THE OUTPUT AND PROFIT CONTRIBUTION OF INFORMATION TECHNOLOGY AND ADVERTISING INVESTMENTS IN BANKS

2007

Alfredo Martín-Oliver and Vicente Salas-Fumás

Documentos de Trabajo
N.º 0740

BANCO DE ESPAÑA
Eurosistema

THE OUTPUT AND PROFIT CONTRIBUTION OF INFORMATION TECHNOLOGY AND ADVERTISING INVESTMENTS IN BANKS

THE OUTPUT AND PROFIT CONTRIBUTION OF INFORMATION TECHNOLOGY AND ADVERTISING INVESTMENTS IN BANKS

Alfredo Martín-Oliver

BANCO DE ESPAÑA

Vicente Salas-Fumás

UNIVERSIDAD DE ZARAGOZA

(*) This paper is the sole responsibility of its authors and the views represented here do not necessarily reflect those of the Banco de España. We thank George G. Pennacchi, the Editor of the Journal of Financial Intermediation, two anonymous referees, Jesús Saurina and the participants in a CEMFI lunch seminar, specially Javier Suárez, Guillermo Caruana, Gerard Llobet and Rafael Repullo, for their helpful comments. Any remaining errors are entirely the authors' own responsibility.

(**) Address for correspondence: Alfredo Martín-Oliver; c/ Alcalá 48, 28014 Madrid, Spain. Tlf: + 34 91 338 6178; Fax: +34 91 338 6102; e-mail: alfredo.martin@bde.es.

Documentos de Trabajo. N.º 0740
2007

ISSN: 0213-2710 (print)
ISSN: 1579-8666 (on line)
Depósito legal: M. 3401-2008
Unidad de Publicaciones, Banco de España

Abstract

This paper examines the contribution of investments in Information Technology (IT) and in advertising to the output and profits of Spanish banks, in the period 1983-2003. We find that the growth in the stock of IT capital explains one third of output growth of banks, and that an additional investment in IT of one million euros may be substituted for twenty-five workers. The paper also finds that advertising investments increase the demand for bank services with an elasticity of 0.22 for deposits and 0.11 for loans. For all the assets considered, the null hypothesis that banks use the profit-maximizing amount of services per period cannot be rejected with the data.

JEL classification: G21; D24.

Keywords: IT capital; advertising; output growth; rate of return; banks.

1 Introduction

Information technology (IT) and advertising capital increasingly substitute physical capital and labor in the production and sale of banking services. Data on Spanish banks used in this paper show that the average stock of IT capital per bank, in 2003, is ten times larger than what it was in 1983; in the same period, the average stock of capital accumulated through advertising expenditures has been multiplied by a factor of 2.4. However, the average stock of physical capital, and the average number of employees per bank in year 2003, is 1.6 times that of 1983. Economics and business scholars have expressed concern about the true contribution of large investments in IT capital to the productivity and profitability of firms,[1] but, somewhat surprisingly, the consequences of the shift towards a more intensive use of immaterial assets in banks have not been given much attention in the literature.[2]

This paper models the multi-branch, multi-asset banking firm and examines contributions to the productivity and profitability of services from labor, and from a list of capital inputs, including physical (branches), information technology (IT) and advertising capital. The model specifies if a particular input is valuable for the bank because it increases production (i.e. it is a production function input), because it increases the demand for loans or the supply of deposits for a given price, or both. We use data from the confidential accounting statements of Spanish banks during the period 1983-2003, to test the assumptions on the production technology, on the demand function of bank services, and on the profit-maximizing conditions of the use of services from labor and capital inputs. In the process, the paper provides estimates of the production and demand elasticity of input services, and of the price elasticity of demand for bank loans and deposits. In addition to providing new evidence on the contribution to productivity and profitability of investment in immaterial inputs of IT and advertising, the paper also tests for scale economies at the branch and at the bank level.

The paper contributes to the literature on the productive efficiency and efficient resource allocations of banking firms [see e.g. Berger et al. (1997)] in several ways. First, it expands the list of banks' operating inputs considered in previous research (labor and physical capital), adding the capital services from IT and advertising capital. The stocks of capital inputs are valued at replacement cost and the services used in production or in increasing demand are valued at the users' costs of capital (financial opportunity costs plus depreciation). Second, the paper presents a new formulation the production technology of banking services at the branch and the bank level (Leontieff-type production function), which is tested for constant returns to scale at the branch and at the bank level. Third, the

1. The so-called "productivity paradox", namely the apparent small contribution of large investments in computers and information technologies (IT), to aggregate productivity growth in developed economies [see e.g. Brynjolfsson (1993); for a review], fostered the use of firm-level data to investigate whether IT capital did in fact contribute to the efficiency and profitability of firms [Lichtenberg (1995); Brynjolffsson and Hitt (1995 and 1996); Dewan and Min (1997); Brynjolfsson, Hitt and Yang (2002)]. The controversy about IT and growth has been even more intense at the macro level; see for example Oliner and Sichel (2000), for a review. Lim, Richardson and Roberts (2004) provide a general assessment of research findings on the effects of IT investment in firm performance before, and after, the mid nineteen-nineties.

2. The papers on the consequences of IT investments in banking we are aware of are Parsons, Gotlieb and Denny (1993) in Canadian banking, Prasad and Harker (1997) in US retail banking, Casolaro and Gobbi (2004) in Italian banking and Beccalli (2007) for a sample of European banks. Beccalli (2007) also refers to reports from the Council of Economic Advisors and the McKinsey Global Institute that find weak links between IT spending and productivity for US banks. Pinho (2000) documents the increase in advertising expenditures by Portuguese banks after the market was liberalized.

production function of banks is estimated using the *GMM*-system method [Blundell and Bond (1998)]; the use of standard panel data econometric techniques in production functions estimation gives unreasonably low estimates of the elasticity of output to capital and, consequently, leads to erroneous conclusions about the existence of constant returns to scale in production [Griliches and Mairesse (1998)].[3]

Our model of the banking firm assumes product differentiation [Hannan (1991)], so banks decide price and non-price variables to maximize profits [Pinho (2000)]. However, the interest of the paper is not in explaining differences in profits across banks, but to evaluate if observed quantities of capital and labor inputs deployed by banks contribute to the productivity and/or total output of banking services. It also studies whether the return to capital invested from such a contribution is higher or equal to the input unit cost. In this respect, the paper applies to the banking firm the general firm-level analysis of the contribution of computers to productivity and profitability [Lichtenberg (1995); Brynjolffsson and Hitt (1995)], but with several extensions: i) inputs can affect both production of and demand for bank services, ii) banks have market power, iii) and the estimations of production and demand functions are performed using advanced econometric techniques. The paper also differs from Beccalli (2007), who studies the effect of IT investment (flow) in the performance (profitability and efficiency) of European banks. We explicitly model and test whether IT capital (stock) affects the production and/or demand of banking services; we then estimate the elasticity of the output with respect to the IT capital and, finally, check whether or not the return on invested IT compensates for the user cost of the input, using the optimal conditions implied by the formal model.

Using data from Spanish banks during the period 1983-2003 we find that: i) Bank branches produce services under a Leontieff-type technology with two inputs, physical capital (in the form of the capacity of the branch) and services from the combination of labor and IT capital. Physical capital (capacity) per branch is a quasi-fixed production input, while services from labor and IT capital are combined under constant returns to scale at branch level. ii) Production of banks is proportional to the number of branches, so the hypothesis of constant returns to scale at the bank level is not rejected. iii) The demand for banking services decreases with the price (market power), and increases with the advertising capital and with the number of bank branches (accessibility), but it is not affected by the IT capital. iv) The growth in IT capital during the period 1989 to 2003 contributes to one third of the growth rate of the aggregate output of banks (sum of loans and deposits). In addition, one million euros of investment in IT capital substitutes for 25 workers, maintaining the same level of output. v) Banks' expenditures in production and demand-enhancing inputs are consistent with those predicted by a profit-maximizing model, **i.e. we find no evidence of under- or over-investment** of banks.

Section 2 provides the conceptual and theoretical foundations for the cost-benefit analysis of investment in a profit-maximizing framework, where inputs can be production-enhancing, value-enhancing or both. Section 3 presents the data base, Spanish banks, and statistics on the quantity and cost of inputs, on output quantity and on interest rates. Section 4 of the paper contains the results of the empirical analysis, including the estimation of production and demand functions, and the test of the profit-maximizing conditions. Section 5 contains a discussion and conclusion from the main results.

---

3. The existing research in the topic also includes several papers on the efficiency of Spanish banks, Grifell-Tatje and Lovell (1996), Kumbhakar et al. (2001), Lovell and Pastor (1997), Maudos (1996). None of them focus on the particular issues of contribution to output and value of bank assets addressed in our paper.

2 The basic model

2.1 Definition of inputs and outputs

In the literature, there are at least three different approaches to the definition of inputs, outputs and production technology of banks [Berger and Humphrey (1992 and 1997)]: the production function approach, the intermediation approach and the value-added approach. In the *production function* approach, banks use labor and capital (inputs) that vary with the number of loan and deposit accounts (physical output). In the *intermediation* or assets approach [Mester1(987)], the output of the bank is the money balance of the loans, so the driver of the input demand is the amount of euros that the bank grants as loans. The inputs are labor, capital and money balance of deposits. Finally, in the *value added* approach, the output of the bank includes all the activities that provide services that consumers are willing to pay for. These services are often grouped in two areas: first, direct services (such as liquidity provision, payments, brokerage, guarantees, securities keeping,…) and second, services from the pure intermediation activity (i.e., raising and lending funds). As financial intermediaries, banks exploit economies of scale in transaction technologies, and manage the information needed to cope with the adverse selection and moral hazard problems that arise in financial transactions (monitoring and screening borrowers, setting debt covenants, evaluating assets pledged as collateral). These activities consume inputs and generate costs that banks must pay for [Benston et al. (1982)]. In addition, banks consume resources in opening branches to provide customers accessibility to the services they demand.[4]

The model of the banking firm used in this paper draws from these different approaches. The final result is a particular case of the model of the product-differentiated banking firm, proposed by Hannan (1991), but with special attention to modeling production as well as demand functions. As in the production function approach, our model assumes that both loans and deposits are output of banks, but it also considers that money balances, and not the number of accounts, are a better proxy for the range of banking services; in other words, output per account increases with the amount of the account balance. The output of the bank is then measured by the sum of money balances of loans and deposits. In our model, bank services are provided at the branch level, so the output and inputs of the bank are equal to output/inputs per branch, times the number of branches.[5]

Branches provide physical space for workers, computers and other physical infrastructure needed to produce output. The opening of a branch requires an investment in *physical capital* that is scaled to its local geographic market, mainly determined by a cap in

---

4. There exists an additional approach to the production activity of banks called the user cost approach, [Hancock (1991)]. Here a bank product is considered an output if it contributes to the revenues of the bank and an input if it subtracts revenues, where the contribution is measured by the difference between financial return and opportunity cost. In general, this approach assigns loans to output, but is ambiguous in terms of deposits, where time deposits are classified as inputs and demand deposits as outputs.

5. This measure of output is also used by Prasad and Harker (1997) but they do not model bank behavior. Papers differ in the choice of inputs and outputs of the banking firm; in particular, whether bank deposits are considered input [Aly et al. (1990)] or output [Casolaro and Gobbi (2004)] of the bank. Other papers consider deposits as inputs and outputs at the same time. Hunter and Timme (1995) treat deposits first as inputs and then as outputs, to evaluate the efficiency in the banking sector. On the other hand, Berger and Humphrey (1991) have captured this double nature of deposits, introducing the interest rate paid in deposits in the cost function, but also including the quantity of deposits in the output of banks as a proxy for the services they provide. Another resource that has both input and output characteristics is the number of bank branches. In this sense, branches may be considered as part of the physical capital that contributes to generate the output of the bank, but they may also be thought of as an output in themselves, since they provide a better service to costumers [Grifell-Tatjé and Lovell (1996)].

customers' transportation costs to that branch. Within a given territory, and for a given distance between bank branches, a larger network of branches will increase the value of banking services for customers and, for a given price it will increase the demand for banking services. Therefore, bank *branches* increase both the production *capacity* of the bank and the customers' *value* of the services. This implies that branches can be considered, simultaneously, an input of the production function and an input of the demand function of banking services.

The branch provides customers with services from the combination of *labor and IT capital*. Higher demand in the branch will require more workers and more IT hardware and software to serve the customers. IT capital, as well as better-trained workers, may increase the value of services for customers and as a result increase their willingness to pay for them. For example, banks can install ATM machines in their branches and speed up some services through customer self-service, which may be valued by the customer. More IT capital can be a way to expand the scope of services that a customer can get from one particular branch, i.e. it facilitates one-stop banking that, again, saves in transportation costs and increases customer value. This suggests that *IT capital* can, on the one hand, increase the production *capacity* and/or substitute labor in the branch and, on the other hand, increase the *value* of banking services provided by the particular bank. Therefore, the paper considers that IT capital is an input of both the production and the demand function, while labor is only a productive input that increases the production capacity of the banks.

In addition to labor, branches (physical capital) and IT capital, the paper includes an additional input called *Advertising capital.* The stock of this capital refers to the information, reputation and other intangible services provided by regularly-implemented advertising campaigns. Demand-capital from advertising is assumed to provide services at the bank level and, therefore, the stock of services will benefit all branches of the bank. Assets accumulated through advertising expenditures are a value-increasing input (it increases the customers' willingness to pay for the bank services), but not a productive input and, consequently, they will be an input in the demand function but not in the production function.[6]

2.2 Production, demand and profit-maximizing problem

Consider a bank that issues equity, *E*, collects deposit, *D*, grants loans, *L*, and borrows/lends in financial or interbank markets, *BO*. In order to collect deposits and to grant loans, the bank employs physical capital *(K),* IT capital *(IK)* and workers *(N).* Since the services attached to these loans and deposits are provided in each branch, the inputs and outputs of banks have to be first defined at the branch level and then aggregated to the bank level. To open a branch requires an investment in physical capital equal to k_b. The investment is fixed and standard across branches (the opening of a branch requires a minimum investment independent of the demand) and the size of the relevant market is limited by the customers' transportation costs. The investment per branch determines the capacity of the outlet. Define the number of workers per branch (n_b) and IT capital per branch (ik_b) as the variable inputs

6. The inputs used by banks can also be grouped into material (labor, computers and physical space) and immaterial (accessibility to branches, variety of services inside the branch, information and reputation capital). This grouping is useful to relate our results to others in the literature on contributions to productivity and value from tangible and intangible assets. The main focus of interest in this literature has been to evaluate the contribution of IT capital to productivity and growth, and to investigate whether or not such contribution brings about an external (intangible) effect that produces extraordinary profits. Often, IT –as well as advertising capital– is included as part of the intangible inputs of the firm. However, this paper follows the approach of Lev (2001) and Cummins (2004) who limit the "intangible capital" to that produced internally and "results from the distinct way firms combine the usual factors of production" [Cummins (2004)]. The static approach to profit maximization followed in the paper excludes internally-generated intangibles, and the only distinction that can be made is between material and immaterial assets.

which can be substituted among themselves, but not with the physical capital. For a given number of branches B and assuming constant returns to scale at the bank level, the total output of the bank, equal to the sum of loans *(L)* and Deposits *(D),* is written as follows.

$$L + D = B \cdot \left[\min\left\{k_b, F\left(n_b, ik_b\right)\right\}\right] \tag{1}$$

Therefore the branch production technology is of the Leontieff-type with a given investment in fixed capital and limited capacity. The function F ( ) is assumed to be an increasing, concave and linear homogeneous function (constant returns to scale) in the two variable inputs, labor and IT capital.[7] Since F ( ) is linear homogeneous, the equation (1) can be formulated as,

$$B \cdot k_b \geq L + D \tag{2}$$

$$F(N, IK) \geq L + D \tag{3}$$

Where $N=Bn_b$ and $IK=Bik_b$ are the total number of workers and total invested IT capital of the bank. Investment per branch k_b is assumed to be a constant, so the total capacity of the bank varies proportionally to the number of branches. In solving the model, it is assumed that branches do not operate at full capacity [restriction (2) is non-binding]. On the other hand, the number of workers and IT equipment are variable inputs that can be adjusted to the demand of the branch [constraint (3) will be binding].

Banks operate in monopolistic competition markets. The bank faces a negatively-sloped interest-rate demand function of loans, $L = L(r_l; CK, IK, B)$ where r_l is the interest rate, and a positively-sloped interest-rate supply function of deposits, $D = D(r_d; CK, IK, B)$, where r_d is the interest rate on deposits. According to the hypothesis on value-enhancing inputs, for a given interest rate, demand and supply increase with the stock of advertising capital CK, with the stock of IT capital IK, and with the number of branches B.

Stocks of money values of financial and productive assets are related as follows:

$$p_k K + p_{ik} IK + p_{ck} CK + L = BO + D + E \tag{4}$$

$$E = p_k K + p_{ik} IK + p_{ck} CK + aL \tag{5}$$

where $K=Bk_b$; and p_k, p_{ik}, p_{ck} are the market prices of one unit of service from the respective capital asset. Equation (4) postulates that total assets are equal to total liabilities, where BO (trade in the interbank or money market) can be positive, negative or zero. Equation (5)

7. The assumption that output of the bank is proportional to the sum of loans and deposits simplifies the exposition. With some complications in the algebra and in the empirical estimation, it could be substituted for by a more general aggregation function of the two outputs, $G(L,D)$.

indicates that bank equity is used to finance the stock of all assets used in production and sales, plus a fixed proportion of loans equal to a>0, determined by regulatory requirements.[8]

Banks draw services from the stock of assets in place during their productive life. These services are valued by the bank in terms of the rental or user cost of capital [Jorgenson (1963)] which we identify by c_k, c_{ik}, c_{ck} for physical, IT and advertising capital, respectively. Appendix 1 provides an explanation of how the user's cost of capital is calculated. Salary per worker is w. The interbank market is perfectly competitive at the interest rate i and the financial cost of equity is α, which, in general, will be higher than the market interest rate because of the risk differential between the two alternatives (see Appendix 1). Credit risk and other uncertainties faced by banks are not explicitly modelled. However, as indicated in Appendix 1, the user cost of capital is calculated for each bank, assuming a financial opportunity cost of equity that includes a risk premium from credit risk (charged in the interest rate of loans) and from financial risk (which depends on the leverage of the bank). Riskier banks are penalized with higher cost of equity.

Taking into account (1), (4) and (5) and the other assumptions, the profit-maximizing behaviour of the bank is written as,

$$\underset{r_l, r_d, B, IK, CK, N}{Max} \; [r_l - (i\,(1-a) + a\alpha)] \cdot L\,(r_l; CK, IK, B) + [i - r_d] \cdot D\,(r_d; CK, IK, B) - c_k p_k k_b B - c_{ik} p_{ik} IK - c_{ck} p_{ck} CK - wN$$

$$s.to \qquad L(r_l; CK, IK, B) + D(r_d; CK, IK, B) = F(N, IK)$$

A more detailed derivation of the first order conditions of the problem is presented in Appendix 2. In the main text, we highlight the results that will be tested in the empirical section. The first refer to the value of the Lerner index in the profit maximizing solution,

$$\frac{r_l - m - \lambda}{r_l} = \frac{1}{e_l} \quad ; \qquad \frac{i - r_d - \lambda}{r_d} = \frac{1}{e_d} \tag{6}$$

Where λ is the Lagrange multiplier of the constraint, $m = [l\,(1\text{-}a) + a\alpha]$ is the financial opportunity cost of loans, and e_l and e_d are the absolute values of loan and deposit demand price elasticity.

The second optimality conditions refer to optimal expenditures on advertising capital *(CK)* and the number of branches *(B),* i.e. the value-enhancing inputs.

$$\frac{c_{ck} p_{ck} CK}{r_l L + r_d D} = \nu_L \frac{\Sigma_{L,CK}}{e_l} + \nu_D \frac{\Sigma_{D,CK}}{e_d} \tag{7}$$

8. Equation (5) could be formulated assuming that regulatory capital is set equal to a proportion of the total assets (loans plus tangible and intangible assets) of the bank, i.e. 8% according to Basel I. This would imply that the financial opportunity cost of tangible and intangible assets will be equal to the weighted average financial cost of interbank finance and equity finance, but the basic model would not change. The equation is written as an equality because the cost of equity is higher than the interbank rate; thus, in the optimal solution, banks will choose the minimum equity required.

$$\frac{c_k p_k k_b B}{r_l L + r_d D} = \nu_L \frac{\Sigma_{L,B}}{e_l} + \nu_D \frac{\Sigma_{D,B}}{e_d} \tag{8}$$

Where $\nu_L = \frac{r_l L}{r_l L + r_d D}$, $\nu_D = 1 - \nu_L$; $\boldsymbol{\Sigma}_{L,CK}$ ($\boldsymbol{\Sigma}_{L,B}$) and $\boldsymbol{\Sigma}_{D,CK}$ ($\boldsymbol{\Sigma}_{D,B}$) are the loan and deposit demand elasticity with respect to Advertising capital (Branches), respectively. Equations (7) and (8) correspond to the well-known Dorffman-Steiner (1954) theorem, originally formulated in terms of the optimal advertising expenditures for a monopolistic firm. They say that in the profit maximizing solution the ratio of user's costs in advertising capital and branches must be equal, respectively, to the weighted ratios of the input elasticity and the price elasticity of demand for loans and for deposits (the weights being the respective ratios of interests of loans and interests of deposits over total interests).

Finally, the profit-maximizing shares of input costs for IT capital and labour are given by:

$$S_{IK} = \frac{c_{ik} p_{ik} IK}{TC} = \Sigma_{(L+D),IK} + A \cdot \left[1 - \Sigma_{(L+D),IK}\right] \tag{9}$$

$$S_N = \frac{wN}{TC} = \Sigma_{(L+D),N} - A \cdot \left[\Sigma_{(L+D),N}\right] \tag{10}$$

where $A = \frac{s_L}{e_l}\frac{\Sigma_{L,IK}}{ac} + \frac{s_D}{e_d}\frac{\Sigma_{D,IK}}{ac}$, $s_L = L/(L+D)$, $s_D = 1 - s_L$; $\Sigma_{L+D,N}$ and $\Sigma_{L+D,IK}$ are the output elasticity (from the production function) with respect to labor and IT capital, respectively. $TC = c_{ik} p_{ik} IK + w\,N$ is the total operating cost of the bank from the labour and IT capital inputs and $ac=TC\ \ (L+D)$ is the average unit operating cost. Notice that, as expected, the two shares of costs add up to 1 since the sum of elasticity is also equal to one (linear homogeneous production function). Equations (9) and (10) capture the external effect of IT expenditures in increasing demand for banking services. If such external effects did not exist, $A = 0$ because $\Sigma_{L,IK} = \Sigma_{D,IK} = 0$, then the optimal cost shares would be just equal to the respective output elasticity of the input. However, under external effects, the share of expenditures in IT capital is augmented (relative to the share of labour expenditures) by the factor *A*, which determines the contribution of IT capital to profits through the increase in the value of banking services.

2.3 Related literature on IT investment, productivity and profitability

Brynjolfsson and Hitt (1995 and 1996) and Lichtenberg (1995) use firm-level data to test whether IT capital contributes to the growth and profit of firms. To do so, they formulated two null hypotheses that, using the notation above, can be written as: i) $H_o \equiv \Sigma_{(L+D),IK} \le 0$; and ii) $H_o^{'} \equiv \frac{\Sigma_{(L+D),IK}}{\Sigma_{(L+D),N}} \le \frac{S_{IK}}{S_N}$. If H_o is rejected, the alternative hypothesis implies that the elasticity of output to IT capital is positive and, therefore, expenditures in IT capital contribute to output growth. On the other hand, the rejection of $H_o^{'}$ means that IT capital contribution to output is higher than what it costs relative to other non-IT inputs (in our case, labor).[9]

The two hypotheses are formulated assuming that firms operate in a competitive output market and choose profit-maximizing (and cost-minimizing) quantities of inputs (that is, quantities satisfy that the marginal productivity is equal to the user cost of the input). No details are provided on why the share of IT expenditures over total expenditures for all inputs should deviate from the share that would result from profit maximization. The only explanation is a reference to externalities similar to those observed in *R&D* activities, together with the possibility that the information system had the effect of increasing the average skill of workers, reducing the probability of mistakes and increasing productivity.

This paper suggests that one possible externality is that IT capital affects both output and demand. In this case, (9) and (10) imply,

$$\frac{S_{IK}}{S_N} - \frac{\Sigma_{L+D,IK}}{\Sigma_{L+D,N}} = \frac{A}{1-A} \cdot \frac{1}{\Sigma_{L+D,N}} = \frac{Aac}{\lambda \Sigma_{L+D,N}} \tag{11}$$

Since the optimal λ has to be positive for an interior solution, the right-hand side of (11) will be positive. Therefore, if banks take into account the external effect of IT capital on demand for banking services, the ratio of the optimal expenditures in IT capital, relative to the optimal expenditures on labour, is expected to be higher than the ratio of the respective output elasticity. Therefore, (11) provides theoretical support to $H_o^{'}$ proposed in the literature: When IT increases the demand of bank services, as well as output from the production function, **profit- maximizing** banks will spend more on IT than they would if IT is only an input of the production function.

Prasad and Harker (1997) apply the methodology proposed by Brynjolfsson and Hitt and by Lichtenberg, to evaluate the contribution of IT capital to productivity and to profitability in US retail banking. In addition to H_0 and H'_0 Prasard and Harker formulate an additional hypothesis (their H_{1b}) that, using our notation, would be written as $\Sigma_{(L+D),IK} \frac{(r_l - m)L + (i - r_d)D}{p_{ik} IK} - c_{ik} > 0$. If this hypothesis is not rejected, then the gross return from the invested IT capital *(IK)* will be higher than the user cost of the IT capital and, consequently the IT capital generates extraordinary (economic) profits for banks. Our model provides an explanation of why H_{1b} postulated by Prasard and Harker can be satisfied under standard profit maximizing behaviour of banks. Assume that $A=0$, that is, IT capital does not contribute to increase the value of banking services. Then, from Appendix 2,[10]

$$\frac{\Sigma_{L+D,IK} \lambda (L+D)}{p_{ik} IK} - c_{ik} = 0 \tag{12}$$

9. An alternative but equivalent formulation of the hypothesis of excess returns from IT investment is that marginal productivity of invested capital in IT be higher than user cost of IT capital [Brynjolfsson and Hitt (1996)]. These authors assume that firms do not have market power.

10. Equation (12) is equivalent to equation (A.4) of the Appendix 2 under A = 0.

Where λ is equal to average operating cost, ac, (from labour and IT capital). If banks have market power, the gross profits from loans and deposits will be higher than the average operating costs; that is $(r_l - m)L + (i - r_d)D > \lambda(L + D)$. Therefore, a sufficient condition for Prasar and Harker's hypothesis to be satisfied is that banks have market power. Moreover, with market power, the condition that states that the gross return from investment must be higher than the opportunity cost of capital will be satisfied for any input, not only for IT capital.

The remainder of the paper will concentrate on testing the assumptions and implications of the model presented in section 2.2. The test includes the hypothesis on the production function (constant returns to scale in IT capital and labour at the branch level, and constant returns to scale at the bank level), on the demand function (branches, advertising capital and IT capital are value-enhancing resources), and on optimal (profit-maximizing) use of labour and of all forms of capital.

3 Data sample and estimation methodology

3.1 Database

The data base for the empirical analysis comes from the population of Spanish commercial and saving banks in the period 1983 to 2003 (around 200 banks that represent 95% of the banking system; the rest belong to the credit cooperatives for which most of the data needed are not available). The raw data from accounting statements of banks had to be transformed in order to obtain values of bank assets at replacement costs. A systematic methodology is applied to obtain the user cost of capital for each asset and bank over time. Martín-Oliver, Salas and Saurina (2007b) provide a detailed description of how the variables used in this analysis have been constructed; we present a summary of the methodology in Appendix 1.

Table 1 shows the year by year statistics (mean, median, standard deviation) of the number of banks and output variables used in the production function estimation. Although the theoretical analysis assumes that the output was equal to the loans plus the deposits, the estimation will be replicated, for purposes of robustness, including in the output of banks the present value of the flow of net commissions in period *t*.[11] This stock is identified as *Commissions.*

The number of banks decreases from 159 in 1983 to 91 in 2003, due to mergers and acquisitions. Part of the increase observed in mean and median values of the output per bank, at constant prices, responds to this decline: taking into account the growth rates of the numerator and the denominator, the aggregate output (including Commissions) of all banks at constant prices grows at average annual rates of 3.61% in 1983-1989, 2.09% (5.36-3.27) in 1989-1994, 5.36% in 1994-1999 and 4.09%, in 1999-2003. Notice also that the median value of output is always lower than the mean; hence, the size distribution of banks reflects that there are a relatively larger number of small banks than of big banks.

Table 2 provides information about the inputs of banks: physical capital, advertising capital and IT capital, all at 1983 prices, and the number of workers. We consider two measures of physical capital, the amount of euros invested (stock), and the number of branches. Once again, to properly interpret the values shown in the Table, we must take into account the decrease in the number of banks over time shown in Table 1. Physical capital in euros shows an erratic evolution, with positive and negative growth rates in alternate five-year periods, while the number of branches steadily increases over time at a rate higher than the decline in the number of banks (except in 1999-2003, where the number of branches per bank grows at a rate of 6.5%, similar to the decrease in the number of banks). IT capital is the input with higher growth rates, while the total number of workers (per bank, times the number of banks) remains fairly stable until 1999, but decreases at an annual rate of 2.3% (4.21-6.50) in the period 1999 to 2003. Spanish banks substitute IT capital for labor as productive inputs, in line with the evidence for firms in the non-financial sectors reported by Dewan and Min (1997). In the twenty-year period, the mean of the stock of IT capital per bank has increased ten times, while the mean of the number of workers has increased by a factor of less than two.

---

11. To obtain a measure of output for commissions, we have worked out, in each time period, the present value of a permanent flow of income with a nominal equal to the current flow of net commissions, and a discount factor equal to the interbank interest rate $Commissions_{it} = \frac{Flow\ Net\ Commisions_{it}}{Interbank_t}$

The description of the data is completed with Table 3, which shows the statistics of the real cost of equity, the real user cost of capital of the assets, the cost of labour and some representative interest rates of loans and deposits (available only from 1988), also in real terms. The cost of equity is an estimate of the financial opportunity cost of the resources invested by shareholders (calculated for each bank taking into account the interest rate of its loans and the financial risk from its leverage position); the user cost of capital is equal to the estimated nominal cost of equity of the bank plus the depreciation rate of the asset (assumed to be the same for all banks) and minus the inflation rate in the price of the asset.[12] On the other hand, the representative interest rates are credit lines, mortgages, personal loans and receivables for loans, and term deposit and *REPO* operations for deposits. These rates correspond to the new operations made by the bank in the respective year (not averages for the stock of loans or deposits).[13] In advertising and IT capital, where depreciation rates are high, the user cost remains rather stable over time, even though the equity costs decrease due to lower interest rates over time. The figure of the user cost reported in the table, around 0.47 for IT capital, is in line with that used in other papers [Lichtenberg (1995); Dewan and Min (1999)]. This decline is more evident in physical capital, where the depreciation rate is much lower. Labor cost per worker, at constant prices, remains stable from 1989 to 1998, and increases slightly in the last five-year period.

3.2 Empirical models and estimations

Profit-maximizing conditions for bank inputs are formulated in terms of cost shares and ratios of costs over revenues, as well as price and non-price elasticity in production and demand [equations (7) to (10)]. Moreover, such conditions vary depending on whether a particular input affects the production function, the demand function, or both. Then, the first step of the empirical analysis will be to estimate the production and demand functions, which will provide answers to the posed questions.

From binding equation (3), the production function of the bank determines output (loans plus deposits) as a function of the IT capital and the number of workers. The function that aggregates the quantities of inputs into output is assumed to be Cobb-Douglass. After taking logs on both sides of the equation, the production function to be estimated can be written as follows,[14]

$$\ln(L + D) = \beta_0 + \beta_1 \ln IK + \beta_2 \ln N + CV + \upsilon \quad (13)$$

where β_j is the output elasticity of input j . Constant returns to scale impose the condition that $\beta_1+\beta_2=1$. On the other hand, if the physical capital was introduced as an explanatory variable in the regression, its estimated coefficient should be zero, since all the variations in output are captured by variations in the other inputs in the Leontieff technology. The control variables, *CV*, will include time dummies, while the error term υ will include time-invariant bank fixed effects, measurement errors and productivity shocks with a long-lasting effect.

12 See details in Martin-Oliver, Salas and Saurina (2007b), as well as in the Appendix 1 of this paper.

13. The interest rates on loans and deposits corresponding to transactions performed during the month are reported monthly by each bank to the Banco de España. Martín-Oliver, Salas and Saurina (2007a) provide details on this source of data.

14. *L+D*, *IK* and *N* per branch are multiplied by the number of branches, so that output and input are bank-level variables.

The demand equations that we consider are derived from multiple-choice models, in which consumers observe and compare different products (banks) and choose the one that maximizes their utility. Berry (1994) shows that the demand function of each product (bank) can be written, under certain conditions,[15] in terms of the log of market share (logit equation) as follows,

$$\ln s_i - \ln s_0 = x_i \beta - \alpha\, p_i + \xi_i \tag{14}$$

where s_i represents the share of loans (deposits) of bank i with respect to the size of the potential market, M, and s_0 stand for the proportion of the population M that does not buy banking products (outside good). On the right-hand side of the equation, x_i refers to the observable characteristics of bank/product i, p_i stands for its price (interest rate) and ξ_i captures the unobservable attributes of i that affect consumer utility. A negative price-elasticity is assumed for loan products and a positive elasticity for deposits (supply).

3.3 Estimation methodology

Considering the problems that arise in this estimation using the standard *GMM* estimator [Griliches and Mairesse (1998)], the production and demand functions will be estimated following the estimation procedure proposed by Blundell and Bond (1999). The model to be estimated is written in the abbreviated form:

$$y_{it} = \beta_n n_{it} + \sum_{j \in J} \beta_k^j k_{it}^j + \gamma_t + (\eta_i + v_{it} + m_{it}) \tag{15}$$

$$v_{it} = \rho\, v_{it-1} + e_{it} \;; \quad |\rho| < 1$$

$$e_{it}, m_{it} \sim MA(0) \qquad J = \{Physical,\ IT\}$$

where y_{it} is the *log* of the output of bank i in year t, n_{it} is the *log* of the number of workers, k_{it}^J is the *log* of the capital stock of type J, and γ_t is a time dummy variable that captures common shocks over time. Finally, in the error component, η_i stands for individual effects of the banks, m_{it} captures potential measurement errors (uncorrelated) of the explanatory variables and, finally, v_{it} reflects productivity shocks, whose impact in time lasts longer than one period. The condition of constant returns to scale *(CRS)* implies $\beta_n + \sum_{j \in J} \beta_k^j = 1$.

The empirical model can be rewritten in a dynamic (common factor) representation form because of the persistence of the productivity shocks:

15. The assumptions are: i) no random coefficients (β is constant across costumers); ii) ε_{ij} identically and independently distributed across products and consumers with the extreme value distribution function; and iii) mean utility of the outside good normalized to zero.

$$y_{it} = \rho\, y_{it-1} + \beta_n n_{it} - \rho\, \beta_n n_{it-1} + \sum_{j \in J} \beta_k^j k_{it}^j - \rho \sum_{j \in J} \beta_k^j k_{it-1}^j + \\ + (\gamma_t - \rho\, \gamma_{t-1}) + (\eta_i (1-\rho) + e_{it} + m_{it} - \rho\, m_{it-1}) \quad (16)$$

Renaming the respective coefficients and grouping the error components, $\gamma_t^* = (\gamma_t - \rho \gamma_{t-1})$, $\eta_i^* = \eta_i (1-\rho)$, $w_{it} = m_{it} - \rho \cdot m_{it-1} + e_{it}$ we obtain the equation to be estimated,

$$y_{it} = \pi_1\, y_{it-1} + \pi_2 n_{it} + \pi_3 n_{it-1} + \sum_{j \in J} \pi_4^j k_{it}^j + \sum_{j \in J} \pi_5^j k_{it-1}^j + \gamma_t^* + (\eta_i^* + w_{it}) \quad (17)$$

The vector of Π must satisfy five restrictions (common factor restrictions; from here referred to as *COMFAC* restrictions) in order to guarantee that the output is generated according to the production function defined in (1). The constraints that must be tested are $\pi_3 = -\pi_1 \cdot \pi_2$ and $\pi_5^j = -\pi_1 \cdot \pi_4^j$ for $j \in J$; *J*= {*Physical, IT*}. Following Blundell and Bond (1999), in a first step we estimate the unconstrained specification of the model (17) using the *System-GMM estimator* and then, if the *COMFAC* restrictions are empirically satisfied, we obtain the restricted estimations of the original parameters of (15), using the minimum distance estimator.[16]

The overall goodness of the estimations will be evaluated through the validity of the moment conditions (Sargan test of over-identifying restrictions) and the test of the null hypothesis of absence of second-order autocorrelation of the residual term (first order autocorrelation is expected since we take first differences in the variables). In the case of measurement errors of the inputs, *(m_{it}),* second order autocorrelation is expected, because of the process *MA(1)* in the error term, and the validity of the estimation will lie in the absence of autocorrelation of third and higher order.

The same econometric approach will be applied to the estimation of the demand for loans and the supply of deposits, where the quantity demanded (supplied) of loans (deposits) is a function of the quantity of inputs such as advertising capital, IT capital and branches, as well as a function of interest rates on loans (deposits). Demand and supply functions will also be affected by external shocks.

---

16. Minimum distance is an estimation technique to obtain a vector of coefficients restricted to a set of conditions based on the unrestricted estimation. The restricted coefficients θ solve the problem $\hat{\theta} = arg\, min[\bar{s} - \omega(c)]' \hat{V}^{-1} [\bar{s} - \omega(c)]'$, where $\bar{s}$ is the vector of unrestricted coefficients, $\omega(c)$ is the vector of conditions that the restricted coefficients are to accomplish, and $\hat{V}$ is a consistent estimator of the variance-covariance matrix of the unrestricted coefficients. For a detailed explanation of this technique, see Arellano (2003).

4 Results

4.1 Production function

The results of the production function estimation, equation (16), are shown in Table 4. In all the specifications, the unrestricted estimations [the first step of the estimation procedure, equation (17)] show no problems in their validity tests, (the *p-values* of the Sargan and second-order autocorrelation statistics are comfortably above 5%). The same applies for the restricted estimation [second step to obtain the original parameters, equation (15)], since the *p* values of the *COMFAC* restriction are close to 1.[17]

The estimated coefficients reveal that productivity shocks in banks are highly persistent (the estimated coefficient of y_{t-1} is around 0.88). Column *(I)* shows the results of the basic model, including labour and IT capital as explanatory variables. Column *(II)* shows the results when physical capital is included as an additional explanatory variable. Finally, Column (III) reports the results when inputs are normalized by the number of branches, and the number of branches is also one of the explanatory variables. In Column *(I),* the estimated elasticity of labour and IT capital in the restricted model are, respectively, $\boldsymbol{\Sigma}_{(L+D),N}$ = 0.867 and $\boldsymbol{\Sigma}_{(L+D),IK}$ = 0.212, both statistically significant at 5% or less. The sum of the two estimated elasticities is 1.079, which explains why the condition of constant returns to scale ($\boldsymbol{\Sigma}_{(L+D),N} + \boldsymbol{\Sigma}_{(L+D),IK} = 1$) cannot be rejected *(p* value of 0.576 in the *CRS* row). Adding physical capital, *K*, as an explanatory variable leaves the remaining results practically unchanged and the estimated coefficient of the new variable is not statistically different from zero [Column *(II)].* If we substitute physical capital by the number of branches as the third explanatory variable, the results (not shown) are identical. Therefore, the hypothesis that physical capital is a quasi-factor of the production and the hypothesis that the banking production function is of the Leontieff-type are not rejected by the empirical evidence.

The last column in Table 4 explains the total output of banks as a function of the labour and the IT capital per branch and of the number of branches. The estimated coefficient of the number of branches can be used to test for constant returns to scale at the bank level, depending whether the value of the coefficient is equal to 1 or not. The results show an estimate of the elasticity of the number of workers, and of the IT capital per branch, of 0.803 and 0.205, respectively, both significant at 1%. The null hypothesis that the sum of the elasticity is equal to 1 is not rejected (existence of *CRS*), which coincides with the result from Column *(I).* The results of Column (*III)* also show that the elasticity of the output to the number of branches is 0.986; the null hypothesis of elasticity equal to 1 cannot be rejected. Therefore, the production technology of banks appears to describe the relationship between inputs and outputs at the branch level, while the output of the bank is simply output per bank times the number of branches. With this result, the constant returns to scale apply also at the bank level.[18]

---

17. Neither the Sargan test nor the 2nd order autocorrelation test are satisfied when the model is estimated using the *first-differences GMM estimator* (estimations not reported). Moreover, the parameters estimated for labour, n_t, and capital k_t^j are lower than those estimated with the *system GMM*, confirming the predictions of Blundell and Bond (1999) and casting doubts on the validity of the model.

18. The production function has been estimated allowing for differences in the output mix of banks, i.e. allowing for different elasticity coefficients for banks that specialize in family lending (high retail orientation) and banks that specialize in business lending (low retail orientation). We generate a dummy variable that takes the value of 1 for banks where loans to families represent 10% (25%) or less of the loans to firms and zero otherwise. The estimated coefficients of the dummy variable times the number of employees and the stock of IT capital were not significantly different from zero in

The final test is of the hypothesis that bank branches require a fixed investment per branch, and the resulting physical capacity is greater than actual production per branch. The production function to be estimated is formulated from equation (2). If the equation is binding, then the log of output (loans plus deposits) can be written as a function of the log of physical capital per branch and the log of the number of branches. The *GMM system* estimation of the model gives an estimated coefficient for physical capital per branch of 0.03, not significantly different from zero (p value of 0.72). Therefore, we conclude that the output of banks is independent of the capacity per branch, which validates the assumption that bank branches do not operate at full capacity.[19]

In all the estimations, the elasticity of output with respect to IT capital is approximately 25% as large as the elasticity of output with respect to labour (0.212/0.867 = 0.25). Since the per-bank median value of the ratio amount of IT capital to number of workers is around 10,000 euros (Table 2), all this implies that the marginal rate of substitution between labour and IT capital, evaluated at the median values of the variables, is $25 \cdot 10^{-6}$ (0.25/10,000): that is, a one-million euro increase in the stock of IT capital implies a reduction of 25 workers, according to the results of the model.[20]

4.2 Loan demand and deposit supply

Equation (14) is estimated separately for total loans and for total deposits of each bank in the sample, following the same procedure as in the production function (the static formulation of (14) can be extended to panel data, adding a sub-index *t* in all the variables). The vector x_j includes the number of branches, advertising capital, and IT capital for each bank; interest rates p_j are averages of marginal interest rates of bank loans and deposits of bank *j* (see descriptive information on interest rates provided in Table 3) [21]. Here, we also consider the possibility of persistence in the shocks of demand, that is, ξ_{jt} follows an autoregressive process and the estimation will then be performed using the same *GMM system* methodology.[22]

---

either of the estimations. It should be noticed that banks whose family loans represent 25% or less of their business loans account for 7% of the total assets, which implies that banks in the sample do not show very high differences in product mix. A second robustness test has been to check the time stability of the production function. The production function has been estimated for the period 1983-1992 and for the period 1993-2003. The estimated elasticities in the two periods are quite similar and the null hypothesis of stability in the production function could not be statistically rejected. Finally, Hughes, Lang, Mester and Moon (1996) contemplate differences in the risk of the production plan of banks and evaluate how not considering these differences in the estimation may bias the production function estimates. The production function has been estimated allowing for differences in elasticity for banks above and below the median in the distribution of the intensity of IT and Advertising capital (considering that different intensity of the inputs may be tied to different risk in production plans) and, once more, the estimated elasticity is not different in one group of banks versus the other.

19. The model under Column (I) in Table 4 has been estimated using Loans + Deposits + Commissions as an alternative measure of output instead of Loans+ Deposits alone (not reported). The elasticity of labour and IT capital are 0.855 and 0.226, respectively, both statistically significant at 1% and less. The estimated elasticities are somewhat larger than when only loans and deposits are included in the output of banks, but the null hypothesis of constant returns to scale is not rejected.

20. This result is not inconsistent with the cost-benefit analysis of the investment in IT to substitute workers. For a user cost of capital of 0.47 (Table 3), a one-million euro investment in IT implies a total user cost of IT capital per year of 470,000 euros. The equivalent cost per worker and year of this user cost is close to 20,000 euros (470,000/25), in line with average labor cost per worker in the period.

21. We have assumed that the size of the potential market for loans (deposits) is equal to the monetary value of all the operations in the banking market, times a factor or proportionality equal to the inverse of the number of loans (deposits) per household (average of 80%). Data on the number of operations is available but incomplete, since they do not fully integrate the whole amount of loans or deposits that a bank produces. Therefore, our estimation of *M* is an approximation of the true measure.

22. In the estimation of the demand function, we take special account of the potential endogeneity of the interest rates (the residuals may capture shifts in consumers' preferences, which modify the price, generating a correlation between residuals and interest rates) and of the number of branches (demand and branches might be mutually determined). In the estimations, the lags of interest rates and the number of branches have been substituted by two additional

Table 5 shows the results of the estimation using data for the 1988-2003 period (information on interest rates is restricted to this time period). The table also includes the *p-values* of the statistics on the validity of the specification, including *COMFAC* restrictions. These *p-values* are all comfortably above the critical value of 5%, confirming the overall statistical validity of the estimations.[23]

The estimated coefficients are all significantly different from zero, except for IT capital. According to this result, no evidence is found from the data that IT is a value-enhancing input, in the sense that it increases the demand of bank services for a given interest rate. The estimated elasticity to number of bank branches is equal to 0.41 in deposits, and 0.31 in loans[24]. Advertising capital also contributes to demand in a statistically significant way, with an estimated elasticity of 0.22 in deposits, and half of that, 0.11, in loans. Demand for loans is negatively associated with the interest rate: the estimated interest rate elasticity of loans is -5.34 $(-5.34 = -5.17 \cdot (1-0.04) \cdot 1.07)$. The supply of deposits increases with the interest rate, with an estimated elasticity of 2.27 [2.27 = 2.32·(1-0.05)·1.03]. Demand for loans is more price sensitive than the supply of deposits. This may be due to the fact that deposits include saving and current accounts that provide liquidity and payment services to customers and, presumably, the deposit balances for liquidity and payment services are highly price-inelastic.[25]

Equation (6) indicates that, at the profit-maximizing interest rates and marginal costs, the price elasticity of loans (in absolute terms) and the price elasticity of deposits are inversely related to relative profit margins (not of variable operating costs) of banks. Therefore, they are an inverse measure of market power. With an estimated price elasticity of around five for loans and around two for deposits, the relative profit margins of banks are, approximately, 20% in loans and 50% in deposits.[26]

4.3 Implications for output growth, costs and profits

Having investigated the contribution of inputs to production and demand of banking services, this section presents the results from the tests of the profit maximizing conditions. In other words, we examine if inputs earn the expected return according to the respective unit cost or, alternatively, they earn some form of extraordinary profit or loss (which would be evidence of under or over investment relative to profit maximizing values). The exposition begins

---

sets of instruments. One is the residuals from the production function estimated above, since any shock that affects the supply side will also affect the level of interest rates (correlation with the explanatory variables of the demand function) but will be independent of shocks in consumers' preferences (uncorrelated with residuals of the demand function). The other instrument is the predicted number of branches as a function of the number of workers and IT capital at the bank level; as this prediction will be uncorrelated with the residual term of the demand function. This latter instrument is based on the fact that if $y = f(x) + u$, $corr(x,u) \neq 0$ and there is a variable *z* that satisfies $x = \gamma + \delta z + v$; $corr(u,v) \neq 0$; then the predictions $\hat{x} = \hat{\gamma} + \hat{\delta} z$ are valid instruments for *x* in $y = f(x) + u$.

23. In the demand for loans function, the presence of 2nd order autocorrelation cannot be rejected at 5%. As we explained at the end of the previous section, these results may be due to the presence of measurement errors. Then, the valid instruments have to be lagged one period of time, and the goodness of the estimation is reflected in the third-order autocorrelation test.

24. The elasticity of the market share with respect to *x* is $\frac{\delta s_i}{\delta x_i} \cdot \frac{x_i}{s_i} = \beta(1-s_i)x_i$, see Berry (2004). Therefore,

$\frac{\delta s_j}{\delta branches_j} \cdot \frac{branches_j}{s_j} =$ 0.43·(1-0.05)since branches enter the equation in logs.

25. Internet banking can change these results in the future, although during the period of study, and for the vast majority of banks, electronic banking has been irrelevant.

26. Demand for loans and deposits has been estimated allowing for differences in elasticity for banks with relatively more and less specialization in retail banking, using the same measure as in the production function (note 18). The null hypothesis of equal elasticity in the two groups of banks could not be rejected.

with IT capital, the input that has generated most interest in the literature to date. No empirical evidence was found in the previous section supporting the notion that IT capital is a value-enhancing input, in the sense of increasing demand for banking services (controlling for interest rate, branches and advertising capital). This evidence would be consistent with the hypothesis that, during the period under investigation, banks' investments in IT have not increased customers' willingness to pay for services, even though IT capital has contributed significantly to the production of these services. According to the results in Table 4, the elasticity of output to IT capital is positive and statistically significant, so that a one hundred percent increase in IT capital increases output by 21.2% [*SYSTEM (I)]*. IT capital is a productive input of banks, in line with evidence found in other studies that also use firm-level data [Lichtenberg (1995); Brynjolffsson and Hitt (1995 and 1996)], but our estimate of the elasticity of output to IT capital is more than twice that obtained in those papers.

Data from Table 2 on growth rates of IT capital over time permit us to obtain the contribution of growth in this capital to total output growth. Growth in IT capital is particularly high during the first five years of the period, 1983-1989, with average annual growth rate in the stock of IT close to 18% in real terms. During the period 1989 to 2003, IT capital grows at an average annual rate of 4.8% (9% of growth per bank and -4.2% of decline in the number of banks). Weighting this growth rate with the elasticity of output to IT capital (equal to 0.212), the contribution of IT capital growth to aggregate bank output growth from 1989 to 2003 is equal to 1.0 % per year (0.048·0.212). Given that the average annual growth rate of aggregate bank output in the same period is 3% (7.2% per bank and -4.2% declines in the number of banks (Table 1), IT capital growth explains 33% (1.0% out of 3%) of the rate of output growth in the past fifteen years. The contribution of IT capital to the growth of banking output is therefore quite substantial, and compares well with that obtained in studies focusing on other economic sectors. From Tables 1 and 2, growth in total number of workers is practically zero in all five- year periods, except for the last one, when it was negative. The remaining 2% in annual average growth of output, not explained by the increase in IT capital, is then the residual or total factor productivity growth from the combination of labor and IT capital to produce bank services.[27]

In line with the concerns expressed in the literature, it is important to distinguish between productive and profitable investments in IT capital. An input is productive when it contributes to output, and it is profitable when it contributes to economic profits. Profitability implies that the return of investment is at least equal to the cost of capital or, alternatively, that the share of input cost in total cost is not higher than the elasticity of output to the respective input [equations (9) and (10) with A=0, supported by the empirical evidence]. The results from the tests of the profit maximizing conditions are presented in Table 6. This table contains the following information. The first two columns correspond to the tests of the null hypothesis that the shares of inputs costs for labor and IT capital, respectively, are equal to estimated elasticity of production to the use of the input. The other two columns refer to the results from the tests of the optimal conditions for branches and advertising capital. The first row shows the estimated contributions to production and to demand of the respective input (elasticity and ratios of elasticity properly weighted) together with their estimated standard deviation (in brackets); the second row shows the average (and standard deviation in brackets) across banks of the shares of production input costs over total operating costs and the ratios of costs of value enhancing inputs over total interests rates in loans and deposits; the third row presents the estimated average and standard deviations of differences in value

27. Part of this growth may also reflect the increase in human capital resulting from better education and training of workers. Notice, however, that real labor cost per worker remains rather stable over time (Table 3).

contribution and cost shares / ratios (from rows one and two); finally row four shows the *p-value* from the test of the null hypothesis that each difference in row three is equal to zero.

The estimated elasticity of 0.867 for labour in the production function is close to the mean value of 0.868 for the average labour input share of total operating costs; the hypothesis of differences in the elasticity and share of labour costs being equal to zero is not statistically rejected (*p-value* close to 1). Therefore, the hypothesis that labour is used up to the point where productivity equals the marginal cost [equation (10)] can not be rejected. For IT capital, estimated elasticity and average cost share are, respectively, 0.212 and 0.132. The two estimated values differ more than in the case of the labour input but the statistical test of differences equal to zero [equation (9)] does not reject the null hypothesis either (*p-value* of 0.427). Therefore, considering the precision of the mean estimates (standard errors), the null hypothesis that the return from investment in IT capital is just equal to the user cost of the capital input cannot be rejected. This implies that the evidence found in this paper does not support the hypothesis that IT capital allows banks to gain a competitive advantage and earn extraordinary profits. The evidence would support the claim [Carr (2003)] that IT investments provide banks with standardized services, and no strategic differentiation is possible. Summarizing the results from Tables 4 and 6, the empirical analysis does not reject the null hypothesis that labour and IT capital contribute to the production of bank services, but their respective contribution to the output of the bank, valued at the marginal operating cost, is just equal to the share of the costs of the input in total cost. Therefore, neither of the two provides banks with externality effects or a competitive advantage (extraordinary profit).

The last two columns of Table 6 present the results of the tests of profit maximizing decisions for branches and for advertising, the two inputs that contribute to increase the value (willingness to pay) of banking services. The method is the same as in columns one and two but now we tests the optimality conditions (7) and (8) of the theoretical model. Taking into account the respective elasticity estimates from Table 5, together with the weights v obtained from bank data, the average contribution of branches and advertising capital to the value of banks' services is estimated to be 0.116 and 0.056, respectively (first row and columns three and four of Table 6).[28] On the other hand, the respective average estimates or the ratio of input costs to revenues shown in row two of Table 6, for branches and advertising, are 0.118 and 0.018, respectively. The average ratio of costs to revenues for branches, physical capital, is quite close to estimated average contribution to value and this explains that the *p-value* from the test of differences equal to zero is close to one. In the case of advertising, the estimated average contribution and the average cost to revenue ratio differ in a larger amount (0.050 and 0.018, respectively) but, once we take into account the standard deviations, the hypothesis of differences equal to zero between contribution and ratio of cost of the input to total revenues is not rejected either (*p-value* of 0.123). The conclusion is, one again, that banks in the sample make investments in branches and in advertising that contribute to increase the value of banking services (Table 5) and the amounts invested are those that maximize profits, i.e., the marginal return from the asset invested is equal to the marginal costs (Table 6).

---

28. The corresponding mean and standard deviation estimates of the distribution of the ratio between input and price demand elasticity that appear in the formula have been obtained applying the delta method.

5 Conclusion

Little is known about the contribution of IT capital to the growth and profitability of banks. The stock of IT capital has been the only productive asset that has increased steadily during the period 1983 to 2003, among the Spanish banks studied in this paper. This occurs while total labour, physical capital and advertising capital of the banking industry remain constant or decrease, in real terms, over the same time period. According to the marginal rate of substitution between IT and labour estimated in the paper, a one-million euro increment in IT capital per bank implies a reduction of 25 workers per bank. IT capital contributes to the output produced by banks, and its growth explains up to one-third of the annual growth rate in the output of banks. However, no evidence is found that IT capital increases the demand for loans or the supply of deposits (value-enhancing input). Overall, the estimated contribution of IT capital to the output of banks is just what would be expected from the profit-maximizing condition of marginal productivity equal to marginal cost. Therefore, the demand for IT capital services by Spanish banks is just that predicted by the profit-maximizing conditions.[29]

Together with the examination of contributions to the productivity and profitability of IT capital, this paper also provides evidence for the contribution of other inputs to the output and the demand for bank services. Particularly, it studies the role played by labour, physical capital (investment per branch and number of branches) and advertising capital on the demand and supply side of banking services. Furthermore, the estimations of the demand functions of services provide estimates of the price elasticity of loans and deposits. The empirical findings indicate that banks produce their output at branch level through a combination of services from labour and from IT capital, under a constant-returns-to-scale production function. The output from labour and IT capital cannot be expanded beyond the fixed capacity of the branch which, in turn, requires a fixed investment per branch. The output and inputs at bank level are just the product of output /inputs per branch times the number of branches; thus, the hypothesis of constant returns to scale at the bank level for the labour and IT capital cannot be rejected by the data. The results also indicate that the representative branch of banks does not operate at full capacity, but banks seem to open branches according to the profit-maximizing conditions of marginal return equal to the marginal cost of the investment.

Advertising capital is relatively low in Spanish banks (for the median bank, around one-seventh of IT capital), and it remains rather stable over time, in real terms. Advertising capital increases the demand for loans, and the supply of deposits, at a given interest rate. The elasticity of the supply of deposits, with respect to advertising capital, is twice (22%) the elasticity of the demand loans (11%), which suggests that expenditure on advertising is more effective for attracting depositors than for attracting borrowers. The null hypothesis that observed advertising services consumed by banks are those predicted by a profit-maximizing model is not rejected.

The paper also provides evidence that the representative bank faces an inelastic demand for loans and an inelastic supply of deposits (elasticity values equal

29. This result is consistent with that found by Beccalli (2007), of no significant differences in the accounting rate of return among banks with different investment in IT capital. Presumably, each bank invests the profit-maximizing amount in each period of time.

to 5.3 and 2.3, respectively). The market power of the representative bank is lower in loans than in deposits, so that the bank earns a 19% gross margin in revenues from loans and a 44% gross margin in payments to deposits. These profit margins are computed after taking into account the long-term variable costs of labour and IT capital, but before the fixed cost resulting from investments in branches, before the user-cost of advertising capital, and before the provisions for credit risk. Consequently, market power does not necessarily imply extraordinary profits for banks, since gross profits may be just the amount needed to compensate for the user costs of physical capital and advertising, and for credit risk.[30]

When estimates of elasticity of output and demand to inputs and prices are combined into tests of the profit-maximizing decisions of banks, the results do not allow us to reject the null hypothesis of efficient (profit-maximizing) allocation of resources. This is contrary to the evidence found in the literature on returns from IT investment, which suggests underinvestment in this input [Litchenberg (1995); Brynjolfsson and Hitt (1995 and 1996)]. However, the results presented here are not easy to compare with previous studies, since this paper uses the econometric technique of *system-GMM* while other research uses *OLS* estimation, and our paper provides evidence that results are sensitive to the estimation methodology.

One possible limitation of this paper, which should be taken into account in future research, is that the evaluation of profitability of the multi-asset banking firm is done under a static profit-maximization model, where capital accumulation is a dynamic process that should be modelled in a dynamic way. Another extension could be to more fully account for differences in the risk-taking behaviour of banks, in line with the analysis of Hughes, Lang, Mester and Moon (1996), who explicitly account for risk differences in the evaluation of the productive efficiency of banks.

30. For the median bank in the sample in terms of size (loans plus deposits), the average estimated gross profits are very close to the sum of yearly average cost of physical capital, advertising, and loan-loss provisions, consistent with long-term zero economic profits.

REFERENCES

ALY, H., R. GRABOWSKI, C. PASURKA and N. RANGAN (1990). "Technical, scale and allocative efficiencies in U.S. banking: an empirical investigation", *Review of Economics and Statistics,* Vol. 72, No. 2, pp. 211-218.

ARELLANO, M. (2003). *Panel data econometrics,* Oxford University Press.

BECCALLI, E. (2007). "Does IT investment improve bank performance? Evidence from Europe", *Journal of Banking and Finance,* forthcoming.

BENSTON, G. J., G. HANWECK and D. B. HUMPHREY (1982). "Scale economies in banking: A restructuring and reassessment", *Journal of Money, Credit, and Banking,* 14, 4, pp. 435-456.

BERGER, A. N., and D. B. HUMPHREY (1991). "The dominance of inefficiencies over scale and product mix economies in banking", *Journal of Monetary Economics,* 28, pp. 117-148.

— (1992a). "Measurement and efficiency issues in commercial banking", in Z. Griliches (Ed.), *Measurement Issues in the Service Sectors,* National Bureau of Economic Research, University of Chicago Press, USA, pp. 245-279.

— (1997). "Efficiency of Financial Institutions: International Survey and Directions for Future Research", *European Journal of Operational Research,* 98, 2, pp. 175-212.

BERRY, S. T. (1994). "Estimating discrete-choice models of product differentiation", *Rand Journal of Economics,* 25, 25, pp. 242-262.

BLUNDELL, R., and S. Bond (1998). "Initial conditions and moment restrictions in dynamic panel data models", *Journal of Econometrics,* 87, pp. 115-143.

— (1999). *GMM estimation with persistent panel data: An application to production function estimation,* The Institute for Fiscal Studies, London, Working Paper Series No. W99/4.

BRYNJOLFSSON, E. (1993). "The Productivity Paradox of Information Technology", *Communications of the ACM,* 36, 12, pp. 67-77.

BRYNJOLFSSON, E., and L. HITT (1995). "Information Technology as a factor of production: The role of differences among firms", *Economics of Innovation and New Technology,* Vol. 3, 4, (Special Issue on Information Technology and Productivity Paradox), pp. 183-200.

— (1996). "Paradox Lost? Firm-level Evidence on the Returns to Information Systems Spending", *Management Science,* 42, 4, pp. 541-558.

BRYNJOLFSSON, E., L. HITT and S. YANG (2002). "Intangible Assets: How the Interaction of Computers and Organizational Structure Affects Stock Market Valuations", *Brookings Papers on Economic Activity: Macroeconomics,* 1, pp. 137-199.

CARR, N. (2003). "IT Doesn't Matter", *Harvard Business Review,* 81, pp. 41-50.

CASOLARO, L., and G. GOBBI (2004). *Information technology and productivity changes in the Italian banking industry,* Working Paper 489, Banca d' Italia.

CUMMINS, J. (2004). *A new approach to the valuation of intangible capital,* Finance and Economics Discussion Series, 2004-17, Board of Governors of the Federal Reserve System (US).

DEWAN, S., and CH. MIN (1997). "The substitution of information technology for other factors of production: a firm level analysis", *Management Science,* 43, 12, pp. 1660-1675.

GRIFELL-TATJÉ, E., and C. A. K. LOVELL (1996). "Deregulation and productivity decline: the case of Spanish savings banks", *European Economic Review,* 40, pp. 1281-1303.

GRILICHES, Z., and J. MAIRESSE (1998). "Production functions: the search for identification", in S. Strom (Ed.), *Essays in Honour of Ragnar Frisch,* Econometric society monograph series, Cambridge University Press, Cambridge.

HANCOCK, D. (1991). *A Theory of Production for the Financial Firm,* Boston: Kluiwer Academic Publishers.

HANNAN, T. (1991). "Foundations of the structure-conduct paradigm in banking", *Journal of Money, Credit and Banking,* 23, 1, pp. 68-84.

HUGHES, J., W. LANG, L. MESTER and C. G. MOON (1996). "Efficient banking under interstate branching", *Journal of Money, Credit and Banking,* 28, pp. 1045-1071.

HUNTER, W. C., and S. G. TIMME (1995). "Core Deposits and Physical Capital: A Re-examination of Bank Scale Economies and Efficiency with Quasi-fixed Inputs", *Journal of Money, Credit and Banking,* 27, 1, pp. 165-185.

JORGENSON, D. (1963). "Capital theory and investment behaviour", *American Economic Review,* 53, pp. 247-259.

KUMBHAKAR, S., A. LOZANO-VIVAS and C. A. LOVELL (2001). "The Effects of Deregulation on the Performance of Financial Institutions: The Case of Spanish Savings Banks", *Journal of Money, Credit and Banking,* 33, 1, pp. 101-120.

LEV, B. (2001). *Intangibles: Management, measurement and reporting.* Washington, D.C.: Brookings Institution Press.

LICHTENBERG, F. (1995). "The output contribution of computer equipment and personnel: a firm level analysis", *Journal of Economics of Innovation and New Technology,* 3, pp. 201-217.

LIM, J., V. J. RICHARDSON and T. ROBERTS (2004). "Information technology investment and firm performance: a meta-analysis", *Proceedings of the 37th Annual Hawaii International Conference on System Sciences,* track 8, vol. 8, 80221.1

LOVELL, C. A. K., and J. PASTOR (1997). "Target Setting: An Application to a Bank Branch Network", *European Journal of Operational Research,* 98, 2, 16, pp. 290-299.

MARTIN-OLIVER, A., V. SALAS and J. SAURINA (2007a). "A test of the Law of One Price in Retail Banking", *Journal of Money, Credit and Banking,* 39, 8, pp. 2021-2040.

— (2007b). *Measurement of Capital Stock and Input Services in Spanish banks,* Working Paper 0711 Banco de España.

MAUDOS, J. (1996). "Eficiencia, Cambio Técnico y Productividad en el Sistema Bancario español: una aproximación de frontera estocástica", *Investigaciones Económicas,* XX (3), pp. 339-358.

MESTER, L. (1987). “A multiproduct cost study of savings and loans”, *The Journal of Finance,* 42, pp. 423-445.

OLINER, S. D., and D. E. SICHEL (2000). “The resurgence of growth in the late 1990s: Is information technology the Story? ”, *Journal of Economic Perspectives,* 14, 4, pp. 3-22.

PARSONS, D., C. C. GOTLIEB and M. DENNY (1993). “Productivity and computers in Canadian banking”, in Z. Griliches and J. Mairesse (Eds.), *Productivity issues in services at the micro level,* Kluwer, Boston.

PINHO, P. S. DE (2000). “The impact of deregulation on price and non price competition in the Portuguese deposit market”, *Journal of Banking and Finance,* 24, pp. 1515-1533.

PRASAD, B., and P. HARKER (1997). *Examining the contribution of Information Technology toward productivity and profitability in U.S. retail banking,* Wharton School Centre for Financial Institutions, Working Paper 97-09, University of Pennsylvania.

TABLE 1.- AVERAGE, MEDIAN AND STANDARD DEVIATION OF OUTPUT PER BANK (CONSTANT EUROS OF YEAR 1983).

Year	Number of Banks	LOANS + DEPOSITS			LOANS + DEPOSITS + COMMISSIONS		
		Mean	Median	Sd. Deviation	Mean	Median	Sd. Deviation
1983	159	1,120,007	403,561	2,187,840	1,164,856	412,462	2,345,536
1984	160	1,138,779	416,151	2,191,791	1,186,270	422,382	2,349,813
1985	162	1,148,951	434,779	2,160,143	1,200,273	439,748	2,318,865
1986	162	1,164,209	454,689	2,138,133	1,220,117	458,407	2,300,782
1987	161	1,239,968	484,768	2,200,911	1,296,136	490,361	2,365,999
1988	159	1,290,666	534,114	2,194,100	1,352,672	540,879	2,355,849
1989	159	1,380,761	550,720	2,323,877	1,446,267	560,894	2,507,772
1990	150	1,471,112	569,539	2,412,645	1,546,970	579,149	2,619,791
1991	145	1,609,639	646,756	2,553,927	1,704,658	661,502	2,779,383
1992	141	1,600,186	659,598	2,489,010	1,697,967	674,361	2,702,549
1993	139	1,653,833	679,729	2,514,269	1,776,774	714,175	2,738,817
1994	135	1,754,729	743,655	2,597,300	1,890,342	793,177	2,831,282
1995	136	1,812,553	758,112	2,659,866	1,936,350	777,637	2,885,500
1996	131	1,922,542	823,868	2,696,653	2,099,930	909,653	2,957,001
1997	129	2,058,575	918,908	2,782,326	2,310,736	1,017,936	3,082,136
1998	122	2,242,385	1,005,400	2,925,271	2,583,299	1,145,080	3,294,184
1999	118	2,388,333	1,107,300	3,003,312	2,795,124	1,387,997	3,363,937
2000	109	2,631,331	1,301,833	3,178,028	2,936,570	1,654,090	3,481,009
2001	104	2,927,504	1,600,197	3,303,000	3,276,334	1,892,592	3,608,268
2002	98	3,260,012	2,029,383	3,412,893	3,657,103	2,257,721	3,730,145
2003	91	3,673,169	2,334,357	3,552,218	4,269,484	2,995,222	3,913,026
Average cumulative growth							
1983-1989	0.00%	3.49%	5.18%		3.61%	5.12%	
1989-1994	-3.27%	4.79%	6.01%		5.36%	6.93%	
1994-1999	-2.69%	6.17%	7.96%		7.82%	11.19%	
1999-2003	-6.50%	10.76%	18.65%		10.59%	19.23%	
1983-2003	-2.79%	5.94%	8.78%		6.49%	9.91%	

Loans (Deposits) are the stock of loans (deposits) of the bank at the end of the year, at constant prices of 1983. Commissions is the present value, at 1983 prices, of a permanent flow of net commissions with nominal equal to the commissions earned by the bank in year *t*; the discount factor is the interbank interest rate in year *t*.

TABLE 2.- STATISTICS OF BANKS' INPUTS IN THE YEARS 1983-2003 (Values per bank)

Year	PHYSICAL			NUMBER BRANCHES			ADVERTISING			IT			NUMBER WORKERS		
	Mean	Median	Sd. Dev.	Mean	Median	Sd. Dev.	Mean	Median	Sd. Dev.	Mean	Median	Sd. Dev.	Mean	Median	Sd. Dev.
1983	32,932	13,274	48,459	138	78	198	1,749	652	2,617	3,472	1,245	5,873	1,151	516	1,918
1984	33,673	14,410	48,085	145	83	207	1,761	724	2,526	4,032	1,646	6,289	1,129	499	1,761
1985	31,453	14,720	44,359	147	83	212	1,762	727	2,468	5,192	2,422	7,753	1,089	496	1,628
1986	30,576	14,546	43,272	136	85	173	1,807	811	2,512	5,804	2,790	8,309	1,028	492	1,492
1987	29,340	13,662	41,021	147	89	200	1,949	924	2,702	7,063	3,485	9,718	1,055	506	1,548
1988	31,490	13,821	47,165	147	93	194	2,096	943	2,875	8,142	4,113	10,406	1,052	531	1,509
1989	31,878	13,831	47,463	153	97	201	2,284	930	3,158	10,048	4,758	13,429	1,131	519	1,688
1990	34,329	16,453	48,292	167	100	225	2,665	946	3,738	12,125	5,413	16,515	1,216	584	1,803
1991	38,290	17,237	53,655	176	104	237	2,968	1,168	4,231	13,072	5,793	17,003	1,309	605	1,955
1992	38,419	18,500	52,481	169	106	210	2,658	1,076	3,422	13,653	5,753	18,690	1,283	599	1,858
1993	45,903	20,249	70,854	183	106	244	2,784	1,040	3,735	15,094	5,857	23,440	1,313	594	1,938
1994	48,836	20,082	77,001	191	108	252	2,844	1,187	3,798	16,053	6,555	24,402	1,328	593	1,910
1995	48,676	20,155	78,190	193	109	258	2,908	1,226	3,916	16,443	6,958	24,467	1,315	594	1,907
1996	51,093	22,795	76,541	203	114	272	3,152	1,330	4,228	17,468	7,480	24,689	1,354	617	1,932
1997	48,159	22,795	67,952	211	116	284	3,285	1,342	4,317	20,887	9,462	32,448	1,351	625	1,879
1998	45,506	23,114	58,880	249	122	377	3,526	1,450	4,697	23,132	11,023	36,520	1,554	674	2,457
1999	48,476	22,325	71,926	242	121	344	3,601	1,652	4,991	23,999	12,277	36,590	1,534	637	2,396
2000	41,725	21,330	52,966	236	129	309	3,564	1,631	4,509	25,375	12,507	38,376	1,425	672	1,897
2001	42,215	21,723	52,586	253	142	326	3,763	1,884	4,566	27,931	14,956	40,061	1,524	765	1,991
2002	53,091	21,096	86,809	285	166	379	3,964	1,915	4,843	32,337	15,604	49,060	1,687	869	2,272
2003	55,033	25,088	85,977	311	187	389	4,149	2,358	4,932	34,208	15,470	50,545	1,815	900	2,331
Average cumulative growth															
1983-1989	-0.54%	0.69%		1.70%	3.63%		4.45%	5.91%		17.71%	22.34%		-0.28%	0.10%	
1989-1994	8.53%	7.46%		4.46%	2.15%		4.38%	4.87%		9.37%	6.41%		3.21%	2.67%	
1994-1999	-0.15%	2.12%		4.73%	2.19%		4.72%	6.61%		8.04%	12.55%		2.87%	1.42%	
1999-2003	3.17%	2.92%		6.29%	10.99%		3.54%	8.90%		8.86%	5.78%		4.21%	8.66%	
1983-2003	2.57%	3.18%		4.07%	4.37%		4.32%	6.42%		11.44%	12.60%		2.28%	2.78%	

All variables are at end-of-year values. Monetary variables refer to replacement cost of the asset, in thousands of euros, in 1983. Physical capital includes tangible assets recorded in the balance sheet, plus an estimate of the replacement cost of the rented branches. Advertising capital is obtained through the permanent-inventory method, applied to yearly expenditures on advertising. IT capital includes IT assets reported in the balance sheet, and the stock calculated applying the permanent-inventory method to the flow of IT expenditures in the income statement. See appendix for additional details.

TABLE 3.- STATISITICS OF COST OF EQUITY, USER COST OF CAPITAL, COST OF LABOUR, AND REPRESENTATIVE INTEREST RATE OF LOANS AND DEPOSITS.

Year	COST OF EQUITY		USER COST OF CAPITAL						LABOUR COST PER WORKER			LOAN INTEREST RATE			DEPOSIT INTEREST RATE		
			PHYSICAL		ADVERTISING		IT										
	Mean	Sd. Dev.	Mean	Sd. Dev.	Mean	Sd. Dev.	Mean	Sd. Dev.	Mean	Median	Sd. Dev.	Mean	Median	Sd. Dev.	Mean	Median	Sd. Dev.
1983	0.13	0.03	0.19	0.03	0.48	0.02	0.60	0.02	14.16	14.05	2.49						
1984	0.14	0.03	0.20	0.03	0.49	0.02	0.60	0.02	14.57	13.90	5.93						
1985	0.15	0.03	0.21	0.03	0.50	0.02	0.59	0.02	15.32	14.42	8.88						
1986	0.13	0.03	0.19	0.03	0.48	0.02	0.57	0.02	17.19	16.11	5.26						
1987	0.16	0.02	0.22	0.03	0.51	0.02	0.56	0.02	18.22	17.34	5.15						
1988	0.15	0.02	0.21	0.03	0.50	0.02	0.55	0.02	19.34	17.47	6.80	109.7	109.6	1.10	104.1	104.2	2.01
1989	0.14	0.02	0.20	0.02	0.49	0.01	0.56	0.01	19.84	18.19	7.96	108.8	108.9	0.93	103.4	103.6	1.96
1990	0.14	0.02	0.20	0.02	0.49	0.01	0.56	0.01	19.05	17.62	5.95	110.1	110.1	1.06	104.2	104.4	1.65
1991	0.14	0.02	0.19	0.02	0.49	0.01	0.55	0.01	18.25	17.63	4.29	110.3	110.4	1.22	104.5	104.8	1.34
1992	0.14	0.02	0.19	0.02	0.49	0.01	0.55	0.01	18.35	17.26	4.70	109.7	109.7	1.09	104.9	105.0	1.04
1993	0.14	0.02	0.19	0.02	0.49	0.01	0.54	0.01	18.65	17.57	4.87	110.2	110.1	1.27	105.9	106.0	0.66
1994	0.12	0.02	0.17	0.02	0.47	0.01	0.52	0.01	18.33	17.59	3.49	106.7	106.6	1.47	102.6	102.6	0.38
1995	0.12	0.02	0.17	0.02	0.47	0.01	0.52	0.01	19.11	17.23	10.22	107.4	107.2	1.36	103.5	103.6	0.54
1996	0.13	0.02	0.18	0.02	0.48	0.01	0.51	0.01	18.18	17.22	4.08	107.0	106.8	1.27	103.4	103.4	0.37
1997	0.12	0.02	0.17	0.02	0.47	0.01	0.49	0.01	18.51	17.21	4.63	106.0	105.9	1.19	102.9	103.0	0.35
1998	0.11	0.02	0.16	0.02	0.46	0.01	0.48	0.01	19.00	17.60	5.25	104.9	104.9	1.15	101.9	101.9	0.28
1999	0.10	0.02	0.15	0.02	0.45	0.01	0.47	0.01	19.64	18.26	7.62	103.4	103.4	1.23	100.2	100.2	0.22
2000	0.09	0.02	0.14	0.02	0.44	0.01	0.47	0.01	19.61	17.77	10.56	103.5	103.5	0.93	100.2	100.3	0.31
2001	0.10	0.02	0.14	0.02	0.44	0.01	0.48	0.01	19.22	18.15	4.67	103.3	103.2	1.01	100.2	100.3	0.29
2002	0.10	0.02	0.14	0.02	0.44	0.01	0.47	0.01	19.47	18.52	4.48	103.1	103.1	1.17	99.9	100.0	0.19
2003	0.09	0.02	0.13	0.02	0.44	0.01	0.47	0.01	18.83	17.78	3.58	102.6	102.5	1.28	99.5	99.5	0.28
Average of the period																	
1983-1988	0.14	0.03	0.20	0.03	0.49	0.02	0.58	0.02	16.47	15.55	5.75						
1989-1993	0.14	0.02	0.19	0.02	0.49	0.01	0.55	0.01	18.83	17.65	5.55	109.8	109.8	1.11	104.6	104.8	1.33
1994-1998	0.12	0.02	0.17	0.02	0.47	0.01	0.50	0.01	18.63	17.37	5.53	106.4	106.3	1.29	102.9	102.9	0.38
1999-2003	0.09	0.02	0.14	0.02	0.44	0.01	0.47	0.01	19.35	18.10	6.18	103.2	103.1	1.12	100.0	100.0	0.26
1983-2003	0.13	0.02	0.18	0.02	0.47	0.01	0.53	0.01	18.23	17.09	5.75	106.68	106.62	1.17	102.58	102.66	0.74

Cost of equity is the real risk-adjusted financial opportunity cost of equity. User cost of capital is the nominal cost of equity plus the depreciation rate and less the growth rate of the assets'price. See appendix for a more detailed exposition of hypotheses used in the elaboration of bank-level data. Labour cost per worker is calculated as personnel expenditures divided by number of workers, expressed in thousands of constant euros, in 1983. The interest rate columns contain the interest rate averages of representative banking products in real terms $\left(\frac{1+i}{1+CPI}\right)$*100: credit lines, receivables, mortgages and personal credits for loans; deposits, and *REPO* operations for deposits. Interest rate database begins in 1988.

TABLE 4.- PRODUCTION FUNCTION ESTIMATION.

	(I)	(II)	(III)[a]
ρ	0.908 ***	0.879 ***	0.888 ***
Labor	0.867 ***	0.828 ***	0.803 ***
Physical Capital		-0.082	
Number Branches			0.986 ***
IT capital	0.212 **	0.217 **	0.205 **
Sargan	0.127	0.206	0.235
2ndautocorrelation	0.110	0.128	0.129
COMFAC	0.259	0.961	0.958
CRS	0.576	0.798	0.981
N.Observations	2646	2646	2646

Notes. The dependent variable is the log of the sum of loans and deposits from Table 1.ρ is the coefficient associated with the persistence of production shocks, and *Labor, Physical Capital, Number Branches , IT capital* stand for the number of workers, physical capital, number of branches and IT capital (all of them in logs), respectively. The model has been estimated using a two-step procedure. In the first step, we estimate the unrestricted model (equation 18) with the *GMM* system estimator, and in the second step we apply the minimum distance estimator to obtain the estimates of the restricted model imposing the *COMFAC* restrictions (equation 16). In this table, we show the estimations of the restricted model. The instruments used in the *GMM* estimation for the first-differenced equation are the levels of the explanatory variables in the periods *t-2* and *t-3*, and for the levels equation are the first-differences of the explanatory variables in periods *t-1* and *t-2*. In the last column (III), the number of workers and the IT capital are divided by the number of branches, to test if the total output of the bank can be written as the output per branch times the number of branches. All the estimations are performed with time dummy variables (coefficients not shown). We also show: the p-values of the Sargan test of the absence of autocorrelation (unrestricted estimation), and the p-values of the validity of the *COMFAC* restrictions and of the existence of Constant Returns to Scale (*CRS*) (restricted estimation).

(*)=significant at 10% (**)= significant at 5% (***)= significant at 1%; standard errors in parentheses.

[a] We introduce Labor and IT capital per branch. The p-value of *CRS* refers to the test of constant returns at branch level ($H_o \equiv b_n + b_k^{IT} = 1$).

.

TABLE 5.- ESTIMATIONS OF DEMAND FOR LOANS AND OF SUPPLY OF DEPOSITS.

	DEMAND OF LOANS	SUPPLY OF DEPOSITS
ρ	0.972 ***	0.977 ***
	(0.013)	(0.019)
i_l	-5.177 **	
	(2.425)	
i_d		2.323 **
		(1.030)
Branches	0.361 ***	0.438 ***
	(0.093)	(0.085)
Advertising Capital	0.110 **	0.221 ***
	(0.050)	(0.066)
IT Capital	0.003	-0.010
	(0.031)	(0.029)
COMFAC restrictions	0.850	0.199
Sargan Test	0.965	1.000
2nd order autocorrelation	0.035	0.238
3rd order autocorrelation	0.288	0.213
N.Observations	1606	1560

The dependent variable is the log of loans and the log of deposits.ρ is the coefficient associated with the persistence of the demand shocks, and i_l, i_d, *Branches, Advertising Capital, and IT capital* are the interest rate of loans, interest rate of deposits, number of branches, advertising capital and IT capital (all of them in logs), respectively. The model has been estimated using a two-step procedure. In the first step, we estimate the unrestricted model with the *GMM* system estimator, and in the second step we apply the minimum distance estimator to obtain the estimates of the restricted model imposing the *COMFAC* restrictions. In this table, we show the estimations of the restricted model. The instruments used in the *GMM* estimation in the first-differenced equation are the levels of the explanatory variables in the periods *t-2* and *t-3*, and in the levels equation are the first-differences of the explanatory variables in periods *t-1* and *t-2*. In the case of interest rates and branches, the instruments have been substituted by the residuals from the production function (Table 4) and the predicted number of branches as a function of the number of workers and IT capital at the bank level. All the estimations are performed with time dummy variables (coefficients not shown). We also show: the p-values of the Sargan test of the absence of autocorrelation (unrestricted estimation) and the p-values of the validity of the *COMFAC* restrictions.

(*)=significant at 10% (**)= significant at 5% (***)= significant at 1%; standard errors in parentheses

TABLE 6.-TEST OF CONDITIONS OF OPTIMAL (PROFIT-MAXIMIZING) EXPENDITURES IN BANKS' INPUTS

PRODUCTION RESOURCES			**VALUE ENHANCING RESOURCES**		
	Labour	***IT***		***Branches***	***Advertising***
Value Contribution $\Sigma_{L+D,K}$	0.867	0.212	Value Contribution $\left(v_L \frac{\Sigma_{L,K}}{e_L} + v_D \frac{\Sigma_{D,K}}{e_D} \right)$	0.116	0.050
	(0.137)	(0.100)		(0.035)	(0.021)
Average Cost Share S_K	0.868	0.132	Average Relative Cost $\frac{P_K c_K K}{r_l L + r_d D}$	0.118	0.018
	(0.001)	(0.001)		(0.006)	(0.001)
Value Contribution - Cost Share $\Sigma_{L+D,K} - s_K$	-0.001	0.079	Value Contribution - Relative Cost $\left(v_L \frac{\Sigma_{L,K}}{e_L} + v_D \frac{\Sigma_{D,K}}{e_D} \right) - \frac{P_K c_K K}{r_l L + r_d D}$	-0.002	0.032
	(0.137)	(0.100)		(0.035)	(0.021)
P value	0.995	0.427	P value	0.949	0.123

This table presents the results of testing equations (9) and (10), in columns of Labour and IT, and equations (7) and (8), in columns of Branches and Advertising, from the profit maximizing decisions of the representative bank. The numbers shown in the table are estimated means and standard errors. When apply, the mean and standard error of the statistical distribution of ratios involving means and standard errors of parameter estimates from Table 5, have been obtained applying the delta method.

Appendix 1: Summary of methodology used to estimate the stock of material and immaterial assets and user cost of capital for Spanish banks

For each bank, data are available on the year-by-year investment flow in Physical assets, Advertising and IT. Data are obtained from confidential accounting statements reported by banks to the Banco de España. The stock of a particular asset in year t, at current replacement cost, is obtained applying the permanent inventory method.

Let I_t be the gross investment flow of new capital services in year *t*; K_t the stock of homogeneous capital services at the end of year *t*; ϕ the depreciation rate of the asset used in production activities during a one-year period; μ the rate of technological progress incorporated into capital services invested during one year, with respect to those invested one year before, and let q_t be the price of one unit of services in period *t*. The permanent inventory method determines the replacement cost of the stock in year t as follows,

$$p_t K_t = p_t I_t + \frac{1-\phi}{1+\mu} \cdot \frac{p_t}{p_{t-1}} \cdot \left(p_{t-1} \cdot K_{t-1} \right) \tag{1}$$

To replace in t one unit of capital service in place at the end of the previous year, *t-1*, with the technical progress in capital goods of the period, only $1/(1+\mu)$ units are needed. Depreciation implies that for each unit of capital in place in *t-1*, there is only $(1-\phi)$ units remaining at the end of the year. This computation of the net capital services is exact when the depreciation of the asset is exponential at rate ϕ.

The term $(1-\phi)/(1+\mu)$ is substituted by $(1-\delta)$ where δ is the overall economic depreciation rate. The value of δ is set to 0.03 for buildings, 0.15 for fixed assets different from IT, 0.35 for IT capital, and 0.35 for advertising capital. These are values in line with others used in the literature. The price index of buildings is taken from the Ministerio de Fomento and the price index of other non-IT fixed capital is set equal to the price deflator of gross capital formation. We assume that the price index of quality-adjusted IT capital is zero, and the price index of advertising capital is the price of market services published by the Spanish Institute of Statistics. The zero inflation rate of the price of IT capital services departs from the 15% to 20% decline assumed in other studies with US data, Litchenberg (1995), because, in Spain, general inflation is much higher than in the US, and technological innovations are introduced at a later time.

The user cost of capital represents the rental price per unit of service the firm would pay in the case that the unit of service was rented in the market. Even though capital services are supplied internally, we assume that there is an opportunity cost for one unit of service equal to the rental price. For capital service *K*, the user cost is given by $C_k = \left(\alpha + \delta - \dot{p}_k\right)$, where α is the financial opportunity cost of capital, δ is the depreciation rate defined earlier, and $\dot{p}_k$ is the rate of change in price of the asset during the period (asset-specific inflation). The calculation of the user cost of capital requires us to know α. Since the paper assumes that material and immaterial operating assets are financed by equity, the estimated cost of α is set equal to the estimated cost of equity for each bank. This, in turn, is set equal to the interest rate charged for loans by the bank, plus a financial risk premium that is inversely related to the proportion of capital to total assets of the bank.

For a more detailed explanation of the methodology for both, replacement costs of invested assets, and user cost of capital, see Martin-Oliver, Salas-Fumás and Saurina (2007b).

Appendix 2: First order conditions of the profit maximizing problem

If λ is the Lagrange multiplier of the constraint, the first order conditions of the profit-maximizing problem are written as,

$$r_l \cdot \left(1-\frac{1}{e_l}\right)-m=\lambda \qquad \text{(A.1)}$$

$$i-r_d \cdot \left(1+\frac{1}{e_d}\right)=\lambda \qquad \text{(A.2)}$$

$$(r_l-m-\lambda)L'_{ck}+(i-r_d-\lambda)D'_{ck}-c_{ck}\,p_{ck}=0 \qquad \text{(A.3)}$$

$$(r_l-m-\lambda)L'_{ik}+(i-r_d-\lambda)D'_{ik}-c_{ik}\,p_{ik}+\lambda F'_{ik}=0 \qquad \text{(A.4)}$$

$$(r_l-m-\lambda)L'_b+(i-r_d-\lambda)D'_b-c_k k_b\,p_b=0 \qquad \text{(A.5)}$$

$$-w+\lambda F'_N=0 \qquad \text{(A.6)}$$

Where e_l and e_d are, respectively, the absolute value of the price elasticity of demand for loans, and the elasticity of supply of deposits (positive); $m=(i\cdot(1-a)+a\alpha)$ is the financial opportunity cost of loans. The Lagrange multiplier is the change in the profit of the bank from a marginal increase in the output produced. From (A.1) and (A.2), we obtain equation (6) in the main text; (A.3) and (A.5) justify equations (7) and (8), while equations (9), (10) come from (A4),(A6).

For variables in their optimal values, from (A.4) and (A.6) the optimal value of the Lagrange multiplier is given by:

$$c_{ik}\,p_{ik}IK+wN=\lambda\left(F'_{ik}IK+F'_N N\right)+\left(\frac{r_l}{e_l}L'_{ik}IK+\frac{r_d}{e_d}D'_{ik}IK\right)$$

$$\lambda=ac-\left(s_L\frac{\Sigma_{L,IK}}{e_l}+s_D\frac{\Sigma_{D,IK}}{e_d}\right)$$

Where ac is the average operating cost for the labour and IT capital inputs, $ac=\frac{c_{ik}P_{ik}IK+wN}{L+D}$. The term in parenthesis in the equation that determines the value of λ,is the weighted sum of loan demand elasticity and of deposit supply elasticity with respect to IT capital ($\Sigma_{L,IK}$, $\Sigma_{D,IK}$), each divided by the respective price elasticity (loan and deposit); the weighting factors are the volume of loans and deposits per unit of total output, $s_L = \frac{L}{L+D}$; $s_D = 1 - s_L$. Consequently, the optimal value of λ is equal to the marginal cost of one additional unit of output, *ac* , minus the marginal benefit in terms of higher customer value from a one-unit increase in IT capital. If the external or demand effects from investing in IT capital do not exist, then the multiplier is just equal to the marginal operating cost of the bank in terms of the cost of labour and the cost of IT capital. Finite, non-negative profits require optimal λ to be positive, so we assume that this holds for the relevant range of parameters.

In this model, the profit-maximizing interest rates of loans and deposits satisfy the condition that $r_l\left(1-\frac{1}{e_l}\right)-\left[i(1-a)+a\alpha\right]=i-r_d\left(1+\frac{1}{e_d}\right)=\lambda$ [equations (A.1) and (A.2)]. Marginal revenue of loans $\left[i(1-a)+a\alpha\right]+\lambda$ is equal to marginal financial costs plus net operating costs. Therefore, (A.1) is just the condition that marginal revenue equals marginal cost. Equation (A.2) is the same as (A.1) but for deposits, where marginal revenue is the market rate *i*.

BANCO DE ESPAÑA PUBLICATIONS

WORKING PAPERS[1]

0626 CRISTINA BARCELÓ: A Q-model of labour demand.

0627 JOSEP M. VILARRUBIA: Neighborhood effects in economic growth.

0628 NUNO MARTINS AND ERNESTO VILLANUEVA: Does limited access to mortgage debt explain why young adults live with their parents?

0629 LUIS J. ÁLVAREZ AND IGNACIO HERNANDO: Competition and price adjustment in the euro area.

0630 FRANCISCO ALONSO, ROBERTO BLANCO AND GONZALO RUBIO: Option-implied preferences adjustments, density forecasts, and the equity risk premium.

0631 JAVIER ANDRÉS, PABLO BURRIEL AND ÁNGEL ESTRADA: BEMOD: A dsge model for the Spanish economy and the rest of the Euro area.

0632 JAMES COSTAIN AND MARCEL JANSEN: Employment fluctuations with downward wage rigidity: The role of moral hazard.

0633 RUBÉN SEGURA-CAYUELA: Inefficient policies, inefficient institutions and trade.

0634 RICARDO GIMENO AND JUAN M. NAVE: Genetic algorithm estimation of interest rate term structure.

0635 JOSÉ MANUEL CAMPA, JOSÉ M. GONZÁLEZ-MÍNGUEZ AND MARÍA SEBASTIÁ-BARRIEL: Non-linear adjustment of import prices in the European Union.

0636 AITOR ERCE-DOMÍNGUEZ: Using standstills to manage sovereign debt crises.

0637 ANTON NAKOV: Optimal and simple monetary policy rules with zero floor on the nominal interest rate.

0638 JOSÉ MANUEL CAMPA AND ÁNGEL GAVILÁN: Current accounts in the euro area: An intertemporal approach.

0639 FRANCISCO ALONSO, SANTIAGO FORTE AND JOSÉ MANUEL MARQUÉS: Implied default barrier in credit default swap premia. (The Spanish original of this publication has the same number.)

0701 PRAVEEN KUJAL AND JUAN RUIZ: Cost effectiveness of R&D and strategic trade policy.

0702 MARÍA J. NIETO AND LARRY D. WALL: Preconditions for a successful implementation of supervisors' prompt corrective action: Is there a case for a banking standard in the EU?

0703 PHILIP VERMEULEN, DANIEL DIAS, MAARTEN DOSSCHE, ERWAN GAUTIER, IGNACIO HERNANDO, ROBERTO SABBATINI AND HARALD STAHL: Price setting in the euro area: Some stylised facts from individual producer price data.

0704 ROBERTO BLANCO AND FERNANDO RESTOY: Have real interest rates really fallen that much in Spain?

0705 OLYMPIA BOVER AND JUAN F. JIMENO: House prices and employment reallocation: International evidence.

0706 ENRIQUE ALBEROLA AND JOSÉ M.ª SERENA: Global financial integration, monetary policy and reserve accumulation. Assessing the limits in emerging economies.

0707 ÁNGEL LEÓN, JAVIER MENCÍA AND ENRIQUE SENTANA: Parametric properties of semi-nonparametric distributions, with applications to option valuation.

0708 ENRIQUE ALBEROLA AND DANIEL NAVIA: Equilibrium exchange rates in the new EU members: external imbalances vs. real convergence.

0709 GABRIEL JIMÉNEZ AND JAVIER MENCÍA: Modelling the distribution of credit losses with observable and latent factors.

0710 JAVIER ANDRÉS, RAFAEL DOMÉNECH AND ANTONIO FATÁS: The stabilizing role of government size.

0711 ALFREDO MARTÍN-OLIVER, VICENTE SALAS-FUMÁS AND JESÚS SAURINA: Measurement of capital stock and input services of Spanish banks.

0712 JESÚS SAURINA AND CARLOS TRUCHARTE: An assessment of Basel II procyclicality in mortgage portfolios.

0713 JOSÉ MANUEL CAMPA AND IGNACIO HERNANDO: The reaction by industry insiders to M&As in the European financial industry.

0714 MARIO IZQUIERDO, JUAN F. JIMENO AND JUAN A. ROJAS: On the aggregate effects of immigration in Spain.

0715 FABIO CANOVA AND LUCA SALA: Back to square one: identification issues in DSGE models.

0716 FERNANDO NIETO: The determinants of household credit in Spain.

0717 EVA ORTEGA, PABLO BURRIEL, JOSÉ LUIS FERNÁNDEZ, EVA FERRAZ AND SAMUEL HURTADO: Update of the quarterly model of the Bank of Spain. (The Spanish original of this publication has the same number.)

0718 JAVIER ANDRÉS AND FERNANDO RESTOY: Macroeconomic modelling in EMU: how relevant is the change in regime?

---

1. Previously published Working Papers are listed in the Banco de España publications catalogue.

0719 FABIO CANOVA, DAVID LÓPEZ-SALIDO AND CLAUDIO MICHELACCI: The labor market effects of technology shocks.
0720 JUAN M. RUIZ AND JOSEP M. VILARRUBIA: The wise use of dummies in gravity models: Export potentials in the Euromed region.
0721 CLAUDIA CANALS, XAVIER GABAIX, JOSEP M. VILARRUBIA AND DAVID WEINSTEIN: Trade patterns, trade balances and idiosyncratic shocks.
0722 MARTÍN VALLCORBA AND JAVIER DELGADO: Determinantes de la morosidad bancaria en una economía dolarizada. El caso uruguayo.
0723 ANTÓN NÁKOV AND ANDREA PESCATORI: Inflation-output gap trade-off with a dominant oil supplier.
0724 JUAN AYUSO, JUAN F. JIMENO AND ERNESTO VILLANUEVA: The effects of the introduction of tax incentives on retirement savings.
0725 DONATO MASCIANDARO, MARÍA J. NIETO AND HENRIETTE PRAST: Financial governance of banking supervision.
0726 LUIS GUTIÉRREZ DE ROZAS: Testing for competition in the Spanish banking industry: The Panzar-Rosse approach revisited.
0727 LUCÍA CUADRO SÁEZ, MARCEL FRATZSCHER AND CHRISTIAN THIMANN: The transmission of emerging market shocks to global equity markets.
0728 AGUSTÍN MARAVALL AND ANA DEL RÍO: Temporal aggregation, systematic sampling, and the Hodrick-Prescott filter.
0729 LUIS J. ÁLVAREZ: What do micro price data tell us on the validity of the New Keynesian Phillips Curve?
0730 ALFREDO MARTÍN-OLIVER AND VICENTE SALAS-FUMÁS: How do intangible assets create economic value? An application to banks.
0731 REBECA JIMÉNEZ-RODRÍGUEZ: The industrial impact of oil price shocks: Evidence from the industries of six OECD countries.
0732 PILAR CUADRADO, AITOR LACUESTA, JOSÉ MARÍA MARTÍNEZ AND EDUARDO PÉREZ: El futuro de la tasa de actividad española: un enfoque generacional.
0733 PALOMA ACEVEDO, ENRIQUE ALBEROLA AND CARMEN BROTO: Local debt expansion… vulnerability reduction? An assessment for six crises-prone countries.
0734 PEDRO ALBARRÁN, RAQUEL CARRASCO AND MAITE MARTÍNEZ-GRANADO: Inequality for wage earners and self-employed: Evidence from panel data.
0735 ANTÓN NÁKOV AND ANDREA PESCATORI: Oil and the Great Moderation.
0736 MICHIEL VAN LEUVENSTEIJN, JACOB A. BIKKER, ADRIAN VAN RIXTEL AND CHRISTOFFER KOK-SØRENSEN: A new approach to measuring competition in the loan markets of the euro area.
0737 MARIO GARCÍA-FERREIRA AND ERNESTO VILLANUEVA: Employment risk and household formation: Evidence from differences in firing costs.
0738 LAURA HOSPIDO: Modelling heterogeneity and dynamics in the volatility of individual wages.
0739 PALOMA LÓPEZ-GARCÍA, SERGIO PUENTE AND ÁNGEL LUIS GÓMEZ: Firm productivity dynamics in Spain.
0740 ALFREDO MARTÍN-OLIVER AND VICENTE SALAS-FUMÁS: The output and profit contribution of information technology and advertising investments in banks.

BANCO DE **ESPAÑA**
Eurosistema

Unidad de Publicaciones
Alcalá, 522; 28027 Madrid
Telephone +34 91 338 6363. Fax +34 91 338 6488
e-mail: publicaciones@bde.es
www.bde.es