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An assessment of Portuguese banks' costs and efficiency*

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October 2009

Abstract

This paper analyses the production technology of Portuguese banks during the 1992-2004 period through the estimation of a translog cost frontier. Banks are modelled as firms which produce loans and other earning assets, choosing the cost minimizing combination of labour, capital and interest bearing debt, subject to holding a predetermined level of equity. According to the results of this study, technological progress has shifted the cost frontier downwards throughout the period under consideration, whereas banks seem to have operated at the same distance from the frontier. Further, increases in production under scale economies have also contributed to the recorded increase in productivity.

JEL Codes: G21, L13

Keywords: bank performace, marginal costs, X-efficiency, total factor productivity change.

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1 Introduction

Banks play a central role in the financial system and also in the real economy, as the 2008 financial crisis has vividly illustrated. Their smooth functioning allows for the intermediation of funds in the economy and provides for a wide range of financial services. In order to guarantee this, banks need not only to adequately monitor their risks, but also to efficiently allocate their resources. Hence, the measurement of bank performance is a critical issue that has deserved considerable attention in the banking literature.

In this paper, we propose to analyse developments in the performance of the Portuguese banking system between 1992 and 2004, a period in which significant changes were observed, including the process of liberalization, consolidation and financial innovation.[1] These changes had a profound impact on the market's structure and on banks' technology and, through the analysis of a cost function, we intend to assess how they affected banks' marginal costs and total productivity, which we decompose into the effect of scale efficiency change, cost efficiency change and technological progress. In this way, we can not only quantify total factor productivity growth, but also identify if changes in productivity were driven by moving to a different point in the cost function, by moving closer to the cost frontier or by changes in the frontier itself.

Previous empirical results on the efficiency of Portuguese banks include the work by Mendes and Rebelo (1999), Mendes and Rebelo (2000), Pinho (2001), Canhoto and Dermine (2003), Lima (2008) and Lima and Pinho (2008). The majority of these studies estimated translog cost functions using Stochastic frontier Analysis (SFA), while in the one by Canhoto and Dermine (2003) a non-parametric frontier was estimated using Data Envelopment Analysis (DEA) and Mendes and Rebelo (2000) employ both methodologies.

[1] See Ribeiro (2007) for a brief overview of the liberalization process.

Even though the above mentioned studies use different empirical and theoretical approaches to the modeling of banks' activity and cover different time periods (starting in 1987 and ending in 2004), all but the one by Mendes and Rebelo(1999) found that the productivity of Portuguese banks has increased. However, as expected given the differences in the approaches, they do not agree on the levels of X-inefficiency. The identification of shifts in best practices and changes in the distance at which banks operate from the efficient frontier also varies across studies according to the methodology employed. In fact, some studies do not allow for the distinction of the two effects, since the frontier is assumed to be constant over time, so that all productivity changes are attributed to changes in cost efficiency. Further, Pinho (2001) and Mendes and Rebelo (2000) found that state-owned banks tend to perform worse on average whereas Canhoto and Dermine (2003) found that banks which were created after 1984 and foreign banks perform better than older banks which operated under the previously prevalent tightly regulated market conditions, including state-owned banks. Further, Mendes and Rebelo (2000) and Lima (2008) found that mergers contributed to increase banks' performance.

The remainder of the paper proceeds as follows. Section 2 presents the methodology and the data used in this paper in order to estimate banks' cost function and productivity. Section 3 presents the empirical results of this paper and is divided into 6 subsections, comprising the discussion of the estimates for Portuguese banks' marginal costs, the shadow cost of equity, scale efficiency, cost efficiency, technological progress and total factor productivity growth. Section 4 presents the concluding remarks.

2 Methodology and data

The modelling of banks' production has been the subject of considerable debate in the literature, essentially due to the controversy regarding the classification of customer deposits as inputs or as outputs. On the one hand, the "production approach" to bank modelling regards banks as firms producing services which are related to loans and deposit accounts, thus identifying as outputs the number of deposit accounts serviced and the number of loans originated and as inputs labour and physical capital. On the other hand, according to the "intermediation approach" (Sealey and Lindley (1977)), banks' main activity is granting loans and investing in securities and other assets using funds obtained through deposits, purchased funds and equity.[2] There are sensible theoretical arguments supporting both approaches, and there is not a clear preference for either of them in empirical applications.[3] However, as remarked in Hughes, Mester and Moon (2001) the inclusion of deposits both as inputs and as outputs would yield misleading results. In this case, the cost function would include both the level of deposits (since deposits are an output) and the price of deposits, whereas the definition of costs would include deposit related interest expenses (since deposits are an input). The argument is that the optimal choice of one input - deposits - would not be influenced by the price of this input, since its quantity is held fixed.

There are two main reasons why holding deposits is an attractive activity for banks. On the one hand, as suggested by the production approach, deposits generate commission income and are a product which adds value in itself, as the general public does not have access to the same investment opportunities as banks. On the other hand, they are a relatively low cost and stable source of funding. Either way, a considerable part of banks' resources is dedicated to the origination and management of deposits. However, even though on a smaller scale, the acquisition and management of any input carries costs.

[2] See Freixas and Rochet (1998), p.p. 77-79, on the production and intermediation approach.

[3] The fact that the production approach identifies as outputs the number of loans originated and deposit accounts constitutes an additional complication since this data is often unavailable. Studies which follow the production approach usually circumvent this issue by proxying the number of loans and deposit accounts by their value.

Hence, we follow Hughes and Mester (1993) in reasoning that deposits should be modelled as inputs (outputs) if the elasticity of total costs deducted of interest paid on deposits to the level of deposits is negative (positive). According to the result of this test (shown in Table 1), we choose to model deposits as inputs. This specification has the further advantage of allowing for a more comprehensive definition of banks' costs, since otherwise the definition of costs would totally ignore funding costs, and so the measurement of efficiency would be limited to operational costs. Such an analysis could yield misleading results as some banks may be willing to bear higher operational costs (with employees and equipment) in order to optimize their funding structure, thus attaining lower funding costs. A similar argument motivates the inclusion of equity as a fixed input since, as remarked in Hughes, Mester and Moon (2001), otherwise banks which find relatively more funding in equity and less in debt would spuriously appear to be more efficient. The fact that equity is treated as a fixed rather than a variable input is justified by regulatory and rating/reputation constraints to the choice of the optimal level of equity. Further, the costs associated to common equity issues lead banks to raise capital in relatively large tranches. As a consequence, current levels of capital need not only suffice to cover risks currently incurred, but should also accommodate future growth of assets. As such, banks may have a higher level of equity than that yielded by the individual static maximization problem.

Hence, banks are assumed to minimize labour, funding and capital related costs $(w_L L + w_F F + w_K K)$ subject to the production of a predetermined amount of loans $(\overline{y}_1)$ and other earning assets $(\overline{y}_2)$ and to the maintenance of a determined level of equity (e_0):[4]

[4]Total loans are adjusted for securitization, essentially since the originating bank is generally still responsible for servicing securitized loans. Hence, if this correction were not to be undertaken, the cost efficiency of banks involved in securitization operations would be underestimated. Securitization in Portugal began in 1997 and grew rapidly in recent years, accounting for around 6% of aggregate loans outstanding in 2004. Nonetheless, some heterogeneity was present among banks, with a particular bank presenting a share of securitized loans as high as 34% on a non-consolidated basis in 2004.

$$
\begin{aligned}
C\left(y_1, y_2, w_L, w_F, w_K, e\right) &= \min_{L,F,K}\left(w_L L + w_F F + w_K K\right) \\
& \quad s.t. \\
F\left(x, e\right) &\geq \overline{y} \\
e &= e_0
\end{aligned}
\tag{1}
$$

where the variables are defined as:

$$
\begin{aligned}
C &\equiv \sum_k w_k x_k \\
y_1 &: \text{Total Loans} \\
y_2 &: \text{Other Earning Assets} \\
w_L &: \text{Price of Labour} \\
w_F &: \text{Price of Funding} \\
w_K &: \text{Price of Capital} \\
L &: \text{Labour} \\
F &: \text{Funding} \\
K &: \text{Capital} \\
e &: \text{ Equity}
\end{aligned}
\tag{2}
$$

The price of funding is computed as the ratio between the flow of interest paid and the stock of interest bearing liabilities and the price of labour is defined as the ratio between labour costs and the number of employees, whereas the price of capital was proxied by the ratio between the sum of depreciation and general administrative costs (excluding labour) and the stock of tangible and intangible assets.

It is well known that banks, as is true with other firms, either due to agency problems or due to differences in managerial ability, do not strictly behave as profit maximizers, and some banks are closer to optimal behaviour than others. Furthermore, as usual in empirical applications, the performance of each bank is also affected by random factors, and the variables used in the estimations may be subject to measurement error. Hence, in order to analyse the cost efficiency of Portuguese banks since the early nineties, the cost function stemming from (1) is estimated using the Stochastic Frontier Analysis model developed in Battese and Coelli (1992), with some simple changes which are necessary to apply the model to cost functions, since it was initially developed for production functions. The main equation to be estimated in the model may be expressed as:

$$\ln C_{i,t} = \ln C\left(t_t, y_{r,i,t}, w_{k,i,t}, e_{i,t}\right) + \left(v_{i,t} + u_{i,t}\right) \tag{3}$$

where $C\left(t_t, y_{r,i,t}, w_{k,i,t}, e_{i,t}\right)$ represents the estimated cost frontier and $C_{i,t}$ are banks' actual costs, so that a banks' observed costs are bounded below by the sum of the estimated cost frontier and a random error $(v_{i,t})$ which is assumed to follow an i.i.d. $N(0, \sigma_v^2)$ distribution and accounts for measurement error of the level of costs, as well as for the effect of other random uncontrollable shocks. The sum of $\ln C\left(t_t, y_{r,i,t}, w_{k,i,t}, e_{i,t}\right)$ and $v_{i,t}$ constitutes the stochastic frontier, and $u_{i,t}$ are non-negative random variables which measure cost inefficiency as the difference between realized cost and the stochastic cost frontier, defined as follows:[5]

$$u_{i,t} = u_i \exp(-\eta(t - T)) \tag{4}$$

[5] Cost inefficiency is commonly referred to in the literature as X-inefficiency.

where u_i are assumed to be independently distributed as truncations at zero of the $N(\mu, \sigma_u^2)$ distribution and μ and η are parameters to be estimated, so that inefficiency is firm specific and is allowed to vary through time. If η is not found to be statistically significant, it can be constrained to zero, so as to maximize the degrees of freedom by estimating no more parameters than needed. The cost efficiency of firm i at time t is:

$$CE_{i,t} = C\left(t_t, y_{r,i,t}, w_{k,i,t}, e_{i,t}\right)/C_{i,t}\epsilon(0,1] \tag{5}$$

A fully efficient bank's actual cost is on the cost frontier, so that its efficiency is 100%, whereas an $X\%$ efficient bank's actual cost is above the frontier, so that it could theoretically produce the same output with only $X\%$ of its actual cost.

In order to provide a good approximation to the true cost function while preserving the available degrees of freedom and avoiding multicollinearity problems, the choice of the functional form in which the cost function is specified should obtain a balance between flexibility and parsimony. While the Cobb-Douglas specification is acknowledged to be too restrictive, the translog functional form provides a flexible local approximation and the Fourier functional form provides a global approximation. Berger and Mester (1997) found the difference between the two latter functional forms to be statistically but not economically relevant. Hence, and given the relatively small number of observations in our sample, the cost function is estimated using a translog functional form, which can be written as:

$$
\begin{aligned}
\ln C_{i,t} = {} & \gamma_0 + \gamma_t t_t + \frac{1}{2}\gamma_{t,t} t_t^2 + \sum_r \gamma_{t,r} t_t \ln y_{r,i,t} + \sum_k \gamma_{t,k} t_t \ln w_{k,i,t} + \sum_r \gamma_r \ln y_{r,i,t} + \\
& + \sum_k \gamma_k \ln w_{k,i,t} + \frac{1}{2}\left(\sum_r \sum_s \gamma_{r,s} \ln y_{r,i,t} \ln y_{s,i,t} + \sum_k \sum_l \gamma_{k,l} \ln w_{k,i,t} \ln w_{l,i,t} \right) + \\
& + \sum_k \sum_r \gamma_{k,r} \ln w_{k,i,t} \ln y_{r,i,t} + \gamma_e \ln e_{i,t} + \frac{1}{2}\gamma_{e,e} \left(\ln e_{i,t}\right)^2 + \\
& + \sum_r \gamma_{e,r} \ln e_{i,t} \ln y_{r,i,t} + \sum_k \gamma_{e,k} \ln e_{i,t} \ln w_{k,i,t} \qquad (6)
\end{aligned}
$$

where the theoretical restrictions stemming from duality theory (i.e. symmetry and linear homogeneity in prices) are imposed:

$$
\begin{aligned}
\gamma_{k,l} &= \gamma_{l,k}, \forall k, l \\
\sum_k \gamma_k &= 1 \\
\sum_k \gamma_{k,r} &= 0, \forall r \\
\sum_l \gamma_{k,l} &= 0, \forall k, l \\
\sum_k \gamma_{e,k} &= 0 \\
\sum_k \gamma_{t,k} &= 0 \qquad (7)
\end{aligned}
$$

In practice, symmetry is implicitly imposed in the specification of the estimated equation whereas homogeneity is obtained by normalizing input prices and total cost by w_K. Introducing vector notation, the normalized variables are defined as:

$$
\begin{aligned}
\ln \tilde{W}' &= \begin{pmatrix} \ln(w_L/w_K) & \ln(w_F/w_K) \end{pmatrix} \\
\ln Y' &= \begin{pmatrix} \ln y_1 & \ln y_2 \end{pmatrix} \\
\ln \tilde{C} &= \ln(C/w_K)
\end{aligned} \tag{8}
$$

And the translog cost function may be written as:

$$
\begin{aligned}
\ln \tilde{C} &= \gamma_0 + \alpha' \ln \tilde{W} + \beta' \ln Y + \frac{1}{2} \ln \tilde{W}' A \ln \tilde{W} + \frac{1}{2} \ln Y' B \ln Y + \frac{1}{2} \ln \tilde{W}' \Gamma \ln Y + \\
&+ \delta_1 t + \frac{1}{2} \delta_2 t^2 + \eta' \ln \tilde{W}' t + \mu' \ln Y' t + \rho \ln e t + \\
&+ \theta_1 e + \frac{1}{2} \theta_2 e^2 + \psi' \ln e \ln Y + \xi \ln e \ln \tilde{W}
\end{aligned} \tag{9}
$$

Relevant elasticities may be derived as a vector of first order partial derivatives:

$$
\begin{bmatrix} \varepsilon_w \\ \varepsilon_y \\ \varepsilon_t \\ \varepsilon_e \end{bmatrix} = \begin{bmatrix} \alpha & A & \Gamma & \eta & \psi \\ \beta & \Gamma' & B & \mu & \xi \\ \delta_1 & \eta' & \mu' & \delta_2 & \rho \\ \theta_1 & \psi' & \xi' & \rho & \theta_2 \end{bmatrix} \begin{bmatrix} 1 \\ \ln \tilde{W} \\ \ln Y \\ t \\ \ln e \end{bmatrix} \tag{10}
$$

Since the data are expressed as deviations from the overall sample mean, we get:

$$\begin{bmatrix} \varepsilon_w \\ \varepsilon_y \\ \varepsilon_t \\ \varepsilon_e \end{bmatrix} = \begin{bmatrix} \alpha & A & \Gamma & \eta & \psi \\ \beta & \Gamma' & B & \mu & \xi \\ \delta_1 & \eta' & \mu' & \delta_2 & \rho \\ \theta_1 & \psi' & \xi' & \rho & \theta_2 \end{bmatrix} \begin{bmatrix} 1 \\ \ln \tilde{W} - \ln \overline{\tilde{W}} \\ \ln Y - \ln \overline{Y} \\ t - \overline{t} \\ \ln e - \ln \overline{e} \end{bmatrix} \tag{11}$$

so that in order to obtain elasticities evaluated at the sample mean, it is enough to consider the first order coefficients:

$$\begin{bmatrix} \varepsilon_w \\ \varepsilon_y \\ \varepsilon_t \\ \varepsilon_e \end{bmatrix} = \begin{bmatrix} \alpha & A & \Gamma & \eta & \psi \\ \beta & \Gamma' & B & \mu & \xi \\ \delta_1 & \eta' & \mu' & \delta_2 & \rho \\ \theta_1 & \psi' & \xi' & \rho & \theta_2 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} \alpha \\ \beta \\ \delta_1 \\ \theta_1 \end{bmatrix} \tag{12}$$

The associated cost share equations implied by Shepherd's lemma:

$$s_{k,i,t} \equiv \frac{w_{k,i,t} x_{k,i,t}}{\sum_k w_{k,i,t} x_{k,i,t}} = \frac{\partial \ln C_{i,t}}{\partial \ln w_{k,i,t}} \tag{13}$$

were not imposed since they hold only under the assumption that no allocative inefficiency exists. Hence, our measure of X-inefficiency comprises both technical and allocative inefficiency.

The dataset used in this study was obtained from banks' financial statements reported to the Banco de Portugal. The database comprises an unbalanced panel of yearly data for all banks operating in Portugal from 1991 to 2004.[6] Data on individual rather than consolidated basis was used since it is available with greater detail for most of the sample

[6] The reason why more recent data is not used is that in 2005 there were changes in accounting standards, so that data until 2004 is not comparable with the more recent data.

period. Since banks which belong to the same financial group often have independent brands and activity structures, the analysis relies on bank level data. Since banks grew quite rapidly during the period under consideration, stock variables are defined as period averages so that meaningful values are obtained for variables which are defined as the ratio between a flow and a stock variable.

All banks operating in Portugal are required to report financial statements to the Banco de Portugal. However, there is a large number of small banks that mostly operate in investment banking and thus have quite a specific activity and cost structure. Hence, in order to obtain a sample of relatively homogenous banks, only institutions with more than 10 branches are considered. Despite having more than 10 branches, 3 other banks were also eliminated from the sample, due to data quality issues or to specific issues concerning their banking activity. Furthermore, the first two years of activity of new banks were also eliminated from the sample, as it seems reasonable to assume that during early stages banks may behave differently than once their activity is stabilized. After applying these filters, a sample of 25 banks, comprising a total of 254 bank-year pairs was obtained. For each year, the sample covers at least 77% of total loans, 80% of total assets and 87% of total deposits in the Portuguese banking system. Further, the market share of the five largest banks, when measured in terms of total assets in the sample, increased from around 57% in 1992 to near 70% in 2004, in similar fashion to what is observed in the whole banking system.

3 Empirical analysis

This section presents the main results of the analysis undertaken. All results are based on the estimation of Equation 6, imposing the restrictions in 7. The results of the estimation of Equation 6 are summarized in Table 2. In the first column of this table, the estimate for bank specific cost inefficiency is allowed to vary through time as shown in Equation 4. However, since the estimate for η is not found to be statistically significant, the second column of Table 2 presents estimation results in which it is restricted to zero in order to avoid the loss of degrees of freedom due to the estimation of redundant parameters. As shown in (12), since the data are expressed as deviations from the overall sample mean, one can easily assess relevant elasticities evaluated at the mean by directly analysing single parameters. A preliminary analysis of estimation results shows that the elasticity of cost with respect to each of the input prices is positive. Furthermore, the input price to which costs react most is the price of funding, which is not surprising considering that funding costs constitute the highest share of total costs. The sum of the parameters on the two outputs is close to one, indicating close to constant returns to scale at the sample mean. The fact that the parameter on the interaction term between the two outputs is negative indicates that there are scope economies in the joint production of loans and other earning assets. There is statistically significant cost reducing technological progress at the sample mean and banks with higher levels of equity tend to have lower costs with other inputs. The estimate for γ indicates that close to 77% of the total error's variance is accounted for by cost inefficiency rather than by the classical random error, providing compelling evidence that the estimation of the cost function as a frontier is appropriate.

The results are analysed in detail in the following subsections, the first of which presents results concerning estimated marginal costs for each bank as well as their behaviour over time. The next subsection discusses the estimates for banks' shadow cost of equity capital. The third subsection discusses results concerning scale efficiency. The following subsections present results concerning cost efficiency and technological progress. In the last subsection changes in total factor productivity are quantified and decomposed in order to assess whether they were driven mainly by changes in the optimum technology, by the technology of each bank approaching the best practices, or simply by banks moving to a different point in the same cost function.

3.1 Marginal costs

Using the estimated parameters for the cost function, marginal cost estimates for the production of each output may be obtained by:

$$mc_{r,i,t} \equiv \frac{\partial C_{i,t}}{\partial y_{r,i,t}} = \frac{C_{i,t}}{y_{r,i,t}} \frac{\partial \ln C_{i,t}}{\partial \ln y_{r,i,t}} \tag{14}$$

Note that Equation 14 yields bank specific marginal cost estimates for both the production of bank loans and of other earning assets. Hence, the time-series presented in Table 3 were constructed by aggregating the individual estimates, using each bank's market share in loans as weights. Since funding costs constitute a major share of banks' variable costs and interest rates have decreased markedly during the period under analysis, the fact that the marginal cost estimates have decreased sharply over time is not surprising (Chart 1). Nonetheless, an interesting question is whether real resource marginal costs also decreased through time. A proxy for banks' non-financial marginal cost is obtained by deducing the estimated marginal cost for each bank of the corresponding funding costs. As shown in columns 5 and 6 of Table 3, this measure also presents a decreasing trend, indicating that, despite contributing to the profile observed in marginal costs through time, the behaviour of interest rates alone is not enough to explain it. It should be mentioned that during the period under analysis there was a change in the structure of banks' loan portfolio, with an increase in the share of loans to households as opposed to a decrease in the weight of loans to the public sector. This structural change should have contributed to an increase in the marginal cost of total loans. As such, the significant reduction in the estimated operational marginal cost of loans was not driven by changes in the composition of the loan portfolio. Chart 1 presents the weighted distribution of the estimates for banks' non-financial marginal costs in the production of loans and other earning assets in 1992, 1996, 2000 and 2004.[7]

As illustrated in Chart 2 and documented in Table 3, the marginal cost of loans has generally been higher than that of other earning assets, indicating that it is more resource consuming to provide an additional loan than it is to invest in securities, which should be related with the screening and monitoring costs involved in granting loans. However, this difference has become less relevant through time. In order to understand this development, one should keep in mind that the output which is defined as other earning assets includes quite heterogeneous products. Furthermore, during the sample period there have been changes to the composition of this output. In fact, whereas during the early 1990's banks had significant resources invested in government bonds and deposits with the central bank, with the liberalization of the banking system and financial innovation banks started to invest in more sophisticated assets which, due to their greater complexity, require the use of more resources.

Furthermore, using data on banks' loan related interest income and stock of outstanding loans, one may compute an implicit interest rate on loans, as shown in column 7 of Table 3. Deducing the marginal cost from this interest rate, a measure of banks' price cost margin is obtained. According to the results shown in the last column of Table 3 and in Chart 3, this measure has decreased through time, which is consistent with the result found in Boucinha and Ribeiro (2009), according to which competition in the banking system has increased during the period under scrutiny.[8]

[7] The estimate for the real resource marginal cost of other earning assets is negative in 2000 for two banks whose investment in securities is very low.

[8] The measure of implicit interest rate used is computed based on interest income and loan stocks which do not include non-performing loans. Hence, it is a proxy for the interest rate that banks charge their costumers, which should be higher than the average interest rate that they actually receive due to loan delinquency. Hence, the decrease in non-performing loans observed throughout the sample period should also have contributed to the observed decrease in banks' price-cost margin.

3.2 Shadow cost of equity

Since the estimated cost function includes the level of equity as a fixed input, it allows for the computation of a measure of the shadow cost of equity capital as:

$$w_k^* = -\frac{\partial C_{i,t}}{\partial e_{i,t}} = -\frac{C_{i,t}}{e_{i,t}} \frac{\partial \ln C_{i,t}}{\partial \ln e_{i,t}} \tag{15}$$

The rationale underlying the computation of the shadow cost of equity is to provide a measure of how much banks are willing to pay for equity, since it indicates the amount that they would save in other costs as a result of an increase in the level of equity.[9]

As shown in Chart 4 the time series obtained by aggregating the estimates for the shadow cost of equity is strongly correlated with market interest rates and with banks' weighted average cost of deposit and market debt funding. This result is consistent with shareholder capital being a source of funding in itself, so that funding costs are the ones which are most affected by the level of equity.

The obtained measure of the shadow cost of equity, presented in Table 4, is lower than (what is generally acknowledged to be a reasonable value for) the actual price of equity. This result is not surprising and supports our choice of modelling equity capital as a fixed rather than a variable input, since it suggests that the regulatory and reputation constraints to the level of equity are in fact relevant, so that banks hold a higher level of equity capital than the one which would solve their static unconstrained optimization problem.

With the purpose of investigating what drives differences in banks' shadow cost of equity, this variable was regressed upon a set of bank specific variables, including each

[9] One must bear in mind the limitations of the model employed, by operating under the framework of a static optimization model estimated using non-consolidated accounting data.

bank's capital ratio and return on equity and dummy variables which identify public banks, branches of credit institutions whose head office is in foreign countries and large banks (the 20% larger banks in each year).[10] In order to avoid simultaneity issues concerning the shadow cost of equity and banks' capital ratio and return on equity, the lag rather than the contemporary value of these variables is used. Since the dummy variable which identifies branches of credit institutions whose head office is in foreign countries is time invariant, identification of the coefficient on this variable is not possible in a regression which includes bank specific fixed-effects. Hence, both fixed-effects and random-effects regressions are shown.

The results of these regressions, shown in Table 5, suggest that more capitalized banks tend to have a higher shadow cost of equity. A positive effect of profitability is also found, which may reflect higher risk incurred by the bank. Possibly reflecting lower perceived risk, state owned banks tend to have a lower shadow cost of equity. Branches of credit institutions whose head office is in foreign countries generally represent a relatively small portion of their banking group's assets, so that their activity hardly influences the group's credit rating and they often resort directly to the head office in order to obtain funding. Hence, it is not surprising to find that these banks tend to have a lower shadow cost of equity on average. Conversely, larger banks, which tend to be more transparent and whose equity is more likely to be traded in public markets, tend to have a higher shadow cost of equity.

3.3 Scale efficiency

The assessment of scale economies has been the subject of extensive discussion in the literature. Even though there are many theoretical arguments supporting their existence

[10] The fact that the dependent variable of this regression is itself an estimate means that the standard errors of this regression are not valid, since they do not account for the variance of the dependent variable.

and they are typically invoked by bank managers as a motivation for mergers, empirical studies often fail to find them in the data. The identification of scale economies has relevant implications since it allows for inference on the adequacy of the market structure from a technological point of view.

This section assesses the presence of scale economies since the liberalization of the Portuguese banking system. A measure of scale economies is typically obtained as:

$$SE_{i,t} \equiv \sum_r \frac{\partial \ln C_{i,t}}{\partial \ln y_{r,i,t}} \tag{16}$$

An elasticity of cost with respect to total loans smaller (larger) than one is obtained in the presence of scale economies (diseconomies). As shown in Table 6, statistically significant scale diseconomies (as defined above) were found during the early 1990's so that, all else equal, an increase in banks' size implied a more than proportional increase in costs. In the more recent period, the estimate for the scale parameter is slightly below one, albeit not statistically different from one, indicating virtually constant returns to scale. One should, nonetheless, keep in mind that the elasticity computed according to Equation 16 is a measure of short-run or constrained scale economies, since the level of equity is held fixed. Furthermore, since the definition of cost employed does not include the cost of equity, the measure of scale economies presented above is actually a measure of cash flow cost economies. This measure is likely to overestimate the true scale parameter, since the fact that the level of equity is held fixed implies that any increase in output must be totally financed by interest bearing debt, so that the cost of debt is forced to increase more than would be realistic.

A measure of scale economies which allows for the level of capital to change in response to changes in output could be obtained by estimating a cost function where equity is treated similarly to the other inputs. However, as mentioned above, we do not think that this would be an optimal solution, as there are important constraints to the choice of banks' level of equity capital. Furthermore, even in the more recent period, only a small number of Portuguese banks are listed in the stock exchange market, so that it is not straightforward to obtain estimates for the cost of equity.

Alternatively, as outlined in Hughes, Mester and Moon (2001), citing an original proposal by Hughes (1999), one can compute a measure of economic scale economies assuming that the observed level of equity capital minimizes economic cost at the shadow price of equity, since it then holds that:

$$C\left(t, y_r, w_k, w_e^*\right) = C(t, y_r, w_k, e) + w_e^* e \tag{17}$$

From the expression above, one can compute a measure of economic scale economies as:

$$ESE_{i,t} \equiv \sum_r \frac{\partial C\left(t, y_r, w_k, w_e^*\right)}{\partial y_r} \frac{y_r}{C\left(t, y_r, w_k, w_e^*\right)} \tag{18}$$

Since the level of equity capital e minimizes economic cost, the constrained marginal cost equals the long run marginal cost:

$$\frac{\partial C\left(t, y_r, w_k, w_e^*\right)}{\partial y_r} = \frac{\partial C(t, y_r, w_k, e)}{\partial y_r} \tag{19}$$

From this result and the definition of the shadow cost of equity in equation 15, expression 18 may be written as:

$$ESE_{i,t} \equiv \sum_r \frac{\partial C(t, y_r, w_k, e)}{\partial y_r} \frac{y_r}{C(t, y_r, w_k, e) - \frac{\partial C}{\partial e} e} \tag{20}$$

or

$$ESE_{i,t} \equiv \frac{\sum_r \frac{\partial \ln C_{i,t}}{\partial \ln y_{r,i,t}}}{1 - \frac{\partial \ln C_{i,t}}{\partial \ln e_{i,t}}} \tag{21}$$

An aggregate time-series of the estimates for scale economies obtained through the aggregation of the individual estimates yielded by the computation of Equation 21 is presented in Table 6. While this measure presents the same decreasing profile as the constrained measure, its level is considerably lower at each year. Hence, accounting for the fact that banks' level of capital is allowed to vary according to changes in banks' output, one finds statistically significant scale economies for the full period under scrutiny, which suggests that the concentration process observed in the Portuguese banking system was at least partly driven by the opportunity to increase productive efficiency.

Estimated scale economies show up to be stronger at the end of the sample when compared to the early 1990's. This result is likely to be linked with the changes to banks' technology brought about by technological progress. In fact, the increasing automation of services should have allowed for a decrease in banks' variable costs at the expense of a more significant initial investment in technology, such as storage and processing of information and communication facilities. These technological developments in turn allowed for the setup of a dense ATM network and of other remote-delivery outlets such as websites, with the corresponding savings in costs associated with the need for less employees and branches. Another factor possibly contributing to the higher scale economies found in the more recent period was the increasing internationalization of banking activity brought about by technological progress, financial innovation and increasing economic integration among EU members. In fact, the expansion of the relevant market for banks' activity beyond national borders brought about new growth opportunities while, to some extent, exposed them to increased competition from non-resident banks. Moreover, even the largest banks in the Portuguese financial system are relatively small when compared to their international counterparts.

3.4 Cost efficiency

Table 7 presents the obtained estimates for the cost efficiency of Portuguese banks between 1992 and 2004. As indicated above, η - the parameter for the change in cost efficiency through time - was not found to be statistically significant, and so was constrained to zero. Hence, the distance at which each bank stands from the cost frontier representing best practices does not seem to have changed during the period under scrutiny.[11] The aggregate estimate for inefficiency lies just below 91%, suggesting that Portuguese banks could theoretically have produced the same output while incurring only 91% of their actual costs. Some heterogeneity across banks was found, with estimated efficiency scores ranging from a minimum of 84% to a maximum of 99%.

3.5 Technological Progress

The estimated cost function also includes a time trend as a translog term, which allows for the computation of both Hicksian neutral and non neutral technological progress. Total cost reducing technological progress, i.e., shifts to the frontier brought about by the adoption of more efficient production techniques, is obtained by $\frac{\partial \ln C}{\partial t}$.[12] As shown in Table 8, technological progress was very low (and not statistically significant) during the first half of the 1990's. More recently, as banks adjusted to the sector's liberalization and the process of consolidation and financial innovation progressed, technological progress

[11] The fact that the aggregate value of the cost efficiency estimate is not constant even though the each bank's efficiency estimate is time invariant is motivated by a composition effect, since, due to mergers/acquisitions and to the emergence of new banks, estimation relies on an unbalanced panel of data.

[12] Note that this measure underestimates technological progress when the quality/variety of products increases through time.

has intensified. These developments should be regarded in the context of global financial integration, which catalysed the swift adoption of more efficient technology. The estimate for technological progress found for 2004 should be interpreted as indicating that, in this year, Portuguese banks operating according to the industry's best practices could produce the same output as in the previous year incurring 3.2% lower total costs.

3.6 Total Factor Productivity Growth

In this section the parameters of the estimated cost function are used to compute a measure of total factor productivity change ($TFPC$) which may be decomposed into the effect of cost efficiency change (EC), of technological progress (TC) and of returns to scale (RTS) (see Bauer (1990) for details):

$$TFPC = EC + TC + RTS \tag{22}$$

or

$$\begin{aligned} \ln\left(\frac{TFP_{i,t}}{TFP_{i,t-1}}\right) \quad = \quad & \ln\left(\frac{CE_{i,t}}{CE_{i,t-1}}\right) + \frac{1}{2}\left(-\frac{\partial \ln C_{i,t}}{\partial t} - \frac{\partial \ln C_{i,t-1}}{\partial t}\right) + \\ & + \frac{1}{2}\sum_r \left[\left(\varepsilon_{r,i,t}\frac{1-ESE_{i,t}}{ESE_{i,t}} + \varepsilon_{r,i,t-1}\frac{1-ESE_{i,t-1}}{ESE_{i,t-1}}\right)\ln\left(\frac{y_{r,i,t}}{y_{r,i,t-1}}\right)\right] \end{aligned} \tag{23}$$

Where ε_r is the elasticity of cost with respect to output r and each term of the decomposition has an interesting interpretation. In fact, according to the expression above, total factor productivity change comprises catching-up to the cost frontier (cost efficiency change), shifts in the frontier itself over time (technical progress) and shifts along the frontier (returns to scale component). The effect of returns to scale represents the pure impact on total costs stemming from changes in output after allowing for input requirements and it is positive if a bank with increasing (decreasing) returns to scale increases (decreases) its production.

It should be taken into account that Equation 23 is presented as proposed in Bauer (1990), with the necessary changes to account for the inclusion of equity in the estimated cost function. As such, the concept of economic scale economies (ESE) is used instead of the classical measure of scale economies presented in Equation 16.

The results for total factor productivity change in the Portuguese banking sector during the period under consideration are summarized in Table 9 and in Chart 3. The most striking result is that total factor productivity change has been mainly driven by technological progress, which became stronger throughout the sample period. Scale efficiency change also made a positive contribution towards total factor productivity growth, especially during the more recent years, since output increased whereas increasing returns to scale were observed.[13] Cost efficiency remained virtually constant throughout the period. Combining the three effects one finds that the slow total factor productivity growth observed during the early 1990's accelerated significantly throughout the decade, reaching a value above 4% in 2004.

4 Concluding Remarks

This paper analyses the production technology of Portuguese banks during the 1992-2004 period through the estimation of a translog cost frontier. Banks are modelled as firms which produce loans and other earning assets, choosing the cost minimizing combination of labour, capital and interest bearing debt, subject to holding a determined level of equity.

[13] This effect is particularly clear in 2000, when significant mergers occurred.

Portuguese banks' marginal costs in the production of loans and other earning assets were found to follow to a large extent the decline in the nominal interest rates throughout the period under consideration. Still, a significant part of the decrease in total marginal costs is explained by a reduction in the real resource marginal cost. In 2004, the last year included in this exercise, the estimate for this measure amounted to 1.2% in the production of loans (the corresponding figure for other earning assets is 1.3%).

Banks' capital structure was accounted for in the analysis by including equity as a fixed input in the cost function. This procedure allowed for the computation of estimates for banks' shadow cost of equity, which should be interpreted as a lower bound to banks' true willingness to pay for equity capital. Hence, it is not surprising to find that they are lower than levels compatible with usually accepted equity risk premia. Furthermore, the estimated shadow cost of equity follows quite closely the developments in market interest rates.

On average, Portuguese banks were found to operate with a cost inefficiency level around 9%, indicating that they could theoretically produce the same output incurring only 91% of their actual cost. The magnitude of cost reducing technological progress was found to increase through time, standing at 2.2% at the (weighted) sample mean and at 3.2% in 2004. Accounting for banks' capital structure, significant scale economies were found, especially in the more recent period. Further, the results point to the existence of economies of scope in the joint production of loans and other earning assets.

Against the background of the liberalization and privatization of the banking system and of increasing financial innovation, the cost frontier representing best practices has shifted downwards over time. The distance between banks' actual costs and the cost frontier, on the other hand, has not changed significantly. Since banks with increasing returns to scale increased their production, there was a move along the cost function which also contributed to an increase in productivity.

Combining these results, estimates for total factor productivity change were computed, amounting to 2.8% each year on average, which results in a total productivity increase of 31.4% between 1992 and 2004. The increase in productivity was more marked in the more recent period, recording a value of 4.2% in 2004.

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Tables and Figures

Table 1. Elasticity of banks' costs with respect to the level of

Year	Estimate at weighted sample mean	p-value (H0: elasticity of deposits=0)
1992	-0.7551	*0.00*
1993	-0.6809	*0.00*
1994	-0.6146	*0.00*
1995	-0.5931	*0.00*
1996	-0.5210	*0.00*
1997	-0.4953	*0.00*
1998	-0.4439	*0.00*
1999	-0.4058	*0.00*
2000	-0.4621	*0.00*
2001	-0.4591	*0.00*
2002	-0.3827	*0.00*
2003	-0.3132	*0.00*
2004	-0.2437	*0.00*
Overall	-0.4211	*0.00*

Notes: This test is performed by estimating a cost function which excludes interest paid on deposits from the definition of total cost (the dependent variable) and from the computation of the price of funding and includes the level of deposits as a fixed input. If the elasticity of costs with other inputs with respect to the level of deposits is negative (positive), then deposits behave as inputs (outputs) and should be modelled as such. Total loans adjusted for securitization are used as weights in the computation of means.

Table 2. Cost frontier estimation

	(1)	(2)
$\ln(W_L)$	0.1148	0.1147
	0.02	*0.02*
$\ln(W_F)$	0.6364	0.6367
	0.01	*0.01*
$\ln(y_1)$	0.5562	0.5566
	0.01	*0.01*
$\ln(y_2)$	0.4589	0.4591
	0.01	*0.01*
$\ln(W_L)^2$	0.0699	0.0696
	0.04	*0.04*
$\ln(W_F)^2$	0.0858	0.0864
	0.03	*0.03*
$\ln(y_1{}^2)$	0.0970	0.0976
	0.01	*0.01*
$\ln(y_2{}^2)$	0.0746	0.0746
	0.01	*0.01*
$\ln(W_L)*\ln(W_F)$	-0.0807	-0.0809
	0.06	*0.06*
$\ln(y_1)*\ln(y_2)$	-0.2496	-0.2499
	0.02	*0.01*
$\ln(W_L)*\ln(y_1)$	-0.0035	-0.0035
	0.03	*0.03*
$\ln(W_L)*\ln(y_2)$	-0.0442	-0.0442
	0.03	*0.03*
$\ln(W_F)*\ln(y_1)$	0.0033	0.0032
	0.02	*0.02*
$\ln(W_F)*\ln(y_2)$	0.0332	0.0328
	0.02	*0.02*
t	-0.0142	-0.0143
	0.00	*0.00*
t^2	-0.0012	-0.0012
	0.00	*0.00*
$\ln(W_L)*t$	-0.0098	-0.0098
	0.01	*0.01*
$\ln(W_F)*t$	-0.0032	-0.0031
	0.01	*0.01*
$\ln(y_1)*t$	-0.0043	-0.0043
	0.01	*0.01*
$\ln(y_2)*t$	0.0011	0.0010
	0.00	*0.00*
$\ln(e)*t$	0.0050	0.0050
	0.01	*0.01*
$\ln(e)$	-0.0486	-0.0492
	0.01	*0.01*
$\ln(e)^2$	-0.0978	-0.0974
	0.02	*0.02*
$\ln(W_L)*\ln(e)$	0.0496	0.0495
	0.04	*0.04*
$\ln(W_F)*\ln(e)$	-0.0182	-0.0178
	0.03	*0.03*
$\ln(y_1)*\ln(e)$	0.0498	0.0488
	0.03	*0.02*
$\ln(y_2)*\ln(e)$	0.1169	0.1174
	0.03	*0.02*
constant	-0.1434	-0.1451
	0.03	*0.02*
μ	0.0682	0.0713
	0.06	*0.04*
η	0.0021	
	0.03	
γ	0.7710	0.7690
	0.13	*0.13*

Note: Standard errors are reported in italics.

Table 3. Marginal cost estimates at the weighted sample mean

year	Marginal cost of loans	Marginal cost of other earning	Short-term money market	Implicit price of funding	Real resource marginal cost of loans	Real resource marginal cost of other earning assets	Implicit interest rate on loans	Margin on loans
1992	14.59%	14.03%	16.72%	10.74%	3.85%	3.29%	17.15%	2.56%
1993	12.43%	11.79%	13.17%	8.94%	3.48%	2.84%	15.45%	3.02%
1994	10.21%	9.41%	11.23%	7.01%	3.20%	2.40%	13.08%	2.86%
1995	10.10%	9.31%	9.79%	7.09%	3.01%	2.21%	12.26%	2.15%
1996	8.35%	7.73%	7.27%	5.71%	2.64%	2.02%	10.72%	2.37%
1997	7.04%	6.45%	5.61%	4.65%	2.39%	1.80%	9.24%	2.20%
1998	5.69%	5.26%	4.23%	3.59%	2.10%	1.66%	7.44%	1.75%
1999	4.53%	4.05%	2.96%	2.65%	1.89%	1.41%	5.78%	1.25%
2000	4.93%	4.40%	4.39%	3.28%	1.64%	1.11%	6.13%	1.20%
2001	4.85%	4.41%	4.26%	3.46%	1.40%	0.95%	6.30%	1.45%
2002	4.12%	4.03%	3.32%	2.76%	1.35%	1.26%	5.36%	1.24%
2003	3.46%	3.54%	2.33%	2.28%	1.17%	1.26%	4.56%	1.10%
2004	3.21%	3.30%	2.11%	2.00%	1.21%	1.29%	4.21%	1.00%

Notes: Total loans adjusted for securitization are used as weights in the computation of means.

Chart 1. Marginal costs

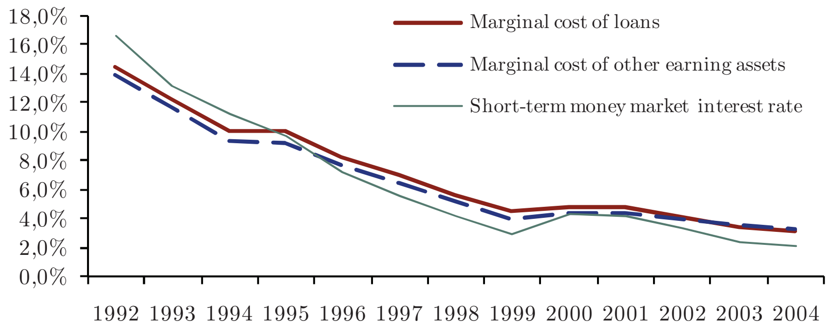


Chart 2. Real resource marginal costs

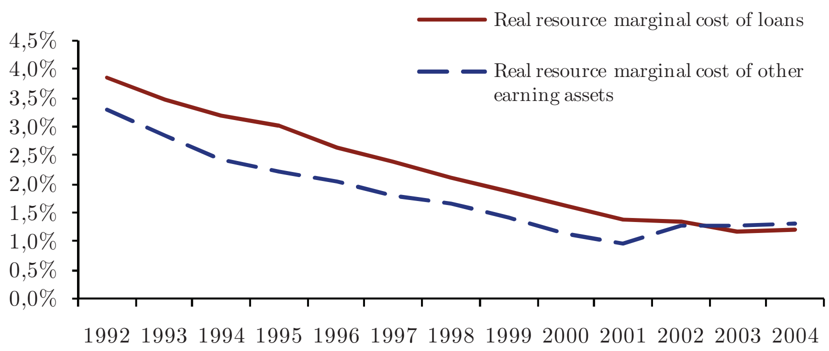


Chart 3. Margin on loans

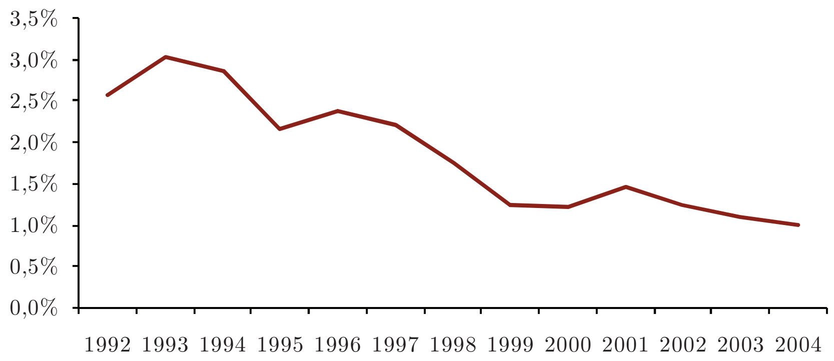
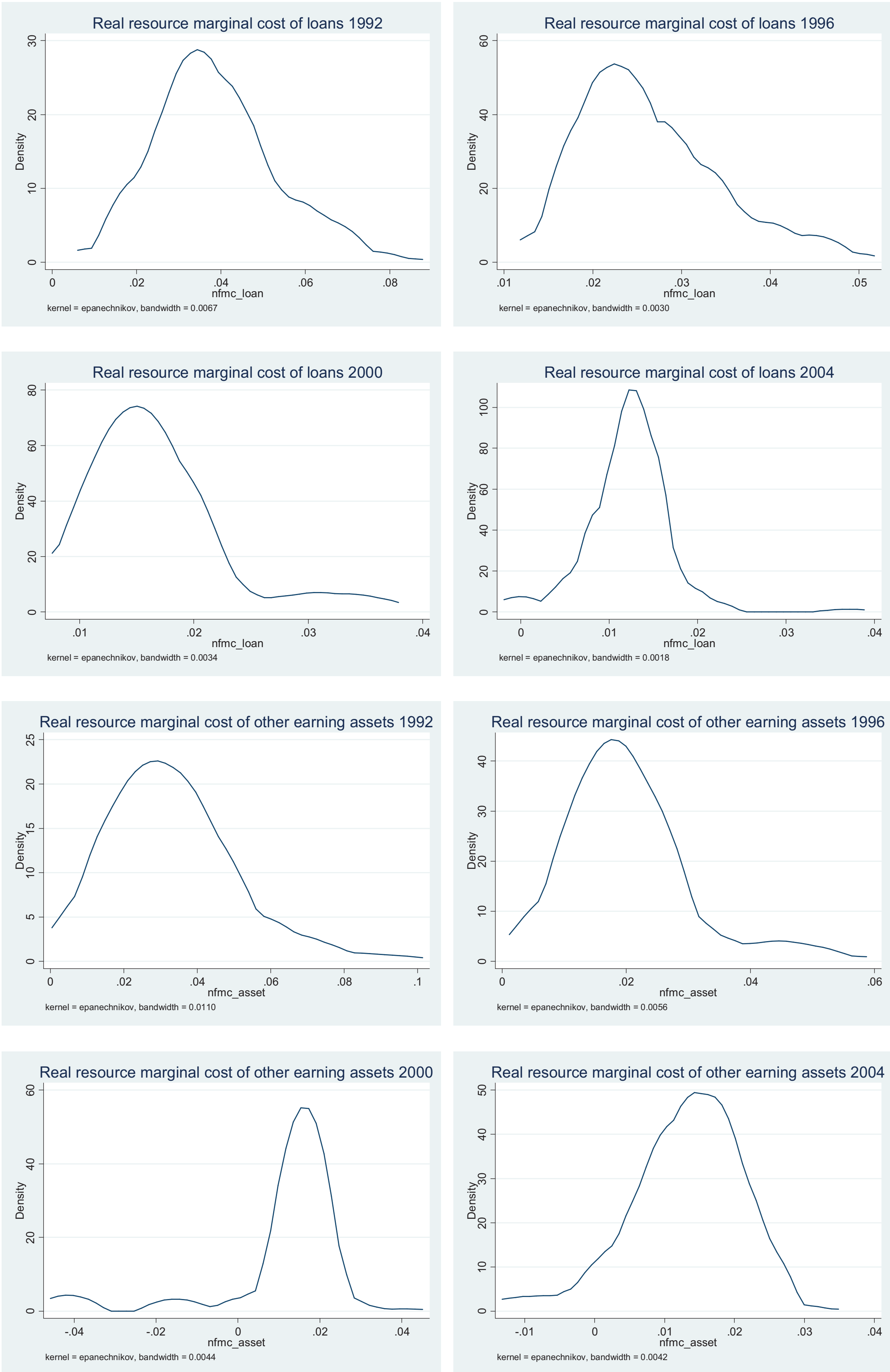


Chart 4. Density of real resource marginal costs



Note: The frequencies used in the histograms are weighted by banks' total loans adjusted for securitization.

Table 4. The shadow cost of equity

Year	Shadow cost of equity (full sample)	Shadow cost of equity (20% largest banks)	Short-term money market interest rate	Long-term government bond interest rate	Equity/Assets ratio	Implicit price of funding
	(1)	(2)	(3)	(4)	(5)	(6)
1992	18.26%	20.68%	16.72%	11.86%	7.56%	10.74%
1993	13.20%	17.02%	13.17%	10.33%	7.41%	8.94%
1994	8.94%	11.60%	11.23%	10.48%	6.97%	7.01%
1995	7.13%	9.52%	9.79%	11.47%	6.54%	7.09%
1996	3.93%	5.51%	7.27%	8.56%	6.29%	5.71%
1997	2.67%	4.09%	5.61%	6.36%	6.07%	4.65%
1998	3.04%	4.04%	4.23%	4.88%	6.39%	3.59%
1999	1.55%	2.96%	2.96%	4.78%	6.50%	2.65%
2000	2.87%	4.92%	4.39%	5.60%	6.04%	3.28%
2001	4.01%	4.94%	4.26%	5.16%	5.85%	3.46%
2002	3.46%	4.46%	3.32%	5.01%	6.13%	2.76%
2003	1.90%	3.56%	2.33%	4.18%	6.36%	2.28%
2004	1.51%	3.04%	2.11%	4.14%	6.33%	2.00%

Notes: Total loans adjusted for securitization are used as weights in the computation of means.

Chart 5. The shadow cost of equity

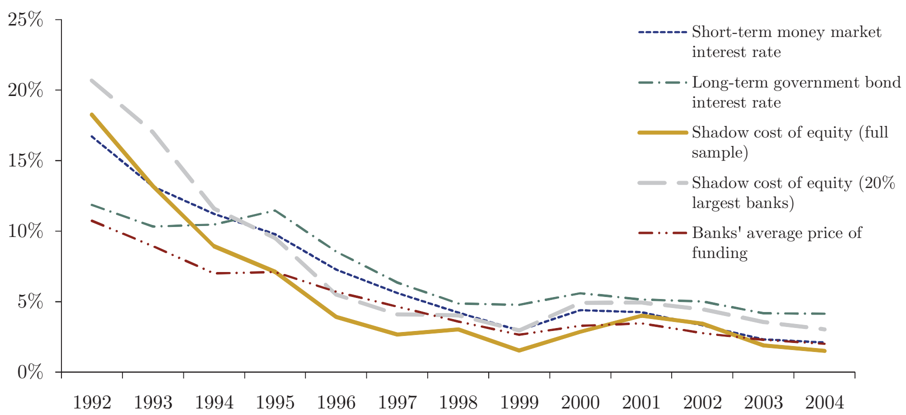


Table 5. Determinants of the shadow cost of equity

	Random-Effects model (1)	Fixed-Effects model (2)
$(\text{Equity/Assets})_{t-1}$	0.84	0.71
	0.14	*0.14*
ROE_{t-1}	0.14	0.13
	0.03	*0.03*
State-owned bank (dummy)	-0.05	-0.04
	0.02	*0.02*
Branch of credit institution whose head office is in foreign countries (dummy)	-0.08	
	0.04	
20% largest banks (dummy)	0.02	0.04
	0.01	*0.02*
Hausman test (p-value)	*0.995*	

Notes: Standard errors are reported in italics. Time dummies and a constant were included in the regression.

Table 6. Scale economies

year	*Scale Economies (SE)*	p-value (*H0*: *SE*=1)	*Economic Scale Economies (ESE)*	p-value (*H0*: *ESE*=1)
1992	1.0919	*0.00*	0.9698	*0.01*
1993	1.0747	*0.00*	0.9678	*0.01*
1994	1.0505	*0.02*	0.9664	*0.00*
1995	1.0349	*0.08*	0.9687	*0.01*
1996	1.0156	*0.41*	0.9665	*0.00*
1997	0.9995	*0.98*	0.9628	*0.00*
1998	1.0010	*0.96*	0.9533	*0.00*
1999	0.9882	*0.57*	0.9457	*0.00*
2000	0.9906	*0.66*	0.9431	*0.00*
2001	0.9933	*0.79*	0.9409	*0.00*
2002	0.9909	*0.71*	0.9363	*0.00*
2003	0.9770	*0.35*	0.9347	*0.00*
2004	0.9658	*0.20*	0.9297	*0.00*
Overall	0.9964	*0.86*	0.9447	*0.00*

Notes: Total loans adjusted for securitization are used as weights in the computation of means. *SE* denotes scale economies as defined in Equation 15 and *ESE* refers to economic scale economies as defined in Equation 20.

Table 7. Cost efficiency estimates

year	Time varying decay model (1)	Time invariant model (2)
1992	90.89%	90.89%
1993	91.13%	91.11%
1994	91.18%	91.14%
1995	91.13%	91.08%
1996	91.10%	91.02%
1997	91.12%	91.03%
1998	90.60%	90.50%
1999	90.66%	90.53%
2000	90.77%	90.63%
2001	90.81%	90.66%
2002	90.84%	90.67%
2003	90.90%	90.71%
2004	91.03%	90.82%
	90.89%	90.76%

Note: Total loans adjusted for securitization are used as weights in the computation of means.

Table 8. Technological progress

year	Technological progress (*eti*)	p-value (*H0*: *eti*=0)
1992	0.19%	*0.62*
1993	-0.08%	*0.42*
1994	-0.33%	*0.22*
1995	-0.67%	*0.11*
1996	-0.96%	*0.02*
1997	-1.29%	*0.00*
1998	-1.44%	*0.01*
1999	-1.76%	*0.03*
2000	-2.23%	*0.00*
2001	-2.54%	*0.00*
2002	-2.78%	*0.00*
2003	-3.04%	*0.00*
2004	-3.19%	*0.01*

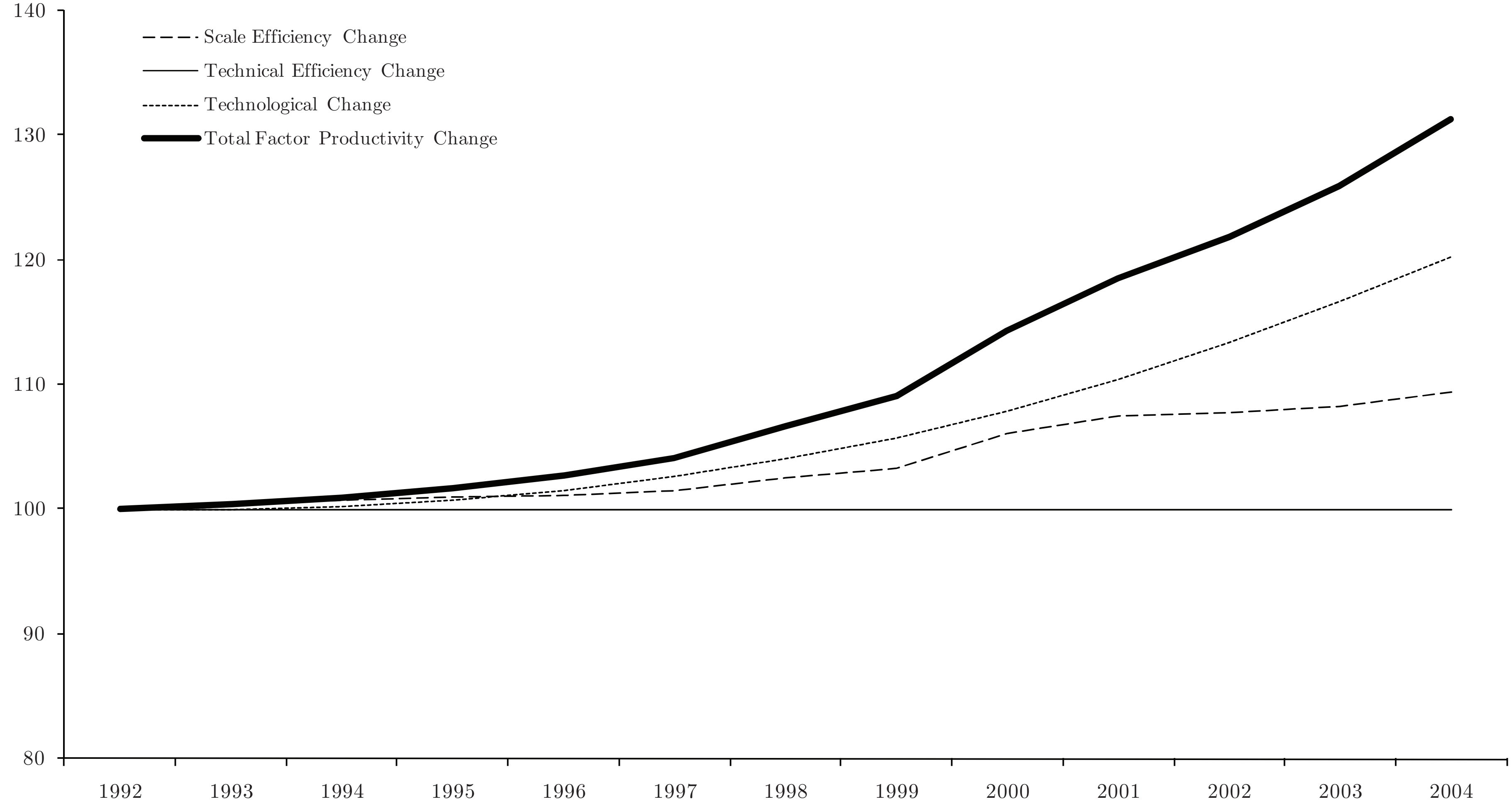
Note: Total loans adjusted for securitization are used as weights in the computation of means.

Table 9. TFP Growth

year	*Scale Efficiency Change*	*Technical Efficiency Change*	*Technological Change*	*Total Factor Productivity Change*
1992				
1993	0.39%	0.00%	-0.05%	0.34%
1994	0.36%	0.00%	0.21%	0.57%
1995	0.28%	0.00%	0.50%	0.78%
1996	0.17%	0.00%	0.82%	0.99%
1997	0.28%	0.00%	1.12%	1.41%
1998	1.00%	-0.01%	1.37%	2.37%
1999	0.73%	0.00%	1.60%	2.33%
2000	2.83%	0.00%	2.00%	4.83%
2001	1.33%	0.00%	2.38%	3.71%
2002	0.18%	0.00%	2.66%	2.83%
2003	0.44%	0.00%	2.91%	3.35%
2004	1.11%	0.00%	3.12%	4.23%

Note: Total loans adjusted for securitization are used as weights in the computation of means.

Chart 6. Total Factor Productivity Growth



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