Università degli Studi di Macerata
Dipartimento di Istituzioni Economiche e Finanziarie

Does IT investment improve bank performance? Evidence from Europe

Elena Beccalli

Temi di discussione n. 33

Does IT investment improve bank performance? Evidence from Europe[*]

Elena Beccalli

Abstract

This paper investigates whether investment in Information Technology (IT) – hardware, software and other IT services – influences the performance of banks. Using a sample of 737 European banks over the period 1993-2000 we analyse whether IT investment is reflected in improved performance (measured using both standard accounting ratios and cost and alternative profit efficiency measures). Despite banks being major investors in IT we find little relationship between total IT investment and improved bank profitability or efficiency indicating the existence of a profitability paradox. However, the impact of different types of IT investment (hardware, software and services) on banks' performance is heterogeneous. Investment in IT services from external providers (consulting services, implementation services, training and education, support services) appears to have a positive influence on accounting profits and profit efficiency, while the acquisition of hardware and software seems to reduce banks' performance.

Elena Beccalli, Dipartimento di Istituzioni Economiche e Finanziarie, Università degli Studi di Macerata, Via Crescimbeni 20, 62100, Macerata, Italy, beccalli.elena@unimc.it

[*] *I am grateful for the constructive comments offered by Philip Molyneux, Peter Miller, Agostino Fusconi, Francesco Cesarini, Andrea Sironi, Pascal Frantz, Francesco Virili, Mario Anolli, and participants at the Wolpertinger 2005 Meeting, the European Accounting Association Conference 2005, research colloquia at Università Cattolica del Sacro Cuore (Milan).*

1 Introduction

The impact of Information Technology (IT) investments in European banking is an important issue as this type of investment constitutes a substantial component of costs and exerts a strong influence on bank operations and strategy. Most financial products and services use IT at some point in the production and delivery process, and a bank's information system places strong constraints on the type of products offered, the degree of customisation possible, and the speed at which banks can respond to competitive opportunities or threats.

A handful of studies (Council of Economic Advisors, 2001; McKinsey Global Institute, 2001) on the performance of IT investments in US banking show weak or non-existent links between IT spending and productivity even in recent years (specifically post-1995). This confirms the persistence in the US banking industry of the productivity paradox, which refers to the absence of a positive impact of IT investments on productivity (as originally identified by Solow, 1987). This finding appears counterintuitive as banks represent the industry with the highest proportion of IT investments both in the US (Council of Economic Advisors, 2001) and in the EU (European Information Technology Observatory, EITO, 1996-2002).

The surprising confirmation of the productivity paradox in US banking provides the major motivation for this study which aims to investigate the relationship between performance and IT investments in the banking industry in the period between 1995 and 2000. This responds to the direction for future research as suggested by Dedrick *et al.* (2003). Furthermore, although the productivity paradox also appears to be an international phenomenon, virtually all of the considerable debate on the subject has been restricted to the US economy. As far as we are aware there are no studies on IT investment and its impact on bank performance in Europe. This is due in part to the difficulties of modelling successfully the peculiar nature of bank's production processes (mainly in terms of the identification of variables that accurately represent the activities of firms), and also in part to the lack of good quality data on bank IT spending. Our aim is to extend the scope of the established literature by examining the experience of EU banking industries and IT investment during the 1990's to see if such spending has had an influence on bank performance and efficiency.

A further motivation for this study stems from the recent interest in investigating the performance of IT investments and its link to the competitive strategy literature: competitive advantage stems from various organisational dynamic capabilities, which can relate to the effective use of IT that results in such things as timely responsiveness, rapid and flexible product innovation, and enhanced management capabilities (Teece and Pisano, 1994). The aim, therefore, is to investigate whether IT investments improve performance and if this is the case it can be inferred that such spending impacts positively on organisational capabilities resulting in improved competitive advantage. This is also related to the recent debate on the strategic role of IT: should IT be seen as a "strategic necessity" (or rather as a commodity and not as a source of strategic differentiation, as argued by Clemons, 1991; Carr, 2003), or does IT represent a "strategic opportunity" (a source of sustainable competitive advantage as counter-argued by Strassman, 2003; Seely Brown and Hagel III, 2003)? The diverse empirical studies that have investigated these types of issues outside the financial sector (Shin, 2001; Tam, 1998; Rai *et al.*, 1997; Hitt and Brynjolfsson, 1996; Barua *et al.*, 1995; Strassmann, 1990; Weill, 1992; Alpar and Kim, 1990) provide mixed evidence and many fail to show a clear link between IT investment and performance.

In order to respond to the direction for future research on the impact of IT spending as proposed by Brynjolfsson (1993), we consider various other business performance measures other than traditional financial ratios. While IT investments can directly affect a bank's production including its output and other operational features, the financial performance of a bank is determined by a broader range of strategic and competitive factors. The limits of traditional financial accounting measures in finding improved performance relating to IT spending likely stem from their inability to quantify and incorporate the various unobservable impact on such features like: improved quality, customer services, speed and responsiveness, product variety and so on (Sambamurthy and Zmud, 1994). As noted by, the inability of traditional performance indicators to take account of output and input mix and non-contemporaneous relationships are often cited (e.g. see Brynjolfsson, 1993) as the two main reasons for widespread findings on the productivity paradox. It is possible that the benefits of IT investments are quite large, but that a proper index of its true impact has yet to be analysed.

To overcome these limits, this study investigates the performance of banks using both traditional financial profitability measures (such as return on equity and return on assets) and a global measure of operational productivity, the so called X-efficiency (both cost and alternative profit efficiency) to test for evidence of the productivity paradox in the EU banking industry. Moreover, given that it takes time for organisations to assimilate new technology and to implement changes in business activities (DeLone and McLean, 1992), we examine whether there is a lag between the realisation of IT investments and the occurrence of potential benefits. Also, instead of treating IT investment as a single entity, we also examine the key components of IT investments (hardware, software and IT services) to see if spending in different IT areas impacts on bank performance measures.

The paper is organised as follows. Section 2 provides a literature review and notes the motivation for our study. Section 3 outlines the methodological approach, and illustrates the sample and data. Finally section 4 describes the empirical results, and section 5 is the conclusion.

2 Literature and motivations

The interest in IT investments in the banking industry comes from the intrinsic nature of banking activities: to process, manage, and strategically use information. Several consequences arise. First, IT has facilitated the development of new, more sophisticated financial products as well as the introduction of alternative delivery channels to the traditional branch network (White, 1998). Second, IT shapes the ways in which banks carry out their business, with the application of new and improved technologies expected to reduce bank costs over time. Third, in the EU, the development of cost-saving technology, together with deregulation, has intensified financial sector competition. As a result, rationalisation and cost management are salient bank strategic objectives (De Bandt and Davis, 2000), and IT investments are perceived as a "necessity" to pursue this strategy. Fourth, banks are increasingly recognising the need to focus strategically on the improvement of quality (through customer information management, multiple-products and multiple-channels approaches), and again IT investment is viewed as a "necessity/opportunity" to pursue this strategy. Finally, technological progress has been cited widely as one of the major sources of change in the financial services industry (Fusconi, 1996; European Commission, 1997; European Central Bank, 1999; Bank for International Settlements, 1999).

Surprisingly, the successful use of IT in the banking industry has not been confirmed by the existing empirical evidence (Council of Economic Advisers, 2001; McKinsey Global Institute, 2001). These studies show weak or non-existing links between IT and productivity in the US even in the period post 1995. The aforementioned studies use measures such as labour productivity growth, expressed as the average annual percentage change in the value added per full time equivalent employee, to investigate productivity issues. However, none examines more traditional accounting performance indicators or more technical productive efficiency estimates to gauge the impact of IT spending.

In interpreting past findings on the productivity paradox, our primary objective is to investigate whether IT investments have improved business profitability (and not simply productivity) in the EU banking industry. The interest is to find out whether banks are able to use IT to gain competitive advantage and earn higher profits than they would have earned otherwise.[1] For this purpose, this study employs multiple measures of (contemporaneous and lagged) bank performance (both standard profitability ratios as well as more advanced operational productivity measures – cost and profit efficiency) to investigate the influence of different elements of IT spending (hardware, software and services) on bank performance.

The competitive strategy theory aims to answer to the above question of whether firms will gain a competitive advantage from IT investment, and therefore higher profits or firm values[2]. If a bank has unique access to IT, then such a bank may be in a position to earn higher profits from that access, and gain a competitive advantage[3]. Conversely, an alternative argument is that IT investment will not confer supernormal profits to any bank in the industry if it is freely available to all participants.[4] In this case, there is no reason to expect, *a priori*, that a bank spending more (or less) on IT than its competitors will have higher (lower) profits. Instead, all banks will use the amount of IT they consider optimal in equilibrium, but none will gain a competitive advantage from such spending. It follows that IT may be viewed as a strategic necessity, and not as a source of competitive advantage. When IT becomes ubiquitous (availability increased, and costs decreased), it becomes a commodity input. From a strategic standpoint, IT becomes invisible: it becomes essential to competition but inconsequential to strategy

[1]Therefore, the reference is not to the production theory, which has been extensively used to evaluate whether IT investments increase productivity. Following on, the aim of the present study is not to investigate whether IT investments enable banks to produce more output given the input.

[2]Note that the theory of production predicts that lower prices of IT will create benefits in the form of lower production costs for a given output (Moore's Law). The Moore's Law, after John Moore, who first documented the trend in microprocessors, states that the price of computing drops by half every 2-3 years. In the last 35 years, the quality-adjusted costs of computing have decreased over 6000-fold relative to equipment prices outside the computer sector (Gordon, 1987).

[3]Only in presence of barriers to entry (defined in accordance to Bain, 1965, as anything that allows firms to earn supernormal profits, such as patents, economies of scale, search costs, product differentiation, or preferential access to scarce resources), IT (or any input) can lead to sustained supernormal profits in the industry. There are two alternative ways in which IT can affect barriers to entry. First, in industries with existing barriers to entry, the innovative use of IT may enable firms to increase profits, provided that barriers to entry remain intact. Second, the use of IT may rise or lower existing barriers or create new ones, thus changing the profitability of individual firms and industries. The impact of IT on barriers to entry is ambiguous

[4]This follows from Porter (1980). In a competitive market with free entry, firms cannot earn sustainable supernormal profits, because that would encourage other firms to enter and drive down prices.

(Carr, 2003).

Within the IT literature, the competitive strategy theory does not clearly predict either a positive or negative relationship between IT spending and profitability / performance. To overcome this ambiguity, this paper combines and extends – for the first time - two large bodies of studies: the IT literature on the economics of IT and the banking efficiency literature. At this purpose, we briefly summarise this literature on the economics of IT, which examines the impact of IT on profitability measures in the short run by adopting a competitive strategy framework.[5]

Compared to the IT productivity paradox[6], the question of whether IT contributes to profitability has not yet been clearly answered. Some of the previous research has examined the correlation between IT spending and operating profitability as measured by ROA (Shin, 2001; Tam, 1998; Rai *et al.*, 1997; Hitt and Brynjolfsson, 1996; Barua *et al.*, 1995; Ahituv and Giladi, 1993; Weill,1992; Strassmann, 1985, 1990), between IT spending and ROE (Shin, 2001; Tam, 1998; Rai *et al.*, 1997; Hitt and Brynjolfsson, 1996; Alpar and Kim, 1990), and between IT spending and profitability as measured by operating profits to operating revenues (Markus and Soh, 1993). Some studies have attempted to examine correlations between IT spending and total shareholder return (Dos Santos *et al.*, 1993; Strassmann, 1990), while

[5]Conversely, the long term variation in average cost due to a given change in technology (known as technical change) has been largely investigated by the banking literature (Hunter and Timme, 1991; Berger and Humphrey, 1992; Bauer *et al.*, 1993; Berger and DeYoung, 2002; Altunbas, Goddard, and Molyneux.,1999; 2001), but not in the IT literature. Most previous empirical measurement of the banking technical change has been based on the econometric approach, which involves the inclusion of a deterministic time trend in the estimation of a production function. However, the drawback of such a representation is that such time variable may capture things other than technological change that occurred over time. It therefore may not represent the pure effect of IT on production and costs (Hunter and Timme, 1991). Much of the studies on technical change refers to banks, and they generally suggest that technical change determined a reduction of costs (reduction increasing with banks size). Hunter and Timme (1991) estimate technological change for large US commercial banks between 1980-86. They find that the real cost of bank production fell by about 1.0% per year, and larger banks realise a greater cost reduction than smaller banks. The number of pan-European studies on the impact of technical change on bank costs remains limited (Altunbas, Goddard, and Molyneux, 1999; 2001): they find that the reduction in costs has accelerated between 1989 and 1996 (resulting in a 3.6% reduction in 1996), and that the impact of technical progress in reducing bank costs systematically increases with banks size.

[6]Previous researches (Brynjolfsson and Hitt, 2000; Jorgenson and Stiroh, 2000) have found that, on average, IT increases productivity for most of the US industries post 1995: therefore, the IT productivity paradox has been resolved for most industries. However, the banking industry is one of the few exceptions, where the IT productivity paradox remains confirmed (Council of Economic Advisors: 2001; McKinsey Global Institute, 2001).

others examined how IT influences intermediate variables of operational performance, which in turn drive profits (Barua *et al.*, 1995). In general these studies have so far failed to show a clear link from IT investment to profitability, although some models are plagued by relatively low predictive power overall. Neither earlier studies (Strassmann, 1990; Ahituv and Giladi, 1993; Markus and Soh, 1993) nor more recent analysis (Shin, 2001; Tam, 1998; Rai *et al.*, 1997; Hitt and Brynjolfsson, 1996; Barua *et al.,* 1995) find evidence of clear positive effects of IT on financial profitability: this seems to suggest the existence of an IT profitability paradox. Although Hitt and Brynjolfsson (1996) document the positive impact of IT on output and consumer surplus, they do not find a significant positive correlation between IT spending and financial/operating performance. Similarly, Barua *et al.* (1995) found that IT investment affects intermediate measures (such as inventory turnover) but found no evidence on the benefits extended to firm performance as measured by return on assets (ROA). As regard to banks, Markus and Soh (1993) find that not all banks achieved clear financial benefits from IT spending: small banks did not show a significant association between IT spending and profitability; while large banks had negative returns from their contemporaneous IT spending. Note that, with the exception of Barua *et al.* (1995) and Rai *et al.* (1997), the models have generally not controlled for various industry-specific or firm-specific factors other than IT spending.

Most of the above studies refer to IT spending not in the banking industry; the only exception is Markus and Soh (1993). For the non-banking industry, previous researches have shown the contribution of IT to operating and financial profitability to be minimal, negative or mixed. This paper therefore aims to examine the IT profitability paradox in the competitive strategy framework for the banking industry, and to extend and integrate the above IT literature by shifting the focus from the traditional profitability measures to an efficiency measure derived from the banking literature, as described in the next paragraph.

3 Methodology

Our study uses a variety of ways to specify the relationship between IT investments and performance in the short term, by regressing contemporaneous and lagged bank performance on the bank IT investments.

3.1 The Sample

This study represents the first attempt to measure the relationship between performance and IT investments in European banking. This study uses information on banks IT investments in the hardware, software and other IT services areas, as well as balance sheet and income statement data for a sample of 737 commercial banks based in five EU countries (France, Germany, Italy, Spain and UK). The sample includes all commercial banks for which annual data were available for some or all years during the period 1993-2000, giving a pooled total of 4414 observations. Table 1 shows the number of banks constituting the sample of each country and the panel over the period under observation.

The bank balance sheet and income statement data were obtained from the London based International Bank Credit Analysis Ltd's 'Bankscope' database and from Financial Analysis Made Easy (FAME) database. Information on bank-specific IT spending was obtained from International Data Corporation (IDC, 2002). Note that no disclosure of IT investments is specifically required by accounting standards, banking laws or stock exchange reporting requirements in the EU. As a consequence there is little detail or consistent disclosure of IT investments contained within financial statements of EU banks. What disclosure there is, is largely voluntary. As such the information obtained are proxies for IT investment provided commercially by International Data Corporation.[7]

3.2 IT investments and economic performance in the short term

In this study the initial approach to test the relationship between bank profitability and IT investments follows the existing IT literature on the paradox in the competitive strategy framework (reviewed above). A country level approach is used (see Dewan and Kraemer, 1998 for a summary of the advantages of the country-level approach). While there is no single standard form for estimating the relationship, we began by analysing simple correlations following Strassmann (1990).[8]

To further examine the relationship between IT investment and perfor-

[7]Therefore the term "investment" does not assume any accounting qualification, and the accounting distinction between "investment" and "spending" is not relevant here (thus the two terms have been used interchangeably throughout).

[8]We test both the non-parametric Spearman's rank correlation and the parametric Pearson's correlation.

mance we estimate the following cross-country models:

$$P_{j,t+i} = \beta_0 + \beta_{jt} IT_{jt} + \varepsilon_{jt} \quad (1)$$

$$P_{jt} = \beta_0 + \beta_{jt} HA_{jt} + \beta_{jt} SO_{jt} + \beta_{jt} SE_{jt} + \varepsilon_{jt} \quad (2)$$

where:

$P_{j,t+i}$ = either annual accounting performance ratios (return on assets and return on equity) or annual X-efficiency (both cost and alternative profit efficiency) of the banking industry of country j at time$t + i$ (where i = 0 and 1);

IT_{jt} = either IT capital investment or IT ratios (IT to equity, IT to total costs, and IT to operating costs) of the bank industry of country j for the annual period ending at time t;

HA_{jt} = computer hardware investment of the bank industry of country j for the annual period ending at time t;

SO_{jt} = software investment of the bank industry of country j for the annual period ending at time t;

SE_{jt} = IT services investment of the bank industry of country j for the annual period ending at time t;

ε_{jt} = error term.

It should be noted that the performance measure used in this model refers either to financial profitability (measured by annual accounting ratios) or to global measures of operational efficiency (estimated by profit or cost X-efficiency). Moreover, we test both the association between IT investments in period t and contemporaneous performance (P_{jt}in the model termed model 1) and the association between IT investments in period $t$and performance in the subsequent period $t + 1$ (P_{jt+1}in the model termed model 1-lag), to test whether there is a lag between the implementation of IT investments and the realization of their benefits.

An analysis of model 1 is performed by using both ordinary least squares (OLS) regressions, and two-stage least squares (TSLS) regressions (as done in Shin, 2001). TSLS regressions are employed to correct the potential bias caused by the simultaneity problem (reverse causality): for example, instead of increased IT investments leading to an increase in profit efficiency, increased profit efficiency could be responsible for increases in IT investments. TSLS regressions are employed with the use of one-year lagged independent variables as instruments. To further investigate the existence (and direction) of causality between IT investments and performance, we use the Granger causality Wald test based on a VAR (Vector Autoregressive) model for each banking industry under investigation (Granger and Newbold, 1986).

Because data on multiple countries is available, we also conduct the analysis by pooling all the countries together and indicating control variables for each country. In order to control for the geographical location, country dummies were used as a control variable. The estimated regression equations (referred to as model 2) were:

$$P_{jt} = \beta_0 + \beta_{jt} IT_{jt} + \ \beta_{jt}\, FR \ + \ \beta_{jt} GE + \ \beta_{jt} ITA \ + \ \beta_{jt} SP \ + \varepsilon_{jt} \qquad (3)$$

$$P_{jt} = \beta_0 + \beta_{jt} HA_{jt} + \beta_{jt} SO_{jt} + \beta_{jt} SE_{jt} + \beta_{jt}\, FR + \ \beta_{jt} GE + \beta_{jt} ITA + \beta_{jt} SP + \varepsilon_{jt} \qquad (4)$$

where: *FR*, *GE*, *ITA*, *SP* = dummy variables for France, Germany, Italy and Spain, respectively.

To control for risk, the standard deviation of ROA was used as a control variable. The estimated regression equations (called model 3) were:

$$P_{jt} = \beta_0 + \beta_{jt} IT_{jt} + \ \beta_{jt}\, St\, dev\, (ROA) \ \ + \varepsilon_{jt} \qquad (5)$$

$$P_{jt} = \beta_0 + \beta_{jt} HA_{jt} + \ \beta_{jt} SO_{jt} \ + \ \beta_{jt} SE_{jt} \ + \beta_{jt}\, St\, dev\, (ROA) \ + \varepsilon_{jt} \qquad (6)$$

where: St dev (ROA) = standard deviation of ROA of the bank industry of country j for the annual period

Finally, to control for size, the natural logarithms of total assets were used as a control variable, to take into consideration that size and IT inputs are skewed positively. The estimated regression equations (called model 4) were:

$$P_{jt} = \beta_0 + \beta_{jt} IT_{jt} + \ \beta_{jt} \ln (TA) \ \ + \varepsilon_{jt} \qquad (7)$$

$$P_{jt} = \beta_0 + \beta_{jt} HA_{jt} + \ \beta_{jt} SO_{jt} \ + \ \beta_{jt} SE_{jt} \ + \beta_{jt} \ln (TA) \ + \varepsilon_{jt} \qquad (8)$$

where: TA = total assets of the bank industry of country j for the annual period ending at time t.

3.2.1 IT investments

In this paper, the IT investment data refer to the total estimated revenues paid to vendors for IT, hardware, software and IT services in five EU banking industries over 1995-2000 (IDC, 2002).

Table 2 shows the total IT investments in EU banking industries over 1995-2000. The total amount of IT investments in the EU banking industry doubled between 1995 and 2001 (from \$21,872 millions to \$42,287 millions). The same trend can be observed in the five EU countries under investigation in this study (from \$16,026 millions to \$31,282 millions). The UK bank industry shows the highest proportion of IT investments in Western Europe (25.01% in 2000), while Spain is the industry with the lowest amount

(5.31% in 2000). The French, German and Italian bank industries account respectively for about 12-16% of the total amount of Western European IT investments. The strongest increase in the IT investments is shown by German banks (+84.99% between 1995 and 2000), the lowest by Italian banks (+67.23% over the same period).

It has been suggested that rather than treating IT investments in total, greater emphasis should be placed on the nature of different types of IT investments (Weill, 1992; Gurbaxani *et al.,* 1998; Lucas, 1993; Strassman 1990). It is reasonable to argue that how investment dollars are differently allocated among various elements of the IT infrastructure should be examined in tandem with how many dollars are spent cumulatively. Thus we move to a finer level of granularity by examining the different IT asset categories. The three categories of IT investment – hardware, software and IT services - comprise the following investments on:

1. Computer Hardware (HA): which includes spending on commercial systems (including central processing unit and basic peripherals, such as data storage devices, terminals, memory, and peripherals), single-user systems (workstations and personal computers), data communications (local area network hardware, wide area network hardware, analog modems, digital access);

2. Software (SO): which includes spending on packaged software, application solutions software, application tools, systems infrastructure software[9];

[9]Packaged software are commercially available programs for sale or lease from system vendors and independent software vendors. Application solutions software includes consumer, commercial, and technical programs designed to provide packaged solutions for specific problems inherent in the business function (e.g., software that automates activities such as office automation, accounting, human resource management, payroll, and word processing) or industry (e.g., software that automates loan processing in banking). Application tools include information access tools (end-user-oriented tools for ad hoc data access, analysis, and reporting) and programmer development tools (software products that support the professional developer in the design, development, and implementation of a variety of software systems and solutions). System infrastructure software can be divided into four primary categories: system management software (used to manage the full range of computing resources for the firm), middleware (independent system software and services that distributed businesses use to share computing resources across heterogeneous technologies), serverware (deliver housekeeping capabilities that are used to coordinate resources between distributed servers or nodes on the network), and system-level software (foundation of system software products that collectively operate the hardware platforms and communications networks upon which business applications are built). (IDC, 2002).

3. Services (SE): spending on consulting services, implementation services, operational services, training and education, support services[10].

Table 3 provides a detailed breakdown of the IT investments into the above three categories: hardware, software, and services. On average in Western European banking hardware investments (to total IT investments) account for 33.86%, software for 16.35% and services for 49.79% of total spending. The trend over 1995-2001 clearly shows an increase in the amount of resources devoted to IT services, and a reduction in the amount used for the acquisition of hardware (the amount invested in software is stable over time). The UK is the bank industry with the highest proportion of resources spent for IT services over total IT investments, while Germany has traditionally invested less in services and more in hardware.

Following the established convention in the IT literature of using IT ratios to test the relationship between IT investments and business performance, we estimate various IT ratios. In the IT literature, ratios typically refer to various size measures, such as number of employees, equity, total costs. Owing to the lack of data about number of employees, in this study we estimate the ratios of IT investments (and their components) to: Equity, Total Costs and Operating costs[11]. The actual choice of the denominator for the IT measure does not affect the results substantially.

Tables 4 and 5 show the ratios of IT investments (and their components) to equity, total costs and operating costs. In 2000 the typical Italian bank spent on IT as much as 0.94% of its total costs (6.19% of its operating

[10]Consulting includes IS strategy, IT and network planning, architectural assessments, IS operational analysis, technical system and network design, supplier assessment, and maintenance planning (it excludes strategic planning, tax, audit, benefits, financial, and engineering consulting). IT consulting can also provide product-specific consulting. Implementation activities are aimed at building technical and business solutions. Operations management services are aimed at taking responsibility for managing components of a company's IS infrastructure, such as help desk and network management or, in the case of information systems outsourcing, the entire IS organization. Specific activities that are included under operations management are help desk management, outsourcing, asset management services, systems management, network management, software update management, information systems outsourcing, processing services, backup and archiving, and business recovery services. Training includes education used to enhance general knowledge and expand the abilities to use IT; while education can include theories, concepts, and data used as a foundation for practical applications. Support services include all the activities that are involved with ensuring that products and systems are performing properly (IDC, 2002).

[11]Total costs include personnel expenses, operating costs, total administrative costs and interest expenses. Operating costs include total operating (non interest) expenses and total administrative costs. Although the ratio of IT to operating costs has not been used in previous IT studies, we believe this ratio may be informative, and we calculated it.

costs), while French, Spanish and the UK banks spent respectively 0.72%, 0.61% and 0.51% of their total costs (7.27%, 6.08% and 5.33% of their operating costs). German banks spent a much higher proportion than banks in other EU countries (2.14% of their total costs in 2000, 10.80% of their operating costs). The UK banking industry shows the lowest percentage of IT investments over total costs (and operating costs). It is worth noting that IT investments increased consistently in 1999 presumably as a consequence of the preparation for the adjustments required for Year 2000 and the adoption of the Euro.

3.2.2 Performance measures for the EU banking industry

Our study uses a variety of ways to define bank performance. As we mentioned earlier, previous IT studies have focused on financial profitability (measured by accounting ratios such as return on equity and return on assets as proxies for business performance). Although these studies are informative, we would argue that they do not use an adequate measure of performance. The reason is that IT enhances organisational capabilities, resulting in improved product variety, quality and customer satisfaction, while enabling the streamlining of administrative processes and facilitating improved labour and management productivity. However such improvements may not be not be reflected in traditional profits measures as they do not take account of changes in the production process and input and output mix.

As a result, this study shifts the emphasis to the use of a measure of operational productivity at the global level, the so called X-efficiency (Leibenstein, 1966). It is generally accepted in the empirical banking literature that X-efficiency measures have advantages over accounting ratios (Berger and Humphrey, 1997) as frontier analysis provides an overall, objectively determined, numerical efficiency value and ranking of firms that is not otherwise available.[12] In this specific study, X-efficiency measures are more likely to incorporate the various impacts of IT investment, for instance – the impact of IT spending on such factors as quality, customer services, responsiveness, product variety and so on is likely to be reflected in improved profit efficiency.

Despite a large literature on IT investments and traditional accounting performance ratios, no studies, to the best of our knowledge, test the relationship between X-efficiency and IT on a cross-country sample. To overcome this lack of investigation, four measures of bank performance have been employed in this study:

[12] In particular, X-efficiency measures can accommodate the diverse production features of banks by including multiple inputs and multiple outputs. Moreover, the results are more objective and all inclusive (Thanassoulis *et al.*, 1996).

1. Return on Assets (ROA), which measures how effectively a bank has utilized its existing physical capital to earn income. This has been widely used in past research on non-bank firms (Shin, 2001; Tam, 1998; Rai *et al.*, 1997; Hitt and Brynjolfsson, 1996; Barua *et al.*, 1995; Ahituv and Giladi, 1993; Weill,1992; Strassmann, 1985, 1990);

2. Return on Equity (ROE), which provides an alternative measure of how effectively a bank has utilized its financial capital. The ROE (and its algebaric derivation: the Economic Value Added, EVA[13]) is increasingly examined by managers because it indicates how well the bank is managing resources invested by stakeholders. This measure has been used in few past studies on non-bank firms (Shin, 2001; Tam, 1998; Rai *et al.*, 1997; Hitt and Brynjolfsson, 1996; Alpar and Kim, 1990);

3. Profit efficiency, which provides a measure of how close a bank comes to earning maximum profits given its output level, the so-called alternative profit efficiency (Berger and Mester, 1997). If a bank's client is willing to pay more for increases in quality or convenience, then the profit efficiency of a bank will reflect some of this increase in intangible value. Some of this intangible value from IT investments made by banks passed on to consumers through competition can be captured in productivity measurement, and not in traditional accounting measures;

4. Cost efficiency, which provides a measure of how close a bank's cost is to what a best practice bank's cost would be for producing the same output bundle under the same conditions. This will give further insights on the effects of IT spending on the cost characteristics of banks.

Table 6 summarises the overall ROA and ROE for European banks by country and by year. Profit and cost efficiency measures are discussed in the next section.

3.2.2.1 Estimating Cost and Profit Efficiency A more productive firm will either produce the same output with fewer inputs and thus experience a cost advantage, or produce higher quality output with the same input, enabling a price premium. Such a concept of operating efficiency (Farrell, 1957) is proxied by a frontier efficient index known as X-efficiency (Leibenstein, 1966) that is a measure of managerial best practice. Frontier efficiency is generally estimated as a tool for measuring bank performance (Berger and Humphrey, 1997).

[13]Note that we do not look at EVA in this paper.

Our study generates estimates of the two most common economic efficiency concepts - cost and alternative profit efficiency - for EU banks over the years 1993-2000. A bank is identified as inefficient if its costs (profits) are higher (lower) than those predicted for an efficient firm producing the same input/output combination, and if the difference cannot be explained by statistical noise. We employ the standard Stochastic Frontier Approach (SFA) to generate estimates of cost and alternative profit efficiencies for each bank along the lines first suggested by Aigner *et al.* (1977). Specifically, we employ the Battese and Coelli (1992) model of a stochastic frontier function for panel data with firm effects which are assumed to be distributed as truncated normal random variables ($\mu \neq 0$)[14] and are also permitted to vary systematically with time (see for more details on the SFA methodology Coelli *et al.*, 1998).

Here the functional form for the cost frontier is a Fourier flexible (FF) form, which is the specification that best fits the underlying cost structure of the EU banking industry. The FF has been shown to be the global approximation which dominates the conventional translog form (see, for example, Gallant, 1981, 1982; McAllister and McManus, 1993; Mitchell and Onvural, 1996).[15] The FF functional form, including a standard translog and all first- and second-order trigonometric terms, as well as a two-component error structure is estimated using a maximum likelihood procedure.[16] This is specified as follows:

$$\ln TC = \alpha_0 + \sum_{i=1}^{3} \alpha_i \ln Q_i + \sum_{j=1}^{3} \beta_j \ln P_j + \tau_1 T \; + \; \lambda_1 \ln E +$$

$$+\frac{1}{2}\left[\sum_{i=1}^{3}\sum_{j=1}^{3} \delta_{ij} \ln Q_i \ln Q_j + \sum_{i=1}^{3}\sum_{j=1}^{3} \gamma_{ij} \ln P_i \ln P_j \; + \; \phi_{11} \; \ln E \ln E \; + \; \tau_{11} T^2\right] +$$

$$+\sum_{i=1}^{3}\sum_{j=1}^{3} \rho_{ij} \ln Q_j \ln P_i + \sum_{i=1}^{3} \kappa_{i1} \ln P_i \ln E \; + \; \sum_{i=1}^{3} \varsigma_{i1} \; \ln Q_j \ln E \; +$$

$$+ \; \sum_{i=1}^{3} \psi T \ln Q_i \; + \; \sum_{l=1}^{3} \theta_l T \ln P_l \; + \; \sum_{i=1}^{3} \left[a_i \; \cos\left(z_i\right) \; + \; b_i \; \sin\left(z_i\right)\right] +$$

[14] There are many variations on this assumption in the literature (for details, see Coelli *et al.*, 1998).

[15] It has been widely accepted that the global property is important in banking where scale, product mix and other inefficiencies are often heterogeneous. Therefore, local approximations, such as the translog, may be relatively poor approximation to the underlying true cost function.

[16] We examined the sensitivity to the form of the distribution by including the third order trigonometric terms.

$$\sum\sum\ [a_{ij}\cos(z_i\ +\ z_j)\ +\ b_{ij}\sin(z_i\ +\ z_j)]\ +\varepsilon(9)$$

The variable definitions are as follows: TC = total costs of production comprising operating costs and interest paid on deposits. Bank outputs (with 1.0 added to avoid taking the log of zero) are Q_1= total loans; Q_2 = securities; Q_3 = off balance sheet business. Bank input prices for labour, loanable funds and physical capital respectively are P_1 personnel expenses/total assets; P_2 = depreciation and other capital expenses / fixed assets; P_3 = interest expenses / total funds. The financial capital variable (E) is included in the specification to control for differences in banks risk preferences (Hughes and Mester, 1993; Mester, 1996). Note that E is fully interactive with the output (Q) and the input prices (P) variables. t is a linear time trend. $\varepsilon$is the two-component stochastic error term. z_i are the adjusted values of the log output $\ln Q_i$ such that they span the interval $[0.1{\cdot}2.\pi,\ 0.9{\cdot}2.\pi]$. $\alpha, \beta, \delta, \gamma,\ \tau,\ \lambda,\ \phi,\ \rho,\ \kappa,\ \varsigma,\ \psi,\ \theta$ are parameters to be estimated.

The alternative profit function has the same specification as the above, the only difference being that the dependent variable is replaced with ln profits ($\ln\pi$), as specified in Berger and Mester (1997). Nevertheless because we are maximizing profits (as opposed to minimizing costs) the inefficiency term, u, is subtracted from the estimated residuals. π represents the profits of the bank, proxied by net income before taxes (with the relevant adjustments to exclude negative values) as done in Altunbas, Evans, and Molyneux (2001).

While there continues to be debate about the definition of input and output used in the cost function, we follow the traditional intermediation approach of Sealey and Lindley (1977), in which inputs (labour, physical capital and deposits) are used to produce earning assets. Two of our outputs (loans and securities) are earnings assets, and we also include off balance sheet items as a third output[17].

This study applies Fourier terms (both for the cost frontier and the alternative profit frontier) only for the outputs, leaving the input price effects to be defined entirely be the translog terms (see for instance Berger, Leusner, and Mingo, 1997; Altunbas, Goddard, and Molyneux.,1999). The usual input price homogeneity restrictions are imposed on logarithmic price terms, whereas they cannot be easily imposed on the trigonometric terms.[18]

[17]Although off balance sheet items do not constitute earning assets, they do represent an increasing source of income for all types of banks and are therefore included in order to avoid understating total output (Jagtiani and Khanthavit, 1996).

[18]Mitchell and Onvural (1996) did not impose restrictions on the trigonometric input price coefficients for computational reasons. However, Gallant (1982) has shown that this should not prevent an estimated FF cost equation from closely approximating the true cost

In addition, the scaled log-output quantities, z_i, are calculated as $z_i = \mu_i (\ln Q_i + w_i)$, $\ln Q_i$ are unscaled log-output quantities, μ_i and w_i are scaled factors, writing the periodic sine and cosine trigonometric functions within one period length 2π before applying the FF methodology (see Gallant, 1981). The μ_i's are chosen to make the largest observations for each scaled log-output variable close to 2π, w_i's are restricted to assume the smallest values close to zero. As in Berger, Leusner, and Mingo, (1997), in this study we restricted the z_i to span the interval $[0.1 \cdot 2.\pi, 0.9 \cdot 2.\pi]$ to reduce approximation problems near the endpoints as discussed by Gallant (1981) and applied by Mitchell and Onvural (1996).

Standard symmetry and input price homogeneity constraints have to be imposed on the total cost function (9). In accordance with the assumed constraint of linear homogeneity in prices, *TC*, $P_1$and $P_2$are normalised by the price of capital,P_3. The figures of TC, Q_i and E have been deflated by using country specific GDP deflators with 1995 as a base year.[19]

Table 7 reports the descriptive statistics for the input, output and control variables for 2000 in real terms. Table 8 shows the results of cost and alternative profit X-efficiency estimations for each EU banking industry. Average cost efficiency levels range between 58.61% (UK) and 76.78% (Italy) in 2000. Most institutions seem to have levels of cost inefficiency of approximately 25%, which are slightly lower than the results of recent studies on the EU banking sector (see the frequency distribution for the 131 average efficiency values for banks from 14 non US countries as proposed by Berger and Humphrey, 1997). During the recent 1994-2000 period, cost efficiency actually worsened in some countries (Germany and Italy), while it improved in other EU countries (France, Spain and UK). However, in year 2000 cost efficiency worsened in all EU banking systems.

Table 8 also reports the results of the application of the alternative profit function. A striking finding of this study is that in the EU countries where cost efficiency increased over the 1994-2000 period, profit efficiency decreased (France Spain and the UK); while in the countries where cost efficiency decreased, profit efficiency increased (Germany). The exception is Italy, where

function. Accordingly the equity variable is not included in the Fourier terms. However, we check the robustness of the model by including the adjusted values of the log output $\ln Q_i$and lnE (as in Altunbas, Goddard, and Molyneux, 2001). The two models provide consistent results.

[19]When comparing accounting data over time, it is important to deflate the values so they are comparable in 'real' terms. Accurate price adjustments should remove not only the effects of inflation but also adjust for any quality changes. Much of the measurement problem arises from the difficulty of developing accurate quality-adjusted price deflators (Brynjolfsson, 1993).

both cost and alternative profit efficiency decreased. Cost efficiency may improve but this may not be reflected in higher profit efficiency if revenues also decline. For example banks may cut costs that reduce service quality / product range that reduces revenue and also may reduce profit efficiency, although cost efficiency improves. Cost inefficient banks may employ more costly staff and systems, but this may generate more revenue boosting profit efficiency.

4 Empirical results

We first examine the relationship between IT investments and bank performance by investigating simple correlation coefficients. Table 9 highlights several results. First, there is a positive and statistically significant correlation between profit efficiency and ROA, and a negative and statistically significant correlation between cost efficiency and both ROA and ROE. This is in-line with expectations. Second, even more interestingly for our purposes, the correlations between profit efficiency and IT investment are negative and statistically significant. This holds true both with nominal values of IT investments and when IT investments are calculated as ratios to equity and to total costs. Third, as regard to financial profitability measures, the correlation sign between ROA and IT ratios is negative and statistically significant, whereas the correlation sign between ROE and IT investments is positive and statistically significant. This preliminary evidence provides our first insight into evidence of the IT profitability paradox: we observe a negative relationship between IT investments and profit efficiency, whereas the relationship is ambiguous with reference to our accounting profit measures. Finally, when we consider the cost side, while the correlation sign between cost efficiency and IT ratios is negative and not statistically significant, the sign between cost efficiency and IT investments is negative and statistically significant. The analysis on the cost efficiency side requires further analysis.

To better investigate the above preliminary evidence, we estimate the set of regressions previously outlined. The results derived from estimating model 1 by OLS are reported in Table 10. The coefficient of profit efficiency is significantly negative, as expected, both when IT to equity, IT to total costs and IT to operating costs are used as explanatory variables. The magnitude of the IT coefficients suggests that changes in IT have a significant effect on profit efficiency. For instance, a 10 percent increase in IT investment to total costs implies a 0.905 percent decline in profit efficiency. Moreover, the high explanatory power of model 1 indicates that IT investments explain a relatively large portion of the variation in our profit efficiency measure. The three versions of model 1 referring to IT ratios explain around 34.1%, 48.6% and 58.8% of the banks' profit efficiency estimates (R^2 = 0.341 when IT to equity is the dependent variable, R^2 = 0.486 when IT to total costs is used, and R^2 = 0.588 when IT to operating costs is employed). This value is much higher than the explanatory power traditionally measured in previous studies using traditional financial profitability measures. The results of the TSLS regression are similar to the results of the OLS regression analysis here above, suggesting that there is no causality bias. Such non-causality is confirmed by the Granger causality Wald test. The null hypothesis of non-causality (i.e. IT investments do not cause profit efficiency) can be rejected at the 1% level for all countries (with the exception of the UK where it can be rejected at the 10% level). Contrarily, the null hypothesis that profit efficiency do not cause IT investments cannot be rejected at the level of 1% for all countries (with the exception of Spain).

These findings confirm that the impact of IT on banks' performance is negative on the profit efficiency side: higher IT investments are not associated with higher profit efficiency. This confirms the productivity paradox, and implies that banks with higher IT investments are not able to apply a premium to the price given the higher quality of their outputs. This finding points to the role of IT as a strategic necessity, rather than a variable able to generate a competitive advantage. This confirms the role of IT as a strategic necessity, rather than a variable able to generate a competitive advantage. The adoption of increasingly expensive IT infrastructures becomes a structural component of the competition in the banking industry.

The relationship between IT investments and traditional accounting performance measures is less clear. We do not find a positive association between our accounting profitability measures and IT investments in most of the specifications of model 1. Moreover, model 1 loses its explanatory power when traditional financial profitability measures are employed instead of profit efficiency. The lack of a clear association between IT investments and accounting profitability and the lower explanatory power of the model are consistent with prior studies in other industries (Shin, 2001; Rai *et al.*, 1997; Hitt and Brynjolfsson, 1996). In terms of short-term cost efficiency, the relationship between cost efficiency and IT ratios appears to be both positive and negative, but always non-significant.[20]

[20] In terms of long-term costs, technical change has made a positive contribution across banking markets, reducing the real annual cost of production by about 3.1%, consistently with prior studies (Altunbas, Goddard, and Molyneux.,1999, 2001). The UK and France benefited most from technical change (with banks experiencing a fall in total costs of 3.50% per annum), while Spain benefited less (reduction of 2.72% per annum). The trend over time shows that the impact of technical change on reducing costs systematically increased

To take into account the lag between the occurrence of IT investments and their impact on bank performance, or rather to test the relationship for non-contemporaneous influences, the results derived from model 1–lag are reported in Table 11. Interestingly, our results are similar to contemporaneous effects – the productivity paradox is still apparent over time when we take into account short-term assimilation, learning and adjustment factors.

To investigate the influence of the geographical location on banks' performance, the results derived from estimating model 2 are reported in Table 12. On average the geographical location of EU banks has a significant influence on the explanation of business performance. German, French and Italian banks show ROA, ROE and profit efficiency consistently (and significantly) lower than the UK benchmark, while their cost efficiencies have been consistently (and significantly) higher than in the UK industry. To relate the impact of geographical location on IT investments, we also calculated the correlation between IT investments (and categories) and business performance (ROA, ROE, profit and cost X-efficiency) for each country of our sample. The negative and statistically significant relationship between profit efficiency and IT investment is confirmed in four national banking industries. The only exception is Germany, where the relationship is positive and significant at 0.05 (as outlined in Table 12). The association between cost efficiency and IT investment is heterogeneous across countries: while it is significantly positive in France and the UK, it is significantly negative in Germany and Italy. This may explain the mixed evidence on cost efficiency obtained by pooling all the countries together.

To take into account the risk of banks' activities, the results derived from model 3 are reported in Table 13. Interestingly, these results confirm the evidence with no control variable for risk. In particular, when profit efficiency is used as a dependent variable, and a proxy for risk is included, the explanatory power of the regression remains high, and the coefficient of profit efficiency remains significantly negative.[21]

To consider the various categories of IT investments (hardware, software and IT services), we re-estimated model 1 by investigating its three compo-

across EU banks from –2.54% in 1993 to –3.91% in 2000.

[21]The inclusion in model 4 of another explanatory variable (ln of total assets as a proxy for size) does not significantly increase the explanatory power of the model when profit efficiency is the dependent variable, as shown in Table 14. This indicates that size does not seem to contribute significantly in the explanation of profit efficiency when combined with IT investments. Conversely, the explanatory power increases consistently when ROE and ROA are used as dependent variables ($R^2 = 0.320$ and $R^2 = 0.285$ when ROE is used; while $R^2 = 0.362$ and $R^2 = 0.173$ when ROA is used). These relatively high R^2 in the ROA and ROE regressions are primarily a result of the size effect.

nents. As shown in Table 15, the impact of each IT category on profitability measures (ROA, ROE and profit efficiency) is mixed. While the sign on the hardware and software investment variables is statistically negative, the coefficient on IT services is positive. On the one hand, IT services from external providers (consulting services, implementation services, training and education, support services) impact positively on banks' profitability. On the other hand, the acquisition of computer hardware and software appear to have a negative impact on banks' profitability. Furthermore, the explanatory power of model strongly increases, and the R^2 jumps to 49% when the explanatory variable is profit efficiency, 57% when is ROE, and 46% when is ROA.

The above results have important implications. The productivity paradox does not affect the totality of IT investments. It seems that the opportunities associated with investments in hardware and software can only be fully exploited when acquired together with external IT services. Consequently, the implication from our findings suggest that banks should reduce their spending on hardware and software, and increase outsourcing if they are to improve their profits performance (however measured).

5 Conclusions

This paper investigates whether investment in Information Technology (IT) –hardware, software and other IT services – influences the performance of banks. Using a sample of 737 European banks over the period 1993-2000 we analyse whether IT investment is reflected in improved performance (measured using both standard accounting ratios and cost and alternative profit efficiency measures). Despite banks being major investors in IT we find little relationship between total IT investment and improved bank profitability or efficiency indicating the existence of a profitability paradox. However, the impact of different types of IT investment (hardware, software and services) on banks' performance is heterogeneous. Investment in IT services from external providers (consulting services, implementation services, training and education, support services) appears to have a positive influence on accounting profits and profit efficiency, while the acquisition of hardware and software seems to reduce banks' profit performance.

Evidence that the substantial investment in IT by banks does not lead to improved profits performance can be explained by various factors. It could be that IT investment is predominantly used for strategic reasons – either to lower or increase entry barriers – and these countervailing forces balance each other out (or even the former outweigh the latter resulting in lowering market power). IT spending may have other influences on competitive strategy (increasing the range and quality of services on offer, speed and convenience of delivery and so on) that have a heteregenous impact across banks resulting in a reduced profits performance on average for the banking sector. These are areas, we suggest, deserving of future research.

References

Aigner, D.J., Lovell, C.A.K., Schmidt, P.: 1977, 'Formulation and estimation of stochastic frontier production function models', *Journal of Econometrics* **6**, 21-37.

Ahituv, N., Giladi, R.: 1993, 'Business Success and Information Technology: Are They Really Related', *Proceedings of the 7th Annual Conference of Management IS*, Tel Aviv University, Israel.

Alpar, P., Kim, M.: 1990, 'A Comparison of Approaches to the Measurement of IT Value', *Proceedings of the Twenty-Second Hawaii International Conference on System Science*, Honolulu, HI.

Altunbas, Y., Goddard, J., Molyneux, P.: 2001, 'Efficiency in European banking', *European Economic Review* **45**, 1931-1955.

Altunbas, Y., Evans, L., Molyneux, P.: 2001, 'Bank Ownership and Efficiency', *Journal of Money, Credit, and Banking* **33**(4), 926-954.

Altunbas, Y., Goddard, J., Molyneux, P.: 1999, 'Technical change in banking', *Economics Letters* **64**, 215-221.

Bain, J.: 1956, *Barriers to New Competition*, Harvard University Press, Cambridge, MA.

Bank for International Settlements: 1999, 'The monetary and regulatory implications of changes in the banking industry', *BIS Conference Papers*, Vol. 7, March.

Barua, A., Kriebel, C., Mukhopadhyay, T.: 1995, 'Information Technology and Business Value: An Analytic and Empirical Investigation', *Information Systems Research* **6**(1), 3-23.

Battese G.E., Coelli, T.J.: 1992, 'Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India', *Journal of Productivity Analysis* **3**, 153-169.

Bauer, P.W., Berger, A.N., Humphrey, D.B.: 1993, 'Efficiency and Productivity Growth in U.S. Banking', in Fried, H.O., Lovell, C.A.K., Schmidt, S.S. (eds.), *The Measurement of Productive Efficiency: Techniques and Application*, Oxford University Press, Oxford.

Berger, A., DeYoung. R.: 2002, 'Technological Progress and the Geographic Expansion of the Banking Industry', Working Paper Federal Reserve Bank of Chicago WP 2002-07, Chicago.

Berger, A. N., Humphrey, D.B.: 1997, 'Efficiency of Financial Institutions: International Survey and Directions for Future Research', *European Journal of Operational Research* **98**, 175-212.

Berger, A. N., Humphrey, D.B.: 1992, 'Measurement and Efficiency Issues in Commercial Banking', in Griliches, Z (eds.), *Measurement Issues in the Service Sectors*, Chicago: National Bureau of Economic Research, University of Chicago Press, Chicago.

Berger, A.N., Leusner, J.H., Mingo J.J.: 1997, 'The efficiency of bank branches', *Journal of Monetary Economics* **40**, 141-162.

Berger, A.N., Mester, L.J.: 1997, 'Inside the black box: what explains differences in the efficiency of financial institutions?', *Journal of Banking and Finance* **21**, 895 - 947.

Brynjolfsson, E.: 1993, 'The productivity paradox of information technology', *Communications of the ACM* **35**(12), 66-77.

Brynjolfsson, E., Hitt, L.M.: 2000, 'Beyond computation: Information technology, organization transformation and business performance', *Journal of Economic Perspectives* **14**(4), 23-48.

Carr, N.G.: 2003, 'IT Doesn't Matter', *Harvard Business Review* **81**(5), 41-50.

Clemons, E.K.: 1991, 'Evaluation of Strategic Investments in Information Technology', *Communications of the ACM* **34**(1), 22-36.

Coelli T.J., Prasada Rao D.S., Battese, G.: 1998, *An Introduction to Efficiency and Productivity Analysis*, Kluwer Academic Publishers, Norwell.

Council of Economic Advisors: 2001, 'The annual report of the council of economic advisors', *The Economics of the President*, U.S. Government Printing Office, Washington, D.C.

Dedrick, J., Gurbaxani, V., Kraemer, K.L.: 2003, 'Information Technology and Economic Performance: Firm and Country Evidence', *ACM Computing Surveys* **35**(1), 1-28.

De Bandt, O., Davis, E.P. : 2000, 'Competition, contestability and market structure in European banking sectors on the eve of EMU', *Journal of Banking and Finance* **24**(6), 1045-1066.

DeLone, W., McLean, E.: 1992, 'Information Systems Success: The Quest for the Dependent Variable', *Information Systems Research* **3**(1), 60-95.

Dewan, S., Kraemeer, K.L.: 1998, 'International Dimensions of the Productivity Paradox', *Communications of the ACM* **41**(8), 56-62.

Dos Santos, B.L., Peffers, K.G., Mauer, D.C. : 1993, 'The Impact of Information Technology Investments Announcements on the Market Value of the Firm', *Information Systems Research* **4**(1), 1-23.

EITO: 1996-2002, *European Information Technology Observatory*, 1996-2002, Frankfurt.

European Central Bank: 1999, *The Effects of Technology on the EU Banking System*, European Central Bank, Frankfurt.

European Commission: 1997, 'Credit Institutions and Banking', *The Single Market Review*, Vol. 3, Subseries II: Impact on Services, Kogan Page, London.

Farrell M.J.: 1957, 'The Measurement of Productive Efficiency', *Journal of Royal Statistical Society*, **120**(A), 253-281.

Fusconi, A.: 1996, 'L'incidenza del fattore tecnologico nella funzione di produzione della banca', in Fusconi A., Loddo S.A., Rosignoli B. (eds.), *Banca e Intermediazione*, Monduzzi Editore, Bologna.

Gallant, A.R.: 1982, 'Unbiased determination of production technologies', *Journal of Econometrics* **20**, 285-324.

Gallant, A.R.: 1981, 'On the bias in flexible functional forms and essentially unbiased form: The Fourier flexible form', *Journal of Econometrics* **15**, 211-245.

Gordon, R.J.: 1987, 'The Postwar Evolution of Computer Prices'. *National Bureau of Economic Research Working Paper* n. 2227, Cambridge, MA.

Granger, C.W.J., Newbold, P.: 1986, *Forecasting Economic Time Series*, Academic Press Inc, California.

Gurbaxani, V., Melville, N., Kraemer, K.: 1998, 'Disaggregating the return on investment to IT capital', *Proceedings of the International Conference on Information Systems*, Helsinki, Finland.

Hitt, L.M., Brynjolfsson, E.: 1996, 'Productivity, business profitability, and consumer surplus: Three different measures of information technology value', *MIS Quarterly* **20**(2), 121-142.

Hughes, J.P., Mester, L.J.: 1993, 'A quality and risk-adjusted cost function for banks: Evidence on the 'too-big-to-fail' doctrine', *Journal of Productivity Analysis* **4**, 293-315.

Hunter, W.C., Timme, S.G.: 1991, 'Technological Change in Large U.S. Commercial Banks', *Journal of Business* **64**, 339-362.

International Data Corporation, IDC: 2002, *Investments in Hardware, Packaged Software and IT Services in Western Countries (1995-2000)*, Milan.

Jagtiani, J. e Khanthavit, A.: 1996, 'Scale and scope economies at large banks, including off balance sheet products and regulatory effects', *Journal of Banking and Finance* **20**, 1271-1287.

Jorgenson, D.W., Stiroh, K.J.: 2000, 'Raising the speed limit: U.S. economic growth in the information age', *Brookings Paper on Economic Activity* **1**(1), 125-211.

Leibenstein, H.: 1966, 'Allocative efficiency vs. "X-efficiency" ', *American Economic Review* **56**, 392-415.

Lucas, H.C.: 1993, 'The business value of Information Technology: a historical perspective and thoughts for future research', in Banker, R., Kauffman, R., Mahmood, M.A. (eds.), *Strategic Information Technology Management: Perspectives on Organizational Growth and Competitive Advantage*, Idea Publishing, Harrisburg, PA.

Markus, L., Soh, C.: 1993, 'Banking on Information Technology: Converting IT Spending into Firm Performance', in Banker, R., Kaufmann, R., Mahmood, M.A. (eds.), *Strategic Information Technology Management: Perspectives on Organizational Growth and Competitive Advantage*, Idea Group Publishing, Harrisburg, PA.

McAllister, P., McManus, D.: 1993, 'Resolving the scale efficiency puzzle in banking', *Journal of Banking and Finance* **17**, 389-405.

McKinsey Global Institute: 2001, *U.S. Productivity Growth 1995-2000: Understanding the Contribution of Information Technology Relative to Other Factors*, McKinsey Global Institute, Washington, D.C.

Mester, L.J.: 1996, 'A study of bank efficiency taking into account risk-preference', *Journal of Banking and Finance* **20**, 1025-1045.

Mitchell, K., Onvural, N.M.: 1996, 'Economies of scale and scope at large commercial banks: Evidence from the Fourier Flexible functional form', *Journal of Money, Credit and Banking* **28**, 178-199.

Porter, M.E.: 1980, *Competitive Strategy*, Free Press, New York.

Rai, A., Patnayakuni, R., Patnayakuni, N.: 1997, 'Technology Investment and Business Performance', *Communications of the ACM* **40**(7), 89-97.

Sambamurthy, V., Zmud, R.W.: 1994, 'IT Management Competency Assessment: A Tool for Creating Business Value Through IT', *Working Paper, Financial Executive Research Foundation.*

Sealey, C., Lindley, J.T.: 1977, 'Inputs, outputs and a theory of production and cost at depositary financial institutions', *Journal of Finance* **32**, 1251-1266.

Seely Brown, J., Hagel III, J.: 2003, 'Does IT Matter? An HBR Debate', *Harvard Business Review*, June, 1-17.

Shin N.: 2001, 'The impact of information technology on financial performance: the importance of strategic choice', *European Journal of Information Systems* **10**, 227-236.

Solow, R.: 1987, 'We'd better watch out', *New York Times Book Review* (July 12).

Strassmann, P.A.: 2003, 'Does IT Matter? An HBR Debate', *Harvard Business Review*, June, 1-17.

Strassmann, P.A.: 1990, *The Business Value of Computers*, Information Economics Press, New Canaan, CT.

Strassmann, P.A.: 1985, *Information Payoff, The Transformation of Work in the Electronic Age*, The Free Press, New York.

Tam, K.Y.: 1998, 'The impact of information technology investments on firm performance and evaluation: evidence from newly industrialised economies', *Information Systems Research* **9**, 85-98.

Teece, D.J., Pisano G.: 1994, 'The dynamic capabilities of firms: an introduction', *Industrial and Corporate Change* **3**(3), 537-56.

Thanassoulis, E.: 2001, *Introduction to the Theory and Application of Data Envelopment Analysis. A foundation text with integrated software*, Kluwer Academic Publishers, USA.

Weill, P.: 1992, 'The Relationship Between Investments in Information Technology and Firm Performance: A Study on the Valve Manufacturing Sector', *Information Systems Research* **3**(4), 307-333.

White, W.R.: 1998, 'The coming transformation of continental European banking?', *BIS Working Papers*, n. 54, Bank for International Settlements, Monetary and Economic Department, Basle.

Table 1: Composition of the sample

	NUMBER OF BANKS					
YEAR	FRANCE	GERMANY	ITALY	SPAIN	UK	PANEL
2000	117	156	86	72	66	497
1999	145	177	92	65	74	553
1998	165	194	91	72	79	601
1997	171	197	87	78	74	607
1996	186	194	85	77	71	613
1995	192	189	74	73	57	585
1994	200	184	74	65	40	563
1993	171	127	63	17	17	395
Total	1347	1418	652	519	478	4414

Table 2: IT investments in European banking

Year	1995	1996	1997	1998	1999	2000	2001
Nominal amount	US $ (millions)						
Western Europe*	21,872	23,468	26,707	30,686	34,277	38,870	42,287
France	3,299	3,473	3,946	4,589	4,998	5,687	6,269
Germany	3,350	3,639	4,319	5,066	5,730	6,440	6,946
Italy	2,854	3,031	3,359	3,795	4,221	4,773	5,239
Spain	1,115	1,207	1,402	1,610	1,777	2,063	2,265
UK	5,408	5,792	6,586	7,541	8,483	9,722	10,563
5 EU countries	16,026	17,143	19,612	22,601	25,209	28,687	31,282
Ratio	Banking System IT Investment / Western Europe IT Investment (%)						
France	15.08	14.80	14.77	14.95	14.58	14.63	14.82
Germany	15.32	15.50	16.17	16.51	16.72	16.57	16.43
Italy	13.05	12.92	12.58	12.37	12.31	12.28	12.39
Spain	5.10	5.14	5.25	5.25	5.19	5.31	5.36
UK	24.73	24.68	24.66	24.57	24.75	25.01	24.98

* Western Europe include: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK.

Table 3: IT asset categories in European banking

	1995	1996	1997	1998	1999	2000	2001
Western Europe (IT Asset Categories Investments / Total IT Investment, %)							
Hardware	37.64	37.32	36.77	35.87	34.78	33.86	31.58
Software	15.68	16.35	16.15	15.78	16.07	16.35	16.99
Services	46.68	46.33	47.09	48.35	49.16	49.79	51.43
France (IT Asset Categories Investments / Total IT Investment, %)							
Hardware	34.80	34.90	33.46	31.44	30.66	29.53	27.54
Software	17.13	17.75	17.23	17.07	17.38	17.29	17.83
Services	48.07	47.35	49.31	51.49	51.95	53.18	54.63
Germany (IT Asset Categories Investments / Total IT Investment, %)							
Hardware	42.67	41.69	40.53	40.74	39.80	38.45	36.02
Software	14.50	15.59	15.57	14.84	15.29	15.72	16.45
Services	42.83	42.73	43.90	44.42	44.91	45.82	47.53
Italy (IT Asset Categories Investments / Total IT Investment, %)							
Hardware	37.95	37.27	36.19	34.78	33.88	34.18	32.21
Software	17.63	17.82	17.36	16.91	16.62	16.23	16.81
Services	44.43	44.91	46.45	48.30	49.50	49.60	50.98
Spain (IT Asset Categories Investments / Total IT Investment, %)							
Hardware	39.79	39.68	39.24	38.93	38.54	39.08	37.36
Software	12.88	13.38	13.11	12.92	14.01	13.92	14.55
Services	47.32	46.93	47.65	48.14	47.44	47.01	48.09
UK (IT Asset Categories Investments / Total IT Investment, %)							
Hardware	32.36	32.45	32.39	31.40	29.84	28.87	26.50
Software	15.90	16.35	16.59	16.22	16.85	17.26	17.83
Services	51.74	51.20	51.02	52.38	53.31	53.86	55.67

Table 4: Ratios of IT investments in European banking

	1995	1996	1997	1998	1999	2000
RATIO OF IT INVESTMENTS TO EQUITY (%)						
France	1.32	1.39	1.63	1.49	1.10	1.21
Germany	0.93	1.07	1.10	1.27	1.39	2.16
Italy	0.50	0.52	0.58	0.47	0.60	0.62
Spain	0.34	0.40	0.53	0.49	0.57	0.38
UK	0.64	0.59	0.62	0.55	0.65	0.60
RATIO OF IT INVESTMENTS TO TOTAL COSTS (%)						
France	0.63	0.73	0.83	0.79	0.97	0.72
Germany	0.79	0.90	0.96	1.13	1.24	2.14
Italy	0.36	0.42	0.54	0.59	1.03	0.94
Spain	0.26	0.31	0.51	0.60	0.80	0.61
UK	0.36	0.27	0.26	0.37	0.51	0.51
RATIO OF IT INVESTMENTS TO OPERATING COSTS (%)						
France	6.19	6.67	7.87	7.67	7.98	7.27
Germany	5.65	6.42	6.62	6.93	6.80	10.80
Italy	4.75	5.11	5.29	5.25	6.16	6.19
Spain	4.29	4.68	5.56	5.78	6.33	6.08
UK	3.24	2.85	3.75	3.08	5.69	5.33

Table 5: Ratios of IT asset categories in European banking

	1995	1996	1997	1998	1999	2000
RATIO OF HARDWARE INVESTMENTS TO EQUITY (%)						
France	0.46	0.48	0.54	0.47	0.34	0.36
Germany	0.40	0.45	0.45	0.52	0.55	0.83
Italy	0.19	0.19	0.21	0.16	0.20	0.21
Spain	0.14	0.16	0.21	0.19	0.22	0.15
UK	0.21	0.19	0.20	0.17	0.19	0.17
RATIO OF HARDWARE INVESTMENTS TO TOTAL COSTS (%)						
France	0.22	0.26	0.28	0.25	0.30	0.21
Germany	0.34	0.39	0.39	0.46	0.50	0.82
Italy	0.14	0.16	0.20	0.20	0.35	0.32
Spain	0.10	0.12	0.20	0.23	0.31	0.24
UK	0.12	0.09	0.08	0.11	0.15	0.15
RATIO OF HARDWARE INVESTMENTS TO OPERATING COSTS (%)						
France	2.16	2.32	2.63	2.41	2.45	2.15
Germany	2.41	2.68	2.68	2.82	2.71	4.15
Italy	1.04	1.16	1.19	1.13	1.41	1.43
Spain	0.91	1.06	1.40	1.47	1.67	1.59
UK	1.05	0.93	1.21	0.97	1.70	1.54
RATIO OF SOFTWARE INVESTMENTS TO EQUITY (%)						
France	0.23	0.25	0.28	0.25	0.19	0.21
Germany	0.13	0.17	0.17	0.19	0.21	0.34
Italy	0.09	0.09	0.10	0.08	0.10	0.10
Spain	0.04	0.05	0.07	0.06	0.08	0.05
UK	0.10	0.10	0.10	0.09	0.11	0.10
RATIO OF SOFTWARE INVESTMENTS TO TOTAL COSTS (%)						
France	0.11	0.13	0.14	0.13	0.17	0.12
Germany	0.11	0.15	0.15	0.17	0.19	0.34
Italy	0.06	0.07	0.09	0.10	0.17	0.15
Spain	0.03	0.04	0.07	0.08	0.11	0.09
UK	0.06	0.04	0.04	0.06	0.09	0.09
RATIO OF SOFTWARE INVESTMENTS TO OPERATING COSTS (%)						
France	1.06	1.18	1.36	1.31	1.39	1.26
Germany	0.82	1.00	1.03	1.03	1.04	1.70
Italy	0.48	0.55	0.57	0.55	0.69	0.68
Spain	0.29	0.36	0.47	0.49	0.61	0.57
UK	0.51	0.47	0.62	0.50	0.96	0.92
RATIO OF IT SERVICES TO EQUITY (%)						
France	0.64	0.66	0.80	0.77	0.57	0.64
Germany	0.40	0.46	0.48	0.57	0.62	0.99
Italy	0.22	0.23	0.27	0.23	0.30	0.31
Spain	0.16	0.19	0.25	0.24	0.27	0.18
UK	0.33	0.30	0.31	0.29	0.35	0.32
RATIO OF IT SERVICES TO TOTAL COSTS (%)						
France	0.30	0.35	0.41	0.41	0.51	0.38
Germany	0.34	0.40	0.42	0.50	0.56	0.98
Italy	0.16	0.19	0.25	0.28	0.51	0.46
Spain	0.12	0.15	0.24	0.29	0.38	0.29
UK	0.19	0.14	0.13	0.19	0.27	0.28
RATIO OF IT SERVICES TO OPERATING COSTS (%)						
France	2.98	3.15	3.88	3.95	4.15	3.90
Germany	2.42	2.74	2.90	3.08	3.05	4.90
Italy	1.22	1.40	1.53	1.57	2.06	2.08
Spain	1.08	1.26	1.70	1.82	2.05	1.92
UK	1.67	1.46	1.91	1.61	3.03	2.87

Table 6: ROA and ROE for each EU banking industry (by country and by year); 1994 -2000

ROA	FRANCE	GERMANY	ITALY	SPAIN	UK
2000	0.0050	0.0035	0.0088	0.0076	0.0094
1999	0.0035	0.0021	0.0081	0.0071	0.0100
1998	0.0037	0.0060	0.0053	0.0070	0.0100
1997	0.0011	0.0026	-0.0010	0.0053	0.0076
1996	0.0002	0.0029	0.0016	0.0051	0.0078
1995	0.0010	0.0031	-0.0006	0.0045	0.0050
1994	-0.0029	0.0033	-0.0010	0.0045	0.0046
ROE	FRANCE	GERMANY	ITALY	SPAIN	UK
2000	0.1364	0.0753	0.1275	0.1053	0.1651
1999	0.0709	0.0540	0.1129	0.1204	0.1721
1998	0.1004	0.1443	0.0764	0.1169	0.1908
1997	0.0333	0.0613	-0.0169	0.0956	0.1560
1996	0.0071	0.0645	0.0256	0.0850	0.1594
1995	0.0277	0.0639	-0.0106	0.0751	0.0965
1994	-0.0864	0.0681	-0.0172	0.0695	0.0917

Table 7: Descriptive Statistics on Cost, Output Quantities and Input Prices and control variable in 2000

TC = total costs ($ thousands); Q_1 = total loans ($ thousands); Q_2 = total securities ($ thousands); Q_3 = off balance sheet ($ t housands); P_1 = personnel expenses/total assets; P_2 = interest expenses/total customer deposits; P_3 = other non-interest expenses/total fixed assets; E = equity ($ thousands).

		AVERAGE	MEDIAN	MIN	MAX	STDEV
FRANCE	TC	785,345	54,202	2,791	31,611,907	3,552,285
	Q1	4,562,591	419,795	3,257	163,011,659	19,274,275
	Q2	982,352	61,164	279	29,650,411	3,939,035
	Q3	6,491,154	334,189	4,653	265,391,880	32,162,418
	P1	0.0181	0.0146	0.0001	0.2153	0.0227
	P2	0.0743	0.0475	0.0141	0.9481	0.1086
	P3	6.6673	2.3538	0.2645	168.0914	20.0954
	E	468,836	68,764	5,583	16,837,879	1,896,816
GERMANY	TC	300,446	30,846	744	16,026,017	1,642,459
	Q1	3,534,534	284,454	1	181,567,708	18,722,021
	Q2	1,136,531	59,691	1	68,669,105	6,948,515
	Q3	1,122,557	30,846	1	60,648,187	6,848,579
	P1	0.0200	0.0140	0.0005	0.2667	0.0285
	P2	0.0478	0.0398	0.0080	0.3971	0.0398
	P3	0.9472	0.4445	0.0025	29.0108	2.6606
	E	297,841	42,989	837	16,990,016	1,576,915
ITALY	TC	509,955	61,041	3,350	6,315,774	1,177,894
	Q1	6,199,707	777,527	1	83,335,848	14,466,331
	Q2	1,432,762	173,911	1,489	16,710,959	3,228,079
	Q3	4,013,126	143,297	1	71,983,549	11,761,540
	P1	0.0218	0.0167	0.0059	0.1506	0.0229
	P2	0.2638	0.0408	0.0062	15.5108	1.6534
	P3	0.7730	0.2272	0.2530	16.9218	2.3632
	E	772,990	107,752	16,749	10,585,006	1,736,756
SPAIN	TC	335,594	34,382	1,116	8,383,813	1,334,975
	Q1	3,655,590	468,368	1	85,509,215	13,019,218
	Q2	1,060,080	18,982	1	33,406,563	4,583,885
	Q3	1,410,616	60,390	1	42,705,243	6,296,161
	P1	0.0178	0.0139	0.0008	0.1017	0.0189
	P2	0.1274	0.0322	0.0023	6.5054	0.7626
	P3	0.2730	0.1894	0.0250	2.0837	0.3190
	E	533,407	68,066	6,327	15,840,475	2,174,261
UK	TC	1,887,739	119,061	1,687	20,805,244	4,352,264
	Q1	16,527,947	772,814	1	241,114,593	39,206,102
	Q2	4,296,457	124,568	35	84,949,269	13,720,903
	Q3	10,576,696	108,813	89	191,644,285	34,009,092
	P1	0.0198	0.0182	0.0010	0.1598	0.0206
	P2	0.0735	0.0625	0.0078	0.3459	0.0481
	P3	1.0171	0.6635	0.0317	9.9403	1.6055
	E	1,619,105	251,072	8,057	22,056,103	3,875,752

Table 8: Cost and Profit Efficiency Estimates for each EU banking industry (by country and by year); 1994-2000

Cost	France		Germany		Italy		Spain		UK	
	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev
2000	0.6419	0.1640	0.7105	0.1538	0.7678	0.1338	0.6643	0.1888	0.5861	0.2124
1999	0.6309	0.1709	0.7207	0.1486	0.7763	0.1275	0.6590	0.1897	0.5654	0.2121
1998	0.6310	0.1774	0.7363	0.1412	0.7766	0.1247	0.6660	0.1886	0.5635	0.2011
1997	0.6208	0.1821	0.7457	0.1398	0.7839	0.1115	0.6630	0.1851	0.5398	0.2021
1996	0.6135	0.1812	0.7537	0.1361	0.7881	0.1052	0.6569	0.1880	0.5524	0.1993
1995	0.6091	0.1836	0.7631	0.1313	0.7919	0.1035	0.6449	0.1907	0.5247	0.1956
1994	0.6024	0.1904	0.7714	0.1288	0.7980	0.1011	0.6445	0.1736	0.5085	0.1874
Profit	France		Germany		Italy		Spain		UK	
	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev
2000	0.4679	0.2147	0.4729	0.2344	0.5039	0.2229	0.4747	0.2423	0.4705	0.2167
1999	0.4819	0.2106	0.4784	0.2284	0.5535	0.1970	0.5347	0.2352	0.5126	0.2038
1998	0.4818	0.2121	0.4750	0.2340	0.5449	0.2137	0.5213	0.2416	0.5529	0.1965
1997	0.4820	0.2157	0.4608	0.2433	0.5527	0.2132	0.5289	0.2307	0.5810	0.1880
1996	0.4770	0.2208	0.4453	0.2374	0.5397	0.2129	0.5302	0.2259	0.6191	0.1729
1995	0.4806	0.2213	0.4245	0.2457	0.5653	0.2167	0.5421	0.2242	0.6121	0.1716
1994	0.4814	0.2048	0.4354	0.2367	0.6245	0.1931	0.5971	0.2090	0.6592	0.1367

Table 9 : Correlation Matrix

Spearman / Pearson	HA	SO	SE	IT	ROA	ROE	Profit Eff	Cost Eff
HA	1.000	0.938***	0.930***	0.974***	0.139	0.440**	-0.163	-0.314*
SO	0.940***	1.000	0.994***	0.989***	0.185	0.469***	-0.23	-0.445**
SE	0.925***	0.993***	1.000	0.986***	0.224	0.496***	-0.18	-0.486**
IT	0.965***	0.994***	0.992***	1.000	0.201	0.487***	-0.55	-0.425**
ROA	0.095	0.173	0.257	0.198	1.000	0.836***	0.339**	-0.267
ROE	0.425***	0.475***	0.562***	0.515***	0.796***	1.000	0.147	-0.460**
Profit Effi	-0.113	-0.018	0.013	-0.030*	0.396***	0.167	1.000	-0.112
Cost Eff	-0.237	-0.386**	-0.453**	-0.384**	-0.318*	-0.507***	0.269	1.000

Spearman / Pearson	ln(HA/E)	ln(SO/E)	Ln(SE/E)	ln(IT/E)	ROA	ROE	Profit Eff	Cost Eff
ln(HA/E)	1.000	0.866***	0.873***	0.917***	-0.498***	-0.357*	-0.518***	0.053
ln(SO/E)	0.933***	1.000	0.977***	0.981***	-0.494***	-0.241	-0.538***	-0.190
ln(SE/E)	0.936***	0.985***	1.000	0.987***	-0.382**	-0.119	-0.551***	-0.286
ln(IT/E)	0.974***	0.985***	0.991***	1.000	-0.429**	-0.188	-0.521***	-0.199
ROA	-0.570***	-0.514***	-0.442**	-0.508***	1.000	0.836***	0.339*	-0.267
ROE	-0.330*	-0.253	-0.153	-0.236	0.796**	1.000	0.147	-0.460**
Profit Eff	-0.631***	-0.527***	-0.546***	-0.584***	0.396**	0.167	1.000	-0.112
Cost Eff	0.126	-0.010	-0.104	-0.006	-0.318*	-0.507***	-0.269	1.000

Spearman / Pearson	ln(HA/TC)	ln(SO/TC)	ln(SE/TC)	ln(IT/TC)	ROA	ROE	Profit Eff	Cost Eff
ln(HA/TC)	1.000	0.926***	0.936***	0.974***	-0.332*	-0.273	-0.676***	0.468***
ln(SO/TC)	0.935***	1.000	0.979***	0.977***	-0.340*	-0.224	-0.613***	0.355*
ln(SE/TC)	0.947***	0.982***	1.000	0.986***	-0.247	-0.130	-0.630***	0.293
ln(IT/TC)	0.979***	0.981***	0.992***	1.000	-0.301*	-0.206	-0.652***	0.366**
ROA	-0.342*	-0.343*	-0.242	-0.303	1.000	0.836***	0.339*	-0.267
ROE	-0.263	-0.223	-0.111	-0.189	0.796***	1.000	0.147	-0.460**
Profit Eff	-0.699***	-0.664***	-0.667***	-0.697***	0.396**	0.167	1.000	0.112
Cost Eff	0.534***	0.425**	0.360*	0.441**	-0.318*	-0.507***	-0.269	1.000

Spearman / Pearson	ln(HA/OC)	ln(SO/OC)	ln(SE/OC)	ln(IT/OC)	ROA	ROE	Profit Eff	Cost Eff
ln(HA/OC)	1.000	0.870***	0.889***	0.937***	-0.290	-0.186	-0.819***	0.099
ln(SO/OC)	0.900***	1.000	0.955***	0.961***	-0.310	-0.171	-0.661***	-0.082
ln(SE/OC)	0.907***	0.975***	1.000	0.984***	-0.128	0.014	-0.693***	-0.196
ln(IT/OC)	0.962***	0.976***	0.987***	1.000	-0.225	-0.085	-0.730***	-0.067
ROA	-0.308	-0.248	-0.114	-0.208	1.000	0.944***	0.209	-0.332
ROE	-0.177	-0.100	0.038	-0.061	0.945***	1.000	0.140	-0.468***
Profit Eff	-0.825***	-0.692***	-0.707***	-0.767***	0.224	0.163	1.000	-0.130
Cost Eff	0.166	-0.002	-0.116	0.002	-0.404**	-0.508**	-0.269	1.000

*, **, *** Correlation significant at the 10%, 5% and 1% respectively (2-tailed).

Table 10: Regression Analysis: Model 1 (OLS regression)

Model 1	Dependent variable	ROA				ROE			
	Parameters	IT	ln(IT/E)	ln(IT/TC)	ln(IT/OC)	IT	ln(IT/E)	ln(IT/TC)	ln(IT/OC)
β_0	CONSTANT	0.003 (0.002)	0.0203 (0.008)	-0.0999 (0.009)	-0.0001 (0.004)	0.0336 (0.020)	-0.0371 (0.1)	-0.0122 (0.102)	0.0651 (0.077)
$\beta_1 P_{jt}$	IT	0.000 (0.000)	-	-	-	0.0001 ** (0.000)	-	-	-
	ln(IT/E)	-	0.0052** (0.002)	-	-	-	-0.0262 (0.02)	-	-
	ln(IT/TC)	-	-	-0.0030 (0.002)	-	-	-	-0.0203 (0.020)	-
	ln(IT/OC)	-	-	-	-0.0016 (0.001)	-	-	-	-0.0081 (0.025)
Diagnostic tests	R	0.198	0.508	0.303	0.208	0.515	0.236	0.189	0.061
	R^2	0.039	0.258	0.092	0.043	0.265	0.056	0.036	0.004
	Adjusted R^2	0.005	0.231	0.059	0.009	0.239	0.022	0.001	-0.032

Model 1	Dependent variable	Profit Efficiency				Cost Efficiency			
	Parameters	IT	ln(IT/E)	ln(IT/TC)	ln(IT/OC)	IT	ln(IT/E)	ln(IT/TC)	ln(IT/OC)
β_0	CONSTANT	0.514*** (0.020)	0.234** (0.073)	0.178* (0.065)	0.235*** (0.044)	0.736*** (0.033)	0.666*** (0.158)	1.039*** (0.142)	0.673*** (0.119)
$\beta_1 P_{jt}$	IT	-0.001 (0.000)	-	-	-	-0.0001 (0.000)	-	-	-
	ln(IT/E)	-	-0.0569*** (0.015)	-	-	-	-0.0010 (0.032)	-	-
	ln(IT/TC)	-	-	-0.0655*** (0.013)	-	-	-	0.0725 (0.028)	-
	ln(IT/OC)	-	-	-	0.0905** (0.014)	-	-	-	0.0004 (0.038)
Diagnostic tests	R	0.030	0.584	0.697	0.767	0.384	0.006	0.441	0.002
	R^2	0.001	0.341	0.486	0.588	0.147	0.000	0.195	0.000
	Adjusted R^2	-0.035	0.318	0.468	0.573	0.117	-0.036	0.166	-0.036

*, **, *** means statistically significant at the 10%, 5% and 1% respectively. Standard deviation in ().

Table 11: Regression Analysis: Model 1-lag

Model 1	Dependent variable	ROA				ROE			
	Parameters	IT	ln(IT/E)	ln(IT/TC)	ln(IT/OC)	IT	ln(IT/E)	ln(IT/TC)	ln(IT/OC)
β_0	CONSTANT	0.005** (0.002)	-0.0286** (0.008)	-0.01548 (0.010)	-0.0028 (0.005)	0.0435** (0.023)	-0.0575 (0.115)	-0.0487 (0.116)	0.0377 (0.087)
$\beta_1 P_{jt}$	IT	0.000 (0.000)	-	-	-	0.0000 (0.000)	-	-	-
	ln(IT/E)	-	-0.0071*** (0.002)	-	-	-	-0.0318 (0.023)	-	-
	ln(IT/TC)	-	-	-0.0042 (0.002)	-	-	-	-0.0286 (0.022)	-
	ln(IT/OC)	-	-	-	-0.0026 (0.002)	-	-	-	-0.0193 (0.028)
Diagnostic tests	R	0.055	0.652	0.405	0.328	0.483	0.272	0.257	0.144
	R^2	0.003	0.425	0.164	0.108	0.233	0.074	0.066	0.021
	Adjusted R^2	-0.040	0.400	0.128	0.069	0.200	0.034	0.025	-0.022

Model 1	Dependent variable	Profit Efficiency				Cost Efficiency			
	Parameters	IT	ln(IT/E)	ln(IT/TC)	ln(IT/OC)	IT	ln(IT/E)	ln(IT/TC)	ln(IT/OC)
β_0	CONSTANT	0.512*** (0.020)	0.228** (0.073)	0.175* (0.063)	0.248*** (0.044)	0.743*** (0.035)	0.610** (0.177)	1.015*** (0.162)	0.666*** (0.130)
$\beta_1 P_{jt}$	IT	-0.000 (0.000)	-	-	-	-0.00001 (0.000)	-	-	-
	ln(IT/E)	-	-0.0575*** (0.015)	-	-	-	-0.0128 (0.036)	-	-
	ln(IT/TC)	-	-	-0.0648*** (0.012)	-	-	-	0.0666 (0.031)	-
	ln(IT/OC)	-	-	-	-0.0843*** (0.014)	-	-	-	0.0022*** (0.041)
Diagnostic tests	R	0.035	0.628	0.744	0.782	0.419	0.074	0.405	0.011
	R^2	0.001	0.394	0.554	0.611	0.175	0.005	0.164	0.000
	Adjusted R^2	-0.042	0.368	0.534	0.594	0.139	-0.038	0.128	-0.043

*, **, *** means statistically significant at the 10%, 5% and 1% respectively. Standard deviation in ().

Table 12: Regression Analysis: Model 2

Model 2	Dependent variable	ROA			ROE		
	Parameters	Π	ln(Π/E)	Ln(Π/TC)	Π	ln(Π/E)	ln(Π/TC)
β_0	CONSTANT	0.0024 (0.005)	0.0243 (0.023)	0.0381*** (0.012)	-0.0059 (0.049)	0.259 (0.240)	0.476*** (0.142)
$\beta_1 P_{jt}$	Π	-0.0001 (0.000)	–	–	0.0001*** (0.000)	–	–
	ln(Π/E)	–	0.0028 (0.004)	–	–	-0.0197 (0.047)	–
	ln(Π/TC)	–	–	0.0051 (0.002)	–	–	0.0567 (0.028)
$\beta_5 FR$	DUMMY FRANCE	-0.0044 (0.003)	-0.0106 (0.004)	-0.0121*** (0.003)	-0.0289 (0.028)	-0.1110 (0.045)	-0.1370*** (0.037)
$\beta_6 GE$	DUMMY GERMANY	-0.0050 (0.003)	-0.0104 (0.004)	-0.140*** (0.003)	-0.0268 (0.026)	-0.0978 (0.042)	-0.1480*** (0.038)
$\beta_7 ITA$	DUMMY ITALY	-0.0002 (0.003)	-0.0047** (0.002)	-0.0075** (0.002)	-0.0239 (0.031)	-0.1030*** (0.025)	-0.1330*** (0.037)
$\beta_7 SP$	DUMMY SPAIN	-0.0060 (0.005)	-0.0008 (0.003)	-0.0030 (0.002)	0.0746 (0.042)	-0.0490 (0.028)	-0.0704** (0.045)
Diagnostic tests	R	0.731	0.688	0.751	0.815	0.706	0.777
	R^2	0.534	0.473	0.564	0.665	0.499	0.604
	Adjusted R^2	0.436	0.363	0.473	0.595	0.394	0.522

Model 2	Dependent variable	Profit Efficiency			Cost efficiency		
	Parameters	Π	ln(Π/E)	ln(Π/TC)	Π	ln(Π/E)	ln(Π/TC)
β_0	CONSTANT	0.680*** (0.038)	0.688*** (0.183)	0.368*** (0.100)	0.526*** (0.022)	0.377*** (0.084)	0.549*** (0.053)
$\beta_1 P_{jt}$	Π	-0.0001** (0.000)	–	–	0.0000 (0.000)	–	–
	ln(Π/E)	–	0.0258 (0.036)	–	–	-0.0348 (0.016)	–
	ln(Π/TC)	–	–	-0.0337 (0.018)	–	–	-0.0010 (0.009)
$\beta_5 FR$	DUMMY FRANCE	-0.128*** (0.021)	-0.0989* (0.034)	-0.0532 (0.022)	0.0799*** (0.012)	0.0960*** (0.016)	0.0691*** (0.012)
$\beta_6 GE$	DUMMY GERMANY	-0.139*** (0.020)	-0.116*** (0.032)	-0.0585 (0.027)	0.193*** (0.012)	0.209*** (0.015)	0.184*** (0.014)
$\beta_7 ITA$	DUMMY ITALY	-0.0759** (0.024)	-0.0123 (0.019)	0.0017 (0.020)	0.241*** (0.014)	0.223*** (0.009)	0.227*** (0.010)
$\beta_7 SP$	DUMMY SPAIN	-0.134*** (0.033)	-0.0288 (0.022)	-0.0275 (0.018)	0.126*** (0.019)	0.0927*** (0.010)	0.104*** (0.010)
Diagnostic tests	R	0.859	0.788	0.814	0.985	0.987	0.984
	R^2	0.737	0.621	0.663	0.971	0.974	0.969
	Adjusted R^2	0.683	0.0542	0.593	0.965	0.968	0.962

Table 13: Regression Analysis: Model 3

Model 3	Dependent variable	ROA				ROE			
	Parameters	IT	ln(IT/E)	ln(IT/TC)	ln(IT/OC)	IT	ln(IT/E)	ln(IT/TC)	ln(IT/OC)
β_0	CONSTANT	0.003 (0.002)	-0.01999 (0.008)	-0.0087 (0.009)	0.0007 (0.004)	0.0353 (0.020)	-0.030 (0.094)	0.0252 (0.098)	0.0825 (0.072)
$\beta_1 P_{jt}$	IT	0.0000 (0.000)	–	-	-	0.000 (0.000)	–	-	-
	ln(IT/E)	–	-0.0051** (0.002)	-	-	–	-0.0222 (0.019)	-	-
	ln(IT/TC)	–	–	-0.0027 (0.002)	-	–	–	-0.0104 (0.019)	-
	ln(IT/OC)	-	-	-	-0.0011 (0.001)	-	-	-	0.0020 (0.024)
β_2 *St dev ROA*	St dev ROA	0.0097 (0.012)	0.00987 (0.010)	0.0088 (0.011)	0.0128 (0.007)	0.164 (0.111)	0.250 (0.112)	0.247 (0.117)	0.267 (0.115)
Diagnostic tests	R	0.248	0.533	0.334	0.397	0.566	0.450	0.414	0.412
	R^2	0.062	0.284	0.111	0.157	0.320	0.202	0.172	0.169
	Adjusted R^2	0.008	0.231	0.046	0.095	0.270	0.143	0.110	0.108

Model 3	Dependent variable	Profit Efficiency				Cost Efficiency			
	Parameters	IT	ln(IT/E)	ln(IT/TC)	ln(IT/OC)	IT	ln(IT/E)	Ln(IT/TC)	ln(IT/OC)
β_0	CONSTANT	0.515*** (0.020)	0.235** (0.074)	0.178 (0.067)	0.237*** (0.045)	0.733*** (0.032)	0.656*** (0.148)	0.994*** (0.139)	0.648*** (0.112)
$\beta_1 P_{jt}$	IT	-0.00002 (0.000)	–	-	-	-0.00001 (0.000)	–	-	-
	ln(IT/E)	–	-0.0559*** (0.015)	-	-	–	-0.0072 (0.030)	-	-
	ln(IT/TC)	–	–	0.0655*** (0.013)	-	–	–	0.0607 (0.028)	-
	Ln(IT/OC)	-	-	-	-0.0897*** (0.015)	-	-	-	-0.0143 (0.037)
β_2 *St dev ROA*	St dev ROA	0.118 (0.115)	0.0654 (0.088)	0.0003 (0.081)	0.0221 (0.072)	-0.286 (0.182)	-0.388 (0.177)	-0.296 (0.167)	-0.388 (0.178)
Diagnostic tests	R	0.195	0.595	0.697	0.768	0.468	0.389	0.528	0.387
	R^2	0.038	0.355	0.486	0.589	0.219	0.152	0.278	0.150
	Adjusted R^2	0.033	0.307	0.448	0.559	0.161	0.089	0.225	0.087

*, **, *** means statistically significant at the 10%, 5% and 1% respectively. Standard deviation in ().

Table 14: Regression Analysis: Model 4

Model 4	Dependent variable	ROA			ROE		
	Parameters	IT	ln(IT/E)	ln(IT/TC)	IT	ln(IT/E)	ln(IT/TC)
β_0	CONSTANT	-0.116 (0.054)	-0.0725* (0.026)	-0.0550 (0.029)	-0.556 (0.54)	-0.934** (0.290)	-0.8600** (0.290)
$\beta_1 P_{jt}$	IT	0.0000 (0.000)	–	–	0.0000 (0.000)	–	–
	ln(IT/E)	–	-0.0050** (0.002)	–	–	-0.0212 (0.018)	–
	ln(IT/TC)	–	–	-0.0021 (0.002)	–	–	-0.0026 (0.018)
$\beta_2 \ln TA$	LN TOTAL ASSETS	0.0079 (0.004)	0.0033 (0.002)	-0.0031 (0.002)	0.0387 (0.035)	0.0573** (0.018)	0.0582** (0.019)
Diagnostic tests	R	0.433	0.602	0.416	0.544	0.566	0.534
	R^2	0.188	0.362	0.173	0.296	0.320	0.285
	Adjusted R^2	0.127	0.315	0.112	0.244	0.270	0.232

Model 4	Dependent variable	Profit Efficiency			Cost Efficiency		
	Parameters	IT	ln(IT/E)	ln(IT/TC)	IT	ln(IT/E)	ln(IT/TC)
β_0	CONSTANT	-1.444*** (0.420)	-0.166 (0.237)	0.0325 (0.214)	1.474 (0.899)	1.750*** (0.492)	1.767*** (0.448)
$\beta_1 P_{jt}$	IT	-0.0001*** (0.000)	–	–	-0.0001 (0.000)	–	–
	ln(IT/E)	–	-0.0547*** (0.014)	–	–	-0.0070 (0.030)	–
	ln(IT/TC)	–	–	-0.0625*** (0.014)	–	–	0.0573 (0.028)
$\beta_2 \ln TA$	LN TOTAL ASSETS	0.129*** (0.028)	0.0255 (0.014)	0.0100 (0.014)	-0.0484 (0.059)	-0.0692 (0.030)	-0.0500 (0.029)
Diagnostic tests	R	0.669	0.640	0.704	0.410	0.406	0.523
	R^2	0.447	0.410	0.496	0.168	0.165	0.273
	Adjusted R^2	0.406	0.366	0.458	0.106	0.103	0.219

*, **, *** means statistically significant at the 10%, 5% and 1% respectively. Standard deviation in ().

Table 15: Regression Analysis: Model 1-multiple

Model 1-multiple	Dependent variable	ROA				ROE			
	Parameters	Ha So Se	ln(Ha/E) ln(So/E) ln(Se/E)	ln(Ha/TC) ln(So/TC) ln(Se/T)	ln(Ha/OC) ln(So/OC) ln(Se/OC)	Ha So Se	ln(Ha/E) ln(So/E) ln(Se/E)	ln(Ha/TC) ln(So/TC) ln(Se/TC)	ln(Ha/OC) ln(So/OC) ln(Se/OC)
β_0	CONSTANT	0.0059*** (0.002)	-0.0401*** (0.009)	-0.0315* (0.011)	-0.0185** (0.005)	0.0547*** (0.013)	-0.2750* (0.098)	-0.237 (0.101)	-0.235 (0.094)
$\beta_1 P_{jt}$	Ha	-0.000001 (0.000)	-	-	-	0.00003 (0.000)	-	-	-
	So	-0.00007*** (0.000)	-	-	-	-0.0009*** (0.000)	-	-	-
	Se	0.00003*** (0.000)	-	-	-	0.0003*** (0.000)	-	-	-
	ln(Ha/E)	-	-0.0108* (0.004)	-	-	-	-0.136** (0.042)	-	-
	ln(So/E)	-	-0.0208* (0.007)	-	-	-	-0.294*** (0.078)	-	-
	ln(Se/E)	-	0.0282** (0.008)	-	-	-	0.431*** (0.088)	-	-
	ln(Ha/TC)	-	-	-0.0090 (0.004)	-	-	-	-0.1410** (0.040)	-
	ln(So/TC)	-	-	-0.0271*** (0.007)	-	-	-	-0.3100*** (0.070)	-
	ln(Se/TC)	-	-	0.0354*** (0.009)	-	-	-	0.4610*** (0.083)	-
	ln(Ha/OC)	-	-	-	-0.0070* (0.002)	-	-	-	-0.127** (0.042)
	ln(So/OC)	-	-	-	-0.0175*** (0.004)	-	-	-	-0.298*** (0.074)
	ln(Se/OC)	-	-	-	0.0241*** (0.005)	-	-	-	0.437*** (0.083)
Diagnostic tests	R	0.737	0.731	0.680	0.738	0.895	0.741	0.758	0.736
	R^2	0.543	0.534	0.463	0.545	0.801	0.549	0.574	0.542
	Adjusted R^2	0.490	0.480	0.401	0.493	0.778	0.496	0.525	0.489

*, **, *** means statistically significant at the 10%, 5% and 1% respectively. Standard deviation in ().

Model 1-multiple	Dependent variable	Profit Efficiency				Cost efficiency			
	Parameters	Ha So Se	ln(Ha/E) ln(So/E) ln(Se/E)	ln(Ha/TC) ln(So/TC) ln(Se/TC)	ln(Ha/OC) ln(So/OC) ln(Se/OC)	Ha So Se	ln(Ha/E) ln(So/E) ln(Se/E)	ln(Ha/TC) ln(So/TC) ln(Se/TC)	ln(Ha/OC) ln(So/OC) ln(Se/OC)
β_0	CONSTANT	0.5360*** (0.024)	0.199 (0.096)	0.134 (0.096)	0.147 (0.068)	0.6750*** (0.029)	0.973*** (0.142)	1.2610*** (0.149)	1.053*** (0.137)
$\beta_1 P_{jt}$	Ha	-0.00005 (0.000)	-	-	-	0.0001 (0.000)	-	-	-
	So	-0.00014 (0.000)	-	-	-	0.0007 (0.000)	-	-	-
	Se	0.00007 (0.000)	-	-	-	-0.0003*** (0.000)	-	-	-
	ln(Ha/E)	-	-0.0995 (0.041)	-	-	-	0.265*** (0.061)	-	-
	ln(So/E)	-	0.0665 (0.077)	-	-	-	0.384** (0.114)	-	-
	ln(Se/E)	-	-0.0305 (0.086)	-	-	-	-0.686*** (0.128)	-	-
	ln(Ha/TC)	-	-	-0.0499 (0.038)	-	-	-	0.2770*** (0.059)	-
	ln(So/TC)	-	-	0.0081 (0.067)	-	-	-	0.2790 (0.104)	-
	ln(Se/TC)	-	-	-0.0221 (0.080)	-	-	-	-0.5210*** (0.123)	-
	ln(Ha/OC)	-	-	-	-0.124*** (0.030)	-	-	-	0.274*** (0.061)
	ln(So/OC)	-	-	-	0.032 (0.053)	-	-	-	0.335** (0.108)
	ln(Se/OC)	-	-	-	-0.0037 (0.060)	-	-	-	-0.629*** (0.121)
Diagnostic tests	R	0.348	0.657	0.701	0.834	0.741	0.770	0.777	0.763
	R^2	0.121	0.431	0.491	0.695	0.550	0.592	0.603	0.582
	Adjusted R^2	0.019	0.366	0.432	0.660	0.498	0.545	0.557	0.534

*, **, *** means statistically significant at the 10%, 5% and 1% respectively. Standard deviation in ().