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Efficiency in banking services: a comparative analysis of Internet-primary and branching banks in the US

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Abstract This paper investigates the provision of financial services by banks as a two-stage production process involving three different basic activities. The first stage includes service activities, while the second stage comprises both investment-related and risk management activities. Financial services performance is assessed in terms of service efficiency and investment and risk management efficiency for years 2002–2010. The major empirical findings are that the Internet-primary bank is more efficient than most branching banks in deposit-raising activities, but with regard to investment and risk management activities, there are many brick-and-mortar banks that match the online bank performance.

Keywords Online banking · Internet-primary banking · Banking efficiency · Data Envelopment Analysis

1 Introduction

Banks play a central role for financial intermediation since they keep the savings of the public that represent the bulk of any developed country's money stock. Many studies maintain that the efficiency of financial services affects economic growth, while bank inefficiency has often been claimed as a major cause of banking crises in an economy. Evaluating banks' performance and monitoring their financial situation have been issues of great concern and of critical importance for various stakeholders such as bank managers, shareholders, customers, investors, governments, and the general public.

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The Internet has already become an important distribution channel to the US banking industry. For the most part, US financial institutions follow a multi-channel distribution model in which the Internet complements the traditional channels (mainly branches and ATMs). Only a small number of banks deliver banking services primarily over the Internet. In his study for the period 1997–1999, De Young (2001) compared financial performance of both Internet-primary and branching banks in the USA. Subsequent research works (De Young 2005; Momparler et al. 2012) investigated the existence of technology-based experience effects and technology-based scale effects that might benefit those banks that make a more intensive use of technology than branching banks.

The drive for innovation and organizational learning has played a key role in the development and marketing of new financial services (Aizpurua et al. 2011; Bettiol et al. 2012; Lindic et al. 2011). Firms involved in innovation activities need to balance exploration and exploitation of organizational knowledge and competences (Cegarra-Navarro et al. 2011; Yang and Li 2011). The Internet-primary banking model was first advanced by firms with a strong commitment to customer-focused service innovation (Van Riel et al. 2011). The influence of sector and size (Caceres et al. 2011), board composition (De Cleyn and Braet, 2012), business culture, and entrepreneurial orientation (Lee et al. 2011; Naranjo-Valencia et al. 2011; Zortea-Johnston et al. 2012) on firms' commitment to innovation have been the subject of many research works. Likewise, service firms' integration in networks through open innovation and co-innovation has deserved the attention of scholars (Lee et al. 2011, 2012).

Innovation management and performance in the service industry have been assessed from different perspectives (Crevani et al. 2011; Cho et al. 2011). However, when it comes to measuring financial services firms' competitiveness, it may differ according to various performance evaluation approaches on the basis of resources, capabilities, brand equity, and social responsibility policies (Ferreira et al. 2011; Server-Izquierdo and Capo-Vicedo 2012; Wang et al. 2012).

Although bank performance has been traditionally assessed on the basis of financial ratios; as a consequence of developments in operational research, there has been a shift toward quantitative techniques. Data Envelopment Analysis (hereafter DEA) is the most commonly used technique in evaluating bank performance (Fethi and Pasiouras 2010). DEA, based on the efficiency concepts defined by Farrell (1957) and initially developed by Charnes et al. (1978), is a well-established non-parametric approach used to evaluate the relative efficiency of a set of comparable entities called decision-making units (DMUs) with multiple inputs and outputs.

There are several alternative models that may be used in DEA methodology to describe performance from different perspectives. However, most studies focus on the technical efficiency of banks (Pasiouras 2008a, b). This efficiency measure reflects the ability of a bank to maximize outputs with a given set of inputs or to produce a given amount of outputs with minimum inputs. Other efficiency indices defined by the DEA-based methodology include pure technical efficiency, scale efficiency, or total factor productivity (Berger and Humphrey 1997; Fethi and Pasiouras 2010). This study focuses on function-oriented efficiency measures in banking through DEA. More specifically, we portray a bank's operations with three basic components (service activities, investment activities, and risk management activities) and apply a DEA model for efficiency measures. Accordingly, service activities efficiency is measured in the first stage, and the efficiency in both investment and risk management efficiency activities is jointly measured in the second stage.

This study measures the efficiency indices for the leading Internet-primary financial institution in the US, ING Bank, and 22 similar-sized branching banks. The branching bank sample comprises all FDIC insured US banks with December 2002 total assets within the range defined by ING Bank total assets ±30 %, excluding banks with less than ten offices and with incomplete data for the 2002–2010 period. In addition, we analyze different components in ING Bank's operations and compare them with branching banks' to assess ING's service efficiency and investment and risk management efficiency with the DEA methodology. Due to the special characteristics of the ING business model and because of its prevalence in the US Internet-primary segment, we deem it appropriate to focus on this bank as a special and relevant case of Internet-primary banking.

The remainder of this paper is organized as follows: In the conceptual framework section, we provide background to place our study in the context of the existing literature. Next, the DEA methodology and the data characteristics are discussed. Then, empirical results are described and interpreted. Finally, the main conclusions, managerial implications, and limitations of our study are put forward.

2 Conceptual framework

Estimating efficiency in the banking sector involves identifying the efficient frontier as a benchmark for measuring the relative performance of each bank or DMU. The relative efficiency score of a DMU will be determined by how close it is to the efficient frontier. The efficient frontier methods can be grouped into two broad categories as follows: non-parametric, and parametric.

Holod and Lewis (2011) point out that non-parametric methods do not put any restrictions on the functional form of the relationship between inputs and outputs. This feature of non-parametric methods is particularly appealing for estimating efficiency of financial institutions which do not have a well-defined production function. Moreover, non-parametric methods do not allow for a random error in the estimation process.

Berger and Humphrey (1997) and Berger (2007) discuss different efficient frontier techniques to determine financial efficiency. Most studies in this field focus on banks' technical efficiency (Lozano-Vivas et al. 2002; Pasiouras 2008a, b). This efficiency measure indicates whether a bank uses the minimum quantity of inputs to produce a given quantity of outputs or maximizes the output quantity, given a certain quantity of inputs. Technical efficiency can be estimated with an input-oriented approach, analyzing how much can inputs be reduced without changing the output produced, or with an output-oriented approach, evaluating how much can output be increased without altering the inputs used. Fethi and Pasiouras (2010) focus on banking studies that obtain efficiency estimations under the input-oriented approach based on the assumption that bank managers have higher control over inputs than over outputs. However, there are other studies that adopt the output-oriented approach or that report the results from both approaches (Casu and Molyneux 2003).

Irrespective of the method of choice for estimating efficiency, it is essential to identify the appropriate inputs and outputs of a banking organization. Unfortunately, due to the nature of a bank's operations, the definition of its inputs and outputs is controversial. Berger and Humphrey (1997) identify the following two main approaches for the selection of inputs and outputs: the production approach, and the intermediation approach.

The production approach assumes that banks produce loans and deposits account services using employees and fixed assets as inputs, and that the number and type of transactions or documents processed measure outputs. On the other hand, the intermediation approach perceives banks as financial intermediaries between savers and investors that use deposits and other liabilities in order to make loans and invest in other earning assets, so total loans and securities are defined as outputs.

The intermediation approach is favored in the literature (Fethi and Pasiouras 2010) because there are difficulties in collecting the detailed transaction flow information required in the production approach. However, the dual role of deposits in the bank production process forces researchers to take either the production or financial intermediation approach. Numerous empirical studies adopt the intermediation approach while other research works use the production approach. Berger and Humphrey (1997) argue that neither of these two approaches is perfect because they cannot fully capture the dual role of financial institutions as providers of transactions/document processing services and also being financial intermediaries. They point out that the production approach may be somewhat better for evaluating the efficiencies of bank branches, and the intermediation approach may be more appropriate for evaluating financial institutions as a whole.

More recently, some studies adopted another variation of the intermediation approach. This is the so-called profit-oriented (or operating) approach which defines revenue components (e.g., interest income, non-interest income) as outputs and cost components (e.g., personnel expenses, interest expenses) as inputs (Das and Ghosh 2006; Pasiouras 2008a, b).

The traditional inputs are fixed assets and personnel. Some studies use the number of personnel (Pasiouras 2008b; Holod and Lewis 2011), while others rely on personnel expenses due to data unavailability (Lozano-Vivas et al. 2002). Also, deposits are often considered to be an input (Isik and Hassan 2002; Casu and Girardone 2004). However, some studies use branches (Chen 2001), loan loss provisions (Pasiouras 2008b), and equity (Sturm and Williams 2004; Pasiouras 2008a) as additional or alternative inputs. Chen (2001) disaggregates deposits into current deposits and time deposits, while Das and Ghosh (2006) use demand, savings, and fixed deposits. Casu and Girardone (2006) use total costs as a single input while Casu and Molyneux (2003) use total costs and total deposits (i.e., customers and short-term funding).

Several studies use two outputs, usually, loans and other earning assets that normally include various items such as government securities, investment securities, trading securities, other securities, equity investments, and other investments (Casu and Molyneux 2003; Casu and Girardone 2004, 2006; Holod and Lewis 2011). However, some studies disaggregate loans into various categories such as housing loans, other loans (Sturm and Williams 2004), real estate loans, commercial loans, and personal loans (Fare et al. 2004), or short-term and long-term loans (Isik and Hassan 2002). Other authors disaggregate other earning assets into investments and liquid assets (Tsionas et al. 2003) or investment in government securities and investments in public and private enterprises (Chen 2001). Yet, other studies use the number of branches as an additional output under the assumption that it represents an additional value for retail customers. Recent studies include non-interest income or off-balance-sheet items as additional outputs (Isik and Hassan 2002; Sturm and Williams 2004; Pasiouras 2008b).

Instead of treating deposits as an input or an output, Sealey and Lindley (1977) define only earning assets as outputs, while deposits, liabilities, labor, and physical capital are inputs in the intermediation process. Berger and Humphrey (1997) identify those balance sheet categories as outputs that contribute to the added value of a bank. To fuel the controversy, Holod and Lewis (2011) consider deposits to be an intermediate product that is an output from the first stage of the bank production process and is an input to the second stage. They ask to what levels can a bank reduce its true inputs (employees and fixed assets) and increase its true outputs (loans and other earning assets), given a certain amount of deposits. Instead, the effect of deposits on the overall bank efficiency is determined by the bank′s relative efficiency at each stage of production.

Consistent with Holod and Lewis (2011), our study describes a bank's production activities as a two-step process. In the first step, banks use labor and physical capital to obtain deposits, an intermediate output in a bank′s production process. In the second step, the deposits become an input in the production of loans and securities. Meanwhile, non-performing loans are jointly produced in this stage and are considered as an undesirable output and assumed to be weakly disposable. Figure 1 illustrates the model.

In line with the above described two-step process, we classify banking operations according to different functions. A bank performs service activities in the first phase

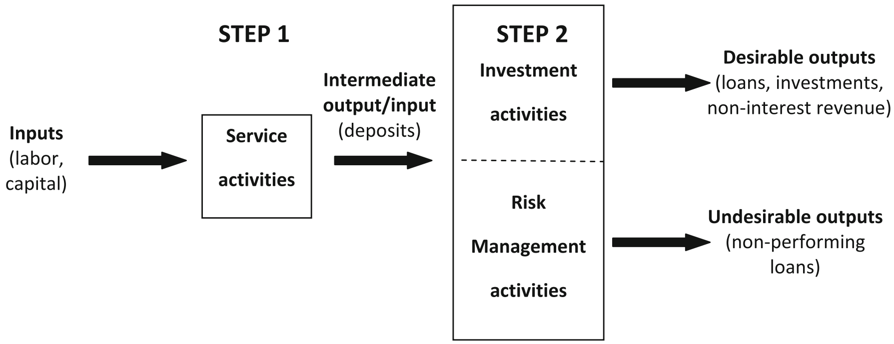

Fig. 1 Steps in the production process of a bank

by using labor and capital. The resulting (intermediate) outputs are deposits which cannot immediately generate revenue. Under this approach, the second phase may be defined as performing investment-related activities. Also, we segregate the investment-related activities into two different groups as follows: activities producing desirable outputs, and those controlling undesirable outputs. The first one refers to loan portfolio activities, while the second stands for activities for controlling non-performing loans. This arrangement makes it simple to measure bank performance according to different activities which are defined as service efficiency and investment and risk management efficiency.

3 Methodology

In this study, we perform different analyses for each stage (Fig. 1) in accordance with their specific characteristics. In the first stage, to analyze efficiency in service activities, we use the Slack Based Measure (SBM) which is one of the efficient frontier DEA models. Also, the Malmquist Productivity Index (MPI) is obtained for all the banks in the sample in order to measure their service efficiency over the period 2002–2010. In the second stage, where efficiency in both investment and risk management activities is analyzed, we use a modified SBM to better handle the presence of an undesirable output (non-performing loans).

There are two main types of efficiency indicators: models that estimate the absolute efficiency analyzed (which include global indices and econometric approaches) and models that use the production frontier to assess relative efficiency of the DMU by comparing its behavior with the efficient frontier. In the context of frontier models, Farrell (1957) pioneered in the research of frontier functions used as references to obtain efficiency measurements for each productive unit. An efficient frontier defines the relationship between inputs and outputs by depicting graphically the maximum output obtainable from the given inputs consumed.

Production frontiers may be estimated by using two types of approaches: (i) stochastic methods; and (ii) the non-parametric and non-stochastic approach. In some works, non-parametric models and parametric frontiers have been used to detect whether there are divergences in the efficiency indices obtained between the two approximations. The results are very similar favoring the application of the non-parametric technique since it offers a large degree of flexibility and eliminates specification errors, as it is not necessary to select a specific functional form. Because of these advantages, we have adopted this approach.

The DEA methodology developed by Charnes et al. (1978) is a non-parametric method for the estimation of production frontiers. DEA measures the relative distance from where a DMU (a bank) lies to the estimated frontier. Those DMUs that are identified as efficient are located on the production frontier and become references for evaluating the efficiency of the remaining DMUs.

With DEA, it is possible to determine the relative efficiency of each bank, as long as they are comparable in the sense that they all consume the same inputs and produce the same outputs, although in different quantities. The result is an efficiency score for each bank and for those banks identified as inefficient, an operating target.

Moreover, DEA provides, among other things, an involving empirical surface which represents the best frontier in practice and an efficient metric for representing a measure of the maximal behavior for each DMU, given its distance from the frontier. In addition, according to Charnes et al. (1996), DEA can handle multiple input and multiple output models and does not require any hypothesis on functional relationships between inputs and outputs, and it does not assume any distribution for inefficiency.

Nevertheless, DEA does not work well when the number of DMUs is small. The so-called "Cooper rule" (Charnes and Neralic 1990) provides that at least the number of DMUs object of analysis should be approximately twice the sum of the number of inputs and outputs.

Charnes et al. (1978) developed the CCR models (the input-oriented and the output-oriented) which assume that production technology verifies the hypothesis of constant returns to scale (hereafter CRS). In addition, Banker et al. (1984) proposed an efficiency analysis model with variable returns to scale (hereafter VRS) known as BCC that can be formulated with both input and output orientations. The efficiency scores obtained using the DEA-BCC model are equal or higher than the scores obtained from the DEA-CCR model. The efficiency indices obtained from CCR and BCC models only take into account the radial inefficiency found for each of the units under study, and they do not compute the inefficiency gaps detected by the slacks.

3.1 The slack based measure (SBM)

For the efficiency index to consider all sorts of inefficiencies (,i.e., both radial and non-radial), DEA has developed alternative models to generate non-radial efficiency measures, both oriented and non-oriented. One of these alternative models is SBM, a non-oriented measure which can be formulated as follows:

$$\begin{aligned}
&\min R_{e0} = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \frac{s_{i0}^-}{x_{i0}}}{1 + \frac{1}{s}\sum_{r=1}^{s} \frac{s_{r0}^+}{y_{r0}}} \\
&s.t.: \sum_{k=1}^{n} l_k x_{ik} = x_{i0} - s_{i0}^- \quad i = 1, \ldots, m \\
&\sum_{k=1}^{n} l_k y_{rk} = y_{r0} + s_{r0}^+ \quad r = 1, \ldots, s \\
&\sum_{k=1}^{n} l_k = 1 \\
&s_{i0}^- 0 \quad i = 1, \ldots, m \\
&s_{r0}^+ 0 \quad r = 1, \ldots, s \\
&l_j 0 \quad j = 1, \ldots, n
\end{aligned} \tag{1}$$

The objective function in (1) shows that the efficiency ratio includes all kinds of inefficiencies, both radial and non-radial, found in each of the inputs and outputs of the model. Furthermore, the value of this non-oriented measure can be interpreted as the ratio of "inputs average deviations to outputs average deviations". It should be noted that this measure confirms certain desirable properties (invariance and monotony) for an efficiency measure, which represents an advantage over other such measures defined in the literature. The model incorporates the convexity constraint for VRS. In the case of considering CRS, the convexity constraint should be waived.

Although both models have been applied extensively in the literature to measure the efficiency of a number of units, the usefulness of these models is their ability to determine the level of inefficiency in the use of inputs for each DMU. Thus, it is possible to know what kind of adjustment (reduction in the case of inputs or increase in the case of outputs) should be made to become an efficient unit. For instance, it will tell us whether the bank is overcapitalized or overstaffed relative to other DMUs. The introduction of prices for different inputs and outputs selected in the analysis of technical efficiency facilitates the study of the economic efficiency of the units.

3.2 Malmquist productivity index (MPI)

Since all the units in the analysis are active over time, it is appropriate to perform a year-by-year study that compares several annual periods simultaneously. The method used for this purpose is MPI which measures variations in the efficiency of each unit, both by itself and by changes in the frontier for each of the different years.

To measure the productivity and technical change between different time periods, we apply MPI which can be divided into the following two components: (i) efficiency change; and (ii) technological change, as shown in Eq. 2:

$$\mathrm{MPI} = \frac{E_{t+1}^{t+1}}{E_t^t}\sqrt{\frac{E_{t+1}^t}{E_{t+1}^{t+1}}\frac{E_t^t}{E_t^{t+1}}} = \mathrm{MEC} \times \mathrm{MTC} \qquad (2)$$

MPI may have the following three alternative values: (i) if MPI < 1, then productivity declines; (ii) if MPI $= 1$, then productivity remains unchanged; and (iii) if MPI > 1, productivity improves.

Equation 2 indicates that the computation of MPI requires solving four linear programming problems. Note that they are CRS DEA models. Equation 3 is used to obtain E_t^t, Eq. 4 is used to obtain E_{t+1}^{t+1}, Eq. 5 is used to obtain E_{t+1}^t and Eq. 6 is used to obtain E_t^{t+1}.

$$\begin{aligned} & E_t^t = Max\varphi \\ & s.t: \\ & \sum_{j=1}^{n}\lambda_j x_{ij}(t) < x_{i0}(t) \qquad i = 1,\ldots m \\ & \sum_{j=1}^{n}\lambda_j y_{rj}(t) > \varphi y_{r0}(t) \qquad r = 1,\ldots s \\ & \lambda_j > 0 \qquad j = 1,\ldots n \end{aligned} \qquad (3)$$

$$
\begin{aligned}
& E_{t+1}^{t+1} = Max\varphi \\
& s.t: \\
& \sum_{j=1}^{n} \lambda_j x_{ij}(t+1) \leq x_{i0}(t+1) \qquad i = 1, \ldots m \\
& \sum_{j=1}^{n} \lambda_j y_{rj}(t+1) \geq \varphi y_{r0}(t+1) \quad r = 1, \ldots s \\
& \lambda_j \geq 0 \qquad j = 1, \ldots n
\end{aligned} \tag{4}
$$

$$
\begin{aligned}
& E_{t+1}^{t} = Max\varphi \\
& s.t: \\
& \sum_{j=1}^{n} \lambda_j x_{ij}(t) \leq x_{i0}(t+1) \qquad i = 1, \ldots m \\
& \sum_{j=1}^{n} \lambda_j y_{rj}(t) \geq \varphi y_{r0}(t+1) \quad r = 1, \ldots s \\
& \lambda_j \geq 0 \qquad j = 1, \ldots n
\end{aligned} \tag{5}
$$

$$
\begin{aligned}
& E_{t}^{t+1} = Max\varphi \\
& s.t: \\
& \sum_{j=1}^{n} \lambda_j x_{ij}(t+1) \leq x_{i0}(t) \qquad i = 1, \ldots m \\
& \sum_{j=1}^{n} \lambda_j y_{rj}(t+1) \geq \varphi y_{r0}(t) \quad r = 1, \ldots s \\
& \lambda_j \geq 0 \qquad j = 1, \ldots n
\end{aligned} \tag{6}
$$

3.3 Independent models: SBM with an undesirable output

An underlying assumption in DEA models is the basic efficiency principle of producing more outputs with less inputs. However, as we have an unwanted output (non-performing loans) in the second stage of our analysis; in the presence of undesirable outputs, the basic model must be reformulated. Many authors have proposed different models for this purpose. Although there are a number of DEA models available, the common practice in a context with undesirable outputs is to use the SBM model because it is a non-radial and non-oriented model that takes into account the slacks of the restrictions. Therefore, a SBM model is used as a basic model which is then modified to incorporate these unwanted outputs.

In the presence of undesirable outputs, one unit $\left(x^0, y_0^g, y_0^b\right)$ is efficient if there is no vector $\left(x, y^g, y^b\right) \in P$ (set of production possibilities), such that $x_0 \geq x$, $y_0^g \leq y^g$, $y_0^b \geq y^{gb}$, with at least a strict inequality. A unit is efficient if, and only if, $\rho^* = 1$ and all slacks (s) equal zero. Otherwise it will be considered inefficient, and it could turn efficient by reducing either the inputs or the undesired outputs and by increasing desired outputs in line with the projections for original values and slack variables.

This model involves the weighting of the desirable and undesirable outputs according to the decision maker's choice. The formulation of the model in mathematical terms is as follows:

$$\rho^* = \frac{1 - \frac{1}{m}\sum_{i=1}^{m}\frac{s_{io}^-}{x_{i0}}}{1 + \frac{1}{s}\left(W_1\sum_{r=1}^{s_1}\frac{s_r^g}{y_m^g} + W_{12}\sum_{r=1}^{s_{21}}\frac{s_r^b}{y_m^{gb}}\right)}$$

$$\begin{aligned} x_0 &= X\lambda + s^- \\ y_0^g &= Y\lambda - s^g \\ y_0^b &= Y\lambda + s^b \\ L &\le e\lambda \le U \\ s^-, s^g&, s^b, \lambda \ge 0 \end{aligned} \tag{7}$$

3.4 Data set

The DEA models discussed were applied to domestic commercial banks in the US. The sample consisted of 23 financial institutions: the main Internet-primary financial bank in the US and a similar-size peer group of 22 branching banks. The sample for this study included firm-year observations on inputs and outputs for the period 2002–2010.

The financial data used in this study were collected from the FDIC database. The similar-size branching banks and thrifts included in our study are those with 2002 final assets within a range defined by ING Bank's assets ±30 %. For branching banks to be included in the sample, they must meet the following two requirements: being active as independent financial institutions throughout the whole period (2002–2010), and operating with more than five branches.

The variables used as inputs in the first stage of the banking production process are "bank premises and fixed assets" (I1) and "salaries and employee benefits" (I2), while the variable used as output is "total deposits" (I/O). In the second stage, we hold "total deposits" (I/O) as the only input; then, "net loans and leases" (OD1), "securities" (OD2), and "total non-interest income" (OD3) as desirable outputs and "loan loss allowance" (OND1) as the undesirable output.

4 Results and discussion

This paper focused on the relative efficiency of two different business models (Internet-primary vs. branching) in the provision of services and in investment and risk management. As mentioned above, a bank's production process is characterized by two stages. In the first stage, we assessed the technical efficiency of services in attracting deposits from its customers, while the efficiency in investment and credit risk management activities was analyzed in the second stage. Credit risk management was measured through non-performing loans and considered as an undesirable output in our model.

In the first stage, in order to assess services efficiency, we used SBM, a DEA model described in the previous section, which incorporates the VRS constraint. In addition, the SBM model provides efficiency scores that contain all sorts of inefficiencies (both radial and non-radial) for every input and output in the model. The SBM efficiency scores for each bank are shown in Table 1. A poor score implies that a bank is using more inputs than required to produce certain amount of intermediate outputs, or else, that it should produce more intermediate outputs with a given amount of inputs.

Table 1 shows that only two banks (6 and 14) were efficient in their deposit-taking activity throughout the entire period 2002–2010, one of them being the only Internet-primary bank in the sample (bank 14). This indicates that while online banking was efficient in attracting deposits, branching banks were clearly inefficient in this activity. For the entire period under consideration, the maximum average efficiency in the collection of deposits was reached in 2002 followed by a sharp decline in years 2003 and 2004. In the period 2005–2007, average efficiency declined further. Since 2007, the level of efficiency began to stabilize, and in 2010, it was around 0.30. Overall, efficiency in deposit-taking services declined by 60 % over the period 2002–2010. This loss of efficiency was entirely due to branching banks as the Internet-primary bank was efficient throughout the whole period.

One major advantage of the SBM model is its ability to determine the level of inefficiency in each of the inputs for each DMU so that the model pinpoints the type of adjustment required (either reduction of inputs or increase of outputs) to become an efficient DMU.

Table 4 in Appendix shows the projections to the closest point of the frontier for each of the inputs (bank premises and fixed assets, and salaries and employee benefits) as well as the intermediate output (total deposits) in the first stage of the production process. Table 4 in Appendix also illustrates that for most inefficient banks, to become efficient, would require significantly higher output rather than lower inputs.

To complete the bank efficiency analysis in this first phase, we performed a dynamic analysis of efficiency for each bank in the sample using MPI. This method measures changes in the efficiency of a bank and helps determine whether year-to-year modifications in the efficiency of a bank are due to fluctuations in technical efficiency (MCE) resulting from changes in inputs or outputs, or else it is caused by the shifting of the technological frontier (MCT). A bank's relative efficiency may change as a result of changes in efficiency for the other banks in the sample so that the maximum efficiency frontier is moved. MPI may have three alternative values as follows: if $\mathrm{MPI} < 1$, then productivity declines; if $\mathrm{MPI} = 1$, then productivity remains unchanged; and if $\mathrm{MPI} > 1$, productivity improves. A similar interpretation applies to the decomposed indices.

We reviewed the trends in the efficiency of the 23 banks in the sample from 2002 to 2010. For the calculation of MPI, we employed Eq. 2 (defined in the previous section) which describes the change in the productivity of a bank as the product of the following two factors: the change in MCE, and the change in MCT. Table 2 summarizes the results.

Table 2 presents the MPI values obtained for the period analyzed as well as their two components, MCE and MCT. The results showed that out of 23 financial institutions surveyed, ten banks scored equal to or greater than 1 in the MCE index. This means that 43 % of the surveyed banks managed to improve their efficiency

Table 1 SBM efficiency scores for stage 1

Banks	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	0.6078	0.4975	0.2871	0.3400	0.3035	0.2312	0.2117	0.2245	0.2015
2	0.8768	0.5350	0.3160	0.2413	0.2050	0.1656	0.1347	0.1409	0.1470
3	0.7293	0.4533	0.2627	0.1978	0.1699	0.1313	0.1156	0.1254	0.1581
4	0.5632	0.3640	0.2092	0.1677	0.1506	0.1246	0.1257	0.1156	0.1294
5	0.7227	0.4721	0.2892	0.2914	0.2536	0.2422	0.3360	0.4415	0.3480
6	1	1	1	1	1	1	1	1	1
7	1	0.6789	0.4172	0.3051	0.2593	0.1959	0.1824	0.2348	0.2345
8	0.8592	0.5353	0.3313	0.2464	0.2269	0.1901	0.1797	0.1894	0.1943
9	0.6965	0.4384	0.2660	0.2145	0.1888	0.1762	0.1776	0.1739	0.2223
10	0.5880	0.4195	0.2823	0.3001	0.2290	0.2330	0.2893	0.3043	0.3440
11	0.9830	0.6118	0.3579	0.2702	0.2336	0.1839	0.1640	0.1787	0.1999
12	0.7997	0.4645	0.2562	0.1814	0.1592	0.1214	0.1126	0.1150	0.1502
13	0.9806	1	0.8319	0.4872	0.3536	0.4219	0.4256	0.5170	0.6118
14	1	1	1	1	1	1	1	1	1
15	0.3367	0.1787	0.2336	0.2193	0.1281	0.1979	0.2043	0.2013	0.1572
16	0.5762	0.6504	0.3673	0.2974	0.2609	0.2671	0.3037	0.4032	0.2616
17	0.6747	0.4026	0.2236	0.1622	0.1641	0.1928	0.3151	0.3147	0.4052
18	0.8581	0.5405	0.3086	0.2275	0.1927	0.1468	0.1239	0.2075	0.2317
19	0.7949	0.4778	0.2809	0.2311	0.2092	0.1595	0.1434	0.1548	0.1498
20	0.7896	0.5048	0.2892	0.2342	0.2247	0.1764	0.1622	0.1785	0.1874
21	0.7008	0.4431	0.2642	0.2166	0.1817	0.1473	0.1633	0.1589	0.1628
22	0.7895	0.5265	0.3710	0.2931	0.2659	0.2059	0.1733	0.1881	0.1764
23	0.7368	0.4391	0.2844	0.2304	0.2213	0.1923	0.2276	0.1972	0.2179
Average	0.7680	0.5493	0.3796	0.3198	0.2862	0.2653	0.2727	0.2941	0.2996
SD	0.1654	0.1999	0.2256	0.2203	0.2259	0.2346	0.2378	0.2406	0.2406
Maximum	1	1	1	1	1	1	1	1	1
Minimum	0.3367	0.1787	0.2092	0.1622	0.1281	0.1214	0.1126	0.1150	0.1294
Efficient DMUs	3	3	2	2	2	2	2	2	2
Inefficient DMUs	21	21	21	21	21	21	21	21	21

during the period under analysis, as they had moved closer to the technological frontier. Notice that all the banks showing improvement in efficiency were branching banks, while the Internet-primary bank efficiency score worsened over the same period (MCE = 0.58).

It is also noteworthy that the average value for the variable measuring technological change was fairly high (MCT = 1.61). This implies that there are shifts in the production frontier which is used to measure the efficiency of each bank. Therefore, there was technological progress from 2002 to 2010. MCT was greater than one in 17 of the 23 banks in the sample. Even though the Internet-primary bank MCT score was higher than 1 (1.10), it was well below the average (1.61).

Table 2 Malmquist Productivity Index (2002–2010)

Bank	MCE	MCT	MPI
1	0.70024	1.72318	1.20664
2	0.96615	2.0396	1.97056
3	1.93553	1.45279	2.81192
4	1.02114	1.51247	1.54444
5	1.86025	0.70033	1.30279
6	1.76597	0.54912	0.96972
7	0.31093	2.52939	0.78647
8	1.0972	2.10122	2.30547
9	1.09823	1.70795	1.87572
10	0.75912	1.45038	1.10102
11	0.35696	3.97438	1.4187
12	0.94713	1.72117	1.63017
13	0.95906	0.94405	0.9054
14	0.57924	1.10351	0.63919
15	0.37613	0.73186	0.27528
16	0.68133	1.6069	1.09483
17	2.27914	0.71741	1.63509
18	1.00426	2.04443	2.05315
19	1.08776	2.30609	2.50848
20	0.94491	1.97793	1.86897
21	0.77573	0.98051	0.76061
22	0.90887	1.58384	1.43951
23	1.12835	1.58307	1.78626
Average	1.02364	1.6105	1.47349
Max	2.27914	3.97438	2.81192
Min	0.31093	0.54912	0.27528
SD	0.50634	0.75024	0.6283

Of all the surveyed banks, 17 had MPI values greater than or equal to 1 with the average MPI being 1.47. Thus, we can argue that in the period analyzed, there was an improvement of productivity in deposit-taking activities. However, it is important to note that ING Bank had a single MPI of 0.64 which showed the loss of productivity of the Internet-primary model vis-à-vis the traditional branching model.

In the second stage of the production process, the levels of relative efficiency in both investment and risk management activities were examined. The intermediate output (total deposits) obtained in the first phase of the production process was used as an input in the second phase of the process, which generates three desired outputs (net loans and leases, securities, and total non-interest income) and an unwanted output (loan loss allowance). Precisely, because of the existence of an unwanted output in our analysis, the efficiency cannot be assessed using the SBM model, as we did in the first phase. In this case, we use a similar (but different) model that includes an additional constraint. This model, like SBM, contains all sorts of inefficiencies and contemplates the existence of VRS and, unlike SBM, allows the study of efficiency when there are undesirable outputs in the analysis. The efficiency scores obtained from a model with undesirable outputs are shown in Table 3. Poor scores imply that banks are either using more inputs than they should to produce certain amount of outputs, or producing insufficient outputs given the amount of inputs used.

Table 3 shows that six out of 23 sampled banks were efficient in their investment and risk management activities for the entire period 2002–2010. In addition, seven other branching banks achieved efficiency for one or more years of the same period. Also, the data displayed in Table 3 indicate that, on average, the sampled banks reached the highest efficiency in the last year analyzed. The only Internet-primary bank in the sample, (number 14) was efficient throughout the whole sample period,

Table 3 Efficiency scores for stage 2 (with undesirable outputs)

Banks	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	0.7132	0.7104	0.6941	1	0.4986	0.4935	0.5581	0.5085	0.5529
2	0.4927	0.5087	0.4981	0.4835	0.5029	0.5143	0.7302	0.6087	0.6220
3	0.6050	0.6196	0.6425	0.6138	0.6298	0.6665	0.8271	0.9086	0.7674
4	1	1	1	1	1	1	1	1	1
5	0.3635	0.3668	0.3854	0.3669	0.4066	0.4174	0.3522	0.1857	0.2321
6	1	1	1	1	1	1	1	1	1
7	0.4514	0.4293	0.4124	0.4257	0.4445	0.4377	0.4413	0.4585	0.5003
8	0.6240	0.7268	0.6808	0.6352	0.6181	0.5918	0.7382	1	1
9	0.5116	0.5136	0.4850	0.4571	0.4630	0.4839	0.5762	0.6252	0.6815
10	0.4945	0.6742	0.5719	0.3797	0.3121	0.3483	0.4413	0.3600	0.4852
11	0.4724	0.5058	0.4754	0.4907	0.5055	0.5193	0.6742	1	0.8621
12	0.6023	0.6192	0.5591	0.5387	0.5271	0.6173	0.7396	0.8194	0.6691
13	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	0.9999	0.7060	0.6043	1
16	1	1	1	1	1	1	1	1	1
17	0.5831	0.4978	0.5286	0.5404	0.5258	0.6235	0.7033	0.7539	1
18	0.6437	0.6463	0.5458	0.4738	0.0406	0.049	0.0599	0.4482	1
19	1	1	1	1	1	1	1	1	1
20	0.5465	0.5495	0.5751	0.5450	0.4951	0.5413	0.6755	0.7780	0.7562
21	0.5405	0.5624	0.5403	0.4940	0.4965	0.5102	0.4773	0.5639	0.6553
22	1	1	0.6326	0.5563	0.4033	0.4399	0.4903	0.4684	0.5343
23	0.5742	0.6238	0.6091	0.5459	0.5057	0.5147	0.3877	0.4331	0.4027
Average	0.7052	0.7197	0.6885	0.6759	0.6250	0.6421	0.6773	0.7185	0.7705
SD	0.2258	0.2197	0.2180	0.2441	0.2712	0.2633	0.2503	0.254	0.2351
Maximum	1	1	1	1	1	1	1	1	1
Minimum	0.3635	0.3668	0.3854	0.3669	0.0406	0.0490	0.0599	0.1857	0.2321
Efficient DMUs	8	8	7	8	7	6	6	8	10

but five branching banks were efficient every single year. These results show that, while in deposit-taking activities, the only Internet-primary bank was clearly more efficient than most branching banks, in investment and risk management activities, Internet-primary banking was not necessarily more efficient than branching banking.

For the whole study period (2002–2010), we noticed that the efficiency in investment and risk management activities was rather stable and acceptable. The average level of efficiency observed in each of the years during the study period ranged from a high of 0.77 to a minimum of 0.62.

Just as we did in the first stage of the production process, in the second phase, we detected the reasons for some inefficiencies through the study of frontier projections for each bank. Table 5 in Appendix presents projections for both the input (total deposits) and different outputs (net loans and leases, securities, total non-interest income, and loan loss allowance) that allow us to ascertain what type of adjustment would be required to reach efficiency.

Table 5 in Appendix shows that for virtually all banks that have proved inefficient for the entire sample period to move to the efficient frontier, they should reduce both the input (total deposits) and the unwanted output (loan loss allowance). Also, it appears that less than half of the inefficient banks in the sample need to increase net loans and leases and securities to reach the frontier. Moreover, after the initial 3-year period (2002–2004), there were only two inefficient banks that are required to increase total non-interest income to project to the border. These results highlight the relative importance of the proper use of deposits as an input and the management of risk in lending in order to get the least amount of bad loans (the undesirable output). ING Bank was on the efficient frontier every year of the studied period. However, unlike in stage 1, where we concluded the greater efficiency of ING Bank in deposit-taking activities, in investment and risk management activities, there were no clear differences between both types of banks as a significant number of the traditional banks in the sample are also efficient in these types of activities.

5 Concluding remarks

The assessment of efficiency in the two phases of the banking production process is a very relevant issue for bank managers, depositors, owners, potential investors, and regulators. This is why the evaluation of efficiency in financial institutions has been a topic widely studied in financial literature, and most studies have focused on the analysis of technical efficiency of banks. However, the comparative study of efficiency between branching and Internet-primary financial institutions has obtained little attention in bank efficiency studies.

The purpose of this paper was to propose a framework to measure the relative efficiency of a sample of 23 banks of similar size and find out whether there are significant differences in efficiency in the production process of two different business models: Internet-primary banking versus branching banking. Furthermore, we try to determine at what stage of the production process are differences found and their possible causes. For this purpose, we used DEA-based efficiency indices that describe banks' performance both in service activities and in investment and risk management activities.

The SBM model efficiency scores for the first phase of the production process showed that the Internet-primary banking was efficient in deposit-taking activities, whereas only one out of 22 branching banks was efficient in these kinds of activities. In addition, all inefficient traditional banks clearly got worsened in their efficiency in terms of attracting deposits during the period 2002–2010.

The dynamic study of banks' efficiency carried out through the Malmquist index shows that 43 % of banks, all of them branching banks, managed to improve their efficiency during the study period, while the Internet-primary bank lost efficiency. It also indicated the existence of a technological development from 2002 to 2010. Quite surprisingly, ING Bank was below average in terms of technological change. Therefore, we can conclude that even though online banking remains efficient in its deposit-taking activities, its efficiency advantage over traditional banks has diminished over the study period.

After analyzing investment and risk management activities conducted by banks with a model that includes unwanted outputs, we found that the average efficiency of the sampled banks was stable and acceptable. However, in the second stage of the production process, we could not conclude that Internet-primary banking was more efficient than traditional banking as over half of the banks surveyed were found to be efficient for some or all of the years studied. Another conclusion from the analysis of this phase of the production process is the great importance of the proper use of bank deposits as an input and the management of risk in lending activities in order to minimize non-performing loans as an unwanted output.

To summarize, the banks surveyed generally reached acceptable levels of efficiency in their investment and risk management activities, but in deposit-taking activities, Internet-primary banking proved to be the most efficient. Generally, lower overhead costs enable Internet-primary banks to offer high deposit rates and low service fees that help them raise deposits.

5.1 Managerial implications

The analysis of efficiency in the collection of deposits suggests that while Internet-primary banking is very efficient, branching banking generally shows room for improvement. In this regard, we would suggest to the managers of traditional banks to make an effort to train their teams in the use of the assets available to capture a greater volume of deposits. Another suggestion to bank managers would be that they design and launch new deposits which are more in line with what the current banking customer is demanding.

Regarding investment and risk management activities, sampled banks' general levels of efficiency are acceptable. But for some branching banks, there are clear inefficiencies stemming, to a large extent, from an excessive use of deposits for credit activities that often turned into bad loans. Accordingly, we would encourage banks to implement more strict requirements while granting loans in order to minimize bad loans.

5.2 Limitations and future research

This study opens some future research prospects. First, operational risks in a bank are many-sided and diverse (credit risk, capital risk, liquidity risk, and so forth). This paper, however, has only addressed credit risk. How to include other types of risks in the models is a topic that requires further study. Second, a bank's investment portfolio includes loans, advances, discounting bills, overdrafts, financial assets, bond investment, and other items, each making different contributions to bank profitability by earning different rates of return and undertaking different levels of risk. Taking into account these discrepancies, the development of more objective efficiency measures is another research topic that is worth exploring in the future. Finally, to analyze the efficiency of risk management and investment activities by banks, we have used a DEA model that incorporates several (desirable and undesirable) outputs assuming they all have the same leverage. However, in practice, it seems logical that not all outputs are equally important. Therefore, further research on this subject could help finding a model that incorporates the actual weight of each output in bank efficiency at this stage of the production process.

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Appendix

See Appendix Table 4, 5.

Table 4 Projections to the frontier stage 1 (in %)

DMU	I/O	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	I1	−54.84	−63.06	−47.85	−67.26	−66.46	−63.65	−53.66	−51.87	−55.34
	I2	0.00	−55.51	−42.24	−57.22	−47.29	−33.85	−20.73	−23.49	−15.06
	I/O	64.53	100.99	248.29	194.14	229.46	332.56	372.45	345.42	396.23
2	I1	−72.77	−80.68	−73.66	−73.78	−76.87	−77.15	−74.55	−73.71	−73.95
	I2	0.00	−69.33	−60.78	−56.33	−50.18	−38.95	−31.78	−30.55	−17.04
	I/O	14.05	86.91	216.46	314.42	387.87	503.92	642.29	609.66	580.49
3	I1	−65.54	−75.00	−59.70	−49.42	−48.13	−39.11	−24.20	−19.55	−30.03
	I2	0.00	−69.98	−58.19	−48.26	−35.04	−17.49	−6.78	−0.19	0.00
	I/O	37.12	120.60	280.72	405.48	488.42	661.85	764.86	697.50	532.51
4	I1	−41.65	−48.58	−23.31	−14.81	−21.59	−25.80	−12.21	−13.23	−19.73
	I2	0.00	−61.12	−50.30	−44.36	−38.49	−22.55	−10.42	−17.15	−10.61
	I/O	77.54	174.75	378.06	496.46	563.90	702.75	695.25	764.88	672.68
5	I1	−37.99	−43.46	−3.89	0.00	0.00	0.00	0.00	0.00	0.00
	I2	0.00	−54.12	−39.49	−40.48	−32.30	−21.32	−30.98	−43.01	−35.23
	I/O	38.37	111.81	245.81	243.22	294.31	312.96	197.61	126.51	187.36

Table 4 continued

DMU	I/O	2002	2003	2004	2005	2006	2007	2008	2009	2010
6	I1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I/O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	I1	0.00	−35.75	−13.83	−18.33	−28.83	−36.69	−29.36	−21.94	−29.59
	I2	0.00	−71.93	−63.15	−60.09	−54.06	−42.35	−37.82	−26.19	−35.43
	I/O	0.00	47.29	139.68	227.81	285.62	410.43	448.22	325.81	326.38
8	I1	−79.67	−86.48	−80.43	−79.42	−80.76	−80.36	−78.24	−77.45	−77.65
	I2	0.00	−71.40	−62.72	−56.87	−48.30	−38.93	−35.97	−35.57	−29.37
	I/O	16.39	86.82	201.89	305.86	340.71	426.10	456.36	427.91	414.77
9	I1	−70.12	−87.32	−80.83	−77.77	−78.01	−78.22	−76.58	−74.71	−77.86
	I2	0.00	−57.97	−33.33	−20.65	−15.12	0.00	0.00	0.00	0.00
	I/O	43.58	128.13	275.99	366.26	429.53	467.60	463.17	474.97	349.76
10	I1	−57.77	−48.84	−32.52	−34.05	−53.55	−59.02	−59.20	−64.09	−68.53
	I2	0.00	−23.24	−1.45	−0.32	0.00	0.00	0.00	0.00	0.00
	I/O	70.07	138.35	254.25	233.21	336.66	329.13	245.60	228.61	190.72
11	I1	−84.94	−90.50	−86.32	−85.83	−87.05	−86.78	−84.78	−85.07	−86.16
	I2	−11.45	−75.27	−66.08	−60.46	−52.73	−40.20	−33.40	−33.30	−30.05
	I/O	1.73	63.45	179.39	270.12	328.10	443.92	509.85	459.54	400.26
12	I1	−56.51	−66.60	−51.76	−44.22	−46.82	−37.36	−36.55	−33.98	−57.96
	I2	0.00	−63.18	−51.40	−42.51	−32.30	−7.13	0.00	0.00	0.00
	I/O	25.05	115.27	290.35	451.31	528.11	723.83	788.33	769.92	565.68
13	I1	0.00	0.00	0.00	0.00	−20.82	−32.44	−12.84	0.00	−9.07
	I2	−9.79	0.00	−31.03	−14.69	0.00	0.00	0.00	−1.02	0.00
	I/O	1.98	0.00	20.21	105.25	182.83	137.02	134.97	93.42	63.44
14	I1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I/O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	−66.97	0.00
15	I1	−24.80	−4.97	−33.20	−49.29	−51.30	−66.70	−70.29	−72.50	−71.64
	I2	0.00	−0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I/O	197.03	459.48	328.16	356.07	680.79	405.40	389.56	396.89	536.15
16	I1	−51.21	−74.00	−60.65	−50.46	−53.97	−68.34	−65.86	−58.69	−59.27
	I2	0.00	−45.45	−19.62	−32.66	0.00	0.00	0.00	0.00	−2.19
	I/O	73.54	53.74	172.23	236.26	283.36	274.41	229.24	148.02	282.28
17	I1	−64.16	−76.48	−71.17	−64.79	−50.19	0.00	0.00	0.00	0.00
	I2	0.00	−50.88	−34.73	−7.88	0.00	−14.58	−36.87	−42.05	−47.30
	I/O	48.21	148.37	347.31	516.63	509.48	418.72	217.35	217.73	146.78
18	I1	−65.89	−74.72	−60.72	−55.11	−52.27	−54.50	−43.87	−65.98	−73.95
	I2	−10.46	−73.88	−60.31	−53.09	−42.90	−28.20	−14.69	−44.16	−41.57
	I/O	16.53	85.02	224.01	339.62	418.85	581.04	707.13	382.01	331.52
19	I1	−74.91	−85.93	−82.12	−81.62	−83.91	−83.72	−80.33	−80.06	−80.91
	I2	−33.22	−81.17	−75.17	−71.11	−65.35	−53.31	−45.04	−44.97	−33.73
	I/O	25.80	109.29	256.02	332.79	377.92	527.09	597.31	546.03	567.63

Table 4 continued

DMU	I/O	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	I1	−66.55	−76.22	−65.35	−62.91	−69.83	−67.08	−66.51	−72.10	−72.95
	I2	0.00	−68.66	−60.11	−55.18	−50.09	−38.77	−31.56	−32.28	−22.82
	I/O	26.65	98.11	245.73	326.93	345.06	467.04	516.54	460.37	433.63
21	I1	−61.70	−69.05	−63.78	−63.23	−68.76	−70.62	−70.13	−70.22	−72.50
	I2	0.00	−53.02	−36.69	−29.42	−15.07	0.00	0.00	0.00	0.00
	I/O	42.69	125.69	278.50	361.75	450.26	578.91	512.38	529.28	514.29
22	I1	−38.48	−56.86	−60.20	−62.86	−65.89	−63.04	−52.66	−49.96	−46.31
	I2	0.00	−65.17	−57.37	−54.29	−46.56	−34.06	−18.75	−14.32	−3.49
	I/O	26.66	89.93	169.56	241.13	276.04	385.76	477.08	431.55	467.00
23	I1	−56.39	−65.44	−49.80	−38.26	−51.61	−52.94	−49.39	−52.45	−60.13
	I2	0.00	−61.42	−51.28	−46.81	−38.37	−22.44	0.00	0.00	0.00
	I/O	35.72	127.72	251.56	333.97	351.84	420.08	339.45	407.11	359.01

Table 5 Projections to the frontier stage 2 (in %)

DMU	I/O	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	I/O	−11.38	−9.27	−17.47	0.00	−18.59	−23.29	−25.35	−32.15	−28.27
	OND1	−24.99	−37.67	−30.45	0.00	−77.30	−71.10	−54.73	−66.89	−59.47
	OD1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD2	0.00	0.00	0.00	0.00	147.78	119.28	38.33	0.00	0.00
	OD3	70.59	53.35	22.04	0.00	0.00	0.00	0.00	0.00	0.00
2	I/O	−38.16	−32.61	−35.04	−35.43	−32.17	−30.37	−18.67	−4.56	−26.68
	OND1	−31.22	−61.87	−60.80	−67.10	−69.78	−67.29	−21.22	−0.88	−32.57
	OD1	0.00	0.00	0.00	0.00	0.00	0.00	4.56	0.00	0.00
	OD2	0.00	0.00	0.00	0.00	0.00	10.52	0.00	338.05	9.50
	OD3	59.37	9.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	I/O	−22.10	−17.42	−18.22	−20.45	−18.02	−9.75	−1.70	−2.82	−11.29
	OND1	−47.68	−61.78	−49.74	−53.73	−54.77	−55.71	−15.57	0.00	−18.46
	OD1	29.46	14.24	14.48	16.41	16.69	45.30	66.40	41.76	38.22
	OD2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	I/O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OND1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	I/O	−43.75	−36.46	−44.51	−39.69	−24.04	−29.50	−29.55	−1.62	0.00
	OND1	0.00	0.00	0.00	−35.59	−72.54	−84.61	−75.73	−14.95	−67.27
	OD1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.59
	OD2	247.50	427.83	246.34	279.64	303.20	159.49	372.87	999.90	999.90
	OD3	81.06	11.59	17.41	0.00	0.00	0.00	0.00	0.00	0.00

Table 5 continued

DMU	I/O	2002	2003	2004	2005	2006	2007	2008	2009	2010
6	I/O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OND1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	I/O	−32.54	−42.05	−51.46	−45.29	−33.06	−30.48	−32.20	−37.92	−38.70
	OND1	−49.45	−45.65	−35.45	−45.32	−80.51	−77.54	−61.13	−54.71	−45.05
	OD1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD2	7.94	0.00	0.00	35.20	62.12	120.45	138.56	48.25	0.00
	OD3	140.49	73.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	I/O	−20.38	−16.06	−19.11	−20.60	−22.01	−24.99	−18.94	0.00	0.00
	OND1	−53.42	−28.78	−37.64	−49.19	−51.50	−49.52	−12.95	0.00	0.00
	OD1	5.36	6.67	0.00	2.41	2.55	11.92	19.98	0.00	0.00
	OD2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	I/O	−21.08	−25.71	−47.88	−36.39	−36.74	−32.19	−30.49	−33.52	−26.45
	OND1	−71.01	−68.94	0.00	−73.88	−70.82	−71.34	−37.69	−12.67	−15.83
	OD1	8.97	12.40	13.91	13.36	7.31	26.67	10.72	0.00	0.00
	OD2	103.54	48.71	30.87	0.00	0.00	0.00	0.00	0.00	0.00
	OD3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	I/O	0.00	−0.97	0.00	−14.59	−14.53	−15.38	−31.78	−8.90	−15.36
	OND1	−67.73	−66.27	−41.01	−64.16	−54.36	−52.54	−65.99	−55.27	−88.05
	OD1	6.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	182.56
	OD3	403.86	82.56	326.02	557.00	880.15	700.04	129.47	752.64	999.90
11	I/O	−41.11	−32.83	−45.75	−36.12	−34.80	−31.59	−27.87	0.00	−8.32
	OND1	−42.70	−54.40	−16.51	−60.36	−57.89	−58.81	−7.70	0.00	0.00
	OD1	0.00	0.00	0.00	0.00	0.16	13.99	18.77	0.00	0.00
	OD2	19.89	33.57	35.19	0.00	0.00	0.00	0.00	0.00	38.08
	OD3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	I/O	−23.30	−19.10	−44.09	−25.63	−25.41	−15.86	−11.31	−7.14	−29.22
	OND1	−34.90	−58.95	0.00	−75.92	−80.52	−67.45	−32.53	0.00	−11.57
	OD1	0.00	0.00	0.00	0.60	0.00	15.40	21.92	1.42	0.00
	OD2	0.00	0.00	0.00	0.00	7.44	0.00	0.00	78.59	0.00
	OD3	59.32	7.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	I/O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OND1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	I/O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OND1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5 continued

DMU	I/O	2002	2003	2004	2005	2006	2007	2008	2009	2010
	OD2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	I/O	0.00	0.00	0.00	0.00	0.00	0.00	−7.71	0.00	0.00
	OND1	0.00	0.00	0.00	0.00	0.00	−0.02	−47.20	−43.13	0.00
	OD1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD2	0.00	0.00	0.00	0.00	0.00	0.00	42.70	263.43	0.00
	OD3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	I/O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OND1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	I/O	−27.87	−50.22	−45.85	−22.25	−22.71	−11.15	−6.92	−5.80	0.00
	OND1	−41.42	0.00	0.00	−77.52	−82.03	−70.95	−49.85	−25.97	0.00
	OD1	0.00	0.00	14.67	30.66	32.18	42.19	43.33	71.76	0.00
	OD2	0.00	0.00	0.00	0.00	3.64	0.00	1.21	0.00	0.00
	OD3	17.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	I/O	−16.94	−11.90	−25.85	−23.41	0.00	0.00	0.00	−5.58	0.00
	OND1	−57.07	−47.33	−46.03	−65.38	−10.44	−18.66	0.00	0.00	0.00
	OD1	0.00	0.00	0.00	0.00	21.79	29.91	40.56	0.00	0.00
	OD2	0.00	75.91	77.03	173.68	999.90	999.90	999.90	663.82	0.00
	OD3	2.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	I/O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OND1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	I/O	−23.29	−28.39	−28.08	−31.55	−37.34	−28.46	−26.69	−20.53	−24.38
	OND1	−55.12	−48.31	−39.78	−44.62	−51.59	−53.54	−6.97	0.00	0.00
	OD1	40.16	37.07	31.01	19.83	4.52	32.35	30.30	12.84	0.00
	OD2	36.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	I/O	−18.07	−20.42	−22.91	−24.21	−20.78	−23.90	−26.72	−23.28	−14.18
	OND1	−57.52	−47.10	−52.07	−66.89	−64.14	−72.89	−69.16	−49.38	−59.75
	OD1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD2	38.09	0.00	0.00	0.00	0.00	76.37	113.72	68.10	6.59
	OD3	98.91	107.59	99.94	119.81	164.78	0.00	0.00	0.00	0.00
22	I/O	0.00	0.00	−10.82	−11.81	−16.73	−28.99	−30.86	−37.41	−29.95
	OND1	0.00	0.00	−47.49	−75.42	−63.53	−79.36	−67.97	−67.25	−62.21
	OD1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD2	0.00	0.00	39.69	124.95	448.25	130.37	42.20	0.00	0.00
	OD3	0.00	0.00	63.66	0.00	0.00	0.00	0.00	0.00	0.00

Table 5 continued

DMU	I/O	2002	2003	2004	2005	2006	2007	2008	2009	2010
23	I/O	−12.17	−11.24	−18.66	−13.58	−13.34	−19.94	−35.18	−8.34	−7.12
	OND1	−54.54	−52.36	−48.29	−39.07	−41.46	−60.90	−49.88	−54.81	−61.63
	OD1	0.18	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	OD2	153.92	95.74	56.42	232.65	303.86	150.53	253.62	505.21	598.86
	OD3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

References

Aizpurua LI, Saldaña PEZ, Saldaña AZ (2011) Learning for sharing: an empirical analysis of organizational learning and knowledge sharing. Int Entrepren Manag J 7(4):509–518

Banker RD, Charnes A, Cooper WW (1984) Some models for estimating technical and scale inefficiencies in data envelopment analysis. Manage Sci 30:1078–1092

Berger AN (2007) International comparisons of banking efficiency. Finan Markets Inst Instrum 16:119–144

Berger AN, Humphrey DB (1997) Efficiency of financial institutions: international survey and directions for future research. Eur J Oper Res 98:175–212

Bettiol M, Di Maria E, Finotto V (2012) Marketing in SMEs: the role of entrepreneurial sense making. Int Entrepren Manag J 8(2):223–248

Caceres R, Guzman J, Rekowsky M (2011) Firms as source of variety in innovation: influence of size and sector. Int Entrepren Manag J 7(3):357–372

Casu B, Girardone C (2004) Financial conglomeration: efficiency, productivity and strategic drive. Appl Finan Econ 14:687–696

Casu B, Girardone C (2006) Bank competition, concentration and efficiency in the single European Market. The Manchester School 74:441–468

Casu B, Molyneux P (2003) A comparative study of efficiency in European banking. Appl Econ 35:1865–1876

Cegarra-Navarro JG, Sanchez-Vidal ME, Cegarra-Leiva D (2011) Balancing exploration and exploitation of knowledge through an unlearning context: an empirical investigation in SMEs. Manag Decis 49(7):1099–1119

Charnes A, Neralic L (1990) Sensitivity analysis of the additive model in Data Envelopment Analysis. Eur J Oper Res 48:332–341

Charnes A, Cooper WW, Rhodes E (1978) Evaluating program and managerial efficiency: an application of data envelopment analysis to program follow through. Manage Sci 27:668–697

Charnes A, Charnes J, Rousseau J (1996) Sensitivity and stability of efficiency classifications in Data Envelopment Analysis. J Prod Anal 7:5–18

Chen T-Y (2001) An estimation of X-inefficiency in Taiwan's banks. Appl Finan Econ 11:237–242

Cho I, Park H, Choi J (2011) The impact of diversity of innovation channels on innovation performance in service firms. Serv Bus 5(3):277–294

Crevani L, Palm K, Shilling A (2011) Innovation management in service firms: a research agenda. Serv Bus 5(2):177–193

Das A, Ghosh S (2006) Financial deregulation and efficiency: an empirical analysis of Indian banks during the post reform period. Rev Finan Econ 15:193–221

De Cleyn SH, Braet J (2012) Do board composition and investor type influence innovativeness in SMEs? Int Entrepren Manag J 8(3):285–308

De Young R (2001) The financial performance of pure play Internet banks. Econ Perspect 25(1), first quarter, Bank of Chicago

De Young R (2005) The performance of Internet-based business models: evidence from the banking industry. J Bus 78(3):893–947

Fare R, Grosskopf S, Weber WL (2004) The effect of risk-based capital requirements on profit efficiency in banking. Appl Econ 36:1731–1743

Farrell MJ (1957) The measurement of productive efficiency. J R Stat Soc A 120:253–281
Ferreira JJ, Marques CS, Azevedo C (2011) Competitiveness, resources, and capabilities: empirical evidence from retail banking. Serv Bus 5(4):313–337
Fethi MD, Pasiouras F (2010) Assessing bank efficiency and performance with operational research and artificial intelligence techniques: a survey. Eur J Oper Res 204:189–198
Group ING (2008) Focus blijftgericht op risico. ING Shareholder 4:14
Han-Min Wang D, Hui-Kuang YuT, Ye F-R (2012) The value relevance of brand equity in the financial services industry: an empirical analysis using quantile regression. Serv Bus 6(4):459–471
Holod D, Lewis HF (2011) Resolving the deposit dilemma: a new DEA bank efficiency model. J Bank Finance 35:2801–2810
Isik I, Hassan MK (2002) Technical, scale and allocative efficiencies of Turkish banking industry. J Bank Finance 26:719–766
Lee SM, Lim SB, Pathak RD (2011) Culture and entrepreneurial orientation: a multi-country study. Int Entrepren Manag J 8(3):285–308
Lee SM, Hwang T, Choi D (2012a) Open innovation in the public sector of leading countries. Manag Decis 50(1):147–162
Lee SM, Olson DO, Trimi S (2012b) Co-innovation: convergenomics, collaboration, and co-creation for organizational values. Manag Decis 50(5):817–831
Lindic J, Marques da Silva C (2011) Value proposition as a catalyst for a customer focused innovation. Manag Decis 49(10):1694–1708
Lozano-Vivas A, Pastor JT, Pastor JM (2002) An efficiency comparison of European banking systems operating under different environmental conditions. J Prod Anal 18:59–77
Momparler A, Climent FJ, Ballester JM (2012) The impact of scale effects on the prevailing Internet-based banking model in the US. Serv Bus 6(2):177–195
Naranjo-Valencia JC, Jimenez–Jimenez D, Sanz-Valle R (2011) Innovation or imitation? The role of organizational culture. Manag Decis 49(1):55–72
Pasiouras F (2008a) International evidence on the impact of regulations and supervision on banks' technical efficiency: an application of two-stage data envelopment analysis. Rev Quant Financ Acc 30:187–223
Pasiouras F (2008b) Estimating the technical and scale efficiency of Greek commercial banks: the impact of credit risk, off-balance sheet activities, and international operations. Res Int Bus Finan 22:301–318
Sealey C, Lindley J (1977) Inputs, outputs, and a theory of production and cost at depository financial institutions. J Finan 32:1251–1266
Server-Izquierdo RJ, Capo-Vicedo J (2012) Corporate social responsibility of financial organizations in the social economy: a case study on savings banks. Serv Bus 6(1):99–115
Sturm J-E, Williams B (2004) Foreign bank entry, deregulation and bank efficiency: lessons from the Australian experience. J Bank Finance 28:1775–1799
Tsionas EG, Lolos SEG, Christopoulos DK (2003) The performance of the Greek banking system in view of the EMU: results from a non-parametric approach. Econ Model 20:571–592
Van Riel ACR, Semeijn J, Hammedi W, Henseler J (2011) Technology-based service proposal screening and decision-making effectiveness. Manag Decis 49(5):762–783
Yang TT, Li CR (2011) Competence exploration and exploitation in new product development: the moderating effects of environmental dynamism and competitiveness. Manag Decis 49(9): 1444–1470
Zortea-Johnston E, Darroch J, Matear S (2012) Business orientations and innovation in small and medium sized enterprises. Int Entrepren Manag J 8(2):145–165