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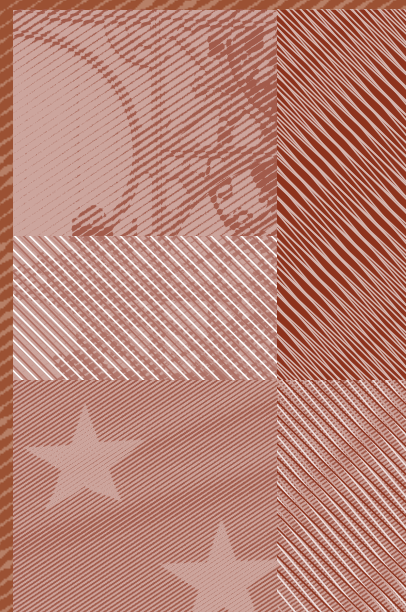
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DRIVERS OF PRODUCTIVITY IN THE SPANISH BANKING SECTOR: RECENT EVIDENCE [(*)]

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Abstract

We analyse the drivers of total factor productivity of Spanish banks from early 2000, including the last financial crisis and the post-crisis period. This allows us to study changes in productivity following a major restructuring process in the banking sector such as the one experienced in Spain. Overall, we find that following a period of continued growth, productivity declined after the height of the crisis, though large banks were less affected. We also find that risk, capital levels, competition and input prices were important drivers of the differences in productivity change between banks. Finally, our results suggest that, by the end of our sample period, there was still some room for potential improvements in productivity via exploiting scale economies and enhancing cost efficiency. These opportunities appear to be generally greater for the smaller banks in our sample.

Keywords: banking, cost efficiency, crisis, scale economies, productivity.

JEL classification: D24, E58, G01, G21, G28, G34.

Resumen

Este estudio analiza los determinantes de la productividad total de los factores de los bancos españoles desde el año 2000 hasta el período poscrisis. En particular, analizamos los cambios en la productividad derivados del proceso de reestructuración que ha experimentado el sector bancario español después de la crisis. Encontramos que, tras un período de continuo crecimiento, la productividad se ha reducido desde el comienzo de la crisis, aunque los bancos más grandes se han visto menos afectados. También identificamos que el riesgo, los niveles de capital, la competencia y los precios de los *inputs* han sido determinantes muy importantes que explican las diferencias en los cambios de productividad entre bancos. Finalmente, nuestros resultados sugieren que, al final de la muestra, existe margen para mejoras adicionales en la productividad, principalmente a través del aprovechamiento de economías de escala y de incrementos de la eficiencia en costes. Identificamos que estas oportunidades son, en general, mayores para los bancos pequeños en nuestra muestra.

Palabras clave: bancos, eficiencia en costes, crisis, economías de escala, productividad.

Códigos JEL: D24, E58, G01, G21, G28, G34.

1. Introduction

The last global crisis changed the financial landscape, reshaped the regulation and supervision of banks, and motivated some major structural changes in the banking sector. Yet, after some years since the onset of the crisis, banks are still facing significant challenges in adapting to this new reality. Further to this, the persistently low interest rate environment in advanced economies, necessary to help support and consolidate economic growth, has put additional pressure on banks' profitability. Many banks needed to restructure their strategies to be able to expand their non-interest income sources and had to step up their efforts to reduce their operating expenses. In this context, several authorities, for example the European Central Bank, also suggested that the financial system should continue to improve cost efficiency by, among other methods, taking advantage of possible economies of scale and scope via consolidation, and diversifying income sources (ECB, 2017).

The Spanish banking sector has not been immune to the materialisation of the imbalances accumulated before the crisis. Following the crisis, the Spanish banking sector underwent a thorough restructuring process with, among other structural changes, a number of mergers coupled with the transformation of almost all saving banks into either social foundations or commercial banks. Further to the reduction of their balance sheets and excess debt, banks also had to search for more diversified income sources, review their business models and reduce overcapacity and operating costs. With this process still under way, a key question for the sector is how to sustain its productivity and, as a corollary, whether there may still be room for further consolidation.

To answer these questions it is necessary to understand the underlying reasons behind the changes in banks' productivity over time. This means analysing the drivers of productivity changes during the period prior to the crisis – when imbalances were building up – and also during the crisis and post-crisis periods – when significant changes to the structure and environment of the sector took place. Consideration of banks' heterogeneity and their performance after a major restructuring process such as the one observed in Spain, is also relevant to the analysis.

Against this background, the aim of this paper is to identify the main drivers of productivity change in the Spanish banking sector, before, during and after the crisis. With that as a basis, we study the effects of changes in productivity in different types of banks and gain empirical insights into whether there may still be room to achieve further gains in scale economies and cost efficiency. To this end, we perform a total factor productivity (TFP) decomposition analysis, which allows us to identify the effects of changes in the major TFP components during the three main stages just described. Specifically, we follow a variable cost stochastic frontier approach using data for Spanish banks between 2000 and 2015.

Another important feature to consider when studying TFP growth is the type of decomposition performed. Typically, previous studies of productivity in Spain decomposed TFP growth into technical, scale and efficiency changes; while effects stemming from equity capital, risk, input prices and competition were generally overlooked. By contrast, our findings suggest that these factors played an important role as drivers of TFP in Spanish banks during the expansion period, the financial crisis and the recovery phase.

Finally, we find that the effects of all these factors tend to be dissimilar across banks of different sizes. When we focus the analysis on the assessment of scale economies and cost efficiency, we observe that gains are still achievable at the end of our sample period in both aspects. Improvement opportunities appear to be generally greater for the smaller banks in our sample.

This paper is organised as follows. Section 2 presents a literature review of previous findings on TFP in the banking sector and in particular in Spain. Section 3 presents the methodology used. Section 4 describes the data. Section 5 discusses the main findings and results. Section 6 analyses some robustness exercises and finally we present the main conclusions.

2. Literature review

The majority of studies into banking productivity focus on the analysis of scale economies and cost efficiency. Allen and Rai (1996) are among the first authors to provide estimations of returns to scale accounting for economic inefficiency in the banking sector in a multi-country study. These authors estimate a stochastic cost frontier to a sample of 194 banks in 15 countries finding mixed results depending on the size of the bank. They find high scale economies in small banks but diseconomies of scale in large banks. Similar results were found by Berger and Humphrey (1997) in a survey of 130 studies that apply frontier efficiency models to the banking sector in more than 21 countries. Studies of European banks have also found evidence of significant scale economies, especially for small banks. Cavallo and Rossi (2001) and Vander Vennet (2002) identify room for small European banks to expand their production scale and significant incentives for consolidation. More recently, Fiorentino et al., (2009) assess the effects of merger processes in Italian and German banks. The authors find that banks enrolled in these processes in both countries increased their productivity mainly due to gains in scale efficiency.

Overall, scale economies have usually been identified for small banks and mixed results have been found for large institutions. However, discrepancies could be due to differences in the specifications used for the estimations in terms of the outputs considered and the omission of risk and equity. Humphrey (1992) analyses the effects of using either stock or flow measures of

banking output. The author concludes that estimates on productivity may vary depending on the importance of a particular output over a period of time, while for scale economies stock measures provide a better fit. Lozano-Vivas and Pasiouras (2014) provide an analysis of the inclusion of off-balance sheet (OBS) activities on the estimation of cost and profit efficiency and productivity using a broad international sample of 84 countries. Their results show that the omission of OBS activities affect profit productivity estimations but seem to have little effect on cost productivity. In the case of efficiency, this seems to affect mainly the estimations for major-advanced and developing economies.[3] The inclusion of other non-traditional banking activities such as fee-based services has been documented as affecting efficiency estimations by Tortosa-Ausina (2003), who identifies that the omission of fee-based services distorts the results when applied to Spanish banks. Hughes et al. (2000), and Hughes et al. (2001) show that the omission of risk-taking in modelling bank costs would lead to misleading estimates of scale economies. This has also been found to be the case when equity is ignored. Hughes and Mester (2013) have identified the necessity of including equity in the estimations in order to avoid misspecifications. The authors also warn that the common measures of returns to scale may be biased given the omission of the cost of equity.

2.1. Total factor productivity in the Spanish banking sector

The productivity of the Spanish banking sector and its main components have been studied in a number of papers, although most of these studies have focused on investigating the effects of deregulation. Regarding scale economies, mixed results have been found. Altunbas and Molyneux (1996) assess returns to scale in the late 1980s and find major scale economies for all types of banks although the ones for small banks are greater. Lozano-Vivas (1998) finds no evidence of scale economies for commercial banks but some diseconomies for saving banks for the period 1985-1991. Cuesta and Orea (2002) extend the period up to 1998 and find small but significant scale economies for Spanish banks and saving corporations during the post-deregulation period. These authors also study the effects of previous merger processes in Spanish banks finding that, although institutions involved in such processes saw a decrease in efficiency levels just after these processes were carried out, they recovered after 4 years at which point they started to present higher efficiency levels than non-merged banks.[4]

Broader analysis of TFP growth has found improvements in the Spanish sector after deregulation. Grifell-Tatjé and Lovell (1997) compute TFP change using nonparametric methods

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[3] The author classify the countries in 4 groups (major-advanced, advanced, transition and developing countries). Similar findings for developing countries have been documented before (see Tabak and Tecles, 2010; Sarmiento and Galan, 2017).

[4] This effect on bank efficiency after merger and acquisition processes was also recently identified in Colombian banks by Galán, et al (2015).

over the post-deregulation period (1986-1993). They identify that deregulation positively influenced productivity growth in both commercial and savings banks. Also, relying on nonparametric methods, Tortosa-Ausina et al (2008) explore the productivity growth of Spanish savings banks over the 1992-1998 post-deregulation period. They conclude that about 90% of savings banks experienced productivity growth in this period, mainly as a consequence of improvements in production possibilities. The remaining savings banks suffered productivity declines due to efficiency losses.[5]

Studies using parametric methods have also found similar results. Maudos (1996) analyses the evolution of productivity in Spanish savings and commercial banks over the deregulation period 1985-94. The paper identifies high technical progress for the whole banking industry but positive productivity growth only for savings banks, owing to large efficiency losses in commercial banks. Low efficiency but high productivity growth, was also identified by Kumbhakar et al (2001), who examine the impact of regulatory reforms on the drivers of productivity of Spanish savings banks for the period 1986-1995. Their results also provide evidence that TFP growth was spurred on by a high rate of technical progress that outweighed the low efficiency present in the sector. Similarly, Kumbhakar and Lozano-Vivas (2005) find that deregulation contributes positively to TFP growth for both commercial and savings banks, though the importance of the effects of domestic and European deregulations was asymmetric.

More recent studies of TFP in the Spanish banking sector also find improvements in productivity driven by technical progress. Martín-Oliver et al (2013) identify intense productivity growth for Spanish banks in the years preceding the recent crisis. When disentangling the sources of this growth, they find that more than two thirds of productivity growth can be explained by the rapid expansion of credit to the housing market, the recourse to securitisation and short-term finance, a decline in liquidity holdings, and increases in the weight of hybrid instruments to the detriment of core capital.

Overall, most studies assessing the effects of deregulation on the productivity of Spanish banks have identified positive TFP growth to be predominantly driven by technical progress which outweighs the efficiency losses identified, in general, for commercial banks. Nonetheless, most of these studies have focused on the effects of the deregulation process carried out in the late 1980s and to the best of our knowledge, none of them have studied the impacts of the last financial crisis and the post-crisis period on TFP of Spanish banks. Also, most previous studies of productivity in Spain decompose TFP growth into technical, scale, and efficiency changes;

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[5] When compared to other banking sectors, Spanish banks productivity has been found to be relatively lower. Pastor, et al (1997) use a nonparametric approach to compute the differences in productivity between banking sectors of different countries. They conclude that the relatively poor performance of Spanish banks is a consequence of their high capitalization, possibly as a prudent response to a high risk economic national environment.

while other effects related to equity, risk, input prices and competition are generally overlooked. In this paper we study a TFP decomposition taking into account all these factors, which we show played an important role as drivers of TFP during the expansion period, the financial crisis and the recovery phase.

3. Methodology

We follow a variable cost frontier approach to measure scale economies and decompose total factor productivity in the Spanish banking sector (Berger and Humphrey, 1991). This approach takes into account an inefficiency component in the estimation which does not allow banks to operate at minimum feasible costs thereby affecting their productivity. Literature on frontier efficiency in banking has witnessed the importance of properly identifying the inefficiency component in costs and profit estimations of the banking sector (Berger and Mester, 1997). In general, studies using frontier efficiency models have found that economic inefficiency widely dominates scale effects in banking (Berger and Humphrey, 1991; Grifell-Tatjéb and Lovell, 1997; Lozano-vivas, 1998). In this context, inefficiency is related to the excessive use of inputs and their inadequate allocation given the input prices and the output produced.

The variable cost frontier is the following:

$$c(\boldsymbol{y}, \boldsymbol{w}, k, r, \boldsymbol{z}, t) = \min_{x}\{\boldsymbol{w}\boldsymbol{x} \ \ s.t. \ T(\boldsymbol{y}, \boldsymbol{x}, k, r, \boldsymbol{z}, t) \leq 0, k = k^{0}\}, \tag{1}$$

where, $\boldsymbol{y}$ is a vector of m outputs, $\boldsymbol{x}$ is a vector of n inputs, $\boldsymbol{w}$ is a vector of input prices, k represents equity capital included as a quasi-fixed input, r represents a risk measure, $\boldsymbol{z}$ is a vector of other bank characteristics affecting the cost frontier, t is a time trend variable intended to capture technical change, and u is the cost inefficiency component.

The estimation is performed using stochastic frontier analysis (SFA) (Aigner, Lovell, and Schmidt, 1977). This is a parametric method which consists of decomposing the error term of an econometric cost function into two components: an idiosyncratic error term and a component capturing cost inefficiency. The specification of the cost stochastic frontier model is the following:

$$\ln C = \ln c\ (\boldsymbol{y}, \boldsymbol{w}, k, r, \boldsymbol{z}, t) + \varepsilon; \ \varepsilon = v + u, \tag{2}$$

where, ε_{it} is an error term composed of the idiosyncratic error (v_{it}), which follows a normal distribution and the inefficiency component (u_{it}), which is assumed to follow a non-negative distribution.

Regarding equity capital, excluding it from the cost function may produce biased estimations of scale economies, efficiency and TFP change (Hughes and Mester, 2013). Certainly, if equity capital is not accounted for in the estimations, then more leveraged banks would be

estimated as being more inefficient than other banks facing the same the same output level and input prices, without recognizing the savings produced by the use of less capital.

Hughes et al. (2000), and Hughes et al. (2001) also provide evidence that systematic differences in risk between banks have significant effects on cost elasticity with respect to output. Therefore, the omission of risk-taking in modelling and estimating bank costs would lead to misleading estimates of scale economies. In fact, Hughes and Mester (2013) find that there is a component of scale economies related to risk-taking that remains unidentified when risk is not accounted for. Similarly, Kovner et al. (2014) find that it is only when controlling for risk that scale economies become evident in large banks. Recently, several studies on bank efficiency and productivity have included risk variables in the estimation. However, usually ex-post risk measures such as non-performing loans are included and some other studies have added more variables trying to capture other types of ex-ante risk such as liquidity or solvency risk. In this regard, we propose to follow a novel approach by including a unified composite ex-ante risk measure that incorporates different types of risk regarding credit, liquidity, solvency, profitability and the macroeconomic environment. This is performed by means of a conditional logit model, which estimates the occurrence of a distress event of within a two-year horizon. The specification of the model and the details of the variables included are presented in the Appendix. The model is estimated with data for the same banks in the sample we describe in more detail for our main model.

We represent the cost frontier with a translog functional form (Mester, 1993). This is a flexible functional form which allows the estimation of a U-shaped cost frontier avoiding some problems of other functional forms (e.g. Cobb-Douglas).[6] The empirical estimated model is:

$$\ln c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m \ln y_{mit} + \sum_{n=1}^{N} \delta_n \ln w_{nit} + \frac{1}{2}\sum_{n=1}^{N}\sum_{k=1}^{N} \delta_{nk} \ln w_{nit} \ln w_{kit} +$$
$$+ \frac{1}{2}\sum_{m=1}^{M}\sum_{j=1}^{M} \beta_{mj} \ln y_{mit} \ln y_{jit} + \sum_{m=1}^{M}\sum_{n=1}^{N} \phi_{mn} \ln y_{mit} \ln w_{nit} + \omega_1 \ln k_{it} +$$
$$+ \omega_2 \ln k_{it}^2 + \sum_{m=1}^{3} \omega_{1m} \ln k_{it} \ln y_{mit} + \sum_{n=1}^{3} \omega_{2n} \ln k_{it} \ln w_{nit} + \theta_1 t + \frac{1}{2} \theta_2 t^2 +$$
$$+ \sum_{m=1}^{M} \theta_{1m} t \ln y_{mit} + \sum_{n=1}^{N} \theta_{2n} t \ln w_{nit} + \varphi t \ln k_{it} + \lambda_1 r_{it} + \frac{1}{2} \lambda_2 r_{it}^2 +$$
$$+ \sum_{m=1}^{M} \lambda_{1m} r_{it} \ln y_{mit} + \sum_{n=1}^{N} \lambda_{2n} r_{it} \ln w_{nit} + \psi t r_{it} + \vartheta r_{it} \ln k_{it} + \boldsymbol{\omega}' \boldsymbol{z}_{it} + v_{it} + u_{it}$$
$$v_{it} \sim N(0, \sigma_v^2); \ u_{it} \sim N^+(\mu_{it}, \sigma_u^2), \ \mu_{it} = \boldsymbol{\gamma}' \boldsymbol{h}_{it} \qquad (3)$$

Linear homogeneity of the cost function is achieved by normalizing total costs and input prices by a chosen input price and symmetry of the cross-effects is accomplished by imposing $\beta_{mj} = \beta_{jm}, \delta_{nk} = \delta_{kn}$. Regarding the inefficiency component, we assume a truncated normal

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[6] A discussion on the advantages of a translog functional form in the estimation of scale economies in banking is presented in Berger and Humphrey (1992).

distribution where the mean is allowed to vary over banks depending on observed specific characteristics included in h (Battese and Coelli, 1992).

Following estimation, *Panzar-Willig* scale economies are computed as the inverse of the elasticity of cost with respect to output (Panzar and Willig, 1977):

$$RTS = (\textstyle\sum_m \partial \ln c / \partial \ln y_m)^{-1}, \tag{4}$$

where, values of *RTS* greater than 1 indicate scale economies and therefore banks would benefit from increasing their output level given that their costs increase less than proportionally. The opposite is true if *RTS* is lower than 1 indicating diseconomies of scale. If *RTS* is equal to 1, then costs increase in the same proportion as output indicating that banks operate on an optimal scale.

However, as previously stated, Hughes et al. (2001) and Hughes and Mester (2013) pointed out that the commonly used *Panzar-Willig* measures of returns to scale would be biased if the cost of equity capital were omitted in the cost function. Since the cost of equity is usually unobserved, they propose to compute economic cost returns to scale by adjusting the *Panzar-Willig* scale economies by a factor which captures the shadow price of equity capital. We compute both measures of scale economies. The economic cost returns to scale are defined as:

$$ECRTS = (1 - \partial \ln C / \partial \ln k)(\textstyle\sum_m \partial \ln c / \partial \ln y_m)^{-1}. \tag{5}$$

The stochastic frontier efficiency approach allows us to derive cost efficiency measures from the inefficiency component estimates. The following transformation returns values within the $(0,1)$ interval, where values closer to 1 indicate higher cost efficiency:

$$CE_{it} = \exp(-u_{it}) \tag{6}$$

3.1. Total Factor Productivity Growth Decomposition

The Divisia index of productivity change in a multi-output context is defined as follows (Denny et al., 1981):

$$T\dot{F}P = \dot{y}_p - \dot{F}, \text{ where } \dot{y}_p = \textstyle\sum_{m=1}^{M} R_m \dot{y}_m \text{ and } \dot{F} = \textstyle\sum_{n=1}^{N} S_n \dot{x}_n , \tag{7}$$

where a dot over a variable indicates its rate of change, $R_m = p_m y_m / R$ is the revenue share of output y_m, p_m is the price of output m, $R = \sum_{m=1}^{M} p_m y_m$ is total revenue, and $S_n = w_n x_n / c$ is the cost share of input x_n. After totally differentiating the cost frontier in (2) and rearranging terms, a decomposition of the TFP index results in (Bauer, 1990):

$$T\dot{F}P = \left[\frac{(1-RTS)}{RTS}\right] \boldsymbol{\varepsilon}_y' \dot{\boldsymbol{y}} - \boldsymbol{\varepsilon}_t - \frac{du}{dt} - \boldsymbol{\varepsilon}_k \dot{k} - \boldsymbol{\varepsilon}_r \dot{r} - \boldsymbol{\varepsilon}_z \dot{z} + (\boldsymbol{s} - \boldsymbol{\varepsilon}_w)' \dot{\boldsymbol{w}} + (\dot{\boldsymbol{y}}_p - \dot{\boldsymbol{y}}_c) , \tag{8}$$

where, $\boldsymbol{\varepsilon}_y, \boldsymbol{\varepsilon}_w, \boldsymbol{\varepsilon}_t, \boldsymbol{\varepsilon}_k, \boldsymbol{\varepsilon}_r$ and $\boldsymbol{\varepsilon}_z$ are vectors of cost elasticity with respect to outputs, input prices, time, equity, risk and other control variables, respectively; du/dt is the rate of change of cost

inefficiency; s is a vector of actual input cost shares; y_p is the revenue-weighted index of output as defined above, and $\dot{y}_c = RTS\ \varepsilon_y'\dot{y}$ is a measure of aggregate output growth using efficient cost elasticity weights instead of observed revenue share weights. Therefore, the right-hand side in (8) represents the TFP change decomposition into the following eight components:

- Scale efficiency change ($[(1 - RTS)/RTS]\ \varepsilon_y'\dot{y}$): this component captures positive (negative) effects on productivity of moving towards (away from) the optimal scale (constant returns to scale). Thus, if returns to scale are equal to 1 or if output does not change then there is no effect of scale efficiency to TFP change.

- Technical change (ε_t): if this elasticity is greater than 0 then the cost frontier moves up *ceteris paribus* implying greater costs at the same production levels. This indicates technical regress and then decreases in TFP. The opposite is true when this value is lower than 0 and therefore productivity will raise.

- Cost efficiency change (du/dt): this component captures the effect of gains and reductions in cost efficiency on productivity. If this term is positive, then inefficiency is increasing and the impact on productivity is negative. On the other hand, when this term is negative banks are moving towards the cost efficient frontier and productivity is enhanced.

- Equity capital change ($\varepsilon_k\dot{k}$): if the elasticity of costs with respect to equity is positive then increases of equity would decrease productivity. The opposite would occur if equity were reduced.

- Risk change ($\varepsilon_r\dot{r}$): this component measures the effect of risk on productivity. If the elasticity of costs with respect to risk were positive then increasing risk would imply decreases in TFP, while the opposite effect is produced if risk decreases or if elasticity is negative.

- Other control variables change ($\varepsilon_z\dot{z}$): if elasticity of costs with respect to control variables is greater than 0 then positive changes in these variables would imply decreases in productivity. The opposite effect is produced if elasticity is negative or if these variables present negative changes.

- Input prices effect ($(s - \varepsilon_w)'\dot{w}$): this component measures the effect on productivity of changes in the allocation of inputs with respect to the optimal. If observed input cost shares are optimal or if input-prices do not change then productivity is unaffected.

- Mark-up effect ($\dot{y}_p - \dot{y}_c$): This captures the impact on productivity change of departures from equiproportional mark-up over marginal cost pricing. Thus, in the presence of marginal cost pricing as in perfect competition ($\dot{y}_p = \dot{y}_c$) there would not be an effect on productivity.

4. Data

The database includes Spanish commercial and saving banks over the period 2000-2015 thus enabling the highly expansive period prior to the crisis and also the crisis and post-crisis years to be taken into consideration. We draw the bank-level data from the nonconsolidated confidential balance sheets and income statements as well as from the complementary files reported by banks to *Banco de España* for each bank and year. Our sample represents 90% of the total assets of banks and savings banks as a whole. When two banks merge, we consider that a new institution is created. The result of this process is an unbalanced panel composed of 50 entities over 16 years.

We consider the bank as a multiproduct firm that combines three types of activities: intermediation services, financial investments and fee-based services, following the intermediation approach (Sealey and Lindley, 1977) under which banks are assumed to use deposits and other inputs in order to produce loans and other outputs. In particular, we consider as outputs i) total loans to the non-financial private sector (y_1); ii) financial investments including debt securities other than sovereign and variable-income assets in the trading portfolio (y_2); and, iii) fee-based services measured as the net income obtained from all services generating fees and commissions (y_3). This output is a flow rather than a stock. On this regard, Humphrey (1992) find that flow measures of outputs provide useful information for productivity estimations when they reflect a relevant feature of the banking sector over a certain period of time. In fact, this final output has become more relevant in recent years and its omission has been identified as biasing the efficiency estimates (Tortosa-Ausina, 2003). As input prices we include: i) price of deposits, measured as interest expenses paid to deposits divided by total deposits (w_1); ii) price of debt, measured as interest expenses and similar charges associated to debt certificates including bonds, divided by total debt (w_2); iii) price of physical capital, measured as administrative expenses (except advertising and publicity expenses, contributions and taxes) plus depreciation and amortization of tangible assets divided by tangible assets (w_3); and, iv) price of labour, measured as personnel expenses divided by the number of employees (w_4);. Contrary to Modigliani-Miller's theorem (Modigliani and Miller, 1958), in the presence of taxes, bankruptcy costs, agency costs, and asymmetric information, differences in capital structure across banks can determine differences in their costs of funding.[7] To take this into account, we include equity capital as a quasi-fixed input (k). The metric of equity capital comprises Tier 1 and Tier 2 capital.[8] The production cost involves the sum of all interest and non-interest expenses.

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[7] Several papers provide evidence on the increment in funding costs for banks due to increases in the capital ratio (see Kashyap, Stein and Hanson, 2010 and Martín-Oliver et al., 2013).

[8] This includes ordinary shares, retained earnings, preferred stocks, undisclosed reserves, asset revaluation reserves, general provisions, general loan loss reserves, debt/equity capital instruments and subordinated term debt.

Table 1. Summary statistics. This table reports descriptive statistics (average, standard deviation, minimum and maximum) of all the variables used four our models. Monetary values are in thousand euros of year 2010.

Variable	Mean	Std. Dev.	Min	Max
Loans	44,638,693	50,562,787	2,753,603	215,465,744
Financial investments	13,321,218	20,577,447	79,405	104,183,888
Fees and commissions income	190,812	225,932	9,033	847,832
Deposits	40,513,738	45,216,461	2,230,888	198,111,312
Debt	8,518,086	12,927,424	-	66,906,868
Fixed assets	690,889	718,551	30,970	3,366,107
Employees	7,811	7,991	1,026	33,186
Deposits interests	786,243	953,850	61,902	5,946,642
Debt interests	320,687	503,457	0.001	2,251,604
Operative expenses	299,403	373,921	28,069	2,127,326
Personnel expenses	550,619	643,087	48,941	2,513,595
Total costs	1,956,952	2,321,684	164,380	11,447,704
Equity capital	5,323,303	9,419,915	173,837	58,499,076
Probability of distress	0.031	0.0843	0.000	0.858
Non-performing loans ratio	0.044	0.059	0.003	0.320
Liquidity ratio	0.099	0.062	0.003	0.452
Solvency ratio	0.058	0.025	0.011	0.143
Return on assets	0.001	0.156	-6.546	0.838
Net interest margin	0.020	0.009	0.001	0.059
Total assets	81,982,536	108,291,218	6,506,217	495,562,464

As mentioned, we also include probability of distress at the bank level as a composite metric of ex-ante risk (*pd*). This variable is estimated according to the specification in the Appendix, where a description of the model and the variables used are presented. In order to control for possible differences associated to the ownership type we include a dummy variable (*saving*) that differentiates between commercial and saving banks.[9] In this regard, it is important to remark that, as a consequence of the crisis, almost all saving banks were transformed into commercial banks or acquired by them. Finally, we include total assets (*size*) in order to account for the potential effect of bank size in cost efficiency. Certainly, previous studies have found size to be an important determinant of both cost and profit efficiency in the banking sector (see, Wheelock and Wilson, 2012; Galan et al, 2015 for some evidence). Table 1 shows a summary statistics of the variables used where all monetary magnitudes are expressed in constant prices of year 2010.

5. Results

We estimate three different models departing from the specification in Equation (3). Model I estimates the traditional cost frontier which does not consider equity capital or risk (that is, $\omega, \lambda, \varphi, \psi, \vartheta = 0$). Model II includes equity as a quasi-fixed input into the cost frontier in order

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[9] This variable is equal to 1 for saving banks and 0 otherwise.

to account for the effects of leverage (that is $\lambda, \psi, \vartheta = 0$). Finally, Model III includes both equity and risk (that is, the full specification in Equation (3)). Table 2 shows the estimation results and the aggregated results for returns to scale and cost efficiency. The signs of the input prices and output variables are as expected. All other things being constant, expanding production, increasing input quantities or having to pay higher prices for inputs, increase average costs. The significance levels are stable across the models. Returns to scale estimates in this case indicate scale economies on average for the Spanish banking sector.

Regarding the inclusion of equity capital, its effect computed from the derivative is positive and significant indicating that increasing equity is costly for banks in the short-run.[10] Estimations of returns to scale become greater when equity is accounted for. However, it becomes necessary to adjust these results by the cost of equity. Estimates of ECRTS are still positive and significantly greater than 1 although slightly lower than the usual RTS. This recognises that increasing the output level implies, to some extent, the need to raise capital, which is costly. Cost efficiency also increases when equity is included, implying that the higher costs, due to equity funding, shift the cost frontier upwards.

Finally, the effect of the proposed composite risk metric computed from the derivative is also positive and significant, implying that engaging in more risk-taking increases costs. Nonetheless, returns to scale are greater than those in Model II, which suggests that raising the production scale allows banks to increase risk at lower than proportional costs. This result is in line with previous findings on how accounting for risk uncovers the effects of scale economies (Hughes and Mester, 2013; Kovner et al., 2014). In fact, Hughes and Mester (2013) find that controlling for risk enables identification of a strong and significant negative relationship between size and risk that is attributable to the benefits of diversification.[11] This would imply more benefits in terms of scale economies for larger banks. The relationship between risk and size also affects banks efficiency. Recently, Sarmiento and Galan (2017) find that the effects of risk-taking on cost and profit efficiency vary with size.[12] In fact, the relationship between size and cost efficiency also seems to be relevant. In all the models, size is identified as significant and positively related to efficiency.[13]

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[10] The delta method of convergence of transformed random variables is used to assess the significance of the derivatives.

[11] Demsetz and Strahan (1997) also find evidence of risk-decreasing diversification in US bank holding companies using an assets pricing model.

[12] In particular, the authors find large banks benefit more from taking higher credit and market risk.

[13] This result is in line with previous studies that have identified large banks as being more cost efficient than small banks (*e.g.* Wheelock and Wilson, 2012; Galan et al, 2015).

Table 2. Estimation results. Mean RTS and ECRTS significance levels are computed with respect to differences from 1 following the delta method of convergence of transformed random variables.

Variables	Model I		Model II		Model III	
ln y_1	1.858	***	1.361	**	1.414	***
ln y_2	1.061	***	0.784	***	0.818	***
ln y_3	0.856	*	0.409	*	0.253	*
ln w_1	2.153	***	2.010	***	1.738	***
ln w_2	0.511	**	0.450	**	0.406	**
ln w_3	0.304	*	0.533	**	0.545	***
ln y_1 ln y_1	0.300	***	0.405	***	0.421	
ln y_1 ln y_2	-0.081	***	-0.041	*	-0.052	***
ln y_1 ln y_3	-0.111	**	-0.119	***	-0.125	***
ln y_2 ln y_2	0.006	*	0.005		0.006	
ln y_2 ln y_3	0.038	*	-0.011		-0.004	
ln y_3 ln y_3	0.039		-0.074		-0.077	**
ln w_1 ln w_1	0.109	**	0.115	**	0.114	***
ln w_1 ln w_2	-0.018	**	-0.003		-0.007	
ln w_1 ln w_3	-0.036	***	-0.010		-0.024	
ln w_2 ln w_2	-0.002		-0.002	*	-0.002	
ln w_2 ln w_3	0.048	***	0.046	***	0.049	***
ln w_3 ln w_3	0.010		-0.028	*	-0.021	
ln y_1 ln w_1	-0.015		-0.033		-0.003	
ln y_1 ln w_2	0.075	***	0.037		0.029	
ln y_1 ln w_3	-0.014		0.035		0.043	
ln y_2 ln w_1	0.063	***	0.038	**	0.030	**
ln y_2 ln w_2	-0.001		0.003		0.003	
ln y_2 ln w_3	-0.035	***	-0.037	***	-0.040	***
ln y_3 ln w_1	-0.091	***	0.013		-0.028	
ln y_3 ln w_2	-0.039	***	-0.044	***	-0.041	***
ln y_3 ln w_3	0.076	***	-0.040		-0.034	*
t	0.029		-0.007		-0.067	
t^2	0.004	***	0.006	***	0.004	***
t ln y_1	-0.004		-0.004		-0.005	
t ln y_2	0.013	***	0.009	***	0.009	***
t ln y_3	-0.011	*	-0.016	***	-0.017	***
t ln w_1	-0.002		0.016	***	0.005	
t ln w_2	-0.002		-0.003		-0.003	
t ln w_3	0.001		-0.009	**	-0.006	**
ln k			1.068	***	1.103	**
ln k ln k			-0.009		-0.018	
ln k ln y_1			-0.175	***	-0.159	***
ln k ln y_2			0.009		0.008	
ln k ln y_3			0.172	***	0.167	***
ln k ln w_1			-0.066	**	-0.045	*
ln k ln w_2			0.036	***	0.038	***
ln k ln w_3			0.079	***	0.062	***
t ln k			0.009	**	0.011	***
pd					1.634	***
pd^2					-8.995	*
pd ln y_1					5.997	
pd ln y_2					1.545	
pd ln y_3					-3.582	***
pd ln w_1					-8.144	***
pd ln w_2					14.700	***
pd ln w_3					1.488	
t pd					-0.765	**
pd ln k					-1.890	
saving	0.076	***	0.070	***	0.074	***
Inefficiency						
ln *size*	-0.106	***	-0.133	***	-0.119	***
σ_u	0.105	***	0.082	***	0.093	***
log-likelihood	349.82		383.21		413.11	
Mean RTS	1.02	***	1.04	***	1.08	***
Mean ECRTS			1.02	***	1.05	***
Mean cost eff.	0.70		0.75		0.82	

***, ** and * refer to the value being significantly different from 0 at 1%, 5% and 10%, respectively.

5.1. Total Factor Productivity Growth and its Decomposition

Focusing on our preferred model that controls for equity and risk (Model III), we compute total factor productivity growth index as in Equation (8). Results by size of banks are presented in Figure 1.[14] In general, TFP had been growing at a rapid pace from 2000 until the onset of the crisis, though large banks had experienced higher growth than small or medium-sized banks. Then, as a consequence of the crisis, TFP growth rates fell for all types of banks, although decreases were larger for small and medium-sized institutions. In the post-crisis years the majority of banks have started to recover their losses in productivity, although this has been more evident in small institutions.

Figure 1. Evolution of TFP index over time by size of banks
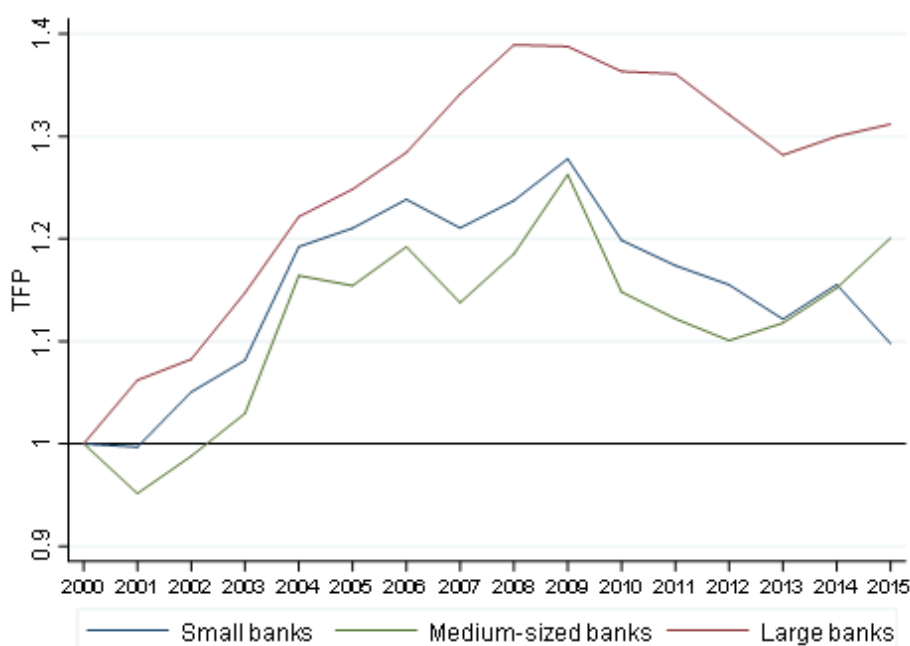
A decomposition of factors explaining the changes in total productivity provides further insights regarding the TFP changes and the differences among banks of different sizes. Figure 2 panels (a) and (b) present this breakdown for small and large banks in terms of their contribution to the change in TFP, respectively. We observe that during the pre-crisis period, the main driver of productivity growth was technical change. This is observable for both types of banks although it is more important for large institutions. Martin-Oliver et al. (2013) find similar results and identify that this was associated with the rapid expansion of credit to the housing market and the

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[14] Banks are classified into small and large banks based on their total assets, where small banks are those below the 25th percentile, medium banks are those between the 25th and the 75th percentile, and large banks are those above the 75th percentile. This classification for large banks coincides with the banks identified as O-SIIs (Other Systemic Important Institutions) in 2017 by *Banco de España* (BdE, 2016) plus Banesto during the period 2000 – 2008.

increased usage of financial instruments such as mortgage securitizations.[15] From the onset of the crisis, estimates of technical change have become negative, indicating that the cost frontier has been shifting upwards, although large banks have presented less negative technical change than small banks. Humphrey (1993) finds similar behaviour in the US after a restructuring process and argues that large banks have the ability to reduce operating costs faster via a more intensive use of branch offices. Their typically larger branch networks can be cut back or restructured.

In general, during the pre-crisis period, cost efficiency was also an important positive TFP growth driver among all types of banks. Competition might have played an important role in promoting efficiency improvements. Certainly, Casu and Girardone (2006) identify that increased competition forced European banks to become more efficient during the early 2000s. With the onset of the crisis banks faced a negative shock to their output, which suddenly shifted the frontier upwards leading to temporary gains in efficiency in the early stage of the crisis. Later, the excess capacity faced by banks and the restructuring process brought about reductions in cost efficiency. In the recovery phase, efficiency gains have been coming back, especially for large banks, which had previously been found to have the ability to reduce operating costs more quickly than small banks (Humphrey, 1993).

The importance of scale efficiency change as a productivity driver has been more limited, although important differences are observed between small and large banks. During the credit expansion years, it contributed negatively to the productivity of small banks while the effect was positive for large banks. This may suggest that, during the pre-crisis period, the expansion of capacity in small banks led to higher increases in costs than the increases obtained in output volume. Then, following the crisis the role of scale efficiency as a driver of productivity has been almost negligible in comparison to other components. We further extend this analysis in more detail below in order to reach conclusions regarding the current situation of returns to scale of Spanish banks.

The effect of equity capital is, in general, negative on productivity change during the whole period, which is related to the cost of equity as a funding source. During the pre-crisis this effect is more evident for large banks, suggesting that they increased equity in a greater proportion than small banks, possibly as a consequence of a more rapid output growth. Then, from the onset of the crisis, banks had to make additional efforts to raise equity capital, which seems to have affected small banks more, probably due to these types of banks facing higher costs of funding via equity.
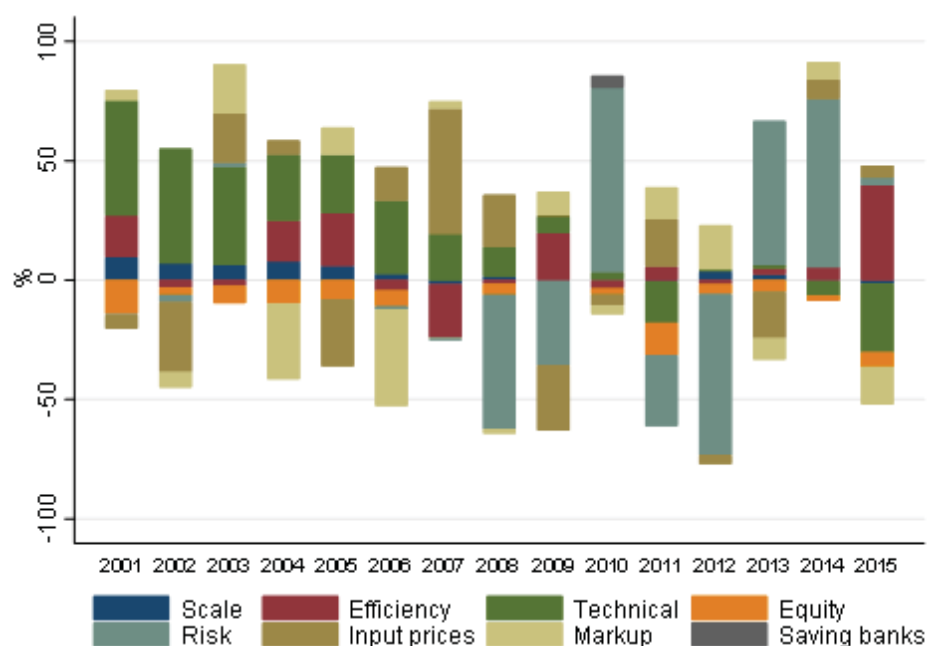
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[15] Mortgage securitisation in Spain between 2000 and 2007 grew at annual rates greater than 40% on average (BdE, 2017c).

Figure 2. Decomposition of TFP growth and its evolution over time

Panel (a): Small banks
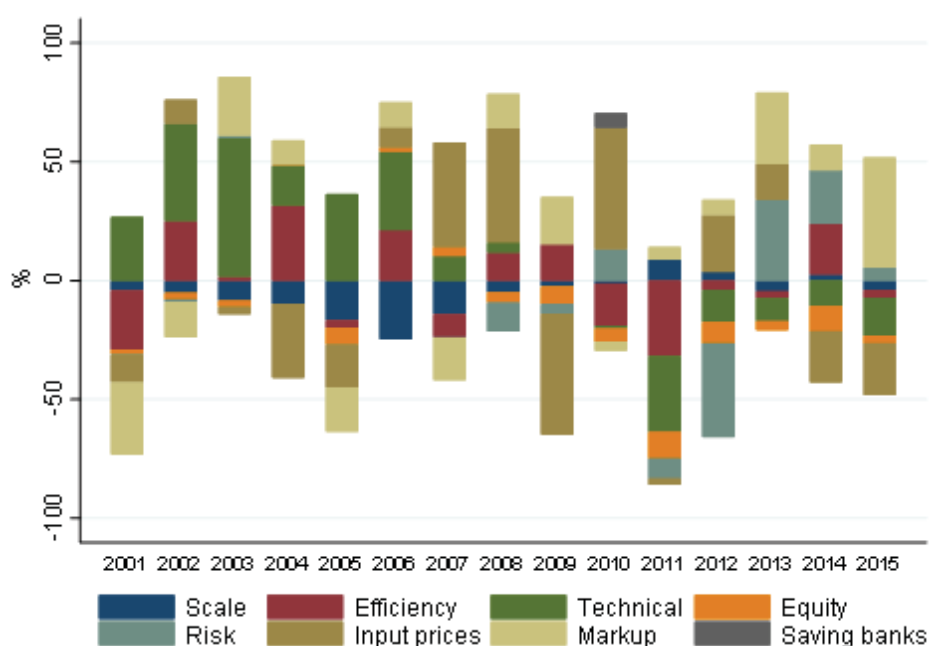
Panel (b): Large banks

Regarding risk, the effect on TFP growth becomes relevant just before the crisis when the vulnerabilities that had built up during the expansion years started to materialise.[16] This effect was greater for large banks, which may have engaged in more risk-taking. Reasons for this vary from the incentives associated with *too-big-to-fail* effects (Bertay et al., 2013) to the higher risk

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[16] Engaging in more risky activities have also been previously documented to be a consequence of increasing competition in Spanish banks (Salas and Saurina, 2003). Nonetheless, this relationship has been found to depend on the degree of concentration (Jimenez et al., 2013).

implied by their activities and business models such as greater complexity, higher leverage, and less-stable funding (Laeven et al., 2014). Around 2010, risk decreases and it leads to TFP growth for all banks, however, during the sovereign crisis risk increases again affecting productivity negatively. During the post-crisis years, risk has substantially decreased, which, in terms of productivity, has benefited large banks more.

With regard to competition, the mark-up component relating to the ability of banks to set output prices above those in perfect competition shows mixed effects in TFP among banks. Nonetheless, its net effect appears to be negative during the expansion years. This suggests that the increase in competition during that period forced banks to reduce output prices. During the crisis, the restructuring processes in the sector, mainly via consolidation, allowed banks to exploit output prices and obtain benefits from this in terms of TFP growth. In this regard, the mark-up component suggests that small banks have benefited more from this in recent years. This may indicate that consolidation processes have allowed small banks to take advantage of increases in output prices, while for large banks the margin to increase them has been more limited.

Input prices exhibit mixed results although they had a clear positive effect on banks productivity during 2007 and 2008 just prior to the financial crisis in Spain. From the onset of the crisis, the change in input prices has been mainly driven by the decrease in the price of deposits as a consequence of the low interest rate environment. This seems to have benefited banks during the last years of the crisis. However, it has had negative effects on productivity in the last two years of our sample period. This can be related to the compression of net interest margins (BDE, 2017b). Small banks have been more affected by this, probably as a result of larger banks having greater access to funding sources other than deposits, and benefitting from lower funding costs (Laeven et al., 2014).

Finally, results suggest that the broad transformation process of savings banks into commercial banks, as a consequence of the crisis, has been a relevant positive productivity driver for those institutions. A definite impact on TFP growth is observed around 2010 when the largest part of this restructuring process was carried out.

5.2. Is there room for improvements in efficiency and exploiting scale economies?

The renewed concerns regarding the low profitability of banks in Europe have opened questions regarding the scope for enhancing both operating cost and scale efficiency in the banking sector (ECB, 2017). Spain has not been immune to this environment and the possibility of improving profits through cost and scale efficiency remains important (BdE, 2017a). Against this background, we analyse cost efficiency and returns to scale of Spanish banks in more detail.

**Figure 3.** Scale economies by size of banks.
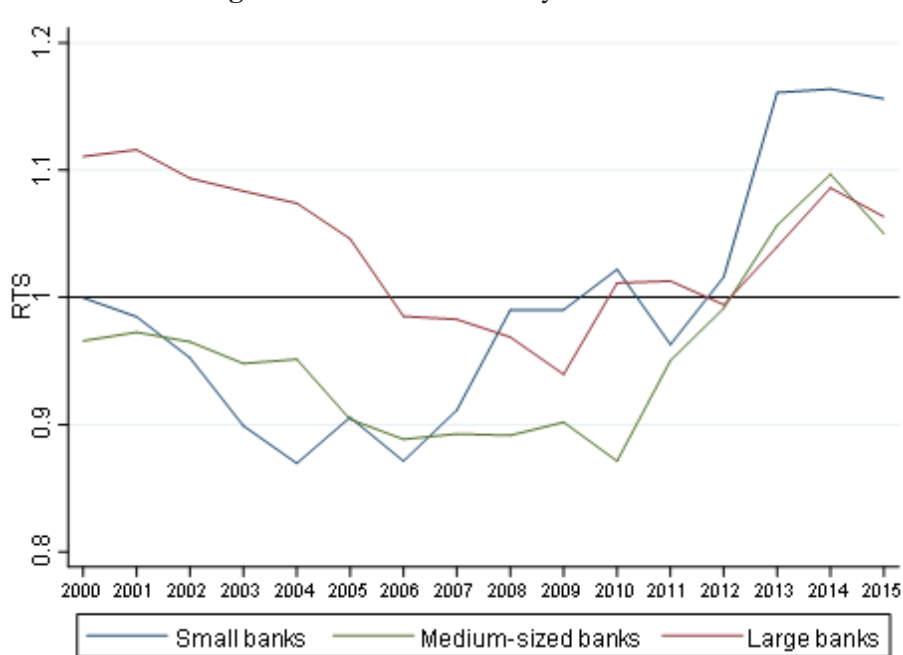
The differences found between banks of different sizes in terms of TFP, suggest the convenience of analysing scale economies and cost efficiency while differentiating by bank size. Figure 3 exhibits estimations of returns to scale by size of banks. It is observed that opportunities for scale economies were increasing gradually between 2000 and 2007. This may suggest that the rapid expansion of their capacity during this period of large credit growth allowed them to exploit scale economies. Following the crisis, the thorough restructuring process of the Spanish banking sector opened new opportunities for scale economies. In the last two years of our sample period, these opportunities have started to be seized, mainly by medium-sized and large banks. This has increased heterogeneity between small and large institutions during the post-crisis period. Overall, increasing returns to scale are identified for all types of banks, although scale economies opportunities have increased more extensively for small banks and remain higher for these institutions.

Mirroring some of the dynamics observed in scale economies, cost efficiency also increased during the pre-crisis period (Figure 4). This could be an effect of the increase in competition which was more evident for small and medium-sized banks, given that such institutions had more room for improvement (Casu and Girardone, 2006). As stated previously, size has a significant positive effect on cost efficiency and large banks exhibited higher efficiency throughout the period under examination. Subsequently, with the onset of the crisis, cost efficiency stalled for large and medium-sized banks and decreased for small institutions. Certainly, small banks seem to have been more affected by the excess of capacity once the crisis arrived, suggesting that these types of banks are less able to cut costs rapidly (Humphrey, 1993).

In the last two years of our sample period, cost efficiency has been recovering as a consequence of the large reduction of branches (more than 30% from 2008; BdE, 2017b) and the benefits of synergies derived from merger processes. This increase in efficiency has been more evident for large banks, which have been more involved in both strategies. All this suggests that while there is still scope for possible improvements in cost efficiency for all banking groups, currently, opportunities appear to be greater for small banks.

Figure 4. Cost efficiency by size of banks.
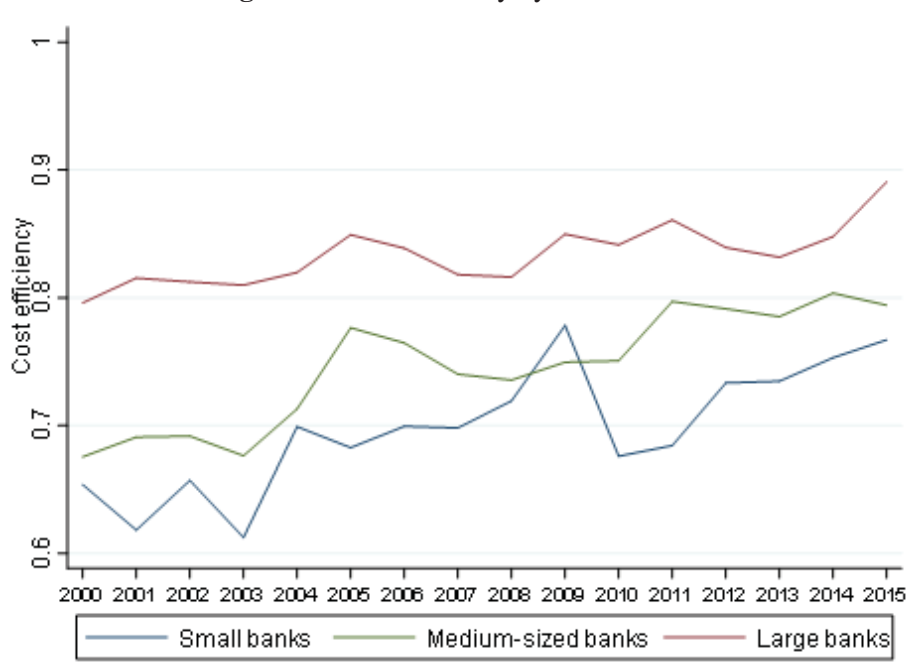
5.3. Robustness

We assess the robustness of the estimates of coefficients and, in particular, of scale economies, efficiency and TFP change to the identification of merged banks; the effects of the crisis; the inclusion of cooperative banks; and to controlling for the restructuring processes of loan losses experienced by some important institutions in Spain after the crisis.

Merged banks

The restructuring process of the Spanish banking sector after the crisis has implied several merger and takeover processes. Thus, exploring potential differences in terms of cost efficiency and productivity between merged and non-merged banks is of interest. For this purpose we estimate Model IV where we include a dummy variable, which is equal to 1 for merged banks and 0 otherwise. We include this variable both in the cost frontier and in the inefficiency component. That is, in Equation (3) we add an extra variable in vectors z and h. Results of the estimation are presented in Table 3. We observe that this variable is highly significant both as a cost frontier shifter and as an efficiency driver. In the former case, the effect is positive on costs, implying that

merged banks have a more expensive cost structure in the short-run. Nonetheless, the effect is also positive on efficiency, which implies that merged banks tend to be more efficient than non-merged institutions. This result has also been observed before in empirical applications, and the greater efficiency has been linked to better management practices and the benefits of synergies (Cuesta and Orea, 2002; Galán et al., 2015).

However, the benefits of new mergers may not be immediate. Previous studies have identified some negative effects of mergers in the short-run in terms of efficiency that may lead to further reductions in productivity (see Amel et al., 2004, for a review). However, Cuesta and Orea (2002) and Galán et al. (2015) have found that although reductions in efficiency are presented immediately after these processes are carried out, around 4 years later the new merged institutions catch up and start to present higher efficiency levels than those of non-merged institutions. Humphrey (1993) also finds that merger processes in the US led to negative technical change in the short-run given that branch networks of merged banks might be consolidated within overlapping market areas.

The crisis:

The most recent global financial crisis and the subsequent sovereign debt crisis had severe consequences for the Spanish banking sector. Banks faced an unusual situation of accelerated increases in NPL, lack of liquidity and solvency concerns which reached its peak in 2012. Credit also dropped dramatically and banks were suddenly immersed in a situation of overcapacity. In order to explore whether the cost structure faced by banks was different during this period and whether it affects the estimated results, we estimate Model V including a dummy variable in vectors z and h of Equation (3). This variable is equal to 1 for the crisis years and 0 otherwise. Results are presented in Table 3. The crisis variable is not found to be significant as a cost frontier shifter, suggesting that the crisis did not imply a change in the cost structure of banks and that the effects are already captured by the other variables in the model. However, it had a negative effect on cost efficiency, which may be the consequence of the excess of capacity of banks and the effects of the restructuring processes of the sector. However, as has been stated previously, the effects of the crisis on efficiency have been highly heterogeneous among banks of different sizes. Overall, estimates of both, returns to scale and cost efficiency before the crisis are lower than those envisaged following the onset of the crisis. This is consistent with our findings using Model III, where we observe that banks increased their production scale during the credit expansion period by exploiting scale economies, while after the crisis the reduction of outputs opened new opportunities to obtain gains from increasing the production scale.

Table 3. Estimation results of additional models, first order regression coefficients. Complete results are presented in Table A1 in the Appendix. Mean ECRTS significance levels are computed with respect to differences from 1 following the delta method of convergence of transformed random variables.

Variables	Model IV M&A		Model V Crisis		Model VI Cooperatives		Model VII SAREB	
$\ln y_1$	1.602	***	1.460	***	1.056	***	1.885	***
$\ln y_2$	0.570	***	0.785	***	0.424	**	0.946	***
$\ln y_3$	0.653	*	0.340	*	0.107		0.465	*
$\ln w_1$	2.094	***	2.200	***	2.013	***	2.250	***
$\ln w_2$	0.142	*	0.485	***	0.085	*	0.361	**
$\ln w_3$	0.457	***	0.577	***	0.311	***	0.444	**
t	0.049		-0.044		-0.039		-0.048	
$\ln k$	1.057	***	1.063	***	1.003	***	1.119	***
pd	1.644	***	1.577	***	1.195	***	1.982	***
saving	0.046	***	0.082	***	0.075	***	0.093	***
M&A	0.313	***						
crisis			-0.015					
cooperatives					0.065	**		
SAREB							-0.074	***
Inefficiency								
$\ln$ size	-0.040	**	-0.126	***	-0.159	***	-0.103	***
M&A	-0.456	***						
crisis			0.071	***				
SAREB							0.0239	
σ_u	0.113	***	0.092	***	0.176	***	0.094	***
log-likelihood	416.73		401.52		394.81		410.85	
Mean ECRTS	1.07	***	1.04	***	1.10	***	1.06	***
Mean cost eff.	0.81		0.86		0.66		0.86	

***, ** and * refer to the value being significantly different from 0 at 1%, 5% and 10%, respectively.

Cooperative banks:

Cooperative banks are financial entities that belong to its members and are usually deeply rooted within local areas and communities as well as being involved in social activities. In Spain cooperative banks are important players in the financial system and although their size is smaller than that of commercial and savings banks, some of them expanded their business significantly during the years prior to the crisis. After the crisis the sector has also been involved in reorganization processes characterized by mergers and acquisitions that have reduced the number of cooperatives but have also created a couple of entities comparable in size to that of some commercial banks. Empirical evidence from previous studies suggest that these types of entities are less cost efficient than commercial banks but their lower risk exposure provided them with greater resilience to the recent financial crisis (see, ILO, 2013; NEF, 2013).[17] Thus, we explore whether or not involving cooperative banks in the cost estimation would change the results, in particular for commercial and saving banks by estimating Model VI.

Results in Table 3 show that scale economies are higher and efficiency is lower on average when cooperatives are included in the sample, suggesting that cooperative banks present greater opportunities to expand their production scale but that this business model tends to be less

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[17] As an example, based on information by the National Union of Credit Cooperatives (UNACC), in Spain commercial and saving banks employ 8 workers per €100 million of assets while this proportion rises to 12 in cooperative banks.

cost efficient. However, estimates of RTS and cost efficiency for commercial and savings banks are similar to those obtained under Model III.

SAREB:

The Management Company for Assets Arising from the Banking Sector Reorganisation (SAREB) is an entity founded in 2012 to manage bad assets from banks. Its aim is to help clean up the sector, allowing banks with a high number of nonperforming assets to transfer them to SAREB. These transfers added up to 51 billion Euros and aided banks in mitigating risk and reducing costs associated with the management of such assets. Thus, SAREB could have effects on cost efficiency and the TFP of these banks. To explore this, we estimate Model VII where we include a dummy variable taking a value equal to 1 for those banks transferring assets to SAREB from the dates of the transfers and 0 for the remaining banks and dates. We include this variable both in the cost frontier and in the inefficiency component. Estimation results in Table 3 show that the SAREB dummy is not significant as an efficiency driver but it is found to have a significant negative impact on costs, which confirms the gains in banks' cost reductions due to the transfer of nonperforming assets to SAREB. Consequently transferring NPLs to SAREB produced a beneficial positive impact on TFP in those banks (see Figure A1 in the Appendix).[18]

Profit efficiency

Finally, we consider it interesting to check to what extent cost efficiency is related to profit efficiency as well as to examine the role of risk on bank profits. For this purpose we estimate an alternative variable profit frontier efficiency model, which considers output quantities and input prices as exogenous in the cost function (Humphrey and Pulley, 1997). This allows us to hold the same specification in Equation (3) but changes the dependent variable for a profit measure and the sign preceding the inefficiency component (the sign becomes negative given that now we have a maximum instead of a minimum frontier). We use net interest margin and return on assets as profit measures in order to avoid the problem of using logarithms with variables that may take negative values such as net profits. In fact, the use of net profits is still controversial in the profit efficiency literature given that the techniques used to solve this issue may introduce biases (see, Bos and Koetter, 2011, for a discussion).

The estimation results are presented in Table A2 in the Appendix, where it is observed that similar conclusions can be derived from both models regardless of the profitability measure used. A negative and significant effect is found for equity, which suggests that raising equity capital reduces profits. Regarding risk, a positive sign is found, indicating that engaging in more risk-taking increases profits. Size is also found to have significant positive effects on profit

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[18] In Figure A1 it is observed that banks transferring bad assets to SAREB experienced an earlier reduction of risk and consequently an earlier recovery of TFP than other banks.

efficiency. Thus, as in the case of cost efficiency, large banks are more profit efficient than small institutions. Recently, Sarmiento and Galán (2017) also find evidence of a positive relationship between size and profit efficiency in Colombian banks, which is augmented by the effects of risk-taking.

6. Conclusions

The Spanish banking sector has undergone a significant transformation in the last 15 years. Following a period of increasing financial integration but also of growing imbalances both on a domestic and European level, the financial crisis led to a sharp reduction of the number of institutions in Spain: from 52 to 20 between 2007 and 2014. This new landscape has drawn the attention both of researchers and policy makers on the conjunctural and structural challenges regarding the sustainability of the banking sector. At the heart of these challenges lie the questions on how productive the sector is, the factors explaining it and the prospects for the future.

To help answer these questions, we perform a complete TFP decomposition and identify the main drivers of productivity growth in Spanish banks between 2000 and 2015. The specification of the estimated stochastic cost frontier accounts for observed time-varying inefficiency heterogeneity and allows us to consider the effects of equity and risk-taking on banks' cost structures. To capture effects from risk-taking, we propose a composite ex-ante risk metric which is able to capture different sources of risks such as credit risk, liquidity, solvency, profitability and macroeconomic conditions.

We find that TFP increased notoriously during the years of credit expansion before the crisis. Main drivers during this period were technical change and cost efficiency improvements, which in turn were related to the innovation in financial instruments (Martin-Oliver et al., 2013) and increasing competition in the sector (Casu and Girardone, 2006). This trend reversed during the crisis period, when the imbalances accumulated in previous years started to materialise in rapid increases of non-performing loans and deterioration of liquidity, solvency and profitability indicators. Afterwards, during the post-crisis period, productivity gradually started to recover, mainly due to the reduction of risk and improvements in efficiency.

In addition, we find significant heterogeneity among banks of different sizes, not only in TFP growth but also in terms of its drivers. Large banks have taken advantage of scale economies and benefited more from technical change during the pre-crisis period, which allowed them to present higher TFP growth rates than small institutions. Once the crisis hit, productivity change in large banks was more sensitive to variations in risk, but the net effect of the crisis was less severe than for small banks, which suffered an important decrease in efficiency. In the recovery phase, the reduction of risk and efficiency gains have been the main positive drivers of

productivity, particularly for large banks. The mark-up component has also contributed positively to TFP of small banks in the post-crisis years while input prices have affected them negatively. In general, the negative effect of raising equity capital has been more limited as a TFP driver; however, its effect has become more important since the last years of the crisis, especially for small banks. Finally, the transformation of savings banks into commercial banks had positive effects on TFP since the cost structure of saving banks was identified to be relatively more expensive.

Our analysis also suggests that, since the onset of the crisis, the reduction of banks' output and the restructuring process have brought new opportunities for exploiting scale economies and enhancing cost efficiency. Some of these opportunities were seized in the last two years of our sample period by almost all types of banks, particularly as result of the consolidation process which followed the crisis. Overall, our results suggest that, by the end of our sample period, there would still be room for further potential improvements in productivity via exploiting scale economies and enhancing cost efficiency in the system. These opportunities appear to be greater for the smaller banks in the sample.

Our results are robust with respect to the effects of the crisis, possible differences between merged and non-merged banks, the inclusion of cooperative banks, profit efficiency considerations, and other adjustments regarding the reorganization process of banks' assets after the crisis. Yet, we should bear in mind that the period we cover is truly extraordinary as it includes one of the major banking crises in history and a wide-ranging restructuring process which followed afterwards. While, in our view, such a context provides unique questions for research, it also creates logical challenges for any empirical study covering such diverse and complex dynamics. We hope this paper provides reasonable insights into the drivers of productivity in the Spanish banking sector and serves as a useful basis for future analysis on this subject.

Appendix.

The probability of distress model

We obtain a composite ex-ante risk measure by means of the estimation of the following conditional *logit* model:

$$P(D_{it+h} = 1|\boldsymbol{x}_{it}, D_{it} = 0) = Logit(\boldsymbol{x}_{it}|, D_{it} = 0),$$

where, D is a binary variable representing the occurrence of a distress event within a two-year horizon. The occurrence of a distress event is defined as the intervention of a bank, its need of recapitalization with public funds, or capital needs derived from stress tests; $\boldsymbol{x}$ is a vector of bank characteristics and macroeconomic factors including the following variables:

    i.   total assets, included in logs;

    ii.   NPLs, measured as the ratio of non-performing loans from governments, credit institutions and other sectors to total loans;

    iii.   the annual growth rate of the NPL ratio;

    iv.   liquidity ratio, computed as the ratio of liquid assets to total assets, where liquid assets are defined as cash and balances with central banks and debt securities issued by resident and non-resident governments;

    v.   solvency ratio, computed as CET1 capital divided by total assets, where CET1 capital includes ordinary shares, noncumulative preferred stock and disclosed reserves;

    vi.   net interest margin, measured as the ratio of net interest income to earning assets;

    vii.   the annual real GDP growth rate; and,

   viii.   the annual growth rate of short-run nominal interest rates.

The probability of distress (*pd*), used as a composite ex-ante risk measure, is a prediction of the probability of a bank experiencing an event of distress, as defined above, within the following two years. Results of estimations are available upon request.

Table A1. Estimation results of additional models.

Variables		Model IV M&A		Model V Crisis		Model VI Cooperatives		Model VII SAREB	
$\ln y_1$		1.602	***	1.460	***	1.056	***	1.885	***
$\ln y_2$		0.570	***	0.785	***	0.424	**	0.946	***
$\ln y_3$		0.653	*	0.340	*	0.107		0.465	*
$\ln w_1$		2.094	***	2.200	***	2.013	***	2.250	***
$\ln w_2$		0.142	*	0.485	***	0.085	*	0.361	**
$\ln w_3$		0.457	***	0.577	***	0.311	***	0.444	**
$\ln y_1 \ln y_1$		0.292		0.423	***	0.502	***	0.488	***
$\ln y_1 \ln y_2$		-0.014		-0.056	***	-0.067	***	-0.073	***
$\ln y_1 \ln y_3$		-0.140	***	-0.138	***	-0.174	***	-0.170	*
$\ln y_2 \ln y_2$		-0.004		0.006		0.006	*	0.009	*
$\ln y_2 \ln y_3$		-0.021		0.000		0.008		0.014	
$\ln y_3 \ln y_3$		-0.038		-0.064	*	-0.024		-0.035	
$\ln w_1 \ln w_1$		0.126	***	0.179	***	0.160	**	0.161	**
$\ln w_1 \ln w_2$		0.003		-0.007		-0.010		-0.001	
$\ln w_1 \ln w_3$		-0.027	***	-0.025		-0.023		-0.023	
$\ln w_2 \ln w_2$		-0.001		-0.002	*	-0.002		-0.001	
$\ln w_2 \ln w_3$		0.054	***	0.050	***	0.051	***	0.054	***
$\ln w_3 \ln w_3$		-0.045	***	-0.023		-0.013		-0.022	
$\ln y_1 \ln w_1$		-0.029		-0.004		-0.024		-0.055	
$\ln y_1 \ln w_2$		0.001		0.034		0.034		0.041	
$\ln y_1 \ln w_3$		0.007		0.056		0.082	**	0.066	
$\ln y_2 \ln w_1$		0.023	***	0.025		0.042		0.048	**
$\ln y_2 \ln w_2$		0.004		0.003		0.007	*	0.003	
$\ln y_2 \ln w_3$		-0.036	***	-0.041	***	-0.043	***	-0.043	***
$\ln y_3 \ln w_1$		0.016		-0.025		-0.002		0.002	
$\ln y_3 \ln w_2$		-0.035	***	-0.046	***	-0.052	*	-0.049	**
$\ln y_3 \ln w_3$		-0.058	***	-0.045	*	-0.064	***	-0.060	*
t		0.049		-0.044		-0.039		-0.048	
t^2		0.006	***	0.005	***	0.00465	***	0.005	***
$t \ln y_1$		-0.016	***	-0.004		-0.00842		-0.009	
$t \ln y_2$		0.008	***	0.008	***	0.0113	***	0.013	***
$t \ln y_3$		-0.003		-0.017	***	-0.0162	***	-0.013	*
$t \ln w_1$		0.011	***	0.010	*	0.0109	*	0.011	
$t \ln w_2$		-0.002		-0.004	**	-0.00366		-0.003	
$t \ln w_3$		-0.003		-0.007	**	-0.0106	***	-0.007	*
$\ln k$		1.057	***	1.063	***	1.003	***	1.119	***
$\ln k \ln k$		-0.055	**	-0.025		-0.0175		-0.010	
$\ln k \ln y_1$		-0.061	**	-0.138	***	-0.164	***	-0.162	
$\ln k \ln y_2$		-0.001		0.008		0.017		0.015	
$\ln k \ln y_3$		0.151	***	0.156	***	0.157	***	0.154	***
$\ln k \ln w_1$		-0.057	**	-0.038		-0.0494		-0.034	
$\ln k \ln w_2$		0.053	***	0.044	***	0.0397	**	0.034	**
$\ln k \ln w_3$		0.103	***	0.060	***	0.0475		0.057	**
$t \ln k$		0.008	***	0.011	***	0.0127	***	0.010	***
pd		1.644	***	1.577	***	1.195	***	1.982	***
pd^2		-4.561		-11.650	**	-3.776		-5.117	
$pd \ln y_1$		9.699	***	5.477		3.335		6.982	*
$pd \ln y_2$		-1.395		1.995		3.355		-0.346	
$pd \ln y_3$		-4.338	*	-2.441		-2.532		-4.315	*
$pd \ln w_1$		-7.914	***	-7.711	***	-12.23		-8.214	
$pd \ln w_2$		13.25	***	11.770	***	18.85		11.95	**
$pd \ln w_3$		5.051	***	0.969		2.902		2.166	
$t\ pd$		-0.646		-0.370		-0.939		-0.521	
$pd \ln k$		-2.814		-2.563		-4.179		-2.024	
saving		0.046	***	0.082	***	0.075	***	0.093	***
M&A		0.313	***						
crisis				-0.015					
cooperatives						0.065	**		
sareb								-0.074	***
Inefficiency	ln *size*	-0.040	**	-0.126	***	-0.159	***	-0.103	***
	M&A	-0.456	***						
	crisis			0.071	***				
	sareb							0.024	

***, ** and * refer to the value being significantly different from 0 at 1%, 5% and 10%, respectively

Figure A1. TFP growth decomposition of banks transferring nonperforming assets to SAREB
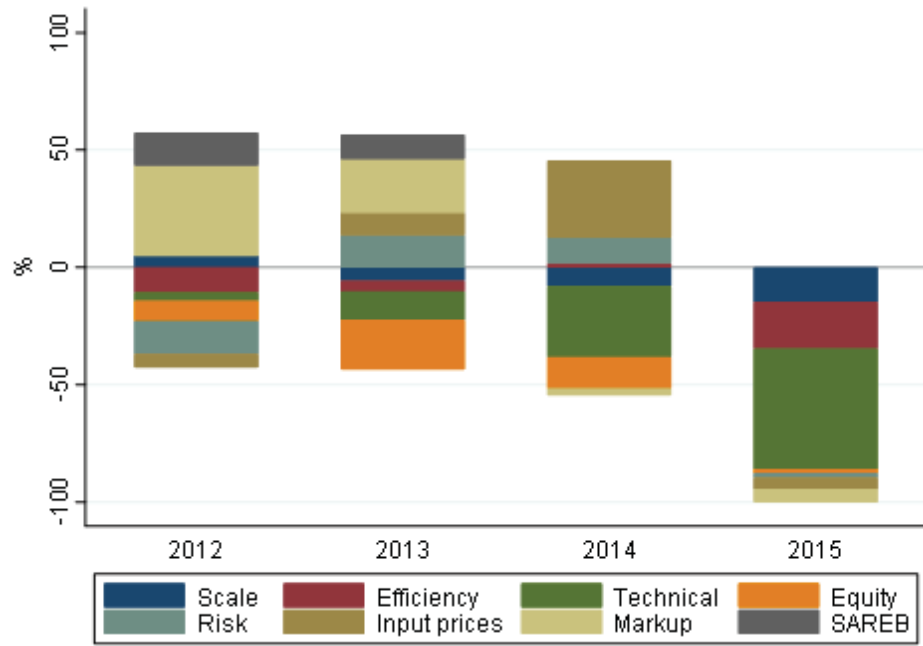
Table A2. Results of profit efficiency models.

Variables	Model VIII - NIM		Model IX - ROA	
ln y_1	0.0145	***	0.0160	***
ln y_2	0.0548	***	0.0601	***
ln y_3	0.1050		0.1140	
ln w_1	-0.0428	***	-0.0470	***
ln w_2	-0.0372	*	-0.0410	*
ln w_3	-0.0776		-0.0850	
ln y_1 ln y_1	-0.0060	*	-0.0056	**
ln y_1 ln y_2	0.0049	***	0.0064	**
ln y_1 ln y_3	-0.0044		-0.0039	
ln y_2 ln y_2	-0.0015	***	-0.0007	**
ln y_2 ln y_3	-0.0010		-0.0001	
ln y_3 ln y_3	0.0046		0.0061	*
ln w_1 ln w_1	-0.0007		0.0002	
ln w_1 ln w_2	-0.0009		0.0001	
ln w_1 ln w_3	-0.0010		0.0000	
ln w_2 ln w_2	0.0000		0.0010	
ln w_2 ln w_3	0.0017		0.0029	
ln w_3 ln w_3	-0.0007		0.0002	
ln y_1 ln w_1	0.0047		0.0062	
ln y_1 ln w_2	0.0049		0.0063	
ln y_1 ln w_3	-0.0082	**	-0.0081	*
ln y_2 ln w_1	-0.0048		-0.0043	
ln y_2 ln w_2	-0.0003		0.0007	
ln y_2 ln w_3	0.0011		0.0022	
ln y_3 ln w_1	0.0020		0.0032	
ln y_3 ln w_2	-0.0025		-0.0017	
ln y_3 ln w_3	0.0039		0.0053	
t	0.0030		0.0030	
t^2	-0.0002		-0.0002	*
t ln y_1	-0.0014		-0.0005	
t ln y_2	0.0002		0.0012	
t ln y_3	0.0007		0.0017	*
t ln w_1	-0.0008		0.0002	
t ln w_2	-0.0003		0.0006	
t ln w_3	0.0008	**	0.0019	
ln k	-0.0904	*	-0.0990	**
ln k ln k	-0.0001		0.0009	
ln k ln y_1	0.0091		0.0111	
ln k ln y_2	-0.0023	**	-0.0015	*
ln k ln y_3	-0.0033		-0.0026	
ln k ln w_1	0.0004		0.0015	
ln k ln w_2	-0.0006		0.0004	
ln k ln w_3	-0.0002		0.0008	
t ln k	0.0005		0.0015	
pd	5.1430	***	5.6060	***
pd^2	1.0320		1.1362	
pd ln y_1	0.0001		0.0011	
pd ln y_2	0.1940	*	0.2144	**
pd ln y_3	0.0134		0.0157	
pd ln w_1	-0.3600		-0.3950	
pd ln w_2	-0.3850		-0.4225	
pd ln w_3	0.1150		0.1275	
t pd	-0.1360	***	-0.1486	**
pd ln k	0.0021		0.0033	
$saving$	0.0010		0.0010	
Inefficiency				
ln $size$	-0.00318	**	-0.003	**
σ_u	0.0394	***	0.0425	***
log-likelihood	1293.48		1319.3	
Mean profit eff. small banks	0.81		0.80	
medium banks	0.88		0.88	
large banks	0.91		0.92	

***, ** and * refer to the value being significantly different from 0 at 1%, 5% and 10%, respectively

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