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INFORMATION TECHNOLOGY AND PRODUCTIVITY CHANGES IN THE BANKING INDUSTRY

by Luca Casolaro* and Giorgio Gobbi*

Abstract

This paper analyzes the effect of information technologies (IT) in the financial sector using micro-data on a panel of over 600 Italian banks over the period 1989-2000. We estimate stochastic cost and profit functions allowing for individual banks' displacements from the efficient frontier and for non-neutral technological change. Data on IT capital stock for individual banks enable us to distinguish between movements along the efficient frontier and shifts of the frontier owing to the adoption of new technologies. We find that both cost and profit frontier shifts are strongly correlated with IT capital accumulation. Banks adopting IT capital intensive techniques are also more efficient. We interpret this last result as evidence of a catching-up effect consistent with the usual pattern of diffusion of the new technologies.

JEL classification: D24, G21, O33.

Keywords: banking, productivity, efficiency, information technology.

Contents

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1. Introduction[1]

The rapidly increasing use of computers in producing and delivering goods and services has spurred a large literature on the effects of information technologies (IT) on productivity growth. Recent research has documented an important contribution of IT capital boosting total factor productivity in the US economy in the late 1990s. Even larger effects are expected in the future as long as learning processes gain momentum and innovations are paralleled by appropriate complementary investment. More skeptical views maintain that the observed increase in productivity is largely due to cyclical factors and that it is not necessarily a consequence of IT capital deepening.

The debate, initially based on industry-level data, has rapidly extended to empirical work using detailed information at the firm level. Industry-level studies, in fact, implying an aggregation over a number of different products and services, are potentially biased by the mis-measurement of quality changes in output, thus underscoring the magnitude of productivity changes. Studies using micro-data have found a strong positive correlation between IT capital accumulation and firms' productivity growth. Also, the impact of IT on firm performance appears to be higher when complemented by innovations in workplace organization and a large staff of highly skilled workers.

This paper contributes to the microeconomic strand of research by studying the effects of IT capital deepening in the banking sector. Several reasons make the banking system a particularly interesting industry for testing the impact of new technologies on productivity growth. First, from a macroeconomic point of view financial services account for between 5 and 10 per cent of GDP in most industrialized countries. Banks contribute to a large proportion of financial-related output playing an important role in key activities for the functioning of the economy, such as the allocation of capital and the provision of liquidity, payment and safekeeping services. Substantial improvements in the level of efficiency of these services can bring widespread welfare effects (Summers, 2000). Second, the

1 The authors thank Allen Berger, Luigi Guiso, Stefano Siviero and all the audience participants at the Bank of Italy and the FED Board seminars for helpful suggestions. We are also indebted with Tim Coelli who kindly made available the econometric software FRONTIER 4.1, used in part of the estimations. Ginette Eramo and Roberto Felici provided outstanding research assistance. All the remaining errors are ours. The views expressed in this paper do not necessarily represent those of the Bank of Italy.

acquisition and the treatment of information is a central activity in banking and the developments of productivity growth in this sector are likely to be highly sensitive to the extensive use of information technology (Berger, 2003). Finally, the stability of the banking system is a primary policy objective. Innovations affecting production costs and profit opportunities can have major consequences on the industry structure and need to be monitored by regulators.

Productivity developments in the banking industry have been extensively studied in relation to deregulation (Humphrey and Pulley, 1997), mergers and acquisitions (Akhavein et al, 1997) and changes in competition (Berger and Mester, 2001). However, limited attention has been paid to the effects of the diffusion of IT, mainly because of the paucity of appropriate quantitative information. Our database, which refers to a panel of more than 600 Italian banks over the period 1989-2000, includes information on both investments and expenses related to computers and software, which allows us to compute estimates of IT capital stock and its user cost at the firm level. Our sample period starts in 1989, when IT technologies had already been adopted by the vast majority of banks, and extends up to year 2000, covering a further wave of IT capital deepening.

Because of the heterogeneity of the shocks that affected the banking industry over the sample period (e.g. macroeconomic fluctuations, changes in regulation, demand shifts), any standard measure of total factor productivity growth (e.g. Solow residuals) is likely to reflect the effects of a large number of factors (Kumbhakar, 2000). The availability of data on investment in hardware and software allows us to test whether changes in total factor productivity (TFP) are correlated with the diffusion of the new technologies. We estimate both cost and profit functions using a methodology developed by Battese and Coelli (1993). A stochastic frontier is jointly estimated with an equation modeling the banks' inefficiency vector as a displacement from the best practice. In the frontier equation TFP shifts are also accounted for by the interaction of a time polynomial with output and input prices.

Using this methodology we aim to capture two different effects on productivity. The first is the shift of the frontier traced by the firms using the best practices within the industry. The second is the dynamics of banks' inefficiency, which are estimated as the distance from the most efficient banks on the frontier; this measure reflects the pattern of diffusion of the new technologies, which is likely to differ across firms. A well-documented, stylized fact, is that the usage of new technologies over time typically follows an S-curve (Geroski, 2000). As long as more and more firms introduce the usage of the new, TFP improving technology on a large scale, we should observe a catching-up effect on the average productivity growth of the industry.

We find that IT capital accumulation is strongly correlated with banks' cost and profit efficiency, implying a strong catching-up effect over the decade. We also find a positive correlation between cost and profit frontier shifts and several measures of IT capital intensity. Moreover, our results confirm, albeit indirectly, that organization does matter. In particular, we find that productivity gains are larger for banks combining in-firm IT capital-deepening with outsourcing of a substantial part of IT expenses, especially those implying a higher number of IT dedicated employees.

The paper is organized as follow. Section 2 reviews prior analysis of the effect of IT capital on productivity growth and on the estimation of inefficiency and productivity in banking. Section 3 lays out the methodology for the empirical analysis and the models to be estimated. In section 4 we present the data and the methodology to compute our measure of IT capital and in section 5 we display our empirical results. Section 6 concludes.

2. Related studies and motivation

Over the last 20 years firms have responded to the fall in the (quality-adjusted) price of computers and related technologies by substituting others production factors for IT capital. Computers share with other landmark technological innovations the feature of being a multipurpose technology, which can be adopted into virtually every economic activity. Historically, this kind of innovation has determined major shifts in the productivity of the economy, even if the available empirical evidence varies greatly as to the impact of IT on productivity according to the time period, country and analytical framework.

Studies of TFP growth rates in the US during the '80s and the early '90s generally found that the use of computers had a negligible impact on productivity (Roach, 1987;

Berndt and Morrison, 1991).[2] More recent papers (e.g. Jorgenson and Stiroh 2000; Oliner and Sichel, 2000; Jorgenson, 2001) find evidence of a non-negligible contribution of IT capital to the recent productivity growth in the US. Daveri (2001) examines the diffusion of IT in Europe during the '90s finding a strong increase of IT capital in UE countries, albeit with a substantial delay with respect to US experience. He also finds that cross-country differences in growth are correlated with the adoption of IT, even if a causal link has not been yet established. More skeptical scholars argue that productivity gains are largely to be ascribed to cyclical factors, claiming that there is clear evidence of a productivity increase only in the computer-producing industry (e.g. Gordon, 1999).

Most of these studies are based on aggregate industry data, which may underestimate the effect of IT on productivity for two reasons. First, the use of computers is often associated with large changes in the quality of output that are difficult to measure accurately (Boskin et al., 1997), especially aggregating broad ranges of products and services. Second, the use of digital technologies is likely to require time to adjust workplace organization and employees skills, and industry data can average out large cross-firm variability due to different stages in IT adoption. Consequently, a number of papers have addressed the issue using micro-data. Brynjolfsson and Hitt (2000) estimate a production function for a panel of 600 large US firms. They find that over a period of three to seven years the contribution of IT investments to output growth substantially exceeds its factor share, implying a positive effect of computers on lung-run productivity growth. The results also suggest that IT capital deepening is part of a larger system of technological and organizational changes within firms. Bresnahan et al. (2002) also find a positive correlation between the accumulation of IT capital, innovation in workplace organization and the use of more highly skilled workers. They also estimate a positive correlation between firms' IT capital stock and their value added. Using Italian micro data, Bugamelli and Pagano (2001) investigate the diffusion of IT in Italian manufacturing firms. They find evidence of a positive correlation between IT investments, reorganizations of the production process and the level of human capital in the labor force.

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[2] The negative results of this vintage of papers inspired the much quoted remark by Robert Solow "we see computers everywhere but in the productivity statistics" (Solow, 1987).

To our knowledge, the only two academic papers specifically investigating the effects of computers in the banking industry are Parsons et al. (1993) and Autor et al. (2000). Both of them use data from case studies. Parsons et al. (1993) estimate a cost function using data from a large Canadian bank over the period 1974-1987 and find a weak but significant correlation between productivity growth and the adoption of computers. Autor et al. (2000) examine the introduction of automatic image processing of checks in one of the 20 largest banks in the United States. They argue that computers are a substitute for low skilled works in standardized tasks, but complementary to computer-skilled labor. Furthermore they emphasize the interdependence between technological and organizational change.

A number of studies have tried to infer the effects of technical change on banking from total factor productivity changes, estimated by fitting cost or profit functions to micro-data. The specification of dual functions in place of the standard primal production function is due to the multiple nature of the banks' output and to the measurement problems associated with services provided through the activities of lending and fund-raising (Hanckock, 1991). For instance, Hunter and Timme (1986) estimate a cost function using data on a sample of large US bank holding companies over the period 1972-1982. Technical change is modeled introducing a time polynomial as an argument of the cost function. Their major finding is that, over the sample, technical change contributed substantially to lowering average costs, especially for larger banks.

Average industry TFP changes, however, can be a poor proxy of technical change whenever there is a wide dispersion of efficiency levels across firms: an increase in average TFP over a given time lapse can be ascribed either to technical progress or to a rise in average technical or allocative efficiency (Bauer, 1990). A large body of applied literature has documented that this is in fact the case in the banking industry (Ferrier and Lovell, 1990, Berger, 1993, Berger, Hunter and Timme, 1993, Berger and Mester, 1997). Using both parametric and non-parametric frontier techniques, in the literature TFP growth has been decomposed into changes in average efficiency and frontier shifts. The latter measures the productivity growth of the banks adopting the best practices in the industry, which is likely to be correlated with technical change. Approximating technical change with frontier shifts, both Bauer et al. (1993) and Humphrey (1992) found that it had a negative effect on the productivity of US banks for most of the '80s. More recently Kumbhakar et al. (2001)

estimate a stochastic profit frontier for Spanish saving banks during the period 1986-1997, finding a positive effect of technical change on TFP. Berger and Mester (2001) also find a correlation between technical change and productivity growth in US banking in the second half of the '90s. Alam (2001), applying a non parametric approach to US banks, finds that during the '80s, productivity growth in banking was driven mainly by technological changes rather than convergence to the efficient frontier.

The general pattern of negligible or negative effects of technical change on productivity growth in the '80s, followed by positive effects in the '90s, seems to fit the banking industry data as well. The existing literature, however, has two major shortcomings.

First, the identification of technical change with frontier shifts in not straightforward, especially when other shocks from different sources affect the path of productivity growth of banks adopting the best practices in the industry. For example, Berg et al. (1992), in a study on Norwegian banking in the '80s, explain the upward shift in the production frontier as an effect of the absorption of the post-deregulation excess capacity. Grifell-Tatje and Lovell (1996) find that deregulation induced a sharp decline in the productivity of the top performer Spanish saving banks in the late '80s.

Second, the dispersion of bank efficiency levels also contains useful information about the effect of technical change. Several studies have tried to measure the average response of the industry to different types of shocks, such as changes in regulation (Humphrey and Pulley, 1997) or mergers and acquisitions (Akhavein et al., 1997). Others have tried to characterize the efficiency levels in terms of market and bank characteristics (Berger and Mester, 1997), or to focus on particular bank features, such as the ownership structure (Altunbas et al., 2001) or the level of specialization (Vennet, 2002)[3]. Lack of data, however, has prevented research to directly explore whether displacements from the best practice are correlated with technological innovation. The pace at which different banks have invested in IT capital may differ substantially. On the one hand, the speed of adoption of the new technologies can be hampered by lack of information on how to implement them or by the

[3] By contrast, the issue is widely debated within the profession. McKinsey (2002) claims that many of the post-1995 IT investments were aimed at rising revenue-increase activities that have yet to be repaid, leading to a decline in banking productivity due to excess capacity.

need for workforce skills that are obtainable only through learning-by-doing processes (following the "epidemic" models of technology diffusion). On the other hand, different firms may want to adopt the new technology at different times because of idiosyncratic adjustment costs (following the "probit" model of diffusion). A difference in the adoption rate of new technologies across banks is likely to be reflected in the distribution of efficiency levels. The methodology used in this paper allows us to tackle both these drawbacks, thanks to the availability of data on IT capital.

3. Methodology

3.1 Stochastic frontiers and inefficiency

To estimate the pattern of inefficiency of the banking sector we apply the stochastic frontier methodology developed by Battese and Coelli (1992), which allows the estimation of both the frontier shifts and the time patterns of the inefficiency vector. The joint estimation of the frontier and the equation relating the inefficiency levels to a set of covariates overcomes the problem caused by the orthogonality assumption usually imposed between residuals and regressors in the standard inefficiency regressions.[4]

Considering a generic (cost or profit) frontier function, we estimate the following system:

$$F_{it} = f\left[Y_{nit}, P_{mit}, t\right] + u_{it} + v_{it} \tag{1}$$

$$u_{it} = \delta z_{it} + w_{it} \tag{2}$$

where F_{it} is the volume of costs or profits, y_{it} are the values of the n output or price variables and the p_{it} are the m input prices. The residual of equation (1) is a composite term formed by a standard white noise residual v_{it} plus an asymmetric distribution term u_{it}, accounting for inefficiency. In equation (2) the u_{it} term is specified as a stochastic process

4 The typical procedure in the past literature was first to estimate the stochastic frontier and predict inefficiency under the assumption of identical distributions, then to estimate an inefficiency equation using the predicted u_{it} term, in contradiction with the prior distributional assumption (see Khumbhakar, Ghosh and McGukin, 1991).

with mean dependent from a vector of covariates z_{it}, and a random component w_{it} defined as the truncation of an independent normal distribution with mean zero and variance σ_U^2 , such that u_{it} is a non-negative truncation of the normal distribution $N(\delta z_{it}, \sigma^2_U)$ (see Battese and Coelli, 1995)[5]. This specification partially mitigates the usual problems the stochastic frontier methodology related with the *ad hoc* assumptions imposed to the inefficiency distribution[6]. The model allows also inefficiency levels to vary over time without imposing the same ordering of firms in terms of efficiency for each period, as in Battese and Coelli (1992).[7] In our setting a bank can be more efficient than another one year and less efficient the following.

The u_i term can be identified, following Jondrow et al. (1982), conditional on the estimated residual $e_i = v_i + u_i$. Battese and Coelli (1988) pointed out that the best predictor of cost inefficiency for firm i is the expression e^{u_i}, for which the following expression holds (Battese and Coelli, 1993):

$$E\left[e^{u_i} \mid e_i\right] = \left[\frac{\frac{\phi}{\sigma_a}\left[(1-\gamma)z_{it}\delta - \gamma e_i\right] - \sigma_a}{\frac{\phi}{\sigma_a}\left[(1-\gamma)z_{it}\delta - \gamma e_i\right]}\right] e^{[\gamma e_i + \sigma_a^2/2]} \qquad (3)$$

where σ_a is equal to the square root of the expression $\gamma(1-\gamma)(\sigma^2_U + \sigma^2_V)$, ϕ is the density function of a standard normal random variable $\gamma = \sigma^2_U / (\sigma^2_U + \sigma^2_V)$, σ^2_U and σ^2_V being respectively the estimated variance of the inefficiency term u_{it} and of the white noise v_{it}.

The parameter γ estimated in the regression represents the part of total variance around the frontier that is explained by inefficiency. A value of γ equal to zero means that the deviations from the frontier are entirely due to noise, while a value equal to one indicates that all the deviations are due to cost inefficiency. The expectation of inefficiency u_{it}

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5 The assumption that the u_{it} are independent distributed $\forall$ i and t, made to simplify the model, is a restriction because it does not account for heteroskedasticity or for possible correlation structures among the residuals.

6 In the results of our estimates, however, we control for their robustness to different inefficiency estimation methods.

7 The relation $z_{it}\delta + w_{it} > z_{i't'}\delta + w_{i't'}$ for $i \neq i'$ does not imply $z_{it'}\delta + w_{it'} > z_{i't'}\delta + w_{i't'}$ for $t \neq t'$

conditional to the entire residual e_{it} measures the ratio between the costs (profits) of a generic firm *i* and those of the most efficient firm i^*, which is on the frontier with an inefficiency level equal to zero ($e_{ui}^* = 1$).

Taking the time derivative of the frontier (1), which is assumed to be multiplicative in its arguments, we obtain the value of the cost and profit frontier shift, defined as:

$$\frac{\partial F_{it}}{\partial t} = \sum_{l=1}^{L} \frac{\partial f(t,.)}{\partial t} + \sum_{n=1}^{N} \frac{\partial f(Y,.)}{\partial t} + \sum_{m=1}^{M} \frac{\partial f(P,.)}{\partial t} \qquad (4)$$

where L is the power of the time polynomial included in the frontier to account for non-neutral technological progress, N is the number of outputs and M is the number of inputs. For each bank *i* a time derivative is computed, representing the projection on the frontier of the bank's time shift in cost or profit, after controlling for its input-output mix and for its level of inefficiency.

3.2 The empirical model

We first estimate a stochastic translog cost function with a time polynomial included as a production factor to allow for non-neutral technological progress. The estimated cost frontier is the following:

$$C = \beta_0 + \sum_{n=1}^{N} \beta_{yn} y_n + \sum_{m=1}^{M} \beta_{pm} p_m + \frac{1}{2}\left(\sum_{n=1}^{N}\sum_{l=1}^{N} \beta_{y_n y_l} y_n y_l + \sum_{m=1}^{M}\sum_{k=1}^{M} \beta_{p_m p_k} p_m p_k \right) + \sum_{n=1}^{N}\sum_{m=1}^{M} \beta_{y_n p_m} y_n p_m$$
$$+ \sum_{n=1}^{N} \beta_{ty_n} y_n t + \sum_{m=1}^{M} \beta_{tp_m} p_m t + \beta_{t1} t + \beta_{t2} t^2 + \phi_1 GNP_t + \phi_2 r_t + v + u \qquad (5)$$

where the N outputs are denoted by y_n, the M input prices by p_m, all expressed in logs and in differences from the sample mean and the standard symmetry and linear homogeneity conditions are imposed[8]. We include in the model the growth rate of the real GNP and the real official discount rate in order to control for the business cycle. The cost inefficiency

[8] The subscripts *i* and *t* are omitted for simplicity.

term u_{it} measures how close the costs of bank i at time t are to those of a bank on the efficient frontier, producing the same output vector under the same technical constraints.

Berger and Mester (1997) argue that in banking analysis the estimation of a profit frontier is more appropriate because the use of a profit function accounts for both output and input side errors in the bank's choice. In the standard profit analysis output prices are taken as exogenous, considering profit inefficiency as a sub-optimal choice with respect to input-output relative prices. This model, however, is not the best suited for the banking industry, where a large share of banks' revenue originates from bilateral contracting in which banks have some bargaining power. We therefore adopt an alternative concept of profit function, proposed by Humphrey and Pulley (1997), where output prices are allowed to vary while output is assumed to be constant, as in the cost function. Using this approach, errors in the choice of outputs do not affect efficiency, while errors in output prices do. The alternative profit approach can be useful when some of the standard assumptions of the profit model cannot be satisfied, as it usually happens in the banking sector. First, in the case of un-measurable differences in the output qualities between banks, the alternative profit approach can be used because it accounts for the additional output coming from higher quality in services. Also, output prices are usually constructed from quantity data and cannot adequately account for the variance of profits.

The efficiency estimation obtained by this approach is a measure of how close a bank is to its maximum profit, given an input price-output quantity mix, i.e. the proportion of profits that bank i is earning with respect to maximum profits, due to excessive costs and/or inadequate revenues[9]. We therefore estimate the following translog alternative profit frontier:

$$\begin{aligned}\pi = \beta_0 + \sum_{n=1}^{N}\beta_{yn}y_n + \sum_{m=1}^{M}\beta_{pm}p_m + \frac{1}{2}\left(\sum_{n=1}^{N}\sum_{l=1}^{N}\beta_{y_n y_l}y_n y_l + \sum_{m=1}^{M}\sum_{k=1}^{M}\beta_{p_m p_k}p_m p_k\right) + \sum_{n=1}^{N}\sum_{m=1}^{M}\beta_{y_n p_m}y_n p_m \\ + \sum_{n=1}^{N}\beta_{ty_n}y_n t + \sum_{m=1}^{M}\beta_{tp_m}p_m t + \beta_{t1}t + \beta_{t2}t^2 + \phi_1 GNP_t + \phi_2 r_t + v + u\end{aligned} \qquad (6)$$

9 In the last years a number of empirical studies on banking efficiency adopted the alternative profit approach. See, between the others (Altunbas et al, 2001, Clark and Siems, 2002, Vennet, 2002).

where the variable u measures inefficiency in terms of forfeited profits. In both cost and profit analysis the inefficiency term is modeled as follows:

$$u_{it} = \delta_0 + \sum_{j=1}^{J} \delta_j z_{itj} + \delta_t t + w_{it} \tag{7}$$

where δ_0 is a constant term, z_{it} are individual time-varying covariates and t is a linear time trend to account for time patterns of inefficiency. We jointly estimate equation (5) (or equation (6)) and equation (7) using maximum likelihood techniques[10] that produce asymptotically consistent and efficient estimates.[11]

As a last step we analyze the frontier shift determinants in order to investigate the existence of a correlation between IT capital and the cost and profit shifts of banks over time. The idea behind this exercise is that frontier shifts are driven by the introduction of new best practices along with the increase of IT capital.[12]

We first compute the time derivative of the frontier function for each bank in each year, which is given by:

$$\mathrm{FS}_{it} = \frac{\partial f}{\partial t} = \beta_{t1} + 2\beta_{t2} t + \sum_{i=1}^{N} \beta_{yt_i} y_i + \sum_{j=1}^{M} \beta_{pt_j} p_j \tag{8}$$

where the f stands for the cost or the profit function. We estimate the panel of banks' frontier shifts for each year with a fixed effects regression of the kind:

$$\mathrm{FS}_{\mathrm{it}} = \beta_2 TECH_{it} + \sum_{j=1}^{J} \beta_j w_{jit} + \lambda_i + \eta_t + v_{it} \tag{9}$$

where $TECH_{it}$ represents a vector of variables that measure the degree of IT adoption for bank i, the w_{jit}s are time-varying bank specific variables, the λ_is are the individual fixed effects and the η_ts are time dummies.

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10 The likelihood function of the system is shown in Battese and Coelli (1993).

11 We do not include the factor share equations, which are derived from the Shepard's Lemma and Roy's Identity restrictions: the inclusion of factor demand equations would have increased the efficiency of the estimates but would have forced the banking system not to display allocative inefficiency.

12 As pointed out by Salter in his seminal empirical investigation on productivity and technical change: "…gross investment is the vehicle of new techniques, and the rate of such investment determines how rapidly new techniques are brought into general use and are effective in raising productivity." (Salter, 1966; pag. 17).

4. Data

4.1 Banks

In the first part of the '90s the IT-related expenses of Italian banks accounted for about 9 per cent of total operating costs, peaking above 13 per cent in 1999 with the introduction of the single currency and the Y2K (Table 1). Annual investment in hardware, adjusted for hedonic price changes, increased by six times and that on software by three times (Table 2). In 2001 the total real value of hardware, software and EDP specific plants per employee was almost six times higher than in 1989.

Moreover, during the '90s the banking industry in Italy, as well as in many other developed countries, underwent far-reaching transformations: a new banking law was passed in 1993; virtually all banks under public control have been privatized; a wave of mergers and acquisitions has swept through the industry; large demand shifts have caused prolonged periods of excess capacity. In the first five years of the decade net return on equity fell from 9.91 to 1.21, while the cost-income ratio increased by almost seven percentage points. Performance subsequently recovered along with a decrease in the burden of staff costs and bad loans and with a strong increase in revenues from services.

In our empirical analysis we employ data referring to an unbalanced panel of 618 Italian banks over the period 1989-2000[13]. We use information from the Supervisory Returns Database of the Bank of Italy, which includes detailed information on IT expenses and investment relating to software, hardware, outsourcing and the number of employees working in the computing centers.

We adjust for banks disappearing in the sample period owing to mergers and acquisitions by computing *pro-forma* balance sheets and profit and loss accounts. Possible effects of M&A on productivity are accounted for by introducing the share of the target banks into the joint assets of the target and the acquiring banks among the explicative variables of both the inefficiencies and the frontier-shifts equations. Acquisitions that maintain the charter of the target bank within a banking group are controlled for by means of a dummy variable.

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[13] This number refers to the sample obtained after the exclusion mentioned above.

We exclude from the sample branches of foreign banks because their balance sheets and profit and loss accounts are strongly affected by the relationships with their parent banks. We also drop 170 banks presenting data problems. In particular, for a large number of small-sized banks, information on IT is rather noisy due to the small scale of activity. This is the case of banks that outsource a large part of data processing activities for which it has not been possible to rely on investment flow to compute IT capital stock (see below). However, the number of banks for which this information becomes available increases over time.

In order to assess cross-sectional differences we divide the sample banks into three groups according to their average total assets during the sample period. The first group includes the smallest two thirds of the sample and contains almost exclusively cooperative banks: we call it the *small banks group*. In the second group, our *medium banks group*, we include banks between the top 33 and the top 10 per cent of total asset distribution, while the *large banks* are those in the top 10 per cent of the distribution.

4.2 Outputs and inputs

The appropriate representation of the bank production process and, in particular, the definition of bank output is a long-standing and controversial issue. In this paper we follow what has come to be known as the *value added approach*, in which all the activities having substantial value added are considered outputs of the bank. We classify services produced and supplied by banks into two broad areas.

The first group includes services for which banks charge direct fees such as payment execution, safekeeping, brokerage and asset management[14]. These outputs are likely to be standardized and in principle it would be possible to have appropriate physical measures for them, such as the number of transactions. However, actual data are collected in a rather aggregate form, and owing to quality heterogeneity they are at best only proxies for output levels. Moreover, banks supply a large number of different services which can hardly be accommodated in an econometric model. We have therefore combined the information on

[14] Clark and Siems (2002) show that banking efficiency is affected by the off-balance-sheet activities of the banks. They find that the inclusion of variables related with non interest income can adequately proxy the effect of the off-balance-sheet activities, contributing to explain interbank differences in profit and cost efficiency.

three main types of proxies in a single composite output using their shares in fee income as weights. Specifically, we have the turnover of current accounts as a proxy for payment services, the total amount of deposited securities as a proxy for both safekeeping and asset management, and loan guarantees as a proxy for off-balance intermediation activity.

The second group of services stems from typical intermediation activity: raising and lending funds. According to the theoretical micro-foundations of financial intermediation, banks "produce" financial contracts exploiting economies of scale in transaction technologies as well as in screening and monitoring activities. The remuneration for the provision of intermediation services is given by the spread between the interest paid on financial liabilities and the interest charged on assets. Since this kind of activity tends to be customer-specific, there is no clear-cut distinction between prices and quantities. Intermediation services are to a large extent not standardized and it is hard to find compelling physical measures. In the applied literature they are usually assumed to be proportional to the face value of assets and liabilities, meaning that a € 100 loan corresponds to two times the amount of services produced with a € 50 loan[15]. In this study the outstanding amounts of loans to and deposits from the non-bank sector are assumed to be the main carriers of these kinds of services. The exclusion of other items, such as interbank accounts and securities, can be motivated on the ground that they contribute little to the value added once their user costs are properly taken into account (Hancock, 1991 and Fixler, 1993). We consider separately short-term loans (those with original maturity up to 18 months) and medium- and long-term loans on the grounds that they are likely to differ substantially in terms of the amount of resources they require for their origination, screening and monitoring. In Italy, most of the short-term loans consist of non-collateralized commercial and industrial lending. By contrast medium and long-term loans mainly include mortgaged lending (Pozzolo, 2001). On the input side we have considered labor and two types of physical capital services: IT capital and other premises and equipment. For operating expenses not related to staff and capital expenditure there is no information enabling us to distinguish between prices and quantities. We have therefore assumed that they enter in the production in fixed proportion with other inputs. The IT price is calculated

[15] This is known as the intermediation approach and is usually contrasted with the production approach in which output is measured by the number of accounts.

as a usage cost, given by the ratio between IT expenses and the value of the capital stock computed before (see below). As a proxy for the price of labor we use the average wage, while the price of the other type of physical capital is constructed as the ratio of the capital expenses divided by its book value[16].

Total operating expenses are the left-hand side variable in the frontier estimation. Price homogeneity of the cost function has been imposed by normalizing both costs and input prices by the price of labor. Outputs and inputs have been deflated by the consumer price index in order to avoid the estimated coefficients of the time variable being affected by inflation. In the profit function the dependent variable is the value of total revenue before taxes.

4.3 IT capital

The IT capital stock has been computed by applying the permanent inventory method to the real investment in hardware, software and premises for computing equipment. The value of banks' investment has been deflated using hedonic price indexes of software and hardware developed by the Bureau of Economic Analysis (BEA)[17] and adjusted for the variation in the ITL/USD exchange rate.[18] The US deflator is the only one available for each group of products; its application to Italian data may be justified by the high share of imported IT equipment and the existence of a global market for these products. Capital stock is obtained as the sum of past investment flows, weighted by the relative efficiency in production of different vintages. We assume the depreciation rate is constant in time but different across goods. Following Seskin (1999) and Jorgenson and Stiroh (2000) software is assumed to depreciate at a yearly rate of 44 per cent, hardware and dedicated premises by 32 per cent yearly.

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[16] We also included estimates of the value of leases consistently with the definition of expenses.

[17] Data have been downloaded from the web site www.bea.org.

[18] We implicitly assume that exchange-rate movements are entirely translated onto consumers.

4.4 Explanatory variables of inefficiency levels and frontier shifts

On the right-hand side of the inefficiency and the frontier-shift regressions we include several explanatory variables to control for banks' individual and environmental characteristics. To investigate the impact of IT capital accumulation on productivity we introduce the variable IT_CAP, representing the amount of IT capital stock per employees, split in a more detailed analysis into software and hardware capital stock (respectively SOFT_CAP and HARD_CAP). The variable IT_STAFF represents staff costs for IT personnel divided by total staff costs; the variable OUTSOURCE is given by the fraction of IT expenses coming from outsourcing of computing services.

The development of alternative distributive channels for bank products is measured by the variable REMOTE, defined as the number of remote customers standardized by the total number of current accounts, and the variable ATM_BR, given by the number of automatic teller machines (ATM) divided by the number of branches. We also try to capture features linked to banks' different specialization through the variables SMALL, which stands for the fraction of loans to small and medium-sized firms, and SERVICE, the ratio of income from services to gross income. We include three variables to account for the composition and the degree of utilization of the staff. The variable MANAGERS is defined as the ratio of managers' costs to total staff costs, REDUNDANCE represents the fraction of staff made redundant by the bank, STAFF_BR is given by the average number of employees per branch. The variable CAP, the ratio of capital and reserves to total assets, controls for the degree of capitalization of the bank, the variable M&A measures the increase in assets obtained with mergers. We also include the variable AGE, given by the expression: $AGE = 1 - 1\big/\sqrt{year - foundyear}$ where *foundyear* is the year of foundation of the bank and year is the current date. In this way, differences in the age of the banks are more important for relatively younger banks. The dummies NW, NE, SOUTH, ISL account for geographical differences, while the dummies GROUP1 and GROUP2 have value one if the bank is part of a large group (the top 25 per cent of the group's total assets distribution) or of a medium or small group (the last 75 per cent) respectively. Summary statistics of the variables used in the empirical analysis are reported in Table 3.

5. Results

5.1 Frontier estimates and "catching-up" effects

Figure 1 contains a plot of the average inefficiencies estimated from the cost frontier[19]: the overall sample inefficiency averages 9.2 per cent, with substantial differences across size classes. The result is consistent with previous studies that found X-inefficiency effects to dominate scale inefficiency (Berger and Humphrey, 1991; Berger, 1993). The results of the profit inefficiency analysis are similar to those of the cost one, even if the displacements from the profit frontier present a smaller estimated average value (8.1 per cent) because of the inclusion of quality improvements in the profit specification. Coherently with previous research (Berger and Mester, 2001), the patterns of inefficiency computed with the profit and cost specifications present substantial differences. Small banks always exhibit the lowest inefficiency levels, while medium and large banks display higher distance from the efficient frontier. The time pattern is the same for all bank classes, displaying an increasing inefficiency over the decade. This finding can be attributed to the different speed at which banks respond to the structural changes and the changes in demand experienced by the industry in the '90s.

The parameters of the inefficiency equations, jointly estimated with the translog cost and profit functions, shed some light on the determination of the inefficiency pattern in the Italian banking industry over the decade (Table 4). The effect of IT capital stock on inefficiency, controlling for geographical characteristics and changes in the structure of the market, is negative and statistically significant in both equations. This result confirms that the most IT-capitalized banks are those with the strongest catching-up effect and those that are more likely to be closer to the efficient cost and profit frontier. In particular, for the median bank, an increase of one standard deviation in the level of IT capital per employee will generate a 3.7 per cent cut in costs and a 7.5 per cent profit boost due to decreased inefficiency.

The variable SERVICE, representing the fraction of earnings not coming from loans, has a negative impact on inefficiency, meaning that the banks which have responded more

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[19] The estimated coefficients of the traslog cost and profit functions, not reported in the paper, are available on request.

quickly to shifts on the demand side have also benefited in terms both of lower costs and higher profits.

The coefficient of the variable REMOTE is negative, albeit significative only in the profit regression, indicating a positive correlation between efficiency and innovation in delivery channels of banking services, even if we cannot exclude a reverse direction of causality. On the contrary, banks with a larger number of ATM per branch display greater inefficiency. One interpretation is that, in the majority of cases, the downsize in staff required by large-scale automation of some basic activities takes time or it is not fully adjusted, leading to some excess capacity. The existence of frictions in the adjustment of labor, which is supported by the estimated negative correlation between inefficiency and the fraction of staff made redundant, is a consequence of major restructuring plans (REDUNDANCE).

Inefficiency is also positively correlated with the ratio of capital to total assets (CAP_ASS). Again the causality link is ambiguous. Large capital ratios may follow from excess capacity or may be due to agency problems: more efficient banks can signal their quality through a high leverage as in Berger and Bonaccorsi di Patti (2002).

Mergers and acquisitions are negatively correlated with inefficiency. Since we use pro-forma data, this result simply means that banks which buy other banks have above-average efficiency scores, a well-established result in the M&A literature (Focarelli et al., 2002). The dummy variables identifying the partnership in a large (GROUP1) or small (GROUP2) banking group have estimated coefficients with positive signs in the cost function and negative signs in the profit regression. Most of these banks have been acquired by a bank holding company during the sample period. Target banks were usually poorly performing, and restructuring within the banking group has initially focused on the revenue side and only later gradually extended to the cost side (Focarelli et al., 2002).

The AGE variable is negatively correlated with inefficiency: this may be due to the time needed by the *de novo* banks to reach their optimal level of capacity utilization. Finally, the geographical dummies show that banks with headquarters in the richest regions of the country (NE and NW) are closer to the efficient frontier than banks located elsewhere.

5.2 Frontier shift regressions

Tables 5 and 6 report the results of the panel data estimation of equation 9 relatively to cost and profit shifts. A negative sign of a coefficient in Table 5 implies that an increase in the value of the corresponding variable is associated with a reduction in industry best practice costs. In a similar way a positive sign of a coefficient in Table 6 implies that an increase in that variable is associated with an increase in best practice profits. The first three columns report the results of different specifications of the IT variables for the entire sample. In the last three columns we check for differences owing to bank size.

In columns A, D, E and F, IT capital deepening is measured simply by total IT capital per employee. The results are consistent with the hypothesis that computers and related technologies lead to substantial increases in total factor productivity, here indirectly measured by frontier shifts. The coefficient of the IT capital variable is different from zero at high significance levels, and the sign is negative for the cost frontier regression and positive for the profit frontier one. The result holds true across all bank size classes (columns D, E, and F) and does not depend on the type of frontier we consider. In particular, as expected the IT capital effect is greater for smaller banks, which are less likely to be closer to the optimal level of IT capital stock and so to suffer excess capacity. For the median bank, an increase of one standard deviation in the level of IT capital per employee will generate a favorable frontier cost shift of the order of the 8 per cent both on costs and profits.

In columns B we have split IT capital into two broad categories: hardware and software. The coefficient of the HARD_CAP variable is negative in the cost function and positive in the profit function and statistically significant, indicating a favorable effect of computers on productivity. The coefficients of SOFT_CAP are estimated less precisely and have an opposite pattern of signs. A possible explanation is that software capital stock is poorly measured because hedonic prices do not account properly for quality improvements (Jorgenson and Stiroh, 2000).

In columns C we introduce a variable aiming to capture the impact of IT on labor organization: the fraction of salary expenses devoted to IT staff. This variable is available only for a sub-sample of banks (about half of the total number). The sign of the coefficient of this variable is positive in the cost frontier and negative in the profit frontier, meaning that the within-firm production of IT services is detrimental to TFP growth. Accordingly, the variable OUTSOURCE, measuring the amount of IT-related expenses for outsourced activities, is positively correlated with favorable frontier shifts in all the columns in Tables 5 and 6. These results are consistent with the findings about the importance of within firm organization for achieving productivity growth through IT capital accumulation.

Once we rule out the effect of excess capacity, considering only fully efficient banks (i.e. the projection of the banks on the efficient frontier) we find that the variables SERVICE, CAP_ASS and ATM_BR are positively correlated with productivity. The number of staff per branch (STAFF_BR), the share of managers' salaries in total salaries (MANAGERS) and that of small business loans in total loans (SMALL) are negatively correlated with TFP growth. All these three variables capture the specialization of retail banks for which the route to innovation has been less straightforward.

6. Conclusions

In this paper we have investigated the effect of information technologies on the Italian banking industry over the period 1989-2000. We have estimated stochastic cost and profit functions allowing for individual banks' displacements from the efficient frontier and non-neutral technological change. Data on IT capital stock for individual banks enabled us to distinguish between movements along the efficient frontier and shifts of the frontier owing to the adoption of new technologies. Several studies have emphasized the role of technological innovation as a primary source of structural changes within the financial industry. However, empirical evidence on the effects of technical progress in increasing TFP and abating unit costs is still scarce.

We found that both cost and profit frontier shifts are strongly correlated with IT capital accumulation. Banks adopting IT capital intensive techniques are also closer in average to the best practice of the banking industry, implying ceteris paribus a higher level of efficiency. We interpret this last result as evidence of a catching-up effect consistent with the usual pattern of diffusion of the new technologies.

Tables and figures

Table 1

BANKS' IT EXPENSES

Year	IT expenses as a percentage of		Composition of IT expenses					
	Gross income	Operating costs	Hardware	Software	Staff	Outsourcing	Others	Total
1989	5.6	9.0	26.1	9.9	32.2	13.9	17.9	100.0
1990	5.8	9.4	27.2	10.8	30.3	14.4	17.3	100.0
1991	6.1	9.5	27.1	10.7	29.8	14.8	17.7	100.0
1992	6.0	9.2	24.4	12.4	28.9	14.9	19.5	100.0
1993	5.5	9.1	23.4	13.2	26.5	16.4	20.5	100.0
1994	6.6	9.8	22.0	13.4	26.8	17.7	20.0	100.0
1995	6.7	9.9	19.2	13.6	25.1	22.3	19.8	100.0
1996	6.4	9.6	16.6	15.2	21.7	25.3	21.2	100.0
1997	6.4	9.4	16.9	16.7	21.2	25.6	19.7	100.0
1998	7.4	12.2	21.3	20.7	16.5	17.8	23.7	100.0
1999	7.6	12.8	19.7	19.7	15.0	26.6	19.0	100.0
2000	7.6	13.5	14.9	18.3	12.4	38.7	15.8	100.0
2001	8.0	14.5	15.6	20.8	10.4	34.1	19.2	100.0

Sources: Bank Supervisory Reports.

Table 2

BANKS' IT INVESTMENT AND CAPITAL STOCK*

(1989=100)

	Nominal IT investments		Real IT investments		IT Capital	
Year	Hardware	Software	Hardware	Software	Total	Per employee
1989	100	100	100	100	100	100
1990	101	126	135	154	129	125
1991	114	149	154	166	155	148
1992	112	179	158	188	176	167
1993	98	191	133	164	179	168
1994	101	222	164	205	193	182
1995	96	295	185	270	215	202
1996	97	268	258	264	254	243
1997	99	337	302	302	300	292
1998	123	430	523	405	421	414
1999	91	370	430	300	458	455
2000	105	393	535	289	522	514
2001	107	453	656	312	612	599

Sources: Bank Supervisory Reports, ISTAT and BEA. * Adjusted for inflation.

Table 3

DESCRIPTIVE STATISTICS: VARIABLES USED IN THE ESTIMATION

All financial variables are measured in ITL million and are adjusted for inflation. Statistics refer to the panel of 618 banks for the period 1989-2000 with the exception of internet banking accounts, available from 1995.

Symbol	Description	Obs.	Mean	Min	Max	St.dev
COST	Log of total cost (divided by the price of labor)	5231	5.077	1.676	10.696	2.006
PROF	Log of gross profit (divided by the price of labor)	5231	8.2889	2.480	10.279	.316
Y1	Log of short-term loans	5231	4.341	-5.276	10.902	1.932
Y2	Log of long-term loans	5231	4.000	-1.440	10.952	1.744
Y3	Log of services weighted commission income.	5231	5.167	-2.624	10.786	1.611
Y4	Log of deposits	5231	-0.181	-5.291	7.151	2.107
P1	Log of IT capital price (divided by the labor price)	5231	2.069	0.253	3.744	0.620
P2	Log of branches price (divided by the labor price)	5231	-0.137	-1.266	1.833	0.530
CAP_ASS	Capital divided by total assets	5231	0.093	0.017	0.396	0.034
AGE	$1-1/\sqrt{\text{bank age}}$	5231	0.842	0.000	0.875	0.082
SERVICE	Net services value revenue divided by gross income	5231	0.060	-0.983	0.556	0.060
SMALL	Value of small loans (under 5 billion lire) over total loans	5231	0.675	0.023	1.000	0.197
GROUP1	Part of a big group (top 25 % of the groups' total asset distribution)	5231	0.059	0.000	1.000	0.236
GROUP2	Part of a medium or small group (last 75 % of the groups' total asset distribution)	5231	0.088	0.000	1.000	0.283
MERACQ	Relative increase in total assets of the bank due to M&A	5231	0.011	0.000	1.536	0.066
STAFF_BR	Number of employees divided by number of branches	5231	11.200	2.000	242.00	10.057
MANAGERS	Wages paid to managers divided by total wages.	5213	36.189	0.520	331.46	26.645
REDUNDANCE	Number of redundant employees divided by total staff	5231	0.001	0.000	0.519	0.012
IT_CAP	Stock of real IT capital per employee (billion lire)	5231	0.056	0.001	0.482	0.044
HARD_CAP	Stock of real hardware capital per employee (billion lire)	5231	0.051	0.000	0.467	0.042
SOFT_CAP	Stock of real software capital per employee (billion lire)	5231	0.004	0.000	0.060	0.004
OUTSOURCE	Share of IT expenses due to outsourcing of services	5100	.3689	0.000	1.000	.2996
IT_STAFF	Wages paid to IT personnel divided by total wages	3031	0.055	0.000	1.000	0.070
REMOTE	Number of phone and electronic banking accounts of households divided by total number of current accounts.	5231	0.018	0.000	1.000	0.091
ATM_BR	Number of ATM divided by number of branches.	5231	0.526	0.000	20.00	0.750
NW	Headquarters in the North-West	5231	0.201	0.000	1.000	0.401
NE	Headquarters in the North-Est	5231	0.408	0.000	1.000	0.492
CE	Headquarters in the Centre	5231	0.211	0.000	1.000	0.408
SOUTH	Headquarters in the South or islands	5231	0.180	0.000	1.000	0.384

Sources: Bank Supervisory Reports.

Table 4

COST AND PROFIT INEFFICIENCY CORRELATES

The dependent variables are respectively the cost and the profit inefficiencies jointly estimated from the translog specification of Table 4. A complete description of the independent variables is given in Table 3.

Variables	COST INEFFICIENCY	PROFIT INEFFICIENCY
CONSTANT	0.2126 ***	0.8587 ***
	0.0568	0.0651
TREND	0.0117 ***	0.0352 ***
	0.0038	0.0068
IT_CAP	-0.9100 ***	-1.7889 ***
	0.1939	0.3683
SERVICE	-1.5195 ***	-1.2455 ***
	0.2018	0.0482
REMOTE	-0.0294	-0.0592 *
	0.0551	0.0347
ATM_BR	0.0192 ***	0.0417 ***
	0.0078	0.0077
REDUNDANCE	-0.0148	-0.8690 ***
	0.2841	0.2184
CAP_ASS	0.0139	3.9501 ***
	0.1510	0.4436
MERACQ	-0.0293	-0.2367 ***
	0.0721	0.0422
GROUP1	0.0661 ***	-0.7449 ***
	0.0210	0.0961
GROUP2	0.1665 ***	-0.6888 ***
	0.0288	0.0877
AGE	-0.0095	-0.6347 ***
	0.0569	0.0266
NW	-0.3572 ***	-0.3838 ***
	0.0609	0.0212
NE	-0.4983 ***	-0.0438 *
	0.0943	0.0228
CE	-0.2293 ***	-0.0156
	0.0384	0.0266
σ^2	0.0521 ***	0.0669 ***
	0.0039	0.0086
γ	0.4419 ***	0.8320 ***
	0.0511	0.0282

Observations = 5231
Cross-sections = 618
Time periods = *12*

Note: Statistically different from zero, respectively, at: *** 99%, **95% and *90% significance level.

Table 5

COST FUNCTION SHIFTS

The dependent variable is the time derivative of the cost function estimated in Table 4. A complete description of the independent variables is given in Table 3. The full sample regression refers to the sample employed for estimations in Tables 4 and 5, reduced by the missing values in the OUTSOURCING and the IT_STAFF variables. The *Large banks* sample refers to the top 10 per cent of banks in total asset distribution, the *Medium banks* sample include banks from the 33 to the 10 per cent and the *Small banks* the last 66 per cent of banks. For the estimated coefficients, a positive sign implies an increasing effect on costs and a correspondent decreasing effect on productivity.

Variables	(A) FULL SAMPLE	(B) FULL SAMPLE	(C) FULL SAMPLE	(D) LARGE BANKS	(E) MEDIUM BANKS	(F) SMALL BANKS
CONSTANT	0.1296***	0.1297***	0.0826***	0.0399	0.0746***	0.2700***
	0.0119	0.0119	0.0129	0.0281	0.0163	0.0211
IT CAP	-0.1597***		-0.1412***	-0.1022**	-0.0747***	-0.1953***
	0.0131		0.0198	0.0501	0.0216	0.0163
HARDW CAP		-0.1753***				
		0.0142				
SOFTW CAP		0.2759*				
		0.1486				
IT STAFF			0.0851***			
			0.0173			
OUTSOURCING	-0.0109	-0.0098***	-0.0220***	-0.0345***	-0.0252***	-0.0018
	0.0024	0.0024	0.0041	0.0105	0.0042	0.0029
ATM BR	-0.0362***	-0.0364***	-0.0368***	-0.0355***	-0.0385***	-0.0326***
	0.0009	0.0009	0.0012	0.0030	0.0016	0.0011
REMOTE	-0.0007	0.0002	-0.0014	0.0092	-0.0172***	0.0265***
	0.0058	0.0058	0.0080	0.0332	0.0062	0.0099
CAP ASS	-0.7754***	-0.7739***	-0.7348***	-0.2278**	-0.6437***	-0.7691***
	0.0250	0.0250	0.0300	0.0973	0.0440	0.0318
SMALL	0.0761***	0.0744***	0.0949***	0.0789***	0.0672***	0.0706***
	0.0063	0.0063	0.0089	0.0259	0.0124	0.0074
SERVICE	-0.2267***	-0.2229***	-0.1980***	-0.1207***	-0.2288***	-0.2819***
	0.0117	0.0118	0.0149	0.0303	0.0176	0.0185
STAFF DEN	0.0023***	0.0023***	0.0024***	0.0022***	0.0028***	0.0025***
	0.0001	0.0001	0.0002	0.0002	0.0003	0.0002
REDUNDANCE	0.0838*	0.0777*	0.0592	-0.0934	-0.1494	0.1383**
	0.0446	0.0446	0.0619	0.1041	0.1109	0.0552
MANAGERS	0.0002***	0.0002***	0.0001***	0.0000	0.0000	0.0004***
	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
MERACQ	0.0133**	0.0134**	0.0159*	-0.0289	0.0096	0.0216***
	0.0066	0.0066	0.0084	0.0429	0.0129	0.0074
GROUP2	-0.0231***	-0.0234***	-0.0251***	-0.0324***	-0.0241***	-0.0263
	0.0026	0.0026	0.0027	0.0114	0.0025	0.0244
GROUP1	-0.0162***	-0.0167***	-0.0174***	-0.0151***	-0.0205***	- -
	0.0026	0.0026	0.0027	0.0053	0.0029	
AGE	-0.0957***	-0.0966***	-0.0607***	-0.0363	-0.0140	-0.2764***
	0.0125	0.0125	0.0124	0.0272	0.0156	0.0239
Observations	5082	5082	2921	435	1318	3329
Banks	612	612	396	49	146	417
R-squared (within)	0.756	0.757	0.787	0.698	0.836	0.760
R-squared (between)	0.001	0.001	0.014	0.049	0.329	0.016
R-squared (overall)	0.440	0.439	0.451	0.405	0.688	0.375

Note: Statistically different from zero, respectively, at: *** 99%, **95% and *90% significance level.

PROFIT FUNCTION SHIFTS

The dependent variable is the time derivative of the profit function estimated in Table 4. A complete description of the independent variables is given in Table 3. The full sample regression refers to the sample employed for estimations in Tables 4 and 5, reduced by the missing values in the OUTSOURCING and the IT_STAFF variables. The *Large banks* sample refers to the top 10 per cent of banks in total asset distribution, the *Medium banks* sample include banks from the 33 to the 10 per cent and the *Small banks* the last 66 per cent of banks. For the estimated coefficients, a positive sign implies an increasing effect on profits and a correspondent increasing effect on productivity.

Variables	(A) FULL SAMPLE	(B) FULL SAMPLE	(C) FULL SAMPLE	(D) LARGE BANKS	(E) MEDIUM BANKS	(F) SMALL BANKS
CONSTANT	-0.1376***	-0.1379***	-0.0940***	-0.0507**	-0.0825***	-0.2575***
	0.0086	0.0086	0.0092	0.0203	0.0119	0.0150
IT CAP	0.1351***		0.1362 ***	0.1271***	0.0699***	0.1545***
	0.0094		0.0141	0.0363	0.0158	0.0116
HARDW CAP		0.1419***				
		0.0102				
SOFTW CAP		-0.0706				
		0.1071				
IT STAFF			-0.0705 ***			
			0.0124			
OUTSOURCING	0.0124***	0.0118***	0.0205 ***	0.0258***	0.0222***	0.0060***
	0.0017	0.0017	0.0029	0.0076	0.0031	0.0021
ATM BR	0.0258***	0.0259***	0.0262 ***	0.0278***	0.0287***	0.0221***
	0.0006	0.0006	0.0008	0.0022	0.0011	0.0008
REMOTE	0.0001	-0.0003	0.0067	0.0255	0.0134***	-0.0238***
	0.0042	0.0042	0.0057	0.0240	0.0046	0.0070
CAP ASS	0.5722***	0.5721***	0.5461 ***	0.2003***	0.4855***	0.5625***
	0.0180	0.0180	0.0214	0.0705	0.0322	0.0225
SMALL	-0.0518***	-0.0509***	-0.0634 ***	-0.0480**	-0.0440***	-0.0473***
	0.0045	0.0045	0.0064	0.0188	0.0091	0.0052
SERVICE	0.2333***	0.2317***	0.2019 ***	0.1234***	0.2293***	0.2899***
	0.0084	0.0085	0.0107	0.0220	0.0129	0.0131
STAFF DEN	-0.0020***	-0.0020***	-0.0021 ***	-0.0018***	-0.0022***	-0.0023***
	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002
REDUNDANCE	-0.0579*	-0.0549*	-0.0222	0.0888	0.1299*	-0.1162***
	0.0321	0.0321	0.0442	0.0754	0.0812	0.0391
MANAGERS	-0.0003***	-0.0003***	-0.0002 ***	-0.0002***	-0.0001***	-0.0005***
	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
MERACQ	-0.0026	-0.0026	-0.0018	0.0264	-0.0025	-0.0081
	0.0048	0.0048	0.0060	0.0311	0.0094	0.0052
GROUP2	0.0190***	0.0192***	0.0195 ***	0.0259***	0.0194***	0.0409***
	0.0019	0.0019	0.0019	0.0083	0.0018	0.0173
GROUP1	0.0152***	0.0155***	0.0160 ***	0.0157***	0.0178***	- -
	0.0019	0.0019	0.0019	0.0038	0.0021	
AGE	0.0694***	0.0700***	0.0393 ***	0.0197	0.0074	0.2134***
	0.0090	0.0090	0.0089	0.0197	0.0114	0.0169
Observations	5082	5082	2921	435	1318	3329
Banks	612	612	396	49	146	417
R-squared (within)	0.801	0.801	0.833	0.785	0.871	0.800
R-squared (between)	0.046	0.044	0.152	0.067	0.307	0.033
R-squared (overall)	0.493	0.490	0.551	0.484	0.706	0.433

Note: Statistically different from zero, respectively, at: *** 99%, **95% and *90% significance level.

Figure 1

INEFFICIENCY ESTIMATES FOR THE COST FUNCTION MODEL

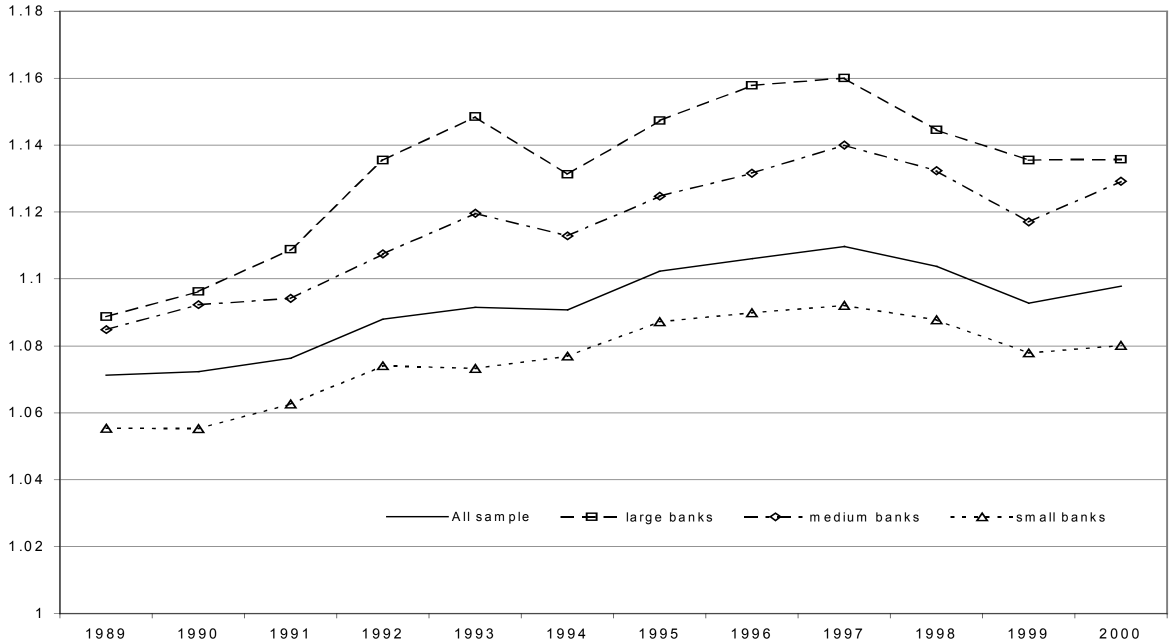
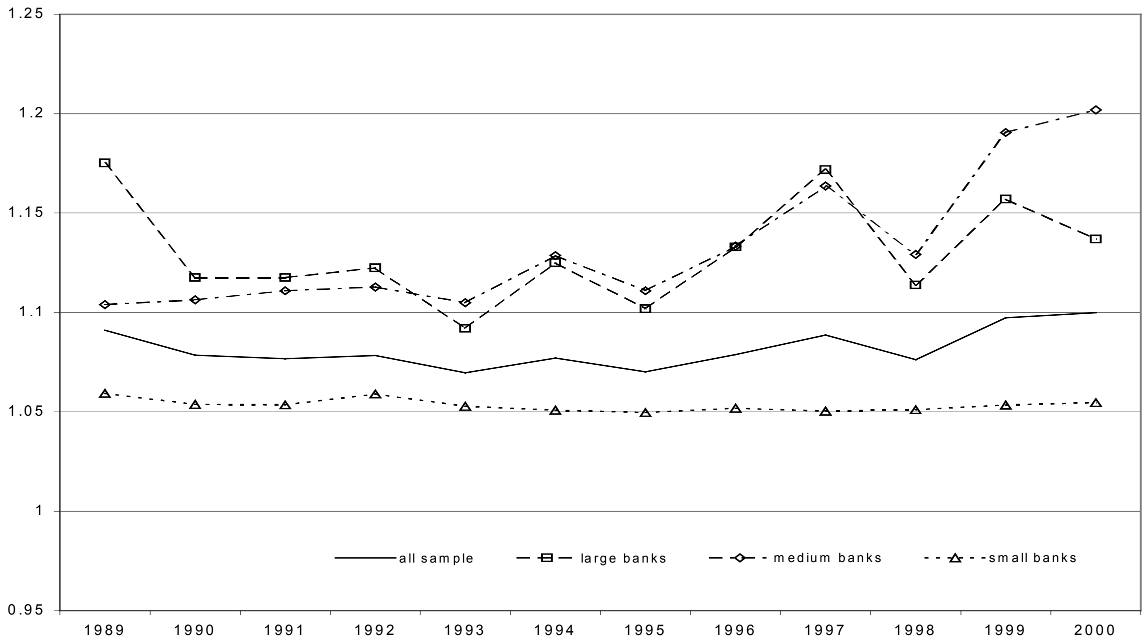


Figure 2

INEFFICIENCY ESTIMATES FOR THE PROFIT FUNCTION MODEL



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