Monitoring Bank Performance in the Presence of Risk

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March 2012. This version: July 2014

Forthcoming in *Journal of Productivity Analysis*

Abstract
This paper proposes a managerial control tool that integrates risk in efficiency measures. Building on existing efficiency specifications, our proposal reflects the real banking technology and accurately models the relationship between desirable and undesirable outputs. Specifically, the undesirable output is defined as non-performing loans to capture credit risk, and is linked only to the relevant dimension of the output set. We empirically illustrate how our efficiency measure functions for managerial control purposes. The application considers a unique dataset of Costa Rican banks during 1998-2012. Results' implications are mostly discussed at bank-level, and their interpretations are enhanced by using accounting ratios. We also show the usefulness of our tool for corporate governance by examining performance changes around executive turnover. Our findings confirm that appointing CEOs from outside the bank is associated with significantly higher performance ex post executive turnover, thus suggesting the potential benefits of new organisational practices.

Keywords: efficiency; risk; accounting; CEO turnover; banking; non-performing loans

JEL classification: G21; G28; G3; M1; M2

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1. Introduction

In this paper we propose a managerial control tool that integrates risk in efficiency estimations. Our new measure extends the work of Kuosmanen (2005) and is applied to the banking activity. Specifically, we devise an efficiency measure that reflects the real banking technology by accurately modelling the relationship between desirable and undesirable outputs, the latter of which represent credit risk. Our estimators match rationales of control (or monitoring) systems that are usually employed in banking. This study is thus embedded in the literature that assessed the relation between risk and bank efficiency and, on occasions, attempted to introduce risk in efficiency measures (see, *e.g.*, Hughes and Mester (1998), Altunbas *et al*. (2000), Park and Weber (2006), Banker *et al*. (2010), Hsiao *et al.* (2010) or Barros *et al*. (2012)). Despite the various efforts, there remains a need to more directly use risk factors as an integrating part of efficiency analyses. Our new measure addresses this call for rigorous efficiency assessments that can be employed for managerial accounting control objectives. We illustrate our proposal via an empirical application that interprets efficiency in the presence of risk. Furthermore, we show how our monitoring tool can be employed for corporate governance purposes by examining the link between executive turnover and future performance.

Bank efficiency has been analysed from multiple angles (see, *e.g.*, the reviews of Berger and Humphrey (1997), Goddard *et al*. (2001) or Fethi and Pasiouras (2010)). Among these, a largely preferred approach relies on non-parametric efficiency frontier techniques. These methods, best known as Data Envelopment Analysis (DEA) are more suitable when multiple inputs are employed to obtain multiple outputs (see, *e.g.*, Ray (2004)). Even if parametric models allow for stochastic errors, they have strong assumptions on functional distributions (which are not needed in non-parametric contexts) and do not allow for multiple objectives to be pursued or desirable and undesirable outputs to be jointly produced. The flexible nature of DEA is especially appealing for applications based on diverse management and accounting frameworks (Grifell-Tatjé and Lovell 1999; Banker *et al*. 2005). Hence, the literature on non-parametric efficiency analysis has experienced important developments (Cook and Seiford 2009; Cooper *et al*. 2011).

Although bank efficiency has been extensively scrutinised, few studies introduced explicit risk variables in efficiency measures. Initially, parametric analyses did so under cost function approaches (McAllister and McManus 1993; Berger and DeYoung 1997; Hughes and Mester 1998; Altunbas *et al*. 2000). For instance, Hughes and Mester (1998) used the level of financial capital as a risk signal that bank managers employ for controlling output quality. Altunbas *et al*. (2000) express quality of loans through the ratio of non-performing loans (NPL) to total loans. According to Berger and DeYoung (1997) and Van Hoose (2010) this variable captures the quality of monitoring over loans. There also exists a stream of literature that introduces risk in non-parametric bank efficiency analysis (Park and Weber 2006; Fukuyama and Weber 2010; Barros *et al*. 2012). In this case, risk takes the form of undesirable outputs, which for financial institutions are typically proxied through NPL. This variable illustrates credit risk, which is crucial for the long-run bank activity (Basel Committee of Banking Supervision 2011).

Yet, this latter stream of literature leaves two unaddressed issues. First, in typical production settings, desirable and undesirable outputs are jointly produced, in the sense that generating desirable outputs is not possible without generating undesirable outputs. This may not apply to banking activity, in which only certain outputs are linked to undesirable outputs such as NPL. Second, existing non-parametric banking studies that introduce credit risk in efficiency assessments often assume constant returns to scale, whereas the technology is more likely to exhibit variable returns to scale (VRS) (Chambers and Pope 1996).

To address these issues, the main contribution of this paper is to propose a tool for monitoring bank efficiency that integrates credit risk in efficiency analyses, while accurately defining the multiple-output bank technology. Due to these characteristics, our proposal is suitable for managerial control systems that aim at setting objectives and evaluating their degree of achievement. We start from the specification of Kuosmanen (2005) that properly models desirable and undesirable outputs when assuming VRS. We extend this model to correctly define the real banking technology. Specifically, undesirable outputs (NPL) are strictly linked only to that dimension of the output set that refers to credit (*i.e.* performing loans). The rest of outputs, such as investment portfolio or service fees, do not have a link with NPL.

We empirically illustrate how our monitoring tool functions for assessing bank performance. The efficiency assessment is systematically interpreted and compared with conventional accounting ratios (*i.e.* return on assets (ROA) and net interest margin (NIM)). Given the managerial control focus, implications are discussed at bank-level, whereas we also briefly analyse the link between risk and performance at industry level. We then employ our proposal to examine performance changes around executive turnover, a specific corporate governance mechanism. Corporate governance literature states that accurate monitoring ex ante signals managers' performance, while ex post monitoring is used to reveal potential gains from executive turnover (Hermalin and Weisbach 2003; Zhang and Rajagopalan 2010). This monitoring activity may well be done via our proposed measure.

The empirical application considers a unique dataset of Costa Rican banks between 1998 and 2012. This setting is attractive since it previously underwent important changes in the regulatory framework jointly with enhancements in monitoring practices. By 1997 bank activity was deregulated among the different players and the supervisory institution had all its monitoring functions in place. Thus, apart from the generally available accounting variables, the dataset presents well-structured information on NPL and organisational architecture. Moreover, in the first half of the analysed time span the monitoring over financial institutions was enhanced, and during the second half of the studied period the impact of the recent financial crisis can be observed (IMF 2003; 2013).

The remainder of this paper is structured as follows. Section 2 provides a brief overview of the existing literature on bank performance and risk, and the consequences of executive turnover on performance. Section 3 proposes our multidimensional efficiency measure in accordance with the theoretical underpinning presented. The Costa Rican banking industry is described in Section 4. In Section 5 the sample, variables and analysis stages are presented. Empirical results are found in Section 6, while the final section provides the concluding remarks.

2. Theoretical underpinnings and the usefulness of efficiency monitoring tools

Technology advances and different episodes of economic fluctuations that have occurred over the past decades led many administrations from developing and developed economies to restructure financial sectors. These legal reforms were introduced to strengthen and stabilise the now deregulated financial systems, and focused on the structure of banking industries and the accurate functioning of supervisory institutions (Yildirim and Philippatos 2007; Banker *et al.* 2010).

Following these profound reforms banks were expected to consolidate and improve their performance as legal changes aimed at enhancing, among others, risk management practices. Banks thus exert a more diligent oversight over their operations to signal their performance and safety to the market and supervisory agencies. The quality of risk management activities in banks is usually linked to credit risk and the levels of capital available to absorb potential financial losses. In this sense, monitoring activities are especially relevant when they are related to NPL's management. In consonance with Berger and DeYoung (1997), Altunbas *et al.* (2000) and Van Hoose (2010), this variable is considered endogenous, and can be modelled as a function of management effort.

As a result, bank outcomes can be seen as an informative signal about the manager's unobserved ability. Using a principal-agent framework, Hermalin and Weisbach (1998) remark that performance offers information about the CEO's ability, and based on this observable measure the board evaluates the quality of the CEO. In addition, the board estimates the CEO's ability, which represents a proxy of the expected performance. Therefore, CEO turnover is a control mechanism linked to the monitoring task of the board (Laux 2010). In this context, efficient managers signal their superior skills by introducing policies that improve the monitoring over their portfolios, which decreases the probability of financial losses. Conversely, poorly performing managers are more likely to incur higher losses due to ineffective loans' monitoring.

Banking literature on these risk- and control-related issues is two folded. On the one hand, there are studies that link risk with performance. To name just a few, analyses exist for the US (Hughes and Mester 1998), Japan (Altunbas *et al*. 2000; Barros *et al*. 2012), South Korea (Park and Weber 2006; Banker *et al*. 2010), Taiwan (Hsiao *et al.* 2010), Brasil (Tabak *et al*. 2011), for various Latin American countries (Yildirim and Philippatos 2007) or for 87 countries around the world (Lozano-Vivas and Pasiouras 2010). Main findings indicate that the level of financial capital is positively related to efficiency and that using risk variables does not contribute to explaining scale inefficiencies (Hughes and Mester 1998; Altunbas *et al*. 2000). Evidence also suggests that NPL—used as a measure of credit risk—negatively influence efficiency (Barros *et al*. 2012). Moreover, Yildirim and Philippatos (2007) and Lozano-Vivas and Pasiouras (2010) find that changes in regulatory frameworks jointly with introducing monitoring tools help improving efficiency levels.

On the other hand, banks face problems derived from inefficient monitoring (or control practices in general) since conflicts of interests may appear between principals, managers and depositors. Hence, research also scrutinises the relations between corporate governance mechanisms and performance. Nonetheless, similarly to the case of the link between risk and performance, relatively few studies focus on the role of corporate governance on bank performance (see, *e.g.*, Simpson and Gleason (1999), Macey and O'Hara (2003),; Crespí *et al.* (2004), de Andres and Vallelado (2008) or Laeven and Levine (2009)).

To the best of our knowledge, these two research streams do not converge. In this paper we propose a way to assess bank performance in the presence of risk, and introduce executive turnover to further isolate the relation between changes in management practices and future performance. CEO replacements are crucial because they are often linked to the monitoring task of the board. There is a general consensus that the probability of CEO turnover is negatively related to performance, and that the board replaces a poorly performing CEO to enhance performance (Huson *et al*. 2001; Hermalin and Weisbach 2003). For these cases, existing findings suggest that improvements in shareholders' wealth and firm operations follow CEO turnover (Denis and Denis 1995; Huson *et al*. 2004).

At this point, it is important to notice that we focus on the origin of the successor rather than the type of departure. Even if distinguishing between voluntary and unexpected replacements is important, Hermalin and Weisbach (2003) and Huson *et al.* (2004) report that a voluntary CEO departure can be due to retirement or the acceptance of an external position. As a result, voluntary departures are not a signal of poor management or performance, and consequently, firms' future performance is expected to show smaller variations when compared with unexpected departures. In this way, not identifying the type of departure only adds noise to the proxy measure of executive turnover, which could lead to a downward biased estimate of performance changes.

Concerning the type of successor, banks can appoint an insider or outsider CEO. When banks decide to promote an internal candidate, no significant improvements in performance are expected, since the new CEO is more likely to continue with the existing policies and routines. Alternatively, under the improved management hypothesis, a bank hires an outsider CEO to seek organisational change driven by this new agent who is not influenced by current mechanics. In this case, management quality is expected to enhance since outsiders usually have stronger incentives to prove their skills to the board by introducing new practices that potentially improve performance (Zhang and Rajagopalan 2010). Accordingly, Borokhovich *et al.* (1996), Farrell and Whidbee (2003) or

Huson *et al.* (2004) report significant positive changes in firm performance when CEO departures were followed by the appointment of a CEO from outside the firm.

3. A proposal for assessing efficiency in the presence of risk

When dealing with multiple inputs yielding multiple outputs, efficiency literature usually employs DEA-based frontier methods grounded in economic production theory (see, *e.g.*, Ray (2004) or Cooper *et al.* (2011)). DEA is a non-parametric technique that approximates the true but unknown technology, imposes no restrictions on the sample distribution, and does not require input or output prices. Efficient decision-making units shape the best practice frontier, while for the rest of units DEA computes an inefficiency score indicating their distance to the frontier. Thus, DEA is a complex benchmarking technique, where all analysed units are compared against each other. Note that the frontier is considered to be the best available technology (*i.e.* it is an approximation of the real technology), and therefore the model projects inefficient units on it without proposing to improve existing best practices.

Various DEA applications made way for developing diverse efficiency measures (see Ray (2004), Cooper *et al.* (2011) or the comprehensive review in Cook and Seiford (2009)). The growing awareness of the utility of DEA jointly with the need of well-defining inputs and outputs vectors led to new streams of research that not only account for inputs and desirable (good) outputs, but also accommodate undesirable (bad) outputs. The joint treatment of good and bad outputs is a current trend in the banking literature (Park and Weber 2006; Fukuyama and Weber 2010; Barros *et al.* 2012), and—to name just another research stream—is widely employed for environmental studies (Färe *et al*. 2004; Kumar 2006; Sueyoshi and Goto 2011).

Let us first specify a general technology with good and bad outputs, which will subsequently be adapted to the particular case of the banking industry. As a baseline we define $\mathbf{x} = (x_1,\ldots,x_N) \in R_+^N$, $\mathbf{y} = (y_1,\ldots,y_M) \in R_+^M$ and $\mathbf{b} = (b_1,\ldots,b_J) \in R_+^J$ as the vectors of inputs, good outputs and bad outputs, respectively. These form the technology *T*, representing the set of all output vectors (**y** and **b**) that can be produced using the input vector (**x**): $T = \{(\mathbf{x},\mathbf{y},\mathbf{b}) : \mathbf{x} \text{ can produce } (\mathbf{y},\mathbf{b})\}$. Obviously, if one does not differentiate between good and bad outputs, then the input vector (**x**) would produce a total output vector given by the sum of vectors **y** and **b**.

When modelling DEA with good and bad outputs, technology (*T*) usually assumes convexity, strong disposability of inputs and good outputs, and weak disposability of bad outputs.[1] The strong disposability constraint imposes that a larger quantity of inputs can be used to produce the same quantity of outputs, or fewer good outputs and the same quantity of bad outputs can be produced from

[1] Strong disposability of inputs and good outputs implies that if $(x,y,b) \in T$, $0 \le y' \le y$ and $x' \ge x$ (for each component) then $(x',y',b) \in T$. Weak disposability of bad outputs and good outputs implies that if $(x,y,b) \in T$ then $(x,\theta y,\theta b) \in T$ for $0 \le \theta \le 1$.

a certain level of inputs. The weak disposability constraint indicates that to reduce bad outputs (a costly process), a unit must produce less total outputs, given fixed input levels. Best practice frontiers are shaped for each year by $k = 1,\ldots,K$ units in the corresponding period.

Yet another assumption, many times treated superficially, relates to the returns to scale. While assuming constant returns to scale has attractive properties, existing literature signalled that on most occasions the true technology experiences variable returns to scale (VRS). For instance, Chambers and Pope (1996) argued that restricting the returns to scale to constant should be avoided unless one analyses firms in long-run equilibrium. Moreover, managerial-oriented assessments should report pure technical efficiency scores. This is because, contrary to technical efficiency under constant returns to scale, pure technical efficiency (VRS) captures outcomes linked to managerial practices and reforming firm operations.

Defining a VRS technology that allows some outputs to be weakly disposable while other outputs are strongly disposable can be problematic due to computational issues. This technology was accurately represented by Kuosmanen (2005). Furthermore, Kuosmanen's specification is the VRS technology that most closely incorporates all observed activities and satisfies strong disposability of inputs and good outputs, weak disposability of bad outputs, and convexity (Kuosmanen and Podinovski 2009; Podinovski and Kuosmanen 2011). It can be defined as follows:

$$
\begin{aligned}
T = \{ (x,y,b) : & \sum_{k=1}^{K} \theta^k \lambda^k y_m^k \geq y_m^{k'} \geq 0, \quad m = 1,2,\ldots,M \\
& \sum_{k=1}^{K} \theta^k \lambda^k b_j^k = b_j^{k'}, \quad \mathrm{j} = 1,2,\ldots,J \\
& \sum_{k=1}^{K} \lambda^k x_n^k \leq x_n^{k'}, \quad \mathrm{n} = 1,2,\ldots,N \\
& \sum_{k=1}^{K} \lambda^k = 1 \\
& \lambda^k \geq 0, \quad k = 1,2,\ldots,K \\
& 0 \leq \theta^k \leq 1, \quad k = 1,2,\ldots,K \}.
\end{aligned} \qquad (1)
$$

Note that equation (1) illustrates a technology that produces good (**y**) and bad (**b**) outputs, and assumes convexity, VRS, and strong disposability of inputs and outputs. Whereas it is more complex than the usual DEA technology that does not differentiate between good and bad outputs, equation (1) does not distinguish between the types of good outputs.[2] That is, the good output vector (**y**) does not differentiate the good outputs that do not necessarily cause jointly produced bad outputs from the good outputs that cause jointly produced bad outputs.

Indeed, depending on the analysed industry, bad outputs may not be linked to all good outputs. When dealing with environmental performance, as exemplified by Podinovski and Kuosmanen (2011), one can think that a good output such as steel is always linked to a bad output, such as harmful emissions. Nevertheless, in other sectors such as banking or service industries not all

[2] To reach the basic DEA technology one just needs to completely remove both the bad outputs constraint and the abatement factor (θ) from expression (1). When modelling both good and bad outputs, this abatement factor enables the contraction of bad outputs only if accompanied by the contraction of good outputs.

good outputs are related to the bad outputs. In our case, banks grant loans, which may prove to be good (performing) or bad (non-performing, *i.e.*, NPL) depending on the intensity of monitoring and customers' behaviours. That is, the composition of the total loans is unaffected by other assets such as investment portfolios. To incorporate all these banking characteristics in efficiency analyses there is—to the best of our knowledge—no formalised modelling of NPL, as most existing studies assume the joint production of all bank outputs (see, *e.g.*, Park and Weber (2006), Fukuyama and Weber (2010) or Barros *et al*. (2012)).

We thus propose to separate the vector of good outputs (**y**) into two vectors of good outputs linked to bad outputs $(\mathbf{u} = (u_1,\ldots,u_I) \in R_+^I)$ and good outputs not linked to bad outputs $(\mathbf{v} = (v_1,\ldots,v_L) \in R_+^L)$. That is, the production of the good output vector (**u**) implies that bad output (**b**) is also produced. Nonetheless, when producing the good output vector (**v**) there need not be any production of bad output (**b**). By using the abatement factor (θ) only for modelling the relation between bad outputs and their related good outputs, the technology is now:

$$
\begin{aligned}
T = \{ (x,u,v,b): & \textstyle\sum_{k=1}^{K} \theta^k \lambda^k u_i^k \geq u_i^{k'} \geq 0, \quad \mathrm{i} = 1,2,\ldots,I \\
& \textstyle\sum_{k=1}^{K} \theta^k \lambda^k b_j^k = b_j^{k'}, \quad \mathrm{j} = 1,2,\ldots,J \\
& \textstyle\sum_{k=1}^{K} \lambda^k v_l^k \geq v_l^{k'}, \quad \mathrm{l} = 1,2,\ldots,L \\
& \textstyle\sum_{k=1}^{K} \lambda^k x_n^k \leq x_n^{k'}, \quad \mathrm{n} = 1,2,\ldots,N \\
& \textstyle\sum_{k=1}^{K} \lambda^k = 1 \\
& \lambda^k \geq 0, \ k = 1,2,\ldots,K \\
& 0 \leq \theta^k \leq 1, \ k = 1,2,\ldots,K \}.
\end{aligned} \tag{2}
$$

Inefficiency is measured using the directional distance function proposed by Chambers *et al.* (1996). In its general form, the directional distance function seeks to simultaneously expand all types of good outputs, and contract bad outputs and inputs. Letting **g** = (g_x,g_u,g_v,g_b) be a directional vector, this function can be written as:

$$D\left(x^{k'},u^{k'},v^{k'},b^{k'} \right) = \max\left\{ \delta : x^{k'} - \delta g_x, u^{k'} + \delta g_u, v^{k'} + \delta g_v, b^{k'} - \delta g_b) \in T^k \right\}. \tag{3}$$

However, the values of the directional vector **g** = (g_x,g_u,g_v,g_b) must be assigned. One could define **g** = (1,1,1,1) to obtain the maximum unit expansion in all good outputs and simultaneous unit contraction in bad outputs and inputs. Another of the many possibilities may be a vector **g** = (*x*,0,0,0) that would yield the percentage contraction in inputs, holding all outputs fixed.

For this paper, the vector **g** = (*x*,*u*,*v*,*b*) is used, similarly to the proportional distance function proposed by Briec (1997). Following equation (3), the value of the directional distance function given **g** = (*x*,*u*,*v*,*b*) when multiplied by 100% is the percent expansion/contraction in *x*,*u*,*v*,*b*. In a more general sense, this specification estimates the simultaneous expansion in all good outputs, contraction in bad outputs and contraction in inputs. Since we assess bank performance from a managerial control perspective, estimations are relevant at bank level. That is, the selected directional vector is in accordance with our objectives and framework as it allows taking into account bank specific characteristics.

This directional distance function can be computed as the solution to a linear programme. The non-linear technology in (2) can be linearised using the substitution from Kuosmanen (2005): $z^k = \theta^k \lambda^k$ and $\mu^k = (1-\theta^k)\lambda^k$, $\forall k$ so that $z^k + \mu^k = \lambda^k$. Next, to model the technology in (2) and compute expression (3) expanding all good outputs and contracting all bad outputs, one must solve:

$$
\begin{aligned}
& D(x^{k'}, u^{k'}, v^{k'}, b^{k'}) = \max \delta \\
\text{s.t. } & \sum_{k=1}^{K} z^k u_i^k \geq u_i^{k'} + \delta u_i^{k'}, \quad \mathrm{i} = 1,2,\ldots,I \\
& \sum_{k=1}^{K} z^k b_j^k = b_j^{k'} - \delta b_j^{k'}, \quad \mathrm{j} = 1,2,\ldots,J \\
& \sum_{k=1}^{K} (z^k + \mu^k) v_l^k \geq v_l^{k'} + \delta v_l^{k'}, \quad 1 = 1,2,\ldots,L \\
& \sum_{k=1}^{K} (z^k + \mu^k) x_n^k \leq x_n^{k'} - \delta x_n^{k'}, \quad \mathrm{n} = 1,2,\ldots,N \\
& \sum_{k=1}^{K} (z^k + \mu^k) = 1 \\
& z^k, \mu^k \geq 0, \; k = 1,2,\ldots,K.
\end{aligned} \tag{4}
$$

An efficient unit, situated on the best practice frontier, will have $D(x^{k'},u^{k'},v^{k'},b^{k'}) = 0$, whereas values of $D(x^{k'},u^{k'},v^{k'},b^{k'}) > 0$ show the degree of inefficiency of the analysed unit. Figure 1 presents a simplified representation of the directional distance function by illustrating the two-dimensional relation between the linked good and bad outputs. It also shows the difference between this function and the more traditional Shephard output distance function.

[Figure 1 about here]

On the one hand, the output distance function expands both linked good and bad outputs simultaneously, placing the output vector A on the boundary point C. On the other hand, the directional distance function starts at point A and scales taking a direction for increasing good outputs and decreasing bad outputs to point B on the boundary. Therefore, $\delta u^{k'}$ is added to the linked good output and $\delta b^{k'}$ is subtracted from the bad output. Additionally, even if not observable in the figure, the good outputs not linked to the bads are expanded by $\delta v^{k'}$, whereas inputs are contracted by $\delta x^{k'}$.

4. The Costa Rican banking industry: Deregulation processes and consolidation

As in other developing economies, the deregulation of the Costa Rican banking sector aimed at improving monitoring activities as well as enhancing banks' competitiveness (Yildirim and Philippatos 2007). Before 1980, Costa Rican banks were tightly regulated in terms of interest rates and activities. Reforms started in 1984 by liberalising interest rate pricing policies. In 1992, the Central Bank removed the demand deposit monopoly to allow private banks to capture resources from the population. Also, banks were allowed to grant loans and operate in foreign currency (US dollars).

In 1995 further reforms improved supervision tasks and the transparency of financial firms (IMF 2003). Due to increased market competition and the complexity of the banking system, the

Central Bank created an independent supervisory agency to monitor banks, the Superintendent of Financial Entities (SUGEF). Similar policies were adopted in the securities and pension funds markets, where monitoring agencies were introduced. In 1997, the National Council of Supervision of the Financial System was created. This is the main supervisory authority of the financial system, which monitors and coordinates the superintendents of the banking system, the stock market, and the pension fund operators (IMF 2003). Thus, full disclosure of bank activities started in 1997.

One last reform took place in 2001, when SUGEF introduced the CAMELS rating framework to further enhance monitoring over financial institutions (IMF 2003). This scheme facilitates monitoring over six major aspects of financial firms: capital adequacy, asset quality, management, earnings, liquidity, and sensitivity to market risk (SUGEF 2000). SUGEF actively monitors all financial firms, including: state-owned commercial banks, private banks, mutual banks, cooperative banks, financial conglomerates, financial (non-banking) firms, credit unions and currency exchange offices. Yet, for the purposes of this paper, and given technology differences, we focus the analysis on those banks that operate under the same market conditions: the state-owned commercial banks, private banks, mutual banks and cooperative banks.

First, state-owned banks are controlled by the Costa Rican government and, according to the financial regulations, they are considered independent firms since politicians do not influence their managerial decisions. This group attracted 54% of the deposits and 48% of the loans in 2012. The second group includes private banks. In 2012, this group controlled 29% of all deposits and 36% of the loans. The third group are the mutual banks, which in 2012 had 7% and 5% of the deposits and loans, respectively. Their deposits are, similarly to the state-owned banks, guaranteed by the government. The last group consists of cooperative banks, which, even if owned by their members, offer their services to any type of customer. In 2012 these firms accounted for 10% and 11% of the deposits and loans, respectively.

At this point some considerations on sample characteristics are in order. First, it is worth noting that all Costa Rican banks operate under the same regulatory regime, and their capacity is unrestricted in terms of financial activities. Second, according to the financial regulations, banks' boards have to be fully composed of outside members. Consequently, the positions of Chairman and CEO cannot be vested in the same person. This is consistent with the concerns of several corporate governance activists about the importance of the firm's leadership structure. In this sense, Fama and Jensen (1983) and Jensen (1993) claim that concentration of decision and control rights in one individual reduces the board's effectiveness and leaves internal control mechanisms in a weaker position for disciplining poor managers. In conclusion, financial laws not only restrict the composition of the board of directors, but also introduce transparency mechanisms that facilitate the access to detailed information on financial operations and organisational architecture.

5. Sample, variables and analysis stages

5.1 Sample and Variables

Data come from the Costa Rican Central Bank, are publicly available, and comprise information for all banks operating in the industry during 1998-2012. This period witnessed a limited number of entries and exits, and, given the similar objectives of the studied financial institutions (see Section 4), we decided to use an unbalanced panel that encompasses all state, private, mutual and cooperative banks that participate in the market. Thus, the total analysed sample comprises 663 firm-year observations.[3]

Banking efficiency literature identifies two main approaches for evaluating financial institutions (see the surveys of Berger and Humphrey (1997), Goddard *et al*. (2001) or Fethi and Pasiouras (2010)). These are the production and intermediation approaches. Under the production approach banks are viewed as producers of both deposits and loans. In this case inputs are labour and capital. The intermediation approach considers that banks attract deposits and purchased funds that are transformed into loans and financial investments. Hence, in this second definition, one should also introduce funds (*i.e.* the raw material to transform) as inputs.

This study utilises the intermediation approach, which is thought to be better suited to the currently deregulated banking activities (Berger and Humphrey 1997; Goddard *et al*. 2001). Apart from traditional balance sheet variables (*e.g.* deposits, assets, securities or loans), one should also account for other non-balance sheet dimensions. We partly capture these dimensions by adding gains from fee-based operations, which can be considered a non-traditional output (Illueca *et al*. 2009). Moreover, due to the purpose of the study and the modelling of outputs, total loans are divided into performing (good) loans and non-performing (bad) loans. Table 1 presents the mean values of inputs and outputs for the analysed period. The selected inputs are: (x_1) deposits, (x_2) fixed assets, (x_3) wages, and (x_4) general administrative expenses. These thoroughly express funding, capital, labour and operating costs, respectively. Outputs are: (u) performing loans, (b) non-performing loans (NPL), (v_1) securities (investment portfolio), and (v_2) service fees (non-interest income).

[Table 1 about here]

Performing and non-performing loans are separated from the total loans using the rules set by the SUGEF. Specifically, NPL (be they mortgages, regular loans or corporate loans) are those past due for at least 90 days. These two output categories represent the linked good (**u**) and bad (**b**) outputs, as banks inevitably produce them simultaneously. In fact, NPL reflect credit risk and data show only positive values for both performing and non-performing loans. However, credit and the other considered outputs are mutually exclusive. Therefore, securities and service fees (**v**) represent banking dimensions unrelated with loans and are introduced as good outputs not linked to the undesirable output (NPL).

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[3] Section 5.2 explains how data are used to construct the best practice frontiers.

Inefficiency scores derived from our proposal in equation (4) are interpreted jointly with accounting ratios to further reveal their managerial implications. Most of these discussions are carried out at bank-level, whereas we also briefly explore the relationship between risk and performance at industry level. Descriptive statistics for the accounting ratios and risk variables are presented in Table 2. Accounting measures evaluate economic performance, and are specified through return on assets (ROA) computed as the ratio of profit to total assets, and the net interest margin (NIM), which is the difference between interest income and interest expense relative to total assets. Risk is measured via two ratios commonly used in previous studies (Altunbas *et al.* 2000; Park and Weber 2006; Banker *et al*. 2010; Barros *et al*. 2012). First, for our main bank-level analysis, the NPL ratio is given by non-performing loans relative to total loans. Second, for supplementary industry-level interpretations, a proxy variable for the capital adequacy ratio (CAR) is calculated as equity plus risk-weighted reserves divided by total assets.

[Tables 2 and 3 about here]

For the analysis related to executive replacements, Table 3 presents the frequency of CEO turnover during 2000-2010 and the type of the incoming manager. We consider that a CEO turnover corresponds to a specific period only if the name of the top manager changes in two consecutive years. Thus, CEO turnover is captured by a dummy variable that takes the value of one if the top executive manager was replaced, and zero otherwise. In addition, two dummy variables take the value of one if the successor is from inside or outside the bank, and zero otherwise. An internal promotion is identified if the new CEO was part of either the board or the top management team in the year prior to her appointment.

5.2. Frontier specifications and analysis stages

We first compute the inefficiency scores following the proposal in equation (4) and using the inputs and outputs specified in Section 5.1. There are, nonetheless, some more considerations necessary. First, literature expresses concerns linked to production possibilities. One example is found in Kumar and Rusell (2002), who point out that the true but unobservable frontier should include the knowledge accumulated from previous periods. Second, pitfalls may appear in the presence of a reduced number of observations and a relatively high number of input and output dimensions.

Both concerns are addressed by using technology specifications including sequential reference sets (Tulkens and Vanden Eeckaut 1995). A sequential reference set implies that the current period technology depends not only on contemporary observations of inputs and outputs, but also on combinations from all previous periods. That is, the technology (*i.e.* the efficiency frontier) is constructed from all observed best practices of banks in the sample (for empirical applications see, *e.g.*, Park and Weber (2006) or Banker *et al*. (2010)). When listing results, scores are reported only for the year under analysis. However, when the analysed period is extensive, sequential frontiers including all previous periods can lead to inefficiency estimates that are difficult to interpret, or even unreliable. This becomes even more so when the analysis includes both progress and regress periods.

Taking into account these concerns jointly with our bank-level focus, we construct frontiers that match control systems. In managerial settings it makes sense to benchmark against best practices from the current period and also to use feedback from the relevant previous periods (Kaplan and Atkinson 2000). Indeed, the benchmarking literature usually states that managerial best practices used as targets for control should be relevant, attainable and—to the possible extent—observable (Camp 1995). On many occasions, frontier targets from the recent previous periods are the objectives employed for control activities, while the current year benchmarks can help verifying whether the bank is currently a good practice. In turn, the current period results and targets become objectives for managerial control in the near future.

To match the managerial control setting described above, we use a three-year "sequential window" that reports scores for the analysed (third) year. Furthermore, for each new period we drop the oldest one, so that the frontier is always shaped by three periods. This is a combination between the sequential frontier approach of Tulkens and Vanden Eeckhaut (1995) and the more traditional window analysis of Charnes et al. (1984). That is, we apply the window analysis rationale of nested relevant periods, but report the results only for the last year, similar to the sequential sets of Tulkens and Vanden Eeckhaut (1995). Note that this approach is natural from a strategic management perspective, as it follows the rationale of mid-term planning and control (see, *e.g.*, Grant (2008)).

The sensitivity of the inefficiency scores is scrutinised by estimating "sequential windows" of different extensions and the usual sequential approach that includes all previous years. Although the magnitude of the scores changes (by construction) the overall tenor of the results and general interpretations do not. For the main discussion, we follow the above managerial rationale of a three-year "sequential window". Results are reported yearly for the period 1998-2012, whereas the reference technology includes the analysed year jointly with the previous two.

These inefficiency scores have a managerial interpretation not only due to the benchmarking for monitoring bank activity, but also because of the particularities of the proportional distance function employed in equation (4). We reach bank-level interpretations that are not always easily aggregated to industry-level results, which are more relevant to regulators (see, *e.g.*, Färe and Grosskopf (2004)). A supplementary industry-level analysis—which we detail in the Appendix and only briefly discuss in Section 6—provides some results on the relationship between risk and bank performance.

Finally, we employ our proposal to examine the link between CEO turnover and future performance. This special case provides an ideal illustration of how the benchmarked inefficiency scores that account for risk can be used for corporate governance purposes. We track performance changes over time spans of five years centred on the replacement year. In line with our theoretical underpinnings, we distinguish between appointing an insider or outsider CEO. Moreover, following

Huson *et al*. (2004), we control for potential problems related to mean reversion of performance time-series. Details on this analysis and its results are presented in Section 6.2.

6. Results

6.1. Efficiency and accounting performance assessments

Prior to reporting the efficiency assessments of our proposal in equation (4) we have run additional tests to confirm the influence of NPL and the significance of correctly introducing them in the banking technology. Specifically, we have computed inefficiency scores following two alternative models. First, a traditional specification of the technology considers total loans as a desirable output, and therefore does not account for credit risk. The second alternative follows Kuosmanen (2005) and introduces NPL as a bad output linked to all good outputs (performing loans, securities and service fees). Bear in mind that in the introduction and the methodology sections we argue that this—even if computationally correct—is not an accurate representation of the real banking technology. The Wilcoxon signed-rank test was used to detect the existing differences between our proposal and the two alternative models for the period 1998-2012. Outcomes clearly demonstrate that our proposal of linking NPL only to their corresponding good output attains inefficiency estimates significantly different at 1% from the traditional model (Z-value -17.326) and the specification that links the bad output (NPL) to all good outputs (Z-value -4.582), respectively. This corroborates that our measure is not only closer to the real banking technology in theoretical terms, but also makes a difference for the interpretation of the results. Thus, in what follows the scores of our proposed NPL model (equation (4)) are analysed.

Keep in mind that scores of zero indicate efficient banks, whereas higher values point to the degree of inefficiency. For illustrative purposes, suppose that a fictitious bank has the following input and output vectors: (x_1, x_2, x_3, x_4, u, v_1, v_2, b) = (600, 310, 200, 150, 400, 320, 70, 100), and a corresponding inefficiency score $\delta = 0.03$. To operate efficiently, this bank should expand performing loans (u) by 400 × 0.03 = 12, securities (v_1) by 320 × 0.03 = 9.6, and service fees (v_2) by 70 × 0.03 = 2.1. It should also simultaneously contract NPL (b) by 100 × 0.03 = 3, while reducing deposits (x_1) by 600 × 0.03 = 18, fixed assets (x_2) by 310 × 0.03 = 9.3, wages (x_3) by 200 × 0.03 = 6, and administrative expenses (x_4) by 150 × 0.03 = 4.5.

Note that the interpretation of the inefficiency scores is bank-specific. This aspect is of crucial importance for the managerial control emphasis, as it accounts for the analysed banks' heterogeneity. The diverse directions of the proportional vector sometimes complicate the interpretation of industry-level results (Färe and Grosskopf 2004). In this context, the yearly average industry inefficiencies represent the evolution of the sector based on heterogeneous bank-specific inefficiencies. Thus, we interpret these average scores given our research perspective.

[Figure 2 and Table 4 about here]

In Figure 2 and Table 4 one can notice that, after peaking in 1999 (0.14), bank-level average inefficiencies generally decrease to the lowest level of 0.03 in 2006. This first half of the studied period is characterised by enhancements in the monitoring activities gradually introduced by the regulatory institutions (IMF 2003). Such reforms aim at enhancing banks' competitiveness and arguably banks need to adapt to the new market conditions (Park and Weber 2006; Lozano-Vivas and Pasiouras 2010). It may well be that the analysed banks anticipated these regulatory changes and adapted their internal control practices to the developing competitive environment. A potential reason for the relative lack of fluctuations in inefficiency scores at the start of the 2000s is that, due to more stable market conditions, reforms were not that drastic as in other Latin American countries (Yildirim and Philippatos 2007). During this first half of the analysed period there is a potential bubble effect. One may think that banks report lower proportions of NPL during 2003-2008 given this potential pre-crisis bubble, but it may also be the case that fewer bad debtors exist during growth periods. These mixed effects due to reforms, potential bubbles and the mere existence of bad debtors are extremely difficult to disentangle.

The second half of the period is dominated by the recent financial crisis. The number of bad debtors increases due to the economic downturn and around 2009-2010 the NPL ratio shows early-2000s levels. Salient changes are observed in 2008 when reported bank-level inefficiency scores reach an average of 0.06. These levels remain roughly unchanged until 2010-2011. Towards the end of the time span, average bank-specific inefficiencies are of 0.05, slightly lower than the main financial downturn period (2008-2010). Although one could expect an earlier and more accentuated recovery, this event was directly influenced by yet another series of regulatory pressures. On the background of the global economic crisis, financial capital requirements became more severe and aimed at, among other objectives, attaining Basel III capital adequacy levels (IMF 2013). Banks gradually adopted these conditions (mostly after 2009), which may have diverted attention of managers from internal operations to meeting the new market standards.

Taking a managerial control perspective, throughout the period banks can use the scores for performance evaluations. Given their comprehensive nature, which accounts for risk and includes distances to relevant competitors during mid-term strategic periods, the inefficiency scores can be the basis of evaluating executives. This specific application is presented in Section 6.2.

[Figure 3 and Table 5 about here]

To provide some complementary industry-level interpretations, we introduce accounting ratios into the analysis. Results for ROA and NIM are shown in Figure 3 and Table 5. The insights from the inefficiency scores are more difficult to observe in these one-dimensional accounting ratios that do not capture the different types of banking activities. ROA results confirm to a great extent the interpretations derived from the inefficiency scores (see, *e.g.*, the negative results for 1999, 2004 or the crisis period). However, ROA shows a more zigzag pattern and does not illustrate the slight improvement at the end of the analysed period. These differences may appear because ROA includes extraordinary results not related to the banks' core activity.

The NIM experiences a rather constant decrease between 2002 and 2009. This ratio could be considered a more useful profitability measure of current and future bank performance as its components (interest income and expenses) represent a large proportion of total bank revenues and costs (Van Hoose 2010). NIM decreases could signal enhanced market competition, which enforces performance and consequently narrows margin spreads (Bikker and Bos 2008). This is consistent with industry reforms introduced during the first half of the studied period (Yildirim and Philippatos 2007).

A supplementary industry-level analysis of the relationship between risk and performance is presented in the Appendix. Results show that banks with higher NPL ratios exhibit higher inefficiency levels.[4] This ratio is useful for internal monitoring, and results indicate that higher levels of NPL are costly for bank operations. Thus, enhancing monitoring levels over loans may be beneficial for bank efficiency. Alternatively, in the long-run high proportions of NPL could sometimes indicate higher risk taking. Incentives for risk taking may exist because equity owners could gain more if the risk borne by the bank increases (Van Hoose 2010). Findings for ROA and NIM confirm that higher NPL ratio levels are negatively related to short-run performance, in line with previous studies (Banker *et al*. 2010; Hsiao *et al.* 2010).

In the case of the CAR, findings illustrate the positive association between capital requirements and accounting results. While no effect of the CAR over inefficiency is reported, this ratio is positively related to ROA and NIM. Significant CAR results may signal that external monitoring helps banks obtain better accounting profitability results. The financial soundness of this variable reduces uncertainty, and allows banks to have better operational flexibility and market positions, which could reduce fund rising costs (Das and Ghosh 2006; Banker *et al.* 2010; Hsiao *et al.* 2010).

6.2. Performance changes following executive turnover

We now employ our proposal to examine the link between CEO turnover and future performance. This allows us to illustrate how inefficiency scores can be used for corporate governance purposes. Namely, we scrutinise the performance changes shown by banks during a five years period centred on the CEO turnover year. In order to correctly examine the performance path followed by banks before and after CEO turnover, we only maintain in the sample those CEOs whose tenures cover the full period analysed (*i.e.* two years before replacement for the outgoing CEOs and two years post-replacement for the incoming ones) (see Table 3).

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[4] Keep in mind that the NPL ratio is computed as NPL over total loans. In the inputs and outputs used for computing the inefficiency scores only NPL appear, and do so as an output. Furthermore, in DEA models, more or less of one output or input does not imply higher or lower inefficiency.

To accurately identify performance changes, we follow the procedure used by Denis and Denis (1995) and Huson *et al*. (2004) to correct for potential problems linked to mean reversion of performance time-series. Performance averages are reported for two sub-periods around CEO turnover: from year –2 to year –1 (ex ante), and from year –1 to year +2 ex post executive replacement (see Table 6). Thus, for each bank, one average performance (inefficiency, ROA and NIM, respectively) value is computed for the years –2 to –1, and another value is calculated for the years –1 to +2. For example, in Panel A of Table 6, the value 0.0756 represents the bank-level average inefficiency scores observed from year –2 to year –1 for the sample of banks that replaced the CEO. For the same banks, the value 0.0593 is the bank-level average inefficiency reported from year –1 to year +2.[5]

To further corroborate the robustness of our results for the accounting ratios, we estimate two alternative variables that account for market trends. These are median-adjusted ROA and NIM, which are obtained by subtracting, for each year, the median value of the corresponding measure for all banks. Note that the inefficiency scores are based on the technology of the sector (*i.e.* a benchmarking assessment), and therefore adjusting to industry-median values is not appropriate. In this fashion, industry-adjusted performance changes following CEO turnover isolate bank-level performance changes from variations attributable to the industry.

[Figures 4 and 5, and Table 6 about here]

Given that we are mainly interested in changes around CEO turnover events, we first run inter-temporal tests for performance shifts between banks that replaced the CEO and those that did not, and between banks that appointed an insider and an outsider executive. The graphical intuition of these tests is illustrated in Figures 4 and 5. Inefficiency tends to be lower in those banks that replaced the CEO (Figure 4). To gain more insights, Figure 5 plots, for the five years period centred on the turnover year, the mean inefficiency values. Furthermore, it differentiates CEO turnover followed by appointing an insider (dotted line) or an outsider (dashed line) from the solid line that includes all CEO replacements. One can notice that the positive link between CEO turnover and future performance appears for those replacements followed by the appointment of a CEO from outside the bank. To the contrary, appointing an insider is associated with inefficiency increases.

Results in Panel A of Table 6 show that mean inefficiency around CEO turnover significantly decreases from 0.08 (–2 to –1) to 0.06 (–1 to +2), and the lower ex post inefficiency is mostly linked to appointing outsider CEOs. Indeed, when the incoming CEO is an outsider inefficiency significantly decreases from 0.09 (–2 to –1) to 0.07 (–1 to +2) and 57% of banks improve their results. Similar findings are obtained for the accounting ratios (Panels B to E in Table 6). For both ROA and NIM (adjusted and unadjusted), performance significantly improves for banks that appointed outsider executives.

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[5] One can refer to Denis and Denis (1995) and Huson *et al*. (2004) for the theoretical grounds and further methodological details on this procedure.

We next examine performance differences between banks that replaced the CEO and those that did not. In this case, the comparisons consider each time period (*i.e.* ex ante or ex post). Inefficiency is not significantly different between banks that report CEO turnover events and those that do not, thus suggesting that absolute inefficiency levels in a certain time period are not the only driver of CEO turnover. Moreover, ex post performance differences between banks that replaced the CEO and those that did not (without separating by the type of successor) also fail to appear. The same holds for ROA and NIM (with the only exception of the median-adjusted NIM from –1 to +2).

Finally, for banks that replaced the CEO we test for performance differences between banks that appointed an insider vis-à-vis an outsider. This last test reveals the missing picture and bridges over the inter-temporal and across successor types comparisons. The last column in Table 6 shows that inefficiency is higher ex ante in banks that appoint an outsider, and it remains higher with respect to insider replacements ex post CEO turnover. It seems that higher inefficiency ex ante is associated with the appointment of outsiders, case in which inefficiency significantly decreases ex post. Whereas insiders are not linked to inefficiency decreases (the inter-temporal test is not significant), inefficiency ex post insider appointments remains lower than in banks with outsider successors. Results are weaker for the accounting ratios, but their tenor does not change, especially for the ex post turnover periods.

These results corroborate that CEO turnover is an important control mechanism, and that its effectiveness becomes especially relevant when the incoming manager is an outsider. More inefficient banks ex ante tend to appoint outsiders, and their inefficiency level significantly decreases ex post. Conversely, insiders are appointed in banks with lower inefficiency ex ante, which may mean that fewer bank operations are modified and thus inefficiency does not significantly change ex post. This could signal not only that managers from outside are not influenced by banks' internal routines, but also that outsiders are more likely to introduce new practices and seek organisational changes, which are expected to improve operating performance (Farrell and Whidbee 2003; Huson *et al*. 2004). In this sense, outsiders may well have stronger incentives to prove the quality of their management skills to the board (Zhang and Rajagopalan 2010).

7. Concluding remarks

This paper takes a managerial control approach to develop a monitoring tool for assessing bank performance. Specifically, it proposes a multidimensional efficiency measure that accounts for the joint production of desirable outputs (performing loans, securities and service fees) and an undesirable output that represents credit risk (non-performing loans (NPL)). While some previous efforts to introduce risk in efficiency assessments exist, these have been scarce (see, *e.g.*, the cost function approach of Hughes and Mester (1998) or Altunbas *et al*. (2000), or the use of NPL in Park and Weber (2006) and Barros *et al*. (2012)). Incorporating risk in efficiency analyses is increasingly important on the background of the financial crisis.

Our proposal extends Kuosmanen's (2005) specification to define the real banking technology that exhibits VRS and in which not all desirable outputs are linked to undesirable outputs. In this study, NPL are strictly linked only to that output category that affects their levels (performing loans), while the rest of outputs are not related to NPL. When modelling the technology, NPL are introduced as an endogenous risk measure that proxies the quality of monitoring over loans.

An empirical application illustrates how the proposed monitoring tool functions. The overall efficiency assessment considers the period 1998-2012, which includes two types of changes in the banking competitive environment. The first half of the period is characterised by gradual changes in the regulatory framework that aimed at enhancing monitoring activities. Results show general average bank-specific inefficiency decreases over this period. ROA results mostly corroborate the inefficiency scores. Also, the NIM slightly decreases, which could signal enhanced market competition and consolidation of banks (Bikker and Bos 2008). During this period—among other reforms—the CAMELS rating scheme was introduced. Findings suggest that banks anticipated this regulatory change and adapted internal practices to the developing market conditions (Grifell-Tatjé and Lovell 1999; Park and Weber 2006; Lozano-Vivas and Pasiouras 2010).

The second half of the analysed period is mostly dominated by the current financial crisis. After experiencing increases during 2006-2008, average bank-specific inefficiency remains relatively unchanged after 2008, with minor improvements towards the end of the period. Given the severe and extended financial crisis, this period witnessed the introduction of more rigorous financial capital requirements by national and international regulatory bodies (see, *e.g.*, IMF (2013) for the Basel III requirements). Banks gradually adopted these conditions after 2009, which may have swayed managers towards the enforcement of the new market standards rather than reducing inefficiency by improving internal operations.

Our comprehensive measure accounts for risk and includes distances to relevant competitors during mid-term strategic periods. From a managerial control perspective, these characteristics enhance the inefficiency scores' attractiveness for corporate governance purposes. If internal and external control mechanisms work properly, inefficiency scores should capture performance changes following CEO turnover events. We find that changes in top executives are followed by inefficiency decreases and greater accounting performance. This mainly holds when the incoming CEOs are outsiders. On the one hand, outsiders are appointed when inefficiency is higher ex ante turnover, and—as opposed to insiders—are associated with ex post inefficiency decreases. On the other hand, banks with lower inefficiency ex ante appoint insiders, which may mean that fewer bank operations are modified and thus inefficiency does not change ex post. According to the improved management hypothesis, these results could indicate that outsiders have a clearer influence on performance since they introduce new organisational practices (Farrell and Whidbee 2003; Huson *et al.* 2004). In addition, managers appointed from outside have stronger incentives to prove their potential quality to the board by showing their management skills (Zhang and Rajagopalan 2010).

There are a series of limitations to our study that, in turn, represent avenues for future research. Our proposal takes a managerial control approach to evaluating bank efficiency. Yet, there are some trade-offs between this bank-specific approach and more industry-oriented analyses. Future research could extend the analysis to include issues of interest to policy makers and regulators. First, by using homogenous directions of the directional vector—instead of a proportional distance function based on observed bank-specific input and output vectors—inefficiency scores can be easily aggregated and interpreted at industry level (see aggregation issues in Färe and Grosskopf (2004)). In this case, vector directions can be chosen according to industry-level policy objectives and thus complement this study's managerial approach that uses bank-level scores.

Second, the effects of reforms or bank corporate governance characteristics (such as ownership type) could, alternatively to our proposal, be modelled using the concept of selective convexity introduced by Podinovski (2005). This method allows for individual judgements of each input and output according to the convexity assumption. Given that relaxing convexity is an attractive topic when discussing the benchmarking role of frontiers, this research avenue could be followed to enhance our corporate governance interpretations. Finally, new analyses could scrutinise scale efficiency issues. Banks operating under increasing, decreasing or constant returns to scale are potentially differently affected by risk and regulatory measures. This study can be a starting point towards analysing these issues from industry policy-making perspectives.

Acknowledgements

We thank two anonymous referees, conference participants at the 2012 Asia-Pacific Productivity Conference in Bangkok and the XX Finance Forum in Oviedo for most constructive comments that substantially improved the paper. This research received financial support from the Spanish Ministry of Science and Innovation. Mircea Epure benefited from grant ECO2010-18967; Esteban Lafuente benefited from grants ECO2010-21393-C04-01 and ECO2013-48496-C4-4-R. Mircea Epure acknowledges financial support from the Spanish Ministry of Economy and Competitiveness, through the Severo Ochoa Programme for Centres of Excellence in R&D (SEV-2011-0075). Usual disclaimers apply.

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Figure 1. The directional distance function with good and bad outputs

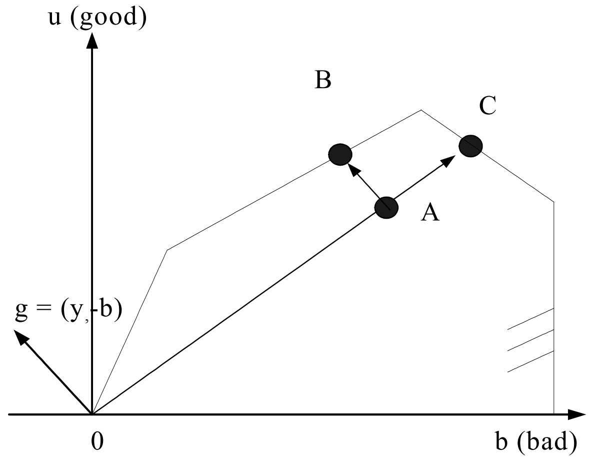


Figure 2. Inefficiency scores: Mean values

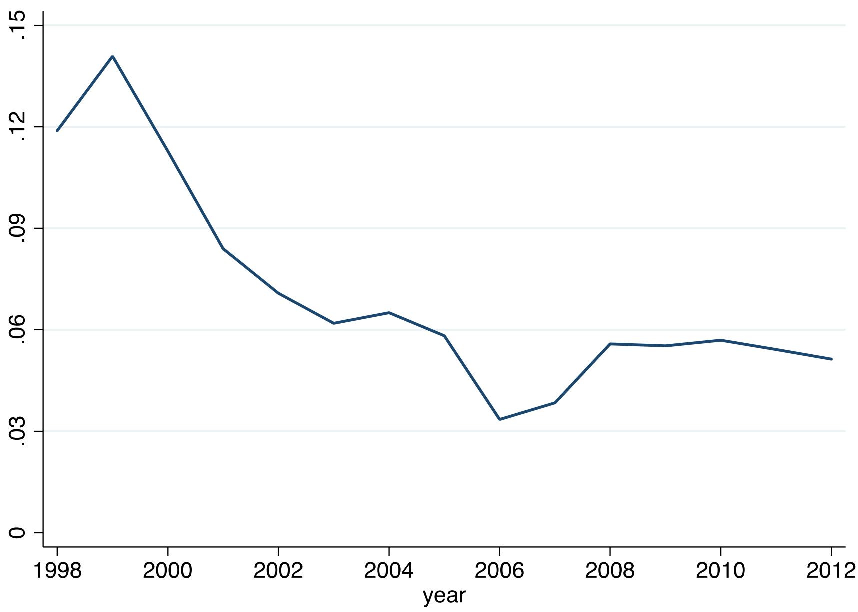
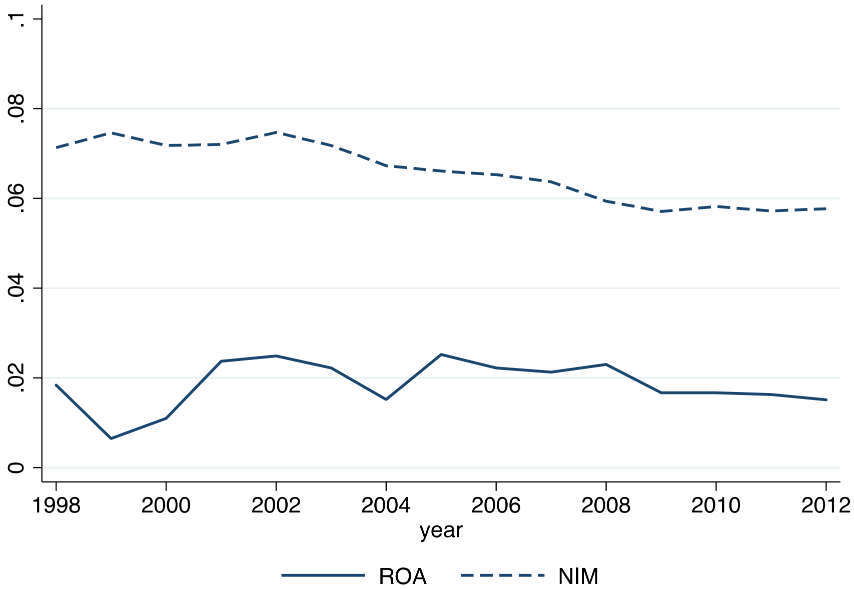


Figure 3. Accounting performance: Mean values



Return on assets (ROA) is defined as the ratio of net profit divided by total assets. The net interest margin (NIM) is the difference between interest income and interest expense relative to total assets.

Figure 4. Inefficiency changes around CEO turnover

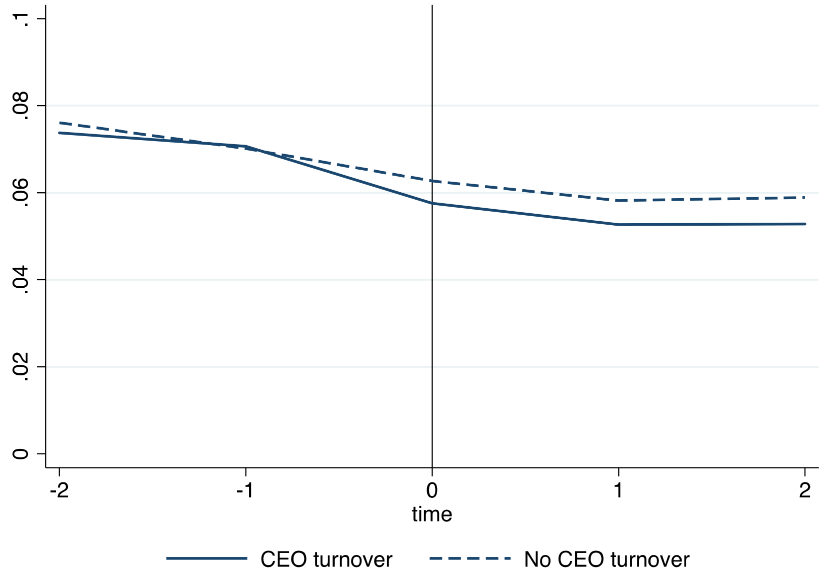


Figure 5. Inefficiency changes around CEO turnover: Insiders vs. Outsiders

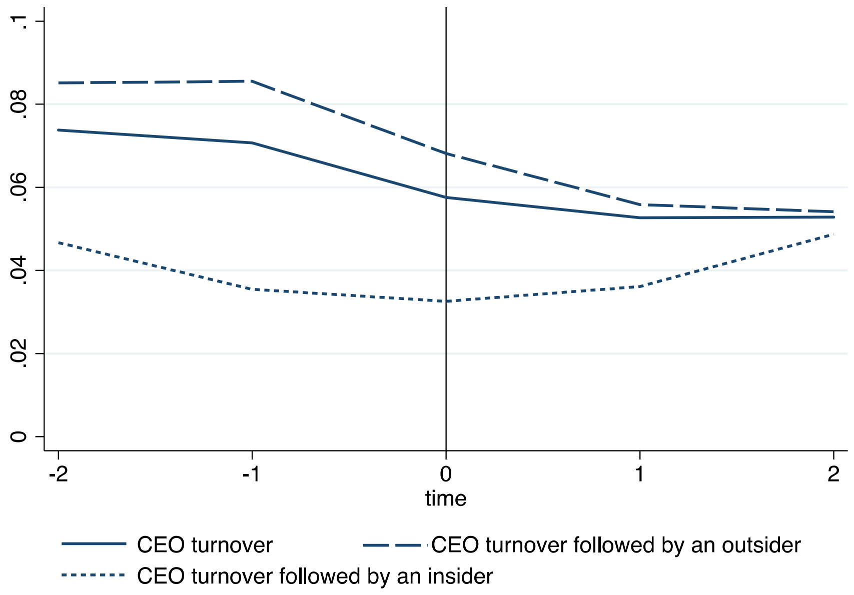


Table 1. Inputs and outputs: Mean values (1998–2012)

Year	Deposits (x_1)	Fixed assets (x_2)	Wages (x_3)	Admin. expenses (x_4)	Total loans (u+b)	Performing loans (u)	NPL (b)	Securities (v_1)	Service fees (v_2)
1998	55,482	5,852	3,243	1,688	43,744	42,486	1,257	30,524	1,564
1999	58,744	6,332	3,539	2,117	48,296	47,063	1,233	34,304	1,714
2000	66,143	4,953	3,723	2,469	59,852	57,785	2,066	36,812	2,064
2001	66,421	5,079	4,202	2,832	70,770	69,153	1,617	36,514	2,271
2002	70,302	5,800	4,577	3,025	78,925	76,429	2,496	41,218	2,430
2003	75,010	5,171	4,879	3,258	88,207	86,746	1,460	43,692	3,027
2004	103,658	5,825	6,115	3,600	102,479	100,492	1,987	66,097	3,695
2005	111,999	6,085	6,504	3,890	117,455	115,881	1,574	66,514	4,138
2006	123,721	6,286	6,856	4,088	136,017	134,215	1,802	67,259	4,582
2007	132,728	6,948	7,398	4,467	175,707	173,696	2,012	53,834	5,340
2008	145,285	7,567	7,267	4,704	206,131	203,023	3,107	42,275	5,817
2009	173,836	7,899	7,702	5,008	205,414	201,146	4,268	55,524	6,265
2010	167,520	7,677	7,784	5,039	200,013	196,267	3,746	60,330	6,338
2011	170,480	7,794	8,243	5,116	220,151	216,206	3,945	51,573	6,792
2012	190,140	8,012	8,953	5,264	246,044	241,868	4,177	62,852	7,477
Total	110,951	6,431	5,925	3,686	128,746	126,341	2,405	49,031	4,097

The sample includes information for the Costa Rican banking firms between 1998 and 2012. All monetary values are expressed in millions of 2012 Costa Rican colones, and are deflated with respect to inflation.

Table 2. Accounting performance and risk variables: Descriptive statistics

Variable	Mean	S.D.	Minimum	Maximum
Total assets	222,463	559,411	410	4,065,165
ROA	0.0184	0.0434	-0.7339	0.1088
NIM	0.0663	0.0345	-0.0373	0.1943
NPL ratio	0.0210	0.0410	0.0000	0.6580
CAR	0.2284	0.1608	0.0441	0.9774

The sample includes information for the Costa Rican banking firms between 1998 and 2012. Total assets are expressed in millions of 2012 Costa Rican colones. Return on assets (ROA) is defined as the ratio of net profit divided by total assets. The net interest margin (NIM) is the difference between interest income and interest expense relative to total assets. The capital adequacy ratio (CAR) divides equity and risk-weighted reserves by total assets. For the non-performing loans (NPL) ratio, NPL are divided by total loans. Number of observations: 663.

Table 3. Frequency table for CEO turnover during 2000–2010

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
ΔCEO	5	3	2	7	3	5	6	2	5	4	7	49
Insider	2	0	0	4	0	1	2	1	1	2	2	15
Outsider	3	3	2	3	3	4	4	1	4	2	5	34

Table 4. Inefficiency scores: Descriptive statistics

Year	Obs.	Mean	S.D.	Min.	Max.
1998	51	0.1188	0.1565	0.0000	0.5143
1999	50	0.1408	0.1738	0.0000	0.6307
2000	50	0.1127	0.1517	0.0000	0.4671
2001	47	0.0839	0.1220	0.0000	0.4316
2002	47	0.0708	0.1079	0.0000	0.3857
2003	46	0.0619	0.0940	0.0000	0.3257
2004	42	0.0650	0.0963	0.0000	0.3248
2005	40	0.0582	0.0843	0.0000	0.3430
2006	41	0.0335	0.0530	0.0000	0.2255
2007	40	0.0384	0.0656	0.0000	0.2322
2008	42	0.0558	0.0857	0.0000	0.3057
2009	42	0.0552	0.0973	0.0000	0.3448
2010	42	0.0569	0.0909	0.0000	0.3318
2011	42	0.0541	0.0806	0.0000	0.3530
2012	41	0.0513	0.0755	0.0000	0.2484
Total	663	0.0728	0.1135	0.0000	0.6307

Note that the number of observations stands for the number of reported scores, whereas the sequential technology also includes banks from the two previous years. Inefficiency is computed according to equation (4).

Table 5. Accounting performance measures: Descriptive statistics

		ROA				NIM			
Year	Obs.	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
1998	51	0.0184	0.0327	-0.1537	0.0777	0.0713	0.0461	0.0078	0.1738
1999	50	0.0065	0.1094	-0.7339	0.0930	0.0746	0.0506	-0.0373	0.1943
2000	50	0.0110	0.0685	-0.4279	0.1009	0.0718	0.0443	0.0046	0.1906
2001	47	0.0237	0.0237	-0.0276	0.1015	0.0720	0.0383	0.0268	0.1694
2002	47	0.0249	0.0257	-0.0296	0.1086	0.0747	0.0364	0.0212	0.1742
2003	46	0.0222	0.0209	-0.0166	0.1075	0.0718	0.0317	0.0306	0.1631
2004	42	0.0152	0.0675	-0.3927	0.1066	0.0673	0.0296	0.0246	0.1602
2005	40	0.0252	0.0181	0.0095	0.1088	0.0661	0.0320	0.0218	0.1769
2006	41	0.0222	0.0160	0.0071	0.0941	0.0653	0.0289	0.0226	0.1455
2007	40	0.0213	0.0174	-0.0056	0.0827	0.0637	0.0272	0.0158	0.1395
2008	42	0.0230	0.0162	0.0059	0.0771	0.0594	0.0240	0.0182	0.1212
2009	42	0.0167	0.0161	-0.0273	0.0751	0.0571	0.0226	0.0212	0.1112
2010	42	0.0167	0.0168	0.0003	0.0812	0.0582	0.0237	0.0175	0.1215
2011	42	0.0163	0.0175	-0.0035	0.0969	0.0572	0.0258	0.0234	0.1327
2012	41	0.0151	0.0191	-0.0528	0.0942	0.0577	0.0251	0.0225	0.1309
Total	663	0.0184	0.0434	-0.7339	0.1088	0.0663	0.0345	-0.0373	0.1943

Return on assets (ROA) is defined as the ratio of net profit divided by total assets. The net interest margin (NIM) is the difference between interest income and interest expense relative to total assets.

Table 6. Performance changes around CEO turnover (2000–2010)

	Governance event		Test: CEO turnover vs. no CEO turnover	Successor		Test: Insider vs. Outsider
	No CEO turnover	CEO turnover		Insider	Outsider	
Panel A: Inefficiency						
Inefficiency: –2 to –1	0.0762 (42:58)	0.0756 (43:57)	0.881	0.0423 (56:44)	0.0903 (37:63)	–1.840*
Inefficiency: –1 to +2	0.0614 (53:47)	0.0593 (52:48)	0.892	0.0332 (38:63)	0.0693 (57:43)	–1.893*
Inter-temporal test	–2.607***	–2.056**		–0.806	–1.890*	
Panel B: ROA						
ROA: –2 to –1	0.0236 (44:56)	0.0186 (44:56)	0.752	0.0150 (44:56)	0.0202 (45:55)	–0.658
ROA: –1 to +2	0.0223 (40:60)	0.0213 (54:46)	0.130	0.0144 (31:69)	0.0239 (63:37)	–2.285**
Inter-temporal test	–3.991***	1.587		–0.874	2.129**	
Panel C: Median-adjusted ROA						
Median adjusted ROA: –2 to –1	0.0080 (45:55)	0.0041 (46:54)	0.654	–0.0005 (50:50)	0.0060 (45:55)	–0.971
Median adjusted ROA: –1 to +2	0.0066 (46:54)	0.0078 (52:48)	–1.332	–0.0006 (38:63)	0.0109 (58:42)	–3.167***
Inter-temporal test	–3.580***	1.566		–1.013	2.060**	
Panel D: NIM						
NIM: –2 to –1	0.0695 (48:52)	0.0665 (50:50)	0.002	0.0531 (56:44)	0.0723 (47:53)	–1.383
NIM: –1 to +2	0.0656 (43:57)	0.0713 (50:50)	–1.155	0.0494 (44:56)	0.0795 (53:47)	–3.167***
Inter-temporal test	–6.272***	2.095**		–0.594	2.317**	
Panel E: Median-adjusted NIM						
Median adjusted NIM: –2 to –1	0.0108 (48:52)	0.0085 (50:50)	0.317	–0.0060 (56:44)	0.0145 (47:53)	–1.761*
Median adjusted NIM: –1 to +2	0.0087 (50:50)	0.0170 (52:48)	–2.330**	–0.0053 (44:56)	0.0256 (55:45)	–3.422***
Inter-temporal test	–2.842***	3.238***		0.734	3.137***	

The table reports comparisons of average performance values across periods and between governance events and CEO successor types. Inefficiency is computed according to equation (4), return on assets (ROA) is the ratio of net profit divided by total assets, and the net interest margin (NIM) is the difference between interest income and interest expense relative to total assets. Median-adjusted ROA and NIM values are obtained by subtracting, for each bank and for each year, the corresponding industry-level median value. The percentage of firms with positive and negative changes in performance are presented in brackets (i.e. figures should be read as "percentage of positive changes : percentage of negative changes"). The Wilcoxon signed-rank test is used for the inter-temporal performance comparisons (within governance event or successor type). The cross-sectional performance comparisons between governance events or successor types are done using the Mann-Whitney test. Cases in which the new CEO's tenure ended before the year +2 are excluded. *, **, *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

Appendix: Analyses of the relationship between risk and performance

A supplementary analysis examines the relationship between risk and bank performance, by estimating the following regression for the full period:

$$\text{Performance}_t^k = \alpha_0 + \beta_1 \text{NPL}_{t-1}^k + \beta_2 \text{CAR}_{t-1}^k + \beta_3 \text{Controls}_{t-1}^k + \psi_t + \upsilon_t^k , \qquad \text{(A1)}$$

where: $k = 1,...,K$ and $t = 1,...,T$ represent the cross-sectional units and the time periods, respectively; ψ_t is the time-specific effect and υ_t^k is the error term. The disturbance takes the form $\upsilon_t^k \sim N[0,\sigma_\upsilon^k]$ when the dependent variable is the inefficiency score. When ROA and NIM are the dependent variables, the error term takes the form $\upsilon_t^k = \varepsilon^k + \eta_t^k$, where ε^k is the unobserved time-invariant firm-specific effect that controls for unobservable heterogeneity, and η_t^k is a stochastic error term that varies cross-time and cross-units. Control variables are bank size, defined as the natural logarithm of total assets (lagged) and time dummies.

Our performance assessments imply using three different dependent variables: inefficiency, ROA, and NIM. Due to their statistical properties, we use different techniques. When the inefficiency score is the dependent variable ($\delta^k \in [0,+\infty)$), we use a truncated regression (Greene 2003; Simar and Wilson 2011). Thus, the model takes the form $\delta^k \approx \alpha + \beta X^{'k} + \upsilon^k$. Parameter estimates are obtained by the maximum likelihood method, and disturbances are constructed through parametric bootstrapping (2,000 replications) to derive more accurate error terms.

Accounting ratios are unbounded by definition, so we can employ econometric tool that allows taking into consideration the unobserved and constant heterogeneity among the analysed banks. Also, the presence of firm specific unobservable fixed effects that can be correlated with some explanatory variables should be accounted for. Consequently, coefficients are estimated using the system generalised method of moments (GMM). For robustness, we also estimate fixed effects regressions and the results do not change.

Table A1. Regression results

	Truncated	GMM	
	Inefficiency	ROA	NIM
NPL ratio (*t*-1)	1.6813** (0.6660)	–0.1268*** (0.0392)	–0.0466** (0.0180)
CAR (*t*-1)	–0.0155 (0.0855)	0.0904*** (0.0080)	0.1652*** (0.0037)
Size (ln assets) (*t*-1)	0.0030 (0.0093)	0.0001 (0.0001)	–0.0006* (0.0003)
Time dummies	Yes	Yes	Yes
Intercept	–0.1001 (0.1886)	0.0028 (0.0147)	0.0344*** (0.0067)
Pseudo R2	0.0668		
Log likelihood	300.8492		
Wald test (chi2)	56.72***	204.42***	433.56***
Sargan test		44.83	40.28
Test for AR1		0.71	–1.99**
Test for AR2		–0.89	0.94
Average VIF	1.87	1.87	1.87
Observations	648 (352 truncated)	648	648

Inefficiency is computed according to equation (4). Return on assets (ROA) is defined as the ratio of net profit divided by total assets. The net interest margin (NIM) is the difference between interest income and interest expense relative to total assets. For the truncated regression using the inefficiency score as dependent variable bootstrapped standard errors (2,000 iterations) are presented in brackets. For GMM regressions (ROA and NIM) robust standard errors are presented in brackets. *, **, *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively. Results do not change significantly when introducing an interaction term between size and ownership type.