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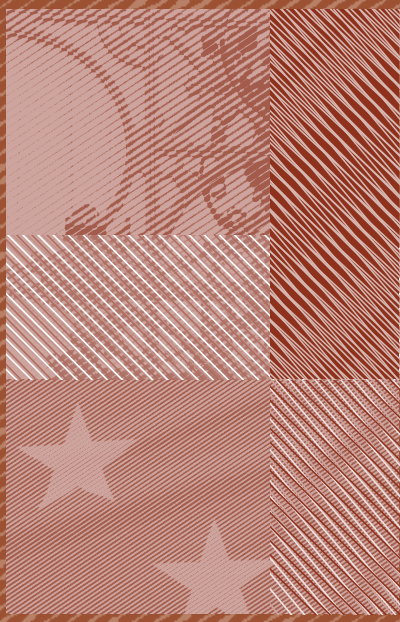

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WHY DID HIGH PRODUCTIVITY GROWTH OF BANKS PRECEDE THE FINANCIAL CRISIS?

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Abstract

The observed high levels of banks' operating efficiency, profits and market values in the years before the financial crisis raise reasonable doubts about the information content of conventional performance measures for the accurate assessment of the efficiency of banking intermediation. In this paper we estimate the productivity of individual Spanish banks and the industry's productivity growth over time using the methodology of Olley and Pakes (1996) and Levinsohn and Petrin (2003), which controls for simultaneity bias. We then examine the contributions of two sets of factors to productivity growth: banking practices that have been signalled as the proximate causes of the crisis, and technical progress in the industry. We obtain that more than two thirds of the estimated productivity growth in the years 2000-2007 is attributable to practices such as the expansion of the housing market, the high recourse to securitization and short-term finance, and the leveraging of banks' balance sheets. The remaining 2.8% cumulative annual growth rate is our estimate for the technical progress in the industry, similar to the estimated rate in the period 1993-2000.

Keywords: productivity of banks, financial stability production function, IT capital, simultaneity bias.

JEL classification: D24, G21.

Resumen

Los elevados niveles de eficiencia operativa, beneficios y valoración que experimentaron los bancos en los años previos a la crisis suscitan dudas razonables sobre el contenido informativo de las medidas de desempeño convencionales en su uso para la evaluación de la eficiencia en la intermediación bancaria. Este trabajo estima la productividad de los bancos españoles a nivel individual, basándose en la metodología de Olley e Pakes (1996) y Levinsohn y Petrin (2003), para corregir por el sesgo de simultaneidad. A partir de esta, estima el crecimiento de la productividad agregada en el sector bancario español. Asimismo, el trabajo analiza las contribuciones al crecimiento de la productividad de dos tipos de factores: las prácticas bancarias que han sido señaladas como causas directas de la crisis y el progreso técnico en el sector. Los resultados muestran que dos terceras partes del crecimiento estimado de la productividad en el período 2000-2007 son atribuibles a cambios en las prácticas bancarias, tales como: la expansión del mercado de la vivienda, el elevado recurso a la titulización de activos y a la financiación a corto plazo, así como el proceso de apalancamiento en los balances bancarios. El restante 2,8 % se interpreta como el progreso técnico estimado para el sector en el período analizado, similar al estimado para el período 1993-2000.

Palabras clave: productividad de los bancos, estabilidad financiera, función de producción, capital tecnológico, sesgo de simultaneidad.

Códigos JEL: D24, G21.

1. Introduction

Banks and other financial intermediaries perform the economic functions of providing liquidity, transferring funds from savors to investors and collecting and diffusing information (Diamond and Dybvig, 1983; Diamond, 1984; Merton, 1995; Gorton and Winton, 2003). These functions involve value adding activities of facilitating payments and managing cash, selecting and monitoring borrowers and providing advice and consultation services. Banks use labor, capital and other inputs to perform these activities and earn revenues from interest rates differentials and fees. The level of efficiency in performing banking intermediation activities is a key factor for economic development (Buera, Kaboski and Shin, 2011; Greenwood, Sanchez and Wang, 2010; Mehra, Piguillem and Prescott, 2011) and changes in the costs of intermediation will have important macroeconomic consequences for investment and growth (Bernanke, Gertler and Gilchrist, 1999; Hall, 2011; Christiano and Ikeda, 2011).

In conventional competitive markets, profits are the reward for providing services demanded by costumers at the lowest cost. The expansion of banks' balance sheets around the world and the record-high growth rates of profits and productivity until 2007 could have been an indicator of substantial efficiency gains in financial intermediation. However, the outburst of the severe financial crisis in 2007 showed that, at least for the case of banks, the usual indicators of performance might fail in informing about their "true" economic results[1]. Potential explanations of this paradox can be the existence of managerial incentives to distort reported profits (Rajan 1994), financial innovations for regulatory arbitrage (Achayra, Schuabl, Suarez 2011), measuring profits and output not adjusted for risk (Haldane, Brennan and Madouros, 2010), and business model innovations that change the nature of banks' output over time (Philippon, 2012), such as the "originate to distribute" model, and the market-based intermediation or shadow banking.

[1] Haldane, Brennan and Madouros (2010) document this paradox with detail. In the UK, the resources labour and physical capital consumed as inputs in the financial intermediation industry, relative to labour and capital of the whole economy, have been decreasing since the nineties while the share of gross value added of the financial intermediation industry in the gross value added of the whole economy rose almost 3 percentage points, to 8%, in 2007. According to the Banker data set, the assets of the 1000 world largest banks more than doubled in the period 2000-2008. During the same time period, the profits of these largest banks increased 150% for an average annual rate of return of 15% (around 20% of return on equity, twice the return in the rest of industries, for the whole banking industry in the UK, US and Europe). In Spain, using the EU-KLEMS data base, estimated annual cumulative productivity growth in the period 1999-2007 was 8% (O'Mahony and Timmer 2009).

In this paper, we rely on bank-level productivity estimations to quantify the productivity growth of the Spanish banking industry in the years before the financial crisis (1992-2007) and examine its determinants. The Spanish case is a good case study for a better understanding of why the usual measures of efficiency and profitability of banks may not inform about the true efficiency gains in financial intermediation. First, the estimated productivity growth of the country's banking industry before the crisis was one of the highest among developed countries. Second, in Spain concurred what Diamond and Rajan (2009) consider as the proximate causes of the crisis: (i) investors perceived a permanent reduction in interest rates when Spain joined the Euro zone, (ii) there was an unprecedented expansion of the housing industry and (iii) banks financed a good part of the loans with wholesale financing and short-term debt. However, Spain has also different features from the USA and other countries in two main aspects[2]. First, securitized loans remained in the balance sheets of banks and they were subject to capital requirements, and, second, savings banks, with market share similar than commercial banks, compete in an equal basis with commercial banks.

The estimates of the bank-level total factor productivity (from now on, *productivity*) are derived from the estimation of the banks' production function. We model the production and sales of bank services at the branch level assuming a Leontief technology (Martín-Oliver and Salas-Fumás, 2008) with two variable inputs, labour and services from information technology assets (IT capital), and a quasi-fixed input (the physical capacity of the branch). Then, the branch-level production function is aggregated to obtain the bank-level production function, which is the function that we empirically estimate with Spanish banks data. The estimation of the technology parameters follows the methodology posited in Olley and Pakes (1996) and extended in Levinsohn and Petrin (2003) to control for the potential simultaneity bias between the unobserved productivity shock and the management decisions on input quantities in response to the shocks.

Next, we explore what is behind the estimated productivity. As indicated, the ultimate goal is to isolate the "true" economic efficiency of the banking industry, as the ultimate indicator of the actual contribution of financial intermediation to economic growth and to macroeconomic stability. For this purpose, we isolate the factors that can determine the estimated productivity values due to reasons different from technical

[2] For a detailed description of the the securitization process in Spain compared with other countries, and of the regulatory treatment of assets' securitized in Spain, see Catarineu and Pérez (2008).

progress and economic efficiency. These factors include, on the one hand, differences in the operating characteristics of banks in the sample (Berger and Mester, 1997; Frei, Harker and Hunter, 2000) and, on the other hand, factors related with the proximate causes of the crisis, which will be the focus of this paper. In other words, we aim at exploring whether certain business decisions of banks (such as concentrating loans in the housing market, issuing securities and short-term debt to finance the loans, increasing leverage, etc) improve the short-term private performance of banks but at the social cost of future financial instability that became evident with the crisis.

Our empirical results show that the productivity growth rate of the Spanish banking industry more than doubled during the years after the Euro, a result that is consistent with other productivity estimates obtained from other methodologies and with aggregate industry data (O'Mahony and Timmer, 2009). However, we also find that an important part of this productivity growth in the pre-crisis years is explained by business decisions that, ex-post, have been identified as drivers of the crisis (expansion of the housing market, securitization, short-term finance and increasing leverage). When removing these and other operational factors from the estimated productivity, the productivity residual grows at a similar rate in the years before and after the introduction of the Euro. In other words, we show that the high growth rates of raw productivity estimated for the banking industry during the years prior to the crisis were not an indicator of efficiency and technical progress.

The paper is related to the long list of published papers on productivity and efficiency of banks[3]. We are the first in estimating the total factor productivity (TFP) from a Leontief-type production function formulated at the branch level. Most of the productivity estimates in banking are obtained with cost or profit functions (Kumbhakar and Lovell, 2000)[4]. This paper is also, up to our knowledge, the first one to estimate the production function and the productivity of banks considering IT capital as a productive input, what seems essential in one of the most IT-capital intensive industries. This paper is also one of the few (together with Bunch, Koch and Kötter, 2009 and Nakane and Weintraub, 2005) that corrects for simultaneity bias in the estimation of the production

[3] Some reference papers in this literature are Sealey and Lindley (1977), Berger and Humphrey (1991, 1992, 1997), Fixler and Zieschang (1992), Berger and Mester (1997). Hughes and Mester (2008) contains an updated review of the literature and Berger (2007) surveys more than 100 papers on cross-country comparisons of banking efficiency.

[4] There have been several papers published on the measurement and determinants of productivity and efficiency of Spanish banks (Grifell-Tatjé and Lowell, 1996; Lozano-Vivas, 1997; Maudos, Pastor, Pérez and Quesada, 2002) but they all use a different methodology and explanatory variables so their results are not comparable with those obtained in this paper.

function of banks following the methodology in Olley and Pakes (1996) and Levinsohn and Petrin (2003).

Our paper is also related with the growing literature interested in measuring the cost efficiency of financial intermediation, either through a more accurate measurement of the output of banks and market-based (shadow banking) intermediaries (Philippon, 2012), or through the calculation of risk-adjusted measures of productivity (Haldane, Brennan and Madouros, 2010; Basu, Inklaar and Wang, 2011). Our contribution regarding this literature is twofold: First, we estimate the production function and the productivity values using bank-level data, whereas the previous papers use aggregate industry data for their estimations. Second, our analysis goes beyond the scope of these papers, obtaining a more accurate estimation of the contribution of technical progress to the productivity growth of the banking industry, and provides an empirical test for some of the theories about the causes of the financial crisis.

The rest of the paper is organized as follows. Section 2 describes the production technology of banks and the methodology used in the estimation of productivity. Section 3 shows the results of the estimation of the production function and average productivity for the Spanish banking industry from bank-level data. Section 4 contains an analysis of the determinants of the observed productivity of Spanish banks, in the context of the banking practices that have been related with the causes behind the recent financial crisis. The conclusions summarize the main results of the paper.

2. Production function estimation

In this section, we describe the methodology proposed for the estimation of the banks' production function. Relying on this, we estimate banks' productivity. Our starting point is based on the empirical fact that retail banks' services are produced at branches, which provide the physical space for employees, computer terminals and other physical infrastructure needed in the production process. If the branches of one bank are relatively similar, the output (inputs) of the bank can be computed as the output (inputs) *per branch*, multiplied by the number of branches. Once in the branch, customers receive services that are produced combining labor and IT capital inputs, being the branch's capacity an indivisible and fixed input. Since bank services are not directly

observable and measurable[5,6], we rely on the assumption that the variability across banks in services produced can be approximated by the sum of loans and deposits, at constant prices.

The production function

The representative bank is assumed to collect deposits, *D*, and grant loans, *L*, deploying physical capital (branches, *B*), IT capital (*IT*) and labor (*N)*. Since the services attached to these loans and deposits are provided in each branch, the inputs and outputs of banks are first defined at the branch level and, then, aggregated to the bank level. Each branch has a given capacity *q*. The number of workers per branch (N_b) and the IT capital per branch (IK_b) can be substituted among themselves, but not with the physical capital. For a given number of branches (*B)*, the total output of the bank defined as the sum of loans (*L*) and deposits (*D*) can be written as follows,

$$L + D = B \cdot \left[\min\left\{q, F\left(N_b, IK_b\right)\right\}\right] \tag{1}$$

Therefore, the branch production technology is of the Leontief-type with a given investment in fixed capital that limits the total capacity of the branch. The function *F*( ) is assumed to be increasing and concave in the two variable inputs, labor and IT capital. Equation (1) assumes constant returns to scale at the bank level (i.e. output of the bank is a scale factor of the output per branch)[7]. If the function *F*( ) at the branch level is linear homogeneous then equation (1) can be written as,

$$L + D = \left[\min\left\{B \cdot q, F\left(N, IK\right)\right\}\right] \tag{2}$$

where $N=B \cdot N_b$ and $IK=B \cdot IK_b$ denote labor and IT inputs, at the bank level, respectively. We assume that the capacity *q* is non-binding for the standard branch, so the observed level of output is determined by the function *F(N, IK)*. For the rest of the paper, the actual specification of the constant returns to scale production function will be written as,

$$L + D = e^{f(\omega)} N^{\alpha} IK^{1-\alpha}, \tag{3}$$

[5] Bank services include the marketing of loans, deposits and payment services; the evaluation of the credit quality of the potential borrowers; the monitoring of loans and possible defaults; provision of liquidity; book keeping and monitoring of deposit accounts; selling and book keeping of saving products and so on.

[6] The paper adopts the production approach instead of the intermediation approach to model the relationship between inputs and outputs in banks; this amounts to using deposits as a measure of output together with loans. The assumption that banks consume inputs (i.e., labour and IT services) to obtain deposits (output) is realistic in the evaluation of the productivity of banks at the branch level and in the aggregate. Other papers that use the sum of loans and deposits as a measure of single output of banks are Humphrey (1992), Prasad and Harker, (1997), Tirtiroglu, Daniels, and Tirtiroglu (2005). A different issue is how banking services tied to lending and those tied to the deposits combine to give a measure of total bank output.

[7] We formally test this assumption and find empirical evidence supporting it.

where $e^{f(\omega)}$ is the total factor productivity term of the production function, which is increasing with the productivity shock ω.

Estimation of the production function: Methodology

The estimation of the parameters of production function (3) follows the methodology proposed by Olley and Pakes (1996) and extended by Levinsohn and Petrin (2003). In both cases the concern is to correct for the endogenous bias in the estimation of the elasticity of output with respect to labor and capital caused by the fact that the quantity of labor input used in production may itself be determined by the value of the productivity shock.

The estimation procedure, adapted to this particular case, proceeds as follows. Let

$$y_{it} = \beta_0 + \beta_n n_{it} + \beta_k ik_{it} + \omega_{tt} + \varepsilon_{it} \tag{4}$$

be the log-transformation of the production function in (3) where ε is a the pure stochastic component. The term ω is a state variable in the firm decision problem and, therefore, it affects the demand for inputs. This variable is observable to the firm's manager but not to econometricians. We do not impose the condition of constant returns to scale, which will be empirically tested.

Let the variable τ be one observable variable that depends on the two state variables ω and *ik*. This proxy variable τ is required to be monotonic in ω for all the values of *ik* so as it is possible to invert the function and yield ω as a function of τ and the level of capital *ik*[8]

$$\omega_{it} = h_t(\tau_{it}, ik_{it})$$

By replacing this expression of the productivity in (5) it is possible therefore to control for ω in the estimation of

$$y_{it} = \beta_n n_{it} + \varphi_t(\tau_{it}, ik_{it}) + \varepsilon_{it} \tag{5}$$

where $\varphi_t(\tau_{it}, ik_{it}) \equiv \beta_0 + \beta_{ik} ik_{it} + h_t(\tau_{it}, ik_{it})$. Subtracting the expectation of (5) conditional on ($\tau_{tt,}$ ik_{tt}) from (5) we obtain

$$y_{it} - E(y_{it} \mid \tau_{it}, ik_{it}) = \beta_n (n_{it} - E(n_{it} \mid \tau_{it}, ik_{it})) + \varepsilon_{it}. \tag{6}$$

[8] Olley and Pakes (1996) propose to use capital investment as proxy variable τ. Levinsohn and Petrin (2003) extend the list of observable variables correlated with the productivity shock that can be used in the estimation procedure to eliminate the potential estimation bias. They argue that adjustment costs could imply that firms decide not to invest even though the productivity shock exists. To overcome this limitation they propose to use intermediate inputs as proxy variables of productivity shocks.

This equation can be estimated using the non-parametric approach proposed by Levinsohn-Petrin that consists on, first, estimating the conditional moments $E(y_t \mid \tau_t, ik_t)$ and $E(n_t \mid \tau_t, ik_t)$ using a locally weighted quadratic least squares approximation and, then, using non-intercept *OLS* to obtain a consistent estimate of β_n[9].

Parameter β_{ik} associated to IT capital is estimated in a second stage. It begins with the assumption that productivity ω_t follows a first-order Markov process,

$$\omega_{it} = E(\omega_{it} \mid \omega_{it-1}) + \xi_{it}$$

where ξ_{it} is the innovation term. Following Olley-Pakes, β_{ik} is identified by assuming that neither IT capital nor the lagged number of workers respond to the innovation in productivity. Function $E(\omega_t \mid \omega_{t-1})$ can be estimated by locally weighted least squares relying on the estimations of ω_t and ω_{t-1} obtained from the first-stage results and one candidate value for the coefficient associated to IT capital denoted as β_{ik}^*. Thus, for a given candidate value, parameter β_{ik} can be estimated from the following equation

$$y_{it} - \hat{\beta}_n n_{it} - E[\omega_{it} \uparrow \omega_{it-1}] = \beta_{ik} ik_{it} + \xi_{it} + \varepsilon_{it}(\beta_{it}^*),$$

where the residuals are expressed in terms of the candidate β_{ik}^*. Let define a set of orthogonality conditions

$$E(\Lambda) = E(z_{it}'(\xi_{it} + \varepsilon_{it})) = 0,$$

where z_t is a vector that includes $\{ik_t, ik_{t-1}, n_{t-1}\}$. Then, $\hat{\beta}_{ik}$ is estimated by minimizing the *GMM* criterion function defined from the orthogonal conditions of the population:

$$Q(\beta^*) = \min_{\beta^*} \sum_{h=1}^{H} \Lambda'(\beta^*) \cdot \Lambda'(\beta^*)$$

where h indexes the H instruments. To measure the precision of our estimates, we use bootstrapped standard errors of the coefficients.[10] Finally, the GMM estimator of β_{ik} is chosen for a grid search as in Levinsohn and Petrin (2003) since this is more robust than using starting candidate value β_{ik}^* (as for example the *OLS* estimator).

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[9] Alternatively, parameter β_n in Equation (5) can be estimated using *OLS* including some approximation for function $\varphi_t(.)$. Olley and Pakes approximate this function with a polynomial expansion in τ_t and ik_t

[10] Petrin, Poi and Levinsohn. (2004) provide an estimation command that implements this methodology in Stata. This command allows the estimation of production function using one or two proxies of productivity and one variable of capital (non-variable inputs). In this paper we will need the inclusion of two variables of capital, i.e. branches and IT capital.

3. The productivity estimation for Spanish banks

Database and variables

We draw bank-level data from the non-consolidated confidential balance sheets and income statements, as well as in complementary files, reported by banks to Banco de España. The sample period spans from 1992 to 2007 and contains information of commercial and savings banks. We exclude credit cooperatives because they do not provide all the information that is needed in the analysis, as well as banks whose market share of assets is smaller than 0.1%. When two banks merge, we consider that a new bank brand is created. Banks considered in our paper represent 89.25% of the Spanish banking industry, in terms of assets, in 2007. This coverage is similar in terms of other variables, such as the number of employees and remains fairly stable across time period.

We consider three different inputs that enter into the production of banking services: (i) the input services from the physical capital (i.e. number of branches of a given capacity), (ii) the services from IT capital and (iii) the services from workers.

The fixed capacity per branch of bank i, q_i, is obtained dividing the replacement cost of its buildings by the number of owned branches (i.e. we assume homogeneous branches for each bank). The total capacity of the bank is equal to $B_i q_i$, where B_i is the total number of branches (owned and rented) of bank i.

Banks report a stock of IT capital in the assets side of the balance sheet and they also report an annual flow of IT expenditures in the income statement. We define the stock of the IT capital of bank i in year t, IK_{it} as the sum of the IT capital in the balance sheet at book value plus the estimated capital stock accumulated from annual expenditures assuming a perpetual inventory model with depreciation rate of 35%. In the calculation of the stock of IT capital at replacement cost, we assume that incorporated technical progress practically compensates the price inflation[11]. Finally, the labor input services of bank i in year t, N_{it} is measured as the average number of employees of bank i during year t.

The output of the banking firm is approximated by the sum of loans and deposits. The balance of loans and deposits in year t are calculated at homogeneous current prices applying the permanent inventory model. Following this scheme, the estimated stock of deposits (loans) in year t is equal to the deposits (loans) in t-1 valued at year t prices using the general inflation price index plus the flow of new deposits

[11] Martín-Oliver, Salas-Fumás and Saurina (2007) explains in detail the methodology used in the calculation of physical and IT capital of Spanish banks.

(loans) in year *t*. After their estimation at current prices, all inputs and outputs in monetary units are deflated and expressed in prices of year 1992.

Table 1 presents the time evolution of the descriptive statistics of the inputs, outputs and number of braches per bank. The data shows that the number of banks in the Spanish industry over time has fallen from 140, in 1992, to 90, in 2007. For the rest of variables of the table, the mean is substantially above the median indicating that the distribution of the variable is highly skewed. The growth rate of the average number of employees per bank is smaller than minus the growth rate of the number of banks, which implies that the total number of industry employees decreases in the period. On the other hand, the stock of IT capital increases over time. This suggests that labor is substituted by IT capital in the input mix of banks. More concretely, the average stock of IT capital per employee has increased 68% during the sample period. The average rates of growth of output per bank and IT per bank where similar (around 7.7% of average annual growth rate) and much higher than the growth rate in the average number of workers per bank (around 1.5%). This implies an important increase in labor productivity along the period (around 130% in 2007 compared with 1992), as well as an increase in the total factor productivity of banks.

Estimation of the production function

The estimates of the parameters of the production function are presented in Table 2. The upper part of the table shows the estimates of the parameters of the production technology, equation (4), ignoring the simultaneity bias (i.e. *OLS*). The lower part reports the estimates controlling for the simultaneity between efficiency shocks and labour input decisions, using investment in IT as a proxy for the productivity shocks (in line with Olley and Pakes, 1996).

The use of the investment in IT capital as the proxy variable τ has been decided after comparing the results with those obtained with other alternatives, mainly externally supplied intermediate inputs, in line with Levinsohn and Petrin (2003) [12] (bellow, we discuss robustness checks in more detail). In banking firms, the link between the productivity shocks and the external purchases of intermediate inputs may

[12] The main reason why Levinsohn and Petrin (2003) posited intermediate inputs as an alternative proxy to investment in capital is the existence of adjustment costs that could result in firms that do not invest in some periods. It would imply a large proportion of zero-investment observations in the sample that could not be used in the estimations. In our application, all banks in the sample invest a positive amount in IT during all the years of the period.

be weaker than in industrial firms because in banks the elasticity of output to variations in the inputs is expected to be small compared with that in industrial firms. In addition, investment in IT was the variable that better fitted the three specification tests posited by Levinsohn and Petrin (2003) in the selection of the proxy variable: i) monotonicity, i.e. higher levels of investments are associated to higher values of the productivity for any level of IT capital (see Figure A1 in the Appendix A); ii) correction of the bias: the estimated coefficient of labour (IT capital) is lower (higher) in the correction of simultaneity than in the OLS estimation, as expected; and finally iii) orthogonality of the freely variable input (labour, in this case) and the innovation in productivity in t+1 (the estimated correlation (-2.07%) is not significant at 10%).

The two columns in the left-hand side of Table 2 correspond to the estimation when the constant returns to scale condition at the bank level is not imposed. The total inputs of each bank are written as the product of inputs per branch times the number of branches. In this specification, the hypothesis of constant returns to scale at the bank level is satisfied if the coefficient associated to (the log of) the number of branches is equal to 1. The right-hand side panel exhibits the estimation results when the constant returns to scale condition at the bank level is imposed: inputs and outputs are all defined at the bank level and the number of branches is excluded from the right-hand side of the equation. p-values associated to the nulls of constant returns to scale at the bank level (i.e. H_0*: the coefficient associated to the number of branches (in logs) equals* 1) and at the branch level (i.e. H_0: $\beta_n + \beta_{ik} = 1$) are reported.

Considering *OLS* estimation results reported in the upper part of Table 2, the null hypothesis of constant returns to scale can be rejected at both, bank and branch level. The respective estimates of the elasticity of output with respect to labour and IT capital are, approximately, 0.69 and 0.22 and the coefficient of *ln*(*branches*) is 0.91. Therefore, the estimation using *OLS* would imply that the production technology of banks, both at the bank and at the branch level, has decreasing returns to scale. Results are different when the estimation is performed taking into account the potential simultaneity between the firm's input decisions and its productivity using IT investment as a proxy of productivity (lower part of Table 2). Now, the null hypotheses of constant returns to scale at the bank level and at branch level cannot be rejected at any standard significance level. Results confirm the presence of simultaneity bias since, compared to the Levinsohn-Petrin estimations, *OLS* coefficients over-estimate the elasticity of the

output to the labour input and an under-estimate the elasticity of the output to the IT capital.

If the null hypothesis of constant returns at the bank level is imposed, the estimated elasticity of output to labour and IT capital are 0.501 and 0.421, respectively (compared to 0.696 and 0.207). This elasticity of output to IT capital implies that if the stock of IT capital per employee doubles then the output per worker (labour productivity) increases by 42.1%. In period 1993-2007, the stock of IT per employee has increased from 10.2 to 16.7 thousands of Euros (64 %). Therefore, deepening of IT capital has increased labour productivity of Spanish banks in 26.9% (0.421 multiplied by 64) from 1993-2007.

Robustness tests

The estimates of the production function using different definitions of intermediate inputs (expenses on electricity and other supplies, on office stationary, on external administrative services and on total operating costs) as alternative proxies of the productivity are reported in Table A1 of Appendix A. As explained above, our final choice has been *investment in IT capital* because the potential candidates did not fulfil the minimum requirements stated by Levinsohn and Petrin (2003). First, the use of *external administrative services*, in spite of providing similar results than *IT investment*, implied the drastic reduction of the sample because of the lack of information (this variable was only available since 1999). Next, neither *total operating expenditures* nor *office stationary* (and, to a lesser extent, *electricity supply*) satisfied the monotonic condition for low levels of IT capital: Figure B1 shows a decline or stagnation of the productivity for high levels of IT capital when the intermediate input increases. As well, all the proxy candidates failed in the condition of absence of correlation between labour and the productivity shock of $t+1$, with the exception of *external administrative services* (-5.3%, non significant at 10%). These reasons may explain why *electricity and other supplies* returned similar estimates than *investment in IT capital*, but with decreasing returns to scale at the branch level (against the findings of Martín-Oliver and Salas-Fumás, 2008) and why *office stationary* and *operating expenses* provided estimated elasticity of the output to the inputs that were too low compared to the rest of estimates (labour is below 0.3 and that IT capital is even smaller than in *OLS*).

Finally, following Levinsohn and Petrin (2003), we estimate the production function for different time periods to allow for variation in the coefficients that measure the contribution of inputs to the output. In particular, we have estimated the production functions (both at bank level and at branch level) distinguishing among three sub-periods: 1992-1997, 1998-2002 and 2003-2007. Differences among estimated coefficients corresponding to different periods are not statistically significant. Therefore, we present only the estimates of the whole sample period and focus on these coefficients to measure and further analyze the productivity level of Spanish banks.

Productivity in the banking industry

Using the estimations of the elasticity parameters reported in Table 2 of the production function in Equation (5), the productivity level of bank *i* in year *t,* denoted as p_{it}, can be estimated as:[13] $\ln p_{it} = \ln(L+D)_{it} - 0.501 \ln N_{it} - 0.421 \ln IK_{it}$. Then, relying on the bank-level productivity estimates, we construct the indicator of industry wide average productivity as the weighted average of the banks' productivity using the shares of the banks in terms of output as weights. Olley and Pakes (1996) distinguish between two sources that may explain the evolution of the industry productivity. On the one hand, the evolution of the (un-weighted) average productivity of the firms in the industry and, on the other hand, a term that captures the differences in productivity that are associated with the size of the bank:

$$p_t = \sum_{i=1}^{N_t} s_{it} p_{it} = \bar{p}_t + \sum_{i=1}^{N_t} (s_{it} - \bar{s}_t)(p_{it} - \bar{p}_t)$$

where p_t is the industry productivity at time *t*, s_{it} is the share of bank *i* at *t* and $\bar{s}_{it}$ and $\bar{p}_{it}$ are the un-weighted means of bank's productivity and output shares, respectively. A positive (negative) value of the second term of the right hand side indicates that larger banks tend to be more (less) productive than smaller ones.[14]

Figure 1 shows the evolution of the industry productivity (p_t) and its two components. The productivity of the banking industry has shown an increasing trend over the whole time period that is attributable to both, productivity gains of the average bank, and to a positive reallocation effect. The facts that bigger entities have been more

[13] As in Olley and Pakes (1996), Nakane and Weintraub (2005) and Buch, Koch and Kötter (2009), we estimate the productivity as a residual from the difference between the observed and the predicted output of the bank in time period *t*, not the productive efficiency (distance to an efficient frontier) to be consistent with the general methodology. Implicit along the paper is also the assumption that the elasticity of output with respect to labor and IT capital are the same for banks of different characteristics; in other words, the heterogeneity of banks only affects the constant of the production function.

[14] For a similar decomposition applied to Spanish manufacturing industry see Fariñas and Ruano (2004).

productive and have increased their output share in the industry results in a higher growth rate of the average industry productivity, compared to the situation where all the banks had been equally productive. This reallocation effect is clearly manifested after the years 1999-2000, when two different mergers (Banco Santander-Central Hispano and BBV-Argentaria) gave rise to the two biggest banks of the Spanish banking system, increasing the contribution of the size effect to the productivity of the industry.

Focusing on the evolution of the productivity of the Spanish banking industry, Figures 2A and 2B shows the annual and the cumulative growth rates of the estimated banking industry productivity p_t, respectively. The weighted average productivity in 2007 is 2.8 times the value in 1993, which implies an increase of 180% during the 15 years period (Figure 2B). Most of the increase in the aggregate productivity occurs in the second part of the period (2000-2007), when the average annual rate of growth was 10.01%, compared to the 3.85% average annual rate during the 1992-1999 period (Figure 2A).

4. What is behind the observed productivity?

Our measure of productivity for each bank and year is the residual obtained from the difference between the actual output of the bank (loans plus deposits) minus the output predicted from the quantities of labor and IT capital. One of the determinants of the productivity differences which matters most for welfare analysis is the underlying differential in intermediation efficiency. We measure the intermediation efficiency of the banking industry as the Hicks-neutral technological progress that determines the time trend in productivity, after removing other sources of cross-section and time variability from the pooled data of banks' productivity. Among these other sources of productivity differences, we particularly focus on the changes in the balance sheet of banks that have been pinpointed as potential factors of the outburst of the financial crisis: increasing risk taking, excessive growth and higher illiquidity risk.

In this section we first document the changes in the assets and liabilities of Spanish banks that preceded the financial crisis. Next, we hypothesize how these changes may have affected the estimated productivity of banks. Finally, we estimate an empirical model on determinants of banks' productivity for the double purpose of testing the hypotheses and estimating the residual technical progress in the banking industry.

4.1. The behavior of Spanish banks in the pre-crisis period

The situation of Spanish banks in the pre-crisis period can be summarized as follows: i) Spain joined the Euro zone benefiting from low interest rates and financial integration when monetary policies by Central Banks around the world, including the ECB, were extremely accommodative; ii) prices and demand of real estate-related assets, including houses, experienced a high increase and banks provided the credit to fund this expansion; iii) Spanish banks used a combination of mortgage-backed securities (MBS) and short-term funding to finance the lending to real estate developers and house buyers; iv) banks were able to comply with regulatory capital and sustain the high level of credit growth by issuing hybrid financial products, cheaper than pure equity. The behavior of Spanish banks during these years is close to what Diamond and Rajan (2009) describe as "proximate causes of the crisis".[15]. Table 3 shows how this situation was translated into important changes in the banks' balance sheets. We present the mean and median values of variables that capture the mortgage and real-estate lending activity, the securitization intensity, the importance of short-term finance and the equity capital ratio (inverse of leverage) of Spanish banks in three successive time periods: the pre-Euro years of 1993-1997, the consolidation period of 1998-2002, and the period of high growth, 2003-2007. A more complete definition of each variable can be found in Appendix B.

According to Table 3, the average proportion of real estate loans increased over time from 12.7% in 1993-97 to 21.0% in 2003-2007, while the proportion of mortgages rose from 32.1% of all loans to 51.8%, confirming the expansion of the lending activity in real estate and housing markets after Spain joined the Euro zone. During the years previous to the Euro, Spanish banks did not participate in securitization activities, but afterwards the number of banks issuing MBS increased steadily: in the period 2003-2007 these securities represent 15.2 % of the total assets for the banks that issue them.

The maturity of the wholesale finance for the banks that get funds from these markets is measured by the weighted maturity of wholesale financing (variable *Duration*), and by the net position of banks in the interbank market. The mean value of *Duration* increased over time, indicating that Spanish banks issued securities of longer

[15] Regulatory arbitrage through securitization (Achayra, Schuabl, Suarez 2011) was not possible among Spanish banks. Banking regulation forced banks to keep the issued securities in their balance sheet unless banks were effectively transferring the risk out of the bank, which did not happen in most of the cases (banks kept worse tranches or granted credit enhancements). Thus, securitized and non-securitized loans had the same impact in terms of regulatory capital requirements.

maturity in wholesale markets at the same time that the weight of long-term loans in real estate and housing was also increasing. Banks' liquidity position was then maintained from this point of view. However, Spanish banks increased their dependence on interbank finance over time, both in terms of a larger number of banks with a net borrowing position in the interbank market (variable *IdB*), and in terms of a higher value of the ratio of borrowing over lending in this market (variable *IB borrow/IB lend*). Comparing the time periods 1992-1997 and 2003-2007, the proportion of banks with a net borrowing position grew from 20.6% to 53.2% and the ratio of the amount borrowed and the amount lent in the interbank rose from 0.86 to 2.56, respectively.

Finally, Table 3 shows a decreasing trend in the equity capital ratio during the 1990's and a drop of the ratio from 9.9% in the period 1998-2002, to 6.8% in the period 2003-2007. However, the regulatory capital ratio stayed relatively stable during this time period (16.15% in 1998-2002 and 14.29% in 2003-2007), which means that regulatory capital requirements derived from the high growth of the years 2003-2007 were fulfilled with debt-like instruments.

4.2. Implications for productivity and productivity growth

We now explain why these changes in the balance sheet of banks can have positive effects on productivity and productivity growth over time.

Real estate and mortgage loans. We identify two reasons why the concentration of loans in real estate and mortgages can have positive effects on productivity: lower screening and higher loan-to-value ratios.

On the one hand, the incentives of banks for screening the credit quality of the borrower in collateralized loans are milder than in loans without collateral (Manove, Padilla and Pagano 2001). Mortgages and real estate loans are collateralized so lower screening will imply more loans granted (or produced) per employee. During the years previous to the crisis screening incentives might have been even milder because the escalation in house and real estate prices was perceived as an additional guarantee for lenders.

On the other hand, the expectation of permanent increase in house prices could have inclined bank managers to grant loans with higher loan-to-value ratios than in periods with flatter expectations. This higher loan-to-value ratio per average loan can be translated to higher productivity since, with the same amount of inputs, banks can

produce a higher balance of loans due to the higher average size of the loans granted. Therefore, our first hypothesis can be stated as follows:

Securitization. We expect that banks that traditionally financed their loans with deposits and, at some point in time, start to obtain finance issuing securities backed with loans will experience an increase in productivity for reasons related with changes in the business model rather than with technical progress.

In traditional banking there is a relationship between the use of inputs (labor and IT capital) and the total output of banks in such a way that an increment of the bank's output (loans plus deposits) has to be accompanied by an increase in the use of inputs. However, in the "originate to securitize" model, banks have become "intermediaries", not "producers" of deposits and loans. The issuance of MBS provided Spanish banks with funds to grant loans directly from the market and outside the network of branches. Therefore, banks obtain funds to grant new loans without opening new branches and/or increasing the use of inputs in old and new ones, something that they could not do if they were to obtain funds from deposits.

Securitization also changed lending practices by banks. The creditworthiness of securitized loans was based on the qualifications of rating agencies and not so much on the detailed soft information collected by bank officers. These agencies did not have close information about the beneficiary of the loan (homeowner, for example), so they could process only hard information such as the credit score of the borrower and the loan-to-value ratio. As a consequence, bank officers stopped collecting this information and focused only on lending to borrowers that could have good credit scores and observable adequate loan-to-value ratios (Diamond and Rajan 2009). Collecting the useful soft information on the credit quality of the borrowers was more time consuming than collecting the hard information of the credit score. This is another reason why issuing MBS banks might have increased the ratio of output relative to inputs.

Short-term wholesale funding. Securitization was not the only way banks had to raise funds in financial markets. Under the umbrella of the Euro, Spanish banks became net borrowers in the interbank market and they issued bonds and other debt instruments to fill the gap between loans and deposits.

Ideally, long-term loans should have been financed with long-term debt instruments but it is well known that, under the expectation of future low interest rates, leveraged banks have incentives to finance with short-term debt, becoming more

illiquid (Diamond and Rajan, 2009b). Moreover, investors were keen to provide banks with short-term finance because it facilitated the option to exit if things went wrong and banks got into trouble (Diamond and Rajan, 2001). Spanish banks were probably affected by these incentives and took advantage of the cheaper and practically unlimited short-term finance through the interbank and the financial markets. Then, it can be expected that banks tended to adopt a financial structure more oriented to short-term leverage, even though their loans had a long-term maturity.

Regulatory capital and leverage ratio. Regulatory capital standards are intended to restrain the growth of bank credit and limit the leverage ratios, preventing excessive risk taking (Kim and Santomero, 1988; Rochet, 1992; Morrison and White, 2005). Over the years leading up to the financial crisis, there is evidence that banks changed the composition of their regulatory capital to a higher proportion of subordinate debt and preferred stocks (Acharya and Schnabl, 2009; Acharya, Gujral and Shin,(2012): Khorana and Perlman, 2010).

The high credit growth rates of loans among Spanish banks together with stable dividend policies increased the regulatory capital requirements above the retained earnings. In order to comply with capital requirements, banks issued hybrid instruments instead of issuing equity[16] because the former were less costly (i.e., interests of hybrid instruments were tax deductible). As a result, we could observe the apparent paradox of banks keeping their regulatory capital ratio at constant levels while they were becoming more leveraged, since the regulatory requirements were fulfilled with debt-like instruments.

4.3. Empirical model on the determinants of banking productivity

The full econometric model on determinants of productivity differences of banks is formulated as follows:

$$\ln p_{it} = \gamma_0 + \sum_j \gamma_j x_{it}^j + \sum_j \varphi_j z_{it}^j + \sum_{t=1993}^{2007} \theta_t d_t + \nu_{it}, \qquad (7)$$

The dependent variable is the log of productivity of bank i in year t obtained as a residual, as explained above. There are three sets of explanatory variables. The first one, x_{it}^j, includes the variables in Table 3 that account for the presumed positive effect on productivity due to credit growth in real estate and mortgages, securitization, short term

[16] Savings banks do not have equity in their balance sheet, so they cannot issue common shares.

finance and leverage. The second block, z_{it}^{j}, correspond to control variables such as ownership, market scope, size, quality of inputs, priced services, growth, merger activity, risk and so on, which have been found relevant in explaining productivity differences among banks in previous studies (Berger and Mester, 1997; Frei, Harker and Hunter, 2000, Carbó, Humphrey and López del Paso, 2007). The precise definition of each of these variables appears in Appendix B and the descriptive statistics in Table 4. The third block of explanatory variables is the time dummy variables d_t, equal to1 when the observation belongs to year t and zero otherwise. The parameters associated to the time-dummy variables, θ_t, capture the time effects on productivity common to all banks in the industry. We estimate a variation of model (7) where the time-dummy variables are replaced by macroeconomic variables of the Spanish economy (i.e., inflation, interest rates and business cycle) together with a time trend variable. In this specification, the coefficient of the time trend variable will be our estimate of the industry technical progress. Finally, v_{it} is the random error term.

The model is estimated using *OLS* with standard errors clustered at bank level and the results are presented in Table 5. Specification I shows the results of estimating the model as it is formulated in [7], whereas in Specification II shows the time dummy variables are substituted by macroeconomic variables (*growth of GDP, inflation* and *interbank interest rate*) and the trend variable. The estimated coefficients of the common variables in both specifications are similar in magnitude and statistical significance.

Productivity and proximate causes of the crisis

Our estimation results confirm that the differences in the observed productivity of banks can be explained, to a large extent, by the changes in the assets composition of banks documented in Table 3 and related to "proximate causes" of the crisis. As expected, the proportion of real estate and mortgages in the loans portfolio of banks is positively correlated with productivity. This result confirms the hypothesis that the specialisation in this type of products in the pre-crisis period can explain part of the observed increase in gross productivity of banks over time. The coefficient of the variable proportion of securitized assets is also positive and statistically significant, confirming that generate-to-securitize is more productive in terms of labour and IT capital services consumed than traditional banking. The negative coefficient of the variable *Deposits/Loans* is

coherent with this result, although it is not statistically significant once we control for the other finance instruments.

The explanatory variables on short-term sources of funds that finance the gap between loans and deposits are also positively related with banks productivity. The estimated coefficient of the variable *IdB·IBborrow/IB lend* is positive and statistically significant at 1%, which implies that the higher the net borrowing position in interbank markets is, the higher is the bank productivity level[17]. The rest of the coefficients related to short-term finance are non-significant (maturity of wholesale finance and the dummy indicating whether or not the bank maintains a net borrowing position in interbank market). Therefore what matters for productivity is the net lending position in the interbank market, not the net borrowing one. Finally, the estimated coefficient of the equity capital ratio is negative and statistically significant. More leveraged banks have higher productivity than the less leveraged ones because the latter were expanding their balance sheets with non-core capital instruments. Nonetheless, these banks managed to keep their regulatory capital ratios relatively constant over time (see Table 3) because they issued hybrid and debt-like instruments that counted as regulatory capital. Therefore, the positive effect of leverage on banks' productivity is due to the increase of leverage within regulatory capital, that is, the increasing weight of hybrid instruments in detriment of core capital.

Control variables

Ownership, size and market scope of banks affect banks' productivity. Saving banks are 25% less productive than commercial banks, while foreign subsidiaries are almost 20% more productive than national commercial banks[18]. Size of the banks has a positive effect on productivity, as well as concentration in local and regional markets. Productivity of banks also varies with the quality of the productive inputs. The positive association between the average salaries of banks and their productivity suggests that higher salaries go together with more productive workers. Next, the positive (although not statistically significant) coefficient of human capital from training and the negative coefficient of the proportion of temporary employees point also to a positive effect of

[17] On the contrary, the coefficients associated to lending position in the interbank market are not significant.

[18] Berger (2007) reviews the literature on productivity comparisons between foreign subsidiaries and national banks; broadly, foreign subsidiaries tend to be more productive than national banks. The results of the comparison may be affected by differences in the portfolio of services and markets served by each group of banks.

human capital on bank's productivity. Finally, a higher proportion of advertising capital in the total operating capital of banks has also a positive effect on productivity.

Banks collecting more revenues in the form of net commissions (relative to total assets) are less productive, possibly because commissions are associated with services that banks provide to their customers and these services are not properly captured by the output measurement used in this paper. Since the inputs (labour and capital services) involved to produce these services are effectively accounted for, we obtain that banks with a business profile more oriented to services that charge commissions are penalized in our productivity measure [19]. Table 5 also shows that a higher annual growth rate in the number of branches has a negative effect on productivity, possibly because of inputs' indivisibilities and lower occupation rate of existing branches' capacity. Next, we find that the organization of banking activities also matters for productivity. On the one side, the use of the internet channel has significant positive effects on banks productivity and, on the other side the effect of geographic diversification (proportion of overseas branches) also contributes in a significantly positive manner to productivity. However, the proportion of employees in branches (and less in headquarters) and the size of the branch do not have significant effects on productivity. Finally, the involvement of banks in mergers or acquisitions and the relative loan loss provisions (as indicator of risk) do not have any significant effect on productivity.

The estimated coefficients of the macro variables included in Specification II show that the inflation (measured as the growth of the consumer price index) has a negative effect on productivity and the interbank interest rate a positive one, whereas the GDP growth rate does not affect productivity.

Technical progress

The estimates of the dummy variables (not reported) in Specification I and the coefficient of the trend in Specification II provide a measure of technical progress, that is, productivity growth once we have accounted for other sources of heterogeneity.

In Specification I, the values of the estimated coefficients of the time dummies imply an average annual growth of 3.17% in the pre-Euro period (1993-1999) and of

[19] We compute the net present value of the flow of commissions assuming a permanent annual flow equal to the current value of the net commissions using as discount factor the current value of the 12-month Interbank interest rate. When we recalculate the productivity measure and estimate the parameters in model (7), the variable commissions over total assets is no longer statistically significant, what would confirm our interpretation of the results.

3.26% in the post-Euro period. This estimate of productivity growth in the post Euro period is much lower than the gross 10% growth rate estimated without controlling for the sources of productivity differences considered in (7). These results also show that the trend in adjusted productivity growth in the pre-Euro period is maintained in the post-Euro period, that is, there are no differences in growth as those observed in gross productivity (Figure 2A)

Specification II intends to isolate technical progress from macroeconomic shocks in the adjusted time trend of industry productivity. The estimated coefficient of the time trend variable is positive and statistically significant with a value of 0.028. Therefore, our estimate of the banking industry growth in technical progress is 2.8% per year in this specification. The difference with respect to the time trend of 3.2% in Specification I can be attributed to macroeconomic shocks different from technical progress on the productivity of banks. Finally, if we include the interaction of the trend with a dummy identifying the years of the Euro in Specification II, this variable is non-statistically significant. This implies that the technical progress grew at the same pace before and after the introduction of the Euro, as we have found from the results of Specification I.

Figure 3 completes the productivity decomposition exercise by explaining the main factors contributing to the change from the "gross" to the "net" estimated productivity trend for the Spanish banking industry. The calculations to decompose the aggregate cumulative productivity growth are done using the (average) cumulative change of every explanatory variable and its estimated coefficient from Specification I.[20] Mortgages and real estate, securitization, leverage and net borrowing interbank position account for the largest share of productivity gap between the "gross" and the "net" time trend in productivity.

From these results, the conclusion must be that the extraordinary growth in aggregate productivity in the Spanish banking industry during the years after Spain joined the Euro zone cannot be attributed to a higher growth rate in technical progress. Rather, the reason must be found in the new monetary conditions faced by Spanish banks in the Euro, which made easier the access of banks to financial markets: Banks obtained funds (securitization, interbank market,...) that were used to finance the

[20] More precisely, the contribution of variable j to the cumulative growth of productivity in year t=1992+s is equal to $\frac{\beta^j \Delta^s x_{it}^j}{\Delta^s \ln p_{it}} \cdot \left(\frac{p_{it}}{p_{it-s}} - 1 \right)$, where $\sum_j \beta^j \Delta^s x_{it}^j = \Delta^s \ln p_{it}$

booming real estate demand market (mortgages). In addition to this practice, banks increased their financial leverage probably to compensate the lower commercial margins in a context of historically low interbank rates.

Robustness exercises

For robustness purposes, we have re-estimated the productivity growth attributed to technical change in the pre- and post- Euro period, starting with the re-estimation of the production function using alternative measures of output. First, we estimated the loans at constant prices using a price index for each bank that takes into account the differences in prices of real estate assets compared with the general inflation rate of the Spanish economy, as well as the different proportion of real estate loans granted by each bank. In this way, we correct for the over-estimation of the output in the second part of the period when inflation of real estate assets was higher. The basic results remain unchanged while the minimum differences in Specification I between the estimated average rate of technical progress in the pre-and the post-Euro period disappear (now, 3.3% in the two periods). Second, we construct a measure of output that is equal to a weighted geometric average of loans and deposits (with weights 0.4 and 0.6, respectively, which are the coefficients of an estimation of the cost function) as an alternative to the sum of loans and deposits. The main results do not change at all and, again, the differences in the average growth rate of technical progress for the two periods disappear.

Another robustness exercise has explored the estimation of the determinants of productivity (Table 5) using fixed effects, to check whether there is unobservable heterogeneity that is biasing the estimates. The results[21] show that the sign of the coefficients remains unchanged, as well as the magnitude, suggesting that the (long) list of explanatory variables included in the regressions capture relatively well the differences across banks and there is no relevant missing information that is biasing the results. Nonetheless, the significance in some coefficients has decreased or even become non-significant (for example salaries) what could be expected because the fixed-effect estimation drops out the cross-section variability and the coefficients are estimated less efficiently.

[21] Results not shown in the paper. Available from the authors upon request.

In the Spanish banking industry the saving banks have significantly different ownership and governance characteristics compared with commercial banks. The empirical evidence reported in Table 5 shows that saving banks are on average less productive than commercial banks. We have examined if this difference in productivity has been stable over time. To do so, we generalize Specification I of Table 5 including as additional explanatory variable the interaction between the dummy variable *Savings* and the time dummy variables. None of the estimated coefficients for the cross-product of savings and time variables are statistically significant. Thus, no difference in the technical progress is observed between commercial and saving banks.

5. Conclusion

Efficient financial intermediation is a key factor for economic development. The high productivity growth in the banking industry around the world until 2008 anticipated a period of prosperity and wealth creation. However, the outburst of the financial crisis revealed that these expectations were totally erroneous. Conventional measures of banks' productivity growth as a proxy for efficiency gains in financial intermediation have been questioned, and new developments are needed to properly asses the technical progress of the banking industry. This paper contributes to this development in two ways: First, with a new methodology in the measurement of productivity of banks and, second, with the measurement of the component of the industry productivity growth attributed to technical progress.

From the methodological point of view, the paper introduces a Leontief production function for banks with IT capital as one of the inputs and it is estimated following the procedure posited in Olley and Pakes (1996) and Levinsohn and Petrin (2003) to control for the simultaneity bias between labour and productivity. These methodological advances have clear implications for policy analysis and productivity estimations of banks: First, the results obtained from the estimation of the production function cannot reject the null hypothesis of constant returns to scale (rejected in *OLS*); the return to scale properties of the production function is a key factor in mergers and restructuring decisions. Second, the estimated elasticity of the output of banks from IT capital services is twice the elasticity estimated using *OLS*. As this elasticity enters into

the calculation of the contribution of IT to labour productivity growth, the estimated contribution of IT capital deepening to labour productivity growth using the OLS would have been half of what it really is. Using the estimates controlling for simultaneity, we find that the cumulative growth in IT capital per employee increased output per employee in 27% during the sample period (1.6% cumulative annual growth), revealing the high contribution of IT capital in the banking industry. Overall, the average annual cumulative growth rate in labour productivity was 4.4% during the sample period (1.6% of IT capital contribution plus 2.8% of technical progress).

As for the measurement of the industry's technical progress, we find that Spanish banks participated of many of the causes that lead to the financial crisis after Spain joined the EMU. More than two thirds of the reported growth in banks' productivity was at the expense of fuelling a housing and real estate credit bubble, creating a liquidity gap between loans and deposits financed with MBS and with interbank loans and increasing financial leverage. This occurred at the same time that the industry maintained a steady annual growth rate in technical progress of 2.8%, similar to the rate in the pre Euro period.

More research is needed to advance in the knowledge on how to reconcile productivity estimates of individual banks with systemic measures of financial stability. We believe that our approach offers a promising start. Haldane, Brennan and Madouros (2010) propose using risk-free measures of output for banks in the calculations of productivity growth of banks within the KLEMS project[22]. One difficulty of this approach is how to obtain the appropriate price for risk. Our approach relies on quantities and does not require information on prices, a clear advantage taking into account the market failures affecting the pricing of risk.

[22] The KLEMS-project serves as an international platform, coordinated by the EU, in which national research and data collection efforts are supported and co-ordinated to create a database on measures of economic growth, productivity, employment creation, capital formation and technological change at the industry level with a clear emphasis on the need for international comparability.

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Table 1. Descriptive Statisitics of Inputs, Outputs and Number of Branches. Values per bank.

	Number of Banks	Number of Branches				Number of Workers				IT capital (m€ 1992)				Loans+Deposits (m€ 1992)			
		Average	Median	25th Perc.	75th Perc.	Average	Median	25th Perc.	75th Perc.	Average	Median	25th Perc.	75th Perc.	Average	Median	25th Perc.	75th Perc.
1992	143	223	105	17	206	1,656	599	176	1,416	19	5.75	1.50	17.39	3,489	1,180	311	2,879
1993	141	222	106	18	209	1,635	594	157	1,391	19	5.87	1.76	16.61	3,654	1,234	324	3,064
1994	137	232	106	18	216	1,670	593	177	1,516	20	6.85	2.05	16.48	3,931	1,308	335	3,279
1995	138	236	109	15	237	1,649	594	156	1,482	20	6.68	2.12	18.18	4,114	1,352	346	3,533
1996	133	251	112	19	243	1,689	617	177	1,473	22	7.54	1.88	19.77	4,435	1,507	444	3,774
1997	131	260	113	19	256	1,709	625	168	1,545	24	9.18	2.02	21.94	4,839	1,645	484	4,415
1998	125	280	116	22	260	1,796	670	208	1,595	29	10.70	2.87	23.70	5,524	1,780	591	4,994
1999	121	291	115	23	276	1,824	631	210	1,745	33	11.81	2.90	25.71	6,040	1,994	646	5,755
2000	113	310	121	21	277	1,943	620	216	1,654	37	12.18	3.30	28.88	7,296	2,117	721	6,199
2001	108	319	135	23	297	2,029	680	246	2,037	41	14.98	3.83	29.62	8,304	2,758	830	7,268
2002	103	332	149	24	342	2,101	797	203	2,128	44	14.65	4.66	30.60	9,140	3,094	872	8,133
2003	97	353	155	34	346	2,190	834	253	2,235	47	12.46	4.89	32.62	10,562	3,647	1,080	9,906
2004	94	378	171	34	383	2,306	859	250	2,396	48	15.34	5.58	39.47	12,072	4,877	1,547	11,782
2005	93	395	176	35	387	2,390	899	285	2,513	51	15.09	6.19	40.06	14,738	5,899	1,718	13,824
2006	92	416	192	31	409	2,492	972	299	2,615	55	15.12	6.84	39.68	17,743	6,821	1,983	16,138
2007	90	443	203	33	480	2,667	1,039	309	2,750	60	17.49	7.24	41.86	20,335	7,470	2,822	19,073
Avg.Growth Rate (%)																	
1992-1997	-1.75	3.07	1.47	2.22	4.35	0.63	0.85	-0.93	1.74	4.96	9.33	5.94	4.65	6.54	6.65	8.85	8.55
1997-2002	-2.41	4.64	1.80	4.01	4.37	1.88	2.41	5.63	2.74	8.11	12.02	9.84	7.10	8.26	7.33	12.01	9.77
2002-2007	-2.48	4.53	1.63	4.90	4.90	1.76	1.24	3.42	2.81	10.07	10.90	6.92	8.89	8.59	8.43	13.12	11.25

Table 2: Estimates of the Production Function

	PRODUCTION FUNCTION (AGGREGATION OF PROD AT BRANCH LEVEL)		PRODUCTION FUNTION (TOTAL)	
	Coeff.	*t*-ratio	Coeff.	*t*-ratio
OLS				
β_L	0.681 ***	11.34	0.696 ***	18.42
β_{IT}	0.233 ***	5.72	0.207 ***	5.44
β_B	0.913 ***	26.19		
p-Value: $\beta_L+\beta_{IT}=1$	0.001		0.000	
p-Value: $\beta_B=1$	0.000			
N.Observations	1322		1810	
Olley-Pakes. PROXY : INVESTMENT IN IT				
β_L	0.413 ***	4.30	0.501 ***	5.95
β_{IT}	0.405 ***	5.66	0.421 ***	2.71
β_B	1.021 ***	12.19		
p-Value: $\beta_L+\beta_{IT}=1$	0.130		0.561	
p-Value: $\beta_B=1$	0.798			
N.Observations	1322		1810	

Table 3. Descriptive statistics of selected variables tied to the proximate causes of the financial crisis.

	AVERAGE			MEDIAN		
	1992-1997	1998-2002	2003-2007	1992-1997	1998-2002	2003-2007
Prop Real Estate Loans	0.127	0.130	0.209	0.115	0.127	0.215
Mortgages/Loans	0.339	0.413	0.522	0.368	0.467	0.610
Deposits/Loans	1.400	1.176	0.976	1.424	1.163	0.972
IdSecuritization	0.000	0.323	0.691	0.000	0.000	1.000
Securitization/Assets	0.000	0.015	0.105	0.000	0.000	0.100
For banks that did securitize	-	0.046	0.152	-	0.036	0.144
Id Wholesale	0.951	0.987	0.993	1.000	1.000	1.000
Duration	1.578	1.665	2.302	0.866	1.188	1.961
IdB	0.206	0.405	0.532	0.000	0.000	1.000
IdB·IB borrow/IB lend	0.600	1.552	2.169	0.000	0.000	1.056
(1- IdB)·IB borrow/IB lend	0.226	0.254	0.195	0.104	0.069	0.000
IB borrow/IB lend	0.859	1.933	2.559	0.324	0.795	1.056
Regulatory capital ratio	0.187	0.162	0.143	0.132	0.118	0.114
Capital / Assets	0.109	0.099	0.068	0.087	0.076	0.047

Duration is expressed in year terms and the rest of variables are ratios expressed in per unit terms.

Table 4. Descriptive Statistics of Control Variables

	1992-1999					2000-2007				
	Average	Median	Std.Dev.	25th Perc	75th Perc	Average	Median	Std.Dev.	25th Perc	75th Perc
OWNERSHIP, SIZE AND GEOGRAPHY										
Savings (D)	0.370	0.000	0.483	0.000	1.000	0.456	0.000	0.498	0.000	1.000
Foreign Branch (D)	0.160	0.000	0.367	0.000	0.000	0.482	0.000	0.500	0.000	1.000
Small (D)	0.300	0.000	0.459	0.000	1.000	0.172	0.000	0.378	0.000	0.000
Medium (D)	0.297	0.000	0.457	0.000	1.000	0.170	0.000	0.376	0.000	0.000
Local (D)	0.328	0.000	0.470	0.000	1.000	0.187	0.000	0.390	0.000	0.000
Regional (D)	0.518	1.000	0.500	0.000	1.000	0.292	0.000	0.455	0.000	1.000
QUALITY OF THE PRODUCTIVE INPUTS										
Salaries (th€ 1992)	34.64	32.29	8.80	29.72	37.17	36.10	34.00	9.56	30.33	39.25
Cost of Equity	0.107	0.106	0.018	0.093	0.121	0.080	0.083	0.012	0.068	0.093
Advertising Capital	0.048	0.037	0.057	0.015	0.063	0.065	0.040	0.111	0.024	0.060
Training Capital	0.008	0.006	0.008	0.003	0.010	0.010	0.008	0.008	0.005	0.012
BUSINESS MODEL AND CREDIT RISK										
*Net Commissions/Assets*100*	0.583	0.507	0.394	0.296	0.787	0.620	0.516	0.446	0.364	0.735
LLP/Loans	0.067	0.007	1.757	0.002	0.013	0.016	0.005	0.236	0.003	0.006
RWA/Assets	0.571	0.527	0.331	0.419	0.640	0.693	0.726	0.300	0.546	0.815
Internet Deposits / Total Deposits	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.098	0.000	0.000
ORGANIZATION AND GROWTH										
Prop.Termporary Employees	0.010	0.001	0.030	0.000	0.008	0.013	0.001	0.037	0.000	0.013
Prop. Employees in Branches	0.619	0.697	0.249	0.570	0.782	0.638	0.734	0.260	0.592	0.796
Growth of the branch network	0.023	0.026	0.036	0.000	0.042	0.036	0.033	0.035	0.014	0.053
Prop Branches Abroad	0.002	0.000	0.008	0.000	0.000	0.008	0.000	0.056	0.000	0.000
Size of branches (th€ 1992)	1,508	640	3,375	430	1,496	981	509	1,867	344	924
Pre-Merge (3 years) (D)	0.044	0.000	0.205	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Post-Merge (3 years) (D)	0.027	0.000	0.163	0.000	0.000	0.013	0.000	0.112	0.000	0.000
MACRO VARIABLES										
Real GDP Growth	0.025	0.024	0.018	0.009	0.039	0.036	0.036	0.007	0.031	0.039
Nominal Interbank Rate	0.080	0.084	0.033	0.052	0.109	0.034	0.035	0.009	0.023	0.044
Inflation	0.038	0.046	0.014	0.023	0.047	0.032	0.034	0.003	0.030	0.035

Note: All the variables expressed in unit terms, except Labor and Size of the Branches that are expressed in thousand of Euros of 1992. (*D*) identifies a dummy variable.

Table 5. Decomposition of Bank Level Productivity

	Specification I		Specification II	
	Coeff.	*t* -ratio	Coeff.	*t* -ratio
BANKS' BEHAVIOR IN THE PRE-CRISIS PERIOD				
Real State and Mortgage loans				
Prop Real Estate Loans	0.379 *	0.192	0.411 **	0.193
Mortgages/Loans	0.391 ***	0.139	0.376 ***	0.138
Securitization				
Deposits/Loans	-0.009	0.053	-0.008	0.053
IdSecuritization	0.064	0.061	0.070	0.057
Securitization/Assets	1.167 ***	0.335	1.152 ***	0.302
Short-term wholesale funding				
Id Wholesale	-0.133	0.105	-0.067	0.068
Duration	0.047	0.040	0.048	0.039
IdB	-0.113 *	0.060	-0.110 *	0.060
IdB ·IB borrow/IB lend	0.036 ***	0.009	0.036 ***	0.009
(1- IdB) ·IB borrow/IB lend	-0.049	0.067	-0.047	0.066
Regulatory capital and leverage				
Regulatory capital ratio	-0.011	0.081	-0.005	0.083
Capital / Assets	-1.270 ***	0.271	-1.269 ***	0.271
CONTROL VARIABLES				
Ownership, size and geography				
Savings (D)	-0.259 ***	0.057	-0.259 ***	0.056
Foreign Branch (D)	0.196	0.132	0.184	0.129
Small (D)	-0.426 ***	0.062	-0.421 ***	0.062
Medium (D)	-0.197 ***	0.042	-0.196 ***	0.042
Local (D)	0.311 ***	0.102	0.309 ***	0.100
Regional (D)	0.236 ***	0.087	0.236 ***	0.087
Quality of the productive inputs				
Salaries (th€ 1992)	0.010 ***	0.004	0.010 ***	0.003
Cost of Equity	-2.626	2.031	-2.563	1.806
Advertising Capital	0.599 **	0.291	0.621 **	0.287
Training Capital	2.872	3.383	2.780	3.366
Business Model and Credit Risk				
*Net Commissions/Assets*100*	-32.109 ***	5.051	-31.945 ***	4.965
LLP/Loans	-0.032	0.079	-0.024	0.082
RWA/Assets	0.053	0.061	0.050	0.061
Internet Deposits / Total Deposits	0.752 ***	0.170	0.733 ***	0.164
Organization and Growth				
Prop.Termporary Employees	-1.020 ***	0.369	-0.969 ***	0.360
Prop. Employees in Branches	0.125	0.146	0.124	0.145
Growth of the branch network	-1.817 **	0.750	-1.806 **	0.743
Prop Branches Abroad	1.019 ***	0.315	1.010 ***	0.304
Size of branches (th€ 1992)	0.000	0.000	0.000	0.000
Pre-Merge (3 years) (D)	0.032	0.061	0.028	0.060
Post-Merge (3 years) (D)	0.021	0.057	0.020	0.057
Macro Variables				
Real GDP Growth			0.540	0.991
Nominal Interbank Rate			1.694 *	0.945
Inflation			-4.261 ***	1.561
Trend			0.028 ***	0.009
Intercept	7.227 ***	0.342	7.234 ***	0.330
TIME DUMMIES	YES		NO	
R^2 (%)	66.76%		64.91%	
N.OBSERVATIONS	1699		1699	

Figure 1. Weighted and Linear Average Level of Productivity: Spanish Banking Industry.

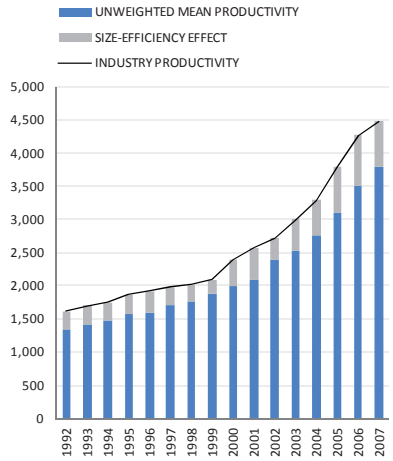


Figure 2. Aggregate Productivity Growth in Spanish Banking Industry

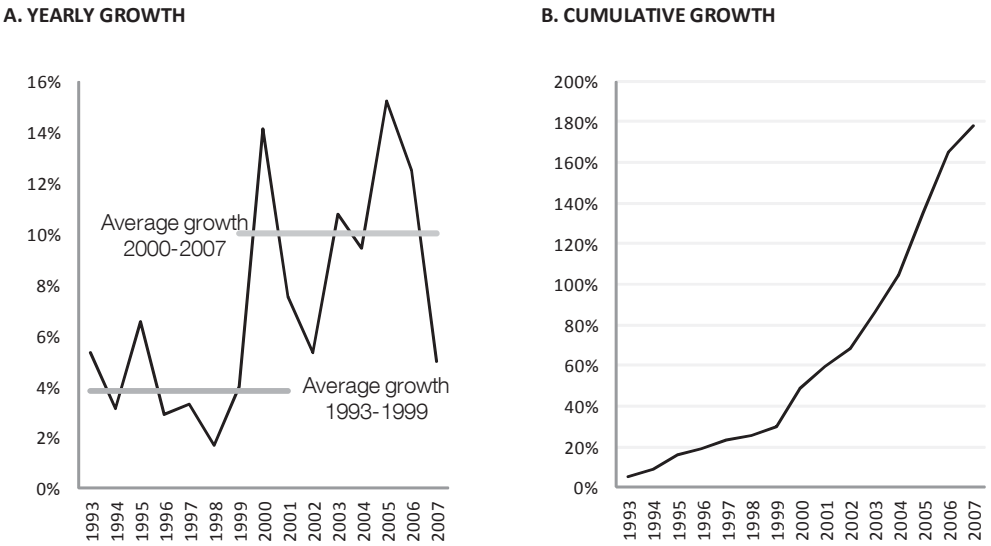
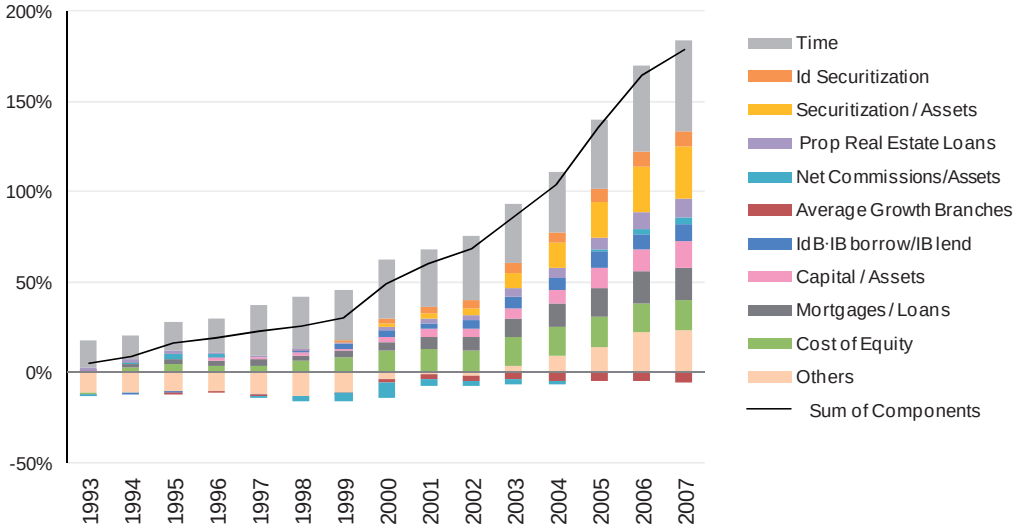


Figure 3. Cumulative Productivity Growth and Contribution of Selected Variables



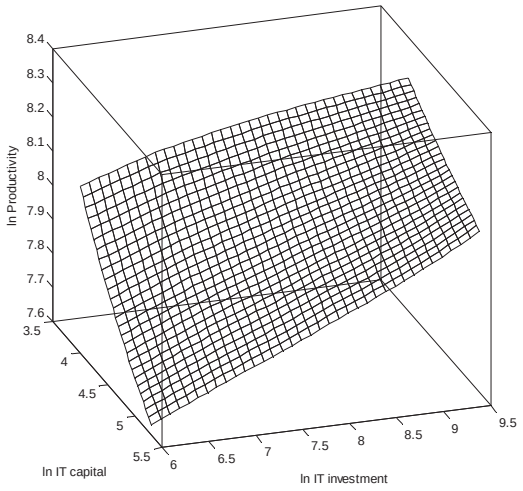
A. Estimation of the Production Function using Alternative Proxies (τ) of Productivity

Table A1: Estimates of the Production Function

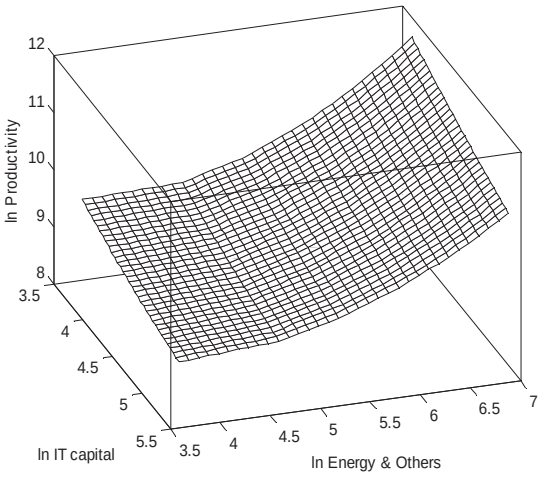
	PRODUCTION FUNCTION (AGGREGATION OF PROD AT BRANCH LEVEL)		PRODUCTION FUNTION (TOTAL)	
	Coeff.	*t*-ratio	Coeff.	*t*-ratio
OLS				
β_L	0.681 ***	11.34	0.696 ***	18.42
β_{IT}	0.233 ***	5.72	0.207 ***	5.44
β_B	0.913 ***	26.19		
p-Value: $\beta_L+\beta_{IT}=1$	0.001		0.000	
p-Value: $\beta_B=1$	0.000			
N.Observations	1322		1810	
Olley-Pakes. PROXY : INVESTMENT IN IT				
β_L	0.413 ***	4.30	0.501 ***	5.95
β_{IT}	0.405 ***	5.66	0.421 ***	2.71
β_B	1.021 ***	12.19		
p-Value: $\beta_L+\beta_{IT}=1$	0.130		0.561	
p-Value: $\beta_B=1$	0.798			
N.Observations	1322		1810	
Levinsohn-Petrin. PROXY : ELECTRICITY SUPPLY AND OTHERS				
β_L	0.324 ***	4.34	0.360 ***	2.67
β_{IT}	0.293 ***	6.94	0.316 *	1.85
β_B	1.029 ***	10.15		
p-Value: $\beta_L+\beta_{IT}=1$	0.000		0.105	
p-Value: $\beta_B=1$	0.778			
N.Observations	1298		1796	
Levinsohn-Petrin. PROXY : OFFICE STATIONERY				
β_L	0.296 ***	5.09	0.413 ***	4.66
β_{IT}	0.215 ***	11.89	0.377 **	2.00
β_B	1.066 ***	15.11		
p-Value: $\beta_L+\beta_{IT}=1$	0.000		0.266	
p-Value: $\beta_B=1$	0.348			
N.Observations	1322		1810	
Levinsohn-Petrin. PROXY : EXTERNAL ADMINISTR. SERVICES				
β_L	0.645 ***	6.01	0.693 ***	6.26
β_{IT}	0.392 ***	11.33	0.767 **	2.10
β_B	1.034 ***	19.6		
p-Value: $\beta_L+\beta_{IT}=1$	0.745		0.160	
p-Value: $\beta_B=1$	0.517			
N.Observations	592		662	
Levinsohn-Petrin. PROXY : TOTAL OPERATING EXPENSES				
β_L	0.331 ***	5.05	0.309 ***	4.63
β_{IT}	0.154 ***	12.57	0.262 *	1.71
β_B	1.064 ***	17.79		
p-Value: $\beta_L+\beta_{IT}=1$	0.000		0.004	
p-Value: $\beta_B=1$	0.283			
N.Observations	1322		1810	

Figure A1: Productivity (ω) as a function of IT capital and τ

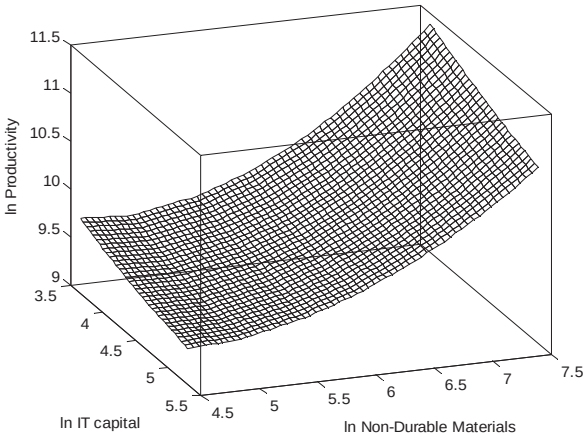
τ = Investment in IT



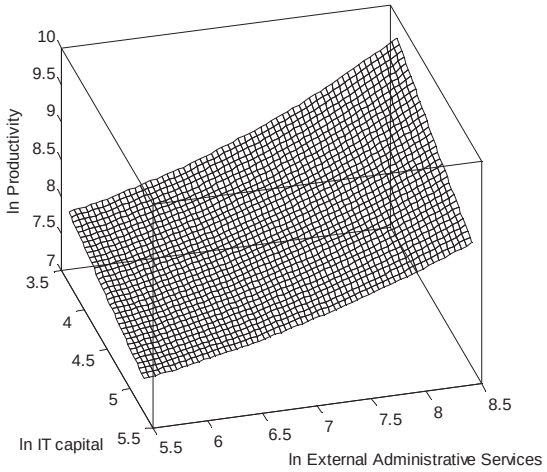
τ = Electricity supply and others



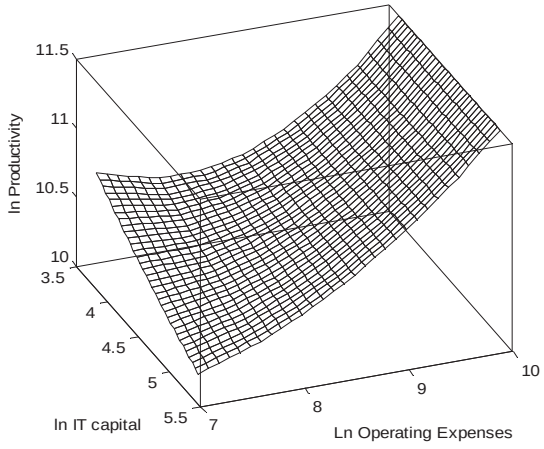
τ = Office Stationery



τ = External Administrative Services



τ = Total Operating Expenditures



B. Definitions of the Explanatory Variables

Table B1. Definition of the variables on diversity of banks

BANKS' BEHAVIOR IN THE PRE-CRISIS PERIOD	
Prop Real Estate Loans	Proportion of real-estate loans in the loan portfolio of the bank
Mortgages/Loans	Proportion of mortgages in the total loans of the bank
Deposits/Loans	Volume of deposits over the volume of loans
IdSecuritization	Dummy variable. It takes the value of 1 if a bank has outstanding securitized assets and 0 otherwise
Securitization/Assets	This variable measures the proportion of securitized assets to total assets if a bank has securitized assets and it takes the value of zero otherwise
Id Wholesale	Dummy variable. It takes the value of 1 if a bank has outstanding market debt in the form of interbank loans or issued bonds and 0 otherwise
Duration	Weighted average maturity (in years) of the wholesale liabilities of the bank
IdB	Dummy variable. I takes the value of 1 if the bank has a net borrowing position and 0 if the bank has a net lending position
IdB ·IB borrow/IB lend	This variable is equal to the ratio of the borrowing funds and the lending funds if the bank has a net *borrowing* position. The variable is set at zero if the bank has a net lending position
(1- IdB) ·IB borrow/IB lend	This variable is equal to the ratio of the borrowing funds and the lending funds if the bank has a net *lending* position. The variable is set at zero if the bank has a net borrowing position
IB borrow/IB lend	This variable is equal to the ratio of the borrowing funds and the lending funds for all the
Regulatory capital ratio	Regulatory capital ratio of the bank
Capital / Assets	Capital ratio computed with capital and assets at replacement cost
CONTROL VARIABLES	
Savings (D)	Dummy variable. It takes the value of 1 if the bank is a savings bank and zero if it is a commercial bank
Foreign Branch (D)	Dummy variable. It takes the value of 1 if the bank is a foreign branch and zero otherwise
Small (D)	Dummy variable. It takes the value of 1 if the assets of the bank are between the 33th and 66th percentiles of the distribution of assets of that year
Medium (D)	Dummy variable. It takes the value of 1 if the assets of the bank are below the upper 33th percentile of the distribution of assets of that year
Local (D)	Dummy variable. It takes the value of 1 if the bank operates in a local market (only 1 out of 50 provinces)
Regional (D)	Dummy variable. It takes the value of 1 if the bank operates in a regional market (from 1 up to 5 provinces)
Salaries (th€ 1992)	Labor expenses in thousands of euros of 1992 divided by the total number of workers
Cost of Equity	Risk adjusted opportunity cost of equity (see note 11)
Advertising Capital	Replacement cost of the stock of Advertising capital over replacement cost of total productive assets of the bank
Training Capital	Replacement cost of the stock of Human capital generated from training expenditures over the replacement cost of the total productive assets of the bank
*Net Commissions/Assets*100*	Ratio of the net commissions to the total assets
LLP/Loans	Flow of Loan Loss Provisions over the volume of loans
RWA/Assets	Ratio of Risk Weighted Assets, according to capital regulation, and the accouting value of assets
Internet Deposits / Total Deposits	Percentage of deposits that are collected through the internet channel
Prop.Termporary Employees	Number of partial-time employees over the total number of workers.
Prop. Employees in Branches	Proportion of workers in branches (complementtary to workers in the headquarters of the bank)
Growth of the branch network	Average Yearly Growth rate of the number of branches during the period 1992-2007
Prop Branches Abroad	Proportion of overseas branches of a bank with respect to its total number of branches
Size of branches (th€ 1992)	Repalcement cost of the stock of physical capital at constant prices divided by number of branches
Pre-Merge (3 years) (D)	Dummy variable. It takes the value of 1 for a merging bank during the 3 years prior the merge takes place.
Post-Merge (3 years) (D)	Dummy variable. It takes the value of 1 for a merging bank during the 3 years after the merge takes place.
Real GDP Growth	Annual Growth Rate of real GDP
Nominal Interbank Rate	12-month nominal interbank interest rate
Inflation	Annual Growth rate of the Consumer Price Index
Trend	Variable that takes the value of 1 for observations in 1992, 2 in 1993, 3 in 1994 and so on…

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