14.8***	3.12	8.58**

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

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

	N	*Assets*	M_{CCD}	$DPE^{t,t+1}$	$DSE^{t,t+1}$	$DT_{BCC}{}^{t,t+1}$	$DS^{t,t+1}$
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 : c^2			3.40	0.31	27.6***	18.1***	102.0***

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

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
$DPE^{t,t+1}$	0.264	4.08***	0.291	5.01***
$DSE^{t,t+1}$	-0.063	-0.44	-0.152	-1.23
$DT_{BCC}{}^{t,t+1}$	0.181	2.13**	0.051	0.68
$DS^{t,t+1}$	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

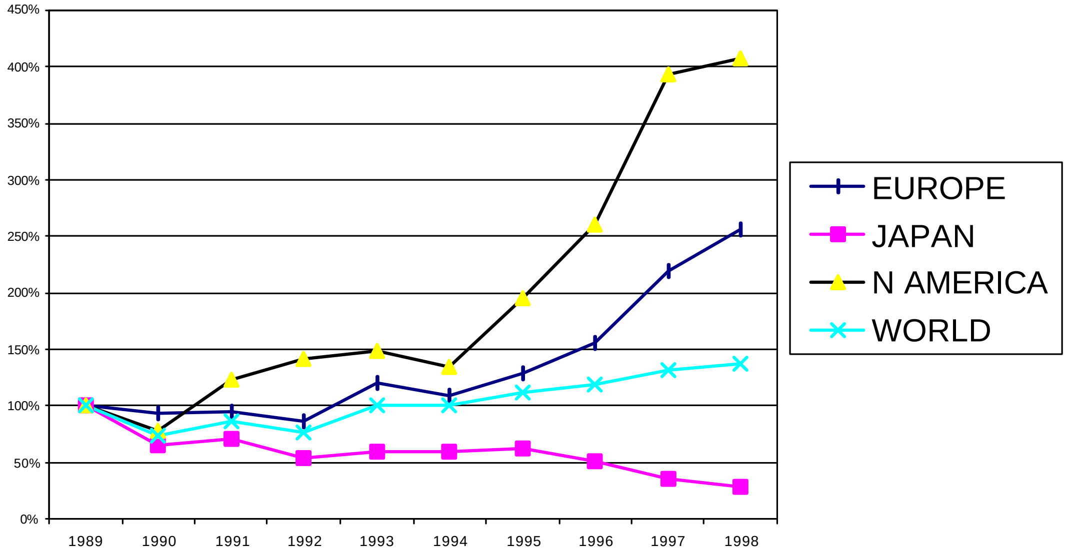

Figure 1.- Evolution of DataStream Bank price indexes

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