CEO compensation and bank efficiency: An application of conditional nonparametric frontiers

By

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Abstract

The paper, by incorporating the latest developments on the probabilistic approach of efficiency measurement, (Bădin et al., 2012) investigates in a dynamic context the effect of Chief Executive Officer (CEO) bonus and salary payments on banks' technical efficiency levels. We apply time-dependent conditional efficiency estimates to analyze a sample of 37 US banks for the period from 2003 to 2012. The empirical evidence reveals a non-linear relationship between CEO bonus and salary payments and banks' efficiency levels. More specifically it is reported that salary and bonus payments affect differently banks' technological change and technological catch-up levels. Finally, the empirical evidence suggests that higher salary and bonus payments are not always aligned with higher technical efficiency levels.

Keywords: Bank efficiency; CEO compensation; Conditional efficiency measures; Data Envelopment Analysis.

1. Introduction

Over the past decades several influential papers[1] have explored empirically the link between Chief Executive Officer (CEO) compensation levels and firms' performance (known as pay-for-performance relationship). These studies examine the pay-for-performance relationship mainly for industrial US firms. They explored how firms' performance[2] determines CEO compensation levels. The majority of the empirical evidence suggest that the relationship is positive,[3] however, there are also a few studies providing evidence of a weak relationship (Conyon and Murphy, 2000; Zhou, 2000; Buck et al., 2003). On the other hand, some other studies report that there is even a negative relationship between excess CEO compensation and firms' performance (Core et al., 1999; Brick et al., 2006). Arguments in the literature (Finkelstein and Boyd, 1998; Bertrand and Schoar, 2003; Crossland and Hambrick, 2007, 2011; Hambrick and Quigley, 2014) suggest that when managerial discretion[4] and CEO compensation are aligned then firm performance should be higher. Furthermore, earlier studies suggest that cash compensation should be structured in such a way that will enable high rewards to be associated with high performance (Jensen and Murphy, 1990a, 1990b; Mehran, 1995; Hall and Leibman, 1997).

Despite the importance of such a relationship in the banking industry, surprisingly a few empirical studies have been exploring the link between CEO compensation and bank performance. This study contributes to current empirical

[1]See, for example, Ciscel and Carroll (1980), Coughlan and Schmidt (1985), Murphy (1985), Jensen and Murphy (1990a,b), Kaplan (1994), Mehran (1995), Hall and Leibman (1997), Finkelstein and Boynd (1998) and Aggarwal and Samwick (1999a,b).
[2]The extant research uses stock prices and financial and accounting based ratios as a measure of firms' performance.
[3]For an extensive literature review see Murphy (1999) and Core et al. (2003).
[4]Managerial discretion is the ability of a CEO (or a top manager) to make strategic decisions that have both direct and indirect impact on firms' performance (Finkelstein and Boyd, 1998; Bertrand and Schoar, 2003)

research on CEO compensation in general and banking in particular. The paper differs from other recent studies in several ways.

Firstly, we explore for the first time the effect of CEO bonus and salary payments on banks' efficiency levels. We use a sample of 37 US bank holding companies over the period from 2003 to 2012. We examine in a nonparametric context the CEO payment-bank performance relationship. Secondly, we apply the latest developments of data envelopment analysis (DEA),[5] as have been introduced by Bădin et al. (2012) and Mastromarco and Simar (2014). Specifically, we model bank technical efficiency by taking into consideration time effects and the effects imposed by CEO compensation levels without imposing the restrictive separability assumption.[6] This is done by treating time and CEO compensation levels as external/environmental factors which in turn influence banks' production process. A number of recent studies, e.g. Holmstrom and Kaplan, 2003; Bizjak, Lemmon and Naveen, 2008; Hayes and Shaefer, 2009; Bizjak, Lemmon and Nguyen, 2011; among others, provide empirical support for the view that there is a common practice of competitive benchmarking to determine CEO compensation. Bizjak et al. (2008) point out that the practice is questionable since it can increase executive pay without taking into account a firm's performance. On the other hand, competitive benchmarking can be used as an efficient tool to retain valuable CEOs. In other words, CEO compensation is not necessarily determined by the firm itself but reflects compensation packages across the sector[7].

Moreover, we apply full and partial time-dependent conditional efficiency measures that enable us to explore separately the effect of time and CEO bonus and

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[5]Recently Chen et al. (2013) have illustrated the usefulness of DEA methodology for the top management level due its ability to measure firms' performance by identifying the firms' imposing competitive advantage.
[6]For details see the studies by Simar and Wilson (2007, 2011).
[7] In a competitive environment, there is a high degree of discretion of how CEOs are compensated, see, for example, Finkelstein and Boynd (1998) for a further discussion.

salary payments on banks' technological change (shifting of the frontier) and technological catch-up (distribution of efficiency).[8] Thirdly, we deploy banks' technical efficiency estimates instead of financial and accounting based ratios that are commonly used. Such an approach circumvents all the disadvantages related to those performance measures. The advantages of using relative rather than absolute measures for the analysis of the pay-for-performance relationship are discussed in detail by Antle and Smith (1986) and Gibbons and Murphy (1990). Steigenberger (2014) then discusses the limitation of financial and accounting ratios as a measure of firms' performance. Fourthly, our model does not impose any assumptions related to the functional form of the examined relationship that allows us to reveal any nonlinearities. This is an important contribution to current research in the banking industry. The previous studies have assumed a linear relationship between CEO remuneration and bank performance.

The structure of the paper is as follows: Section 2 reviews the related literature of the pay-for-performance relationship with a particular emphasis on the banking sector. Section 3 provides a description of the variables used and presents the proposed methodological framework. Finally, Section 4 discusses the empirical findings. Section 5 provides a summary of our findings.

2. Review of the literature

The prevailing empirical research on the CEO compensation-firm performance relationship has mostly been conducted for industrial firms.[9] Coughlan and Schmidt (1985), for example, examine how the changes in compensation affect stock price

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[8]See, for example, Kumar and Russell (2002) and Henderson and Russell (2005).
[9] This was mainly related to data availability issues.

performance. They provide supporting evidence that compensation affects both firms' stock price and sales growth levels. Murphy (1985) analyzes the same relationship by adopting, as a dependent variable, the compensation level and as an independent variable, shareholder returns (rather than accounting profits) and growth of firms sales on the sample of 500 executives from the 73 largest manufacturing companies over the period from 1964 to 1981. The study shows that the performance measures that were adopted are strongly related to CEO compensation. Jensen and Murphy (1990a) also argue that CEOs' financial rewards affect directly firms' performance levels. They conclude that CEOs' remuneration incentives are very important determinants of firms' performance levels. In addition, they provide evidence that CEOs' performance incentives come from stock ownership. Jensen and Murphy (1990b) then emphasise that cash compensation should be structured in such a way that enables high rewards to be associated with high performance. There is, however, evidence that cash compensation and corporate performance are weakly interrelated. Thus, it means that the 'efficient' structure of cash compensation should reflect upon firms' performance levels. In the same spirit, Kaplan (1994) regresses the annual compensation changes on several accounting and share price performance metrics for 119 Japanese companies over the period from 1982 to 1984. He provides evidence of a positive relationship between compensation and firm performance. Mehran (1995) further examines CEO compensation and firm performance. The model uses as dependent variables two performance measures: Return on Assets (ROA) and Tobin's Q. The tested sample includes 153 manufacturing firms during the period from 1979 to 1980. The findings of this study shows that CEO compensation explains significantly firms' performance variations. In other words, the structure of compensation is a crucial determinant for firm performance. Hall and Leibman (1997) provide empirical evidence of a positive relationship between CEO compensation and firms' financial performance. Finkelstein and Boynd (1998) use as a measure of performance Return on Equity (ROE)and ROA. They find that prior firm performance is not linked to CEO compensation but firm size is a key determinant. Aggarwal and Samwick (1999a) show that relative performance evaluations are not linked with CEOs compensation contracts. Aggarwal and Samwick (1999b) provide convincing evidence that there is a link between sensitivity of compensation with the performance of rival firms. They also suggest that relative performance evaluation is very important for our understanding of executive compensation.

On the other hand, there are a number of studies that confirm the relationship between CEO rewards and firms' performance. Brunello et al. (2001), who use a sample of 107 Italian firms, point out the positive relationship between CEO compensation and firms' profit levels. Mitsudome et al. (2008) compare Japanese and US companies and their results indicate that there is a significantly positive relationship between CEO compensation and short-term performance. However, they could not confirm such a relationship for the Japanese firms when they use sales growth levels as a proxy for firm performance.

Barro and Barro's (1990) study was among the first studies to investigate pay-for-performance contracts in the banking industry. They explore the relationship using a sample that includes US commercial banks during the period from 1982 to 1987. They find that the growth of compensation is positively related to accounting earnings and stock returns. That means the compensation growth depends on relative and aggregate performance. Later Hubbard and Palia (1995) provide evidence of a stronger relationship of compensation–performance during the 1980s, i.e., the period of interstate banking permission. They show that bank size also determines the level of compensation. Crawford et al. (1995) examined the sensitivity of CEO performance after the deregulation period for a sample of 37 commercial banks over the period from 1976 to 1982. They provide evidence that during the deregulation period there was an increase in pay-performance sensitivities. Houston and James (1995) analyze a sample of 134 banks over the period from 1980 to 1990 and examine the determinants of CEO cash compensation (salary plus bonus) and CEO stock and option holdings. They find that there is a positive relationship between stockholder wealth with both types of compensation. They also provide evidence that bank CEOs' cash compensation is sensitive to stock market performance. Furthermore, their findings suggest that for larger banks the pay for performance relationship is relatively weak. In contrast, Bliss and Rosen (2001) provide evidence that bank mergers and acquisitions contributed to a significant increase in CEO compensation, despite the fact that shareholder values declined through the lower value of bank shares. Their findings support several other studies suggesting that the size has a positive influence on CEO compensation. Ang et al. (2002), by using a sample of 166 US banks, provide evidence that the compensation of top bank executives is determined by bank performance and the size of the bank. They also show that the payment is higher when it is linked to long-term performance achievements. John and Qian (2003) examine the pay for performance sensitivity for a sample of 120 commercial banks and a sample of 997 manufacturing firms over the period from 1992 to 2000. Their results suggest that pay for performance sensitivity is lower for regulated firms and decreases with firm size and their debt ratio. In addition, they show that banks have lower pay for performance sensitivity than manufacturing firms. Anderson et al. (2004) show on the sample of 97 US bank mergers over the period from 1990 to 1997, that CEO compensation is related to the potential gains obtained from the bank merger.

A recent study by Cuñat and Guadalupe (2009), who analyze the sample of commercial banks and financial services firms from Standard and Poor's 1500 index, show that total shareholder values that are used as a proxy for performance is positively linked with CEO compensation levels. John et al. (2010) examine a sample of bank holding companies during the period from 1993 to 2007. They find that the pay for performance sensitivity of bank CEO compensation decreases with the leverage ratio (defined as one minus the ratio of equity over assets) and it is positively related to the monitoring intensity (measured by subordinated debt rating, non-performing loan ratio and BOPEC rating). Livne et al. (2011) find a positive link between banks' CEO pay and fair value valuation of available for sales assets. Finally, Livne et al. (2013) provide evidence that executive cash bonuses are linked with a simultaneously CEO risk-taking incentives, and a decrease of banks' accounting performance.

The above brief review of the literature indicates that there are some pay-for-performance studies that explore how banks' performance determines CEO compensation levels. However, we find a gap in current research that analyses how CEO compensation affects bank performance. Furthermore, it is also evident that the relative literature applies mostly the parametric approaches to investigate the pay-for-performance relationship. In other words, the model assumes a linear relationship between bank performance and CEO compensation. To this end our paper contributes to the literature by incorporating into our analysis a fully non-parametric framework enabling us to reveal any non-linear links. This can be accomplished by applying the latest developments of the probabilistic approach of efficiency measurement which are presented in the next section.

3. Data and methodology

3.1 Description of variables

We collect data for CEO compensation from Compustat Execucomp Database during the period from 2003 to 2012. The excessive compensation rewards of CEOs in the USA were criticised for a long time. In July 2010, the Dodd-Frank Wall Street Reform and Consumer Protection Act was introduced as a reaction to the Global Financial Crisis, when a large number of financial institutions collapsed. The Dodd-Frank Act is a complex Act dealing with different aspects of financial regulation that should prevent the repetition of the financial crisis in 2008. It embeds, among other regulatory changes, a systemic change of CEO compensation. In particular, the Dodd-Frank Wall Street Reform and Consumer Protection Act proposes provisions that affect executive compensation (Cotter et al (2013) and Kaplan (2012)). These provisions include: i) Advisory votes of shareholders about executive compensation and golden parachutes, including specific disclosure of golden parachutes in merger proxies; ii) disclosure about the role of, and potential conflicts involving, compensation consultants; iii) additional disclosure about certain compensation matters, including pay-for-performance and the ratio between the CEO's total compensation and the median total compensation for all other company employees; iv) the Commission to direct the exchanges to prohibit the listing of securities of issuers that have not developed and implemented compensation claw-back policies; and v) a disclosure about whether directors and employees are permitted to hedge any decrease in market value of the company's stock.

All those changes have been gradually implemented by the US Securities and Exchange Commission (SEC). In the period from 2010–2012, the SEC implemented the rules that require institutional investment managers to report their votes on executive compensation and "golden parachute" arrangements. The SEC also adopted rules concerning shareholder approval of executive compensation and "golden parachute" compensation arrangements. Finally in July 2012, the SEC adopted rules regarding the disclosure about the role of, and potential conflicts involving, compensation consultants. In 2013, the SEC then adopted rules regarding pay ratios. In 2015, the Commission proposed rules regarding disclosure about whether directors and employees are permitted to hedge any decrease in market value of the company's stock and finally the Commission proposed rules regarding pay for performance disclosure.

It is evident that these rules do not impose any significant restrictions on CEO compensation but require disclosure of information about CEO compenstation. In other words, our sample that covers the period from 2003–2012 is not biased due to the systematic changes in CEO remuneration. The main changes were introduced after 2012 that includes also pay performance related compensation disclosure.

We select financial institutions with Standard Industry Classification (SIC) codes between 6000 and 6300. We then exclude manually financial institutions with SIC code 6282 (Investment Advice); SIC codes 6111 (federal credit agency); SIC code 6199 (Finance Services); and SIC code 6211 (Security Brokers and Dealers). The final sample includes 37 US bank holding companies that were active during the period from 2003 to 2012. The Compustat Execucomp Database allows us to extract and divide CEO compensation into several categories. In our analysis, we use for CEO payment the total current compensation values that are directly extracted from the database and include salary and bonuses. As for financial statement data, these data are obtained from Bankscope, which is the most widely used database for financial institutions. We collected defined variables from consolidated financial statements for bank holding companies.

Furthermore, for our DEA context we need to specify banks' production function. Hugh and Mester (2008) argue that bank production is unique to the production of other types of lenders. They show that banks have a special capital structure, i.e. the bank production process is based on the intermediation of deposits into informationally opaque assets. This argument is further supported by Berlin and Mester (2000), who provide empirical evidence of an explicit link between banks' liability structure and banks' lending behaviour. Such findings correspond with the role of banks in the economic system. Banks can reduce the problem of asymmetric information that is reflected consequently by reducing bank risk during its production process. Hugh and Mester (2008) further argue that this leads to efficient and prudent production of financial services.

Thus we apply the intermediation approach as proposed by Sealey and Lindley (1977) and has been followed by empirical research on bank efficiency, (eg. Curi, Lozano-Vivas, Zelenyuk, 2015; Fujii et al., 2014; Fethi and Pasiouras, 2010; Hugh and Mester , 1998)

Under the intermediation approach the inputs used are property, plant and equipment (a proxy for bank capital), deposits and number of employees. Bank outputs are defined as securities and loans. Furthermore, we use CEO salary and bonus payments in our model. Tables 1 & 2 present analytically (per year and per bank) the descriptive statistics of the variables used in our analysis.

[Table 1 and Table 2 about here]

3.2 Time-dependent conditional efficiency measures

Following Koopmans (1951) and Debreu (1951) the production technology is characterized by a set of inputs $x \in \Re_+^p$ that can produce a set of outputs $y \in \Re_+^q$. Then the technically feasible combinations of (x, y) can characterize the production set as:

$$\Psi = \left\{(x, y) \in \Re_+^{p+q} \middle| x \text{ can produce } y\right\}. \quad (1)$$

Then the Farrell (1957) measure of input oriented efficiency score for a unit operating at the level (x, y) can be defined as:

$$\theta(x, y) = \inf\left\{\theta \middle| (\theta x, y) \in \Psi\right\}. \quad (2)$$

According to Daraio and Simar (2005, 2007a) the production set can also be characterized as:

$$\Psi = \left\{(x, y) \middle| H_{X,Y}(x, y) > 0\right\}, \quad (3)$$ where

$$\begin{aligned} H_{X,Y}(x, y) &= \text{Prob}(X \leq x | Y \geq y)\text{Prob}(Y \geq y) \\ &= F_{X|Y}(x|y) S_Y(y) \end{aligned}. \quad (4)$$

Therefore, the production process can be described by the joint probability of (X, Y) on $\Re_+^p \times \Re_+^q$. Then the Farrell-Debreu measure of input oriented efficiency can also be characterized as:

$$\theta(x, y) = \inf\left\{\theta \middle| F_{X|Y}(\theta x | y) > 0\right\} = \inf\left\{\theta \middle| H_{XY}(\theta x, y) > 0\right\}. \quad (5)$$

Mastromarco and Simar (2014) introduce, for the first time, the time-dependent conditional efficiency measures based on the probabilistic approach by Daraio and Simar (2005, 2007a) and the latest developments by Bădin et al. (2012). Similarly, let the time T be an additional conditional variable with those examined in our case (bonus and salary payments). Then for each time period t the attainable set $\Psi_t^z \subset R_+^{p+q}$ can be defined as the support of the conditional probability:

$$H^t_{X,Y|Z}(x,y|z) = \text{Prob}(X \le x, Y \ge y | Z = z, T = t) \\ = F^t_{X|Y,Z}(x|y,z) S^t_{Y|Z}(y|z) \quad , \tag{6}$$

where $F^t_{X|Y,Z}(x|y,z) = \text{Prob}(X \le x | Y \ge y, Z = z, T = t)$, (7)

and $S^t_{Y|Z}(y|z) = \text{Prob}(Y \ge y | Z = z, T = t)$. (8)

Then the full frontier case input oriented technical efficiency of a bank $(x,y) \in \Psi^z_t$, at time t facing the conditions z can be defined as:

$$\theta_t(x,y|z) = \inf\{\theta | F^t_{X|Y,Z}(\theta x|y,z) > 0\}. \tag{9}$$

For the full frontier estimation we have used the assumption of variable returns to scale (VRS). This assumption is commonly used in banking efficiency literature by incorporating directly banks' scale effects. However, it must be noted that there is also support from several authors for the constant returns to scale (CRS) assumption (Kumar and Russell, 2002; Henderson and Russell, 2005; Henderson and Zelenyuk, 2007; Mastromarco and Simar, 2014) since it can provide us with a greater discriminative power compared to the VRS assumption (Zelenyuk and Zheka, 2006).

Furthermore, the *order-α* quantile efficiency measure (also called robust or partial frontiers) for the input oriented case as introduced by Daouia and Simar (2007) can be defined for $\alpha \in (0,1)$ as:

$$\theta_\alpha(x,y) = \inf\{\theta | F_{X|Y}(\theta x|y) > 1 - \alpha\}. \tag{10}$$

Therefore, the *order-α* quantile efficiency measure of a bank $(x,y) \in \Psi^z_t$, at time t facing the conditions z can be defined as:[10]

$$\theta_{t,\alpha}(x,y|z) = \inf\{\theta | F^t_{X|Y,Z}(\theta x|y,z) > 1 - \alpha\}. \tag{11}$$

[10]For the asymptotic properties of conditional measures see Jeong et al. (2010).

For the partial frontiers (conditional and unconditional) we have used $\alpha = 0.5$ which according to Bădin et al. (2012) correspond to the median frontiers and thus enable us to explore the potential shift of the distribution of the efficiencies as a function of time, bonus and salary payments. However, as suggested also by Bădin et al. (2014) we need to apply also α values close to 1 in order to check the robustness of the results obtained from the full frontier when interpreter the results from the full frontiers. For that reason also an $\alpha = 0.95$ has been applied.

We adopt smoothing techniques in order to condition the external variables and compute the conditional efficiency estimators. Therefore, we apply the approach proposed by Bădin et al. (2010) for bandwidth selection (h).[11] Furthermore, our model requires to calculate a nonparametric estimator $F^t_{X|Y,Z}(x|y,z)$, where we condition on $Y \geq y$, time $T = t$ and a particular value of $Z = z$. This can be estimated as:

$$\hat{F}^t_{X|Y,Z}(x|y,z) = \frac{\sum_{j=(i,\upsilon)} \mathrm{I}(x_j \leq x, y_j \geq y) K_{h_z}(z_j - z) K_{h_t}(\upsilon - t)}{\sum_{j=(i,\upsilon)} \mathrm{I}(y_j \geq y) K_{h_z}(z_j - z) K_{h_t}(\upsilon - t)}. \tag{12}$$

We also have to note that h_z and h_t are the bandwidths of optimal size. Whereas $K(.)$ is the kernel function with compact support. However, since we examine two exogenous factors (bonus and salary payments), we use a product kernel with a vector of bandwidths.[12]

Finally, in order to examine the effect of time and CEO salary and bonus payments on banks' performance levels, we adopt the approach introduced by Bădin et al

[11]Bădin et al. (2010) describe in detail the procedure and provide the Matlab codes for the calculation of optimal bandwidth h (also called smoothing parameter).
[12]For more details regarding computational issues of the Data Envelopment Analysis (DEA) estimators and bandwidth selection see the studies by Bădin et al. (2010, 2012) and Mastromarco and Simar, (2014).

al. (2012) by creating the ratios of conditional to unconditional efficiency estimates from the full and partial frontier measures:[13]

$$R_I\left(x,y|z,t\right)=\frac{\theta_t\left(x,y|z\right)}{\theta\left(x,y\right)},\qquad R_{I,\alpha}\left(x,y|z,t\right)=\frac{\theta_{t,\alpha}\left(x,y|z\right)}{\theta_\alpha\left(x,y\right)}. \tag{13}$$

Next, we apply nonparametric regressions and we explore the effect of T and Z by examining the behaviour of $\hat{R}_I\left(x,y|z,t\right)$ and $\hat{R}_{I,\alpha}\left(x,y|z,t\right)$ as a function of T and Z. Thus, we are able to investigate the dynamic effects of CEO bonus and salary payments on banks' technological change (shift of the frontier) and technological catch-up (distribution of efficiency). Based on Kumar and Russell (2002) and Henderson and Russell (2005), banks' technological changes is represented by the 'shifts in banks' production frontier' whereas banks' technological catch-up are represented by the 'movements toward or away from their production frontier'.

We apply a local linear estimator and optimal bandwidths using the least squares cross-validation (LSCV) criterion in the same way as presented by Hall et al., 2004; Li and Racine, 2004, 2007; Hayfield and Racine, 2008 among others.. Since we are using input oriented measures, Bădin et al. (2012) suggest that a tendency of the ratio $\hat{R}_I\left(x,y|z,t\right)$ to increase alongside the conditioning variables indicates an unfavorable effect on banks' technological change (shift of the frontier). In contrast a tendency of the ratio $\hat{R}_I\left(x,y|z,t\right)$ to decrease alongside with the conditioning variables indicates a favorable effect. Similarly, a tendency of the ratio $\hat{R}_{I,\alpha}\left(x,y|z,t\right)$ to increase with conditioning variables indicates again an unfavorable effect on banks' technological catch-up (distribution of efficiency) and unfavorable in the opposite case.

[13]For our calculation of the efficiency estimates we have used the 'FEAR' package which is an integrated program in 'R' language (Wilson, 2008).

4. Empirical findings

Tables 1 and 2 provide a basic information about our sample. As we can see there are large differences within time periods which indicate the presence of potential outliers and dimensionality problems that can significantly distort the precision of our estimates. Therefore we have to reduce the dimension in the input-output space and thus to gain precision and reliability in our analysis. As proposed by Bădin et al. (2012) and Daraio et al. (2015), we apply a variable reduction procedure and we replace the inputs and outputs by their best (non-centered) linear combinations (see for details Daraio and Simar, 2007b, pp. 148–150). As a result of that, we reduce the problem of dimensionality without losing any information, since the resulting univariate input (IF) and output (OF) factors are highly correlated with the original inputs and outputs used. The results from the input/output reduction are:

$$IF = 0.567X_1 + 0.581X_2 + 0.584X_3$$
$$OF = 0.707Y_1 + 0.717Y_2$$

Furthermore, we obtain the following correlations for inputs $\hat{\rho}_{IF,X_k} = (0.926, 0.954, 0.946)$ for $k = 1,2,3$. It means that the obtained IF explains over 90% of total inertia of our original inputs. For the case of the outputs, we obtain $\hat{\rho}_{OF,Y_k} = (0.949, 0.925)$ for $k = 1,2$. In other words, the obtained OF explains again over 90% of total inertia of our original outputs. Thus, we have one input and one output that minimize the problem of dimensionality.[14]

[14] For a discussion on the subject matter see Dyson et al. (2001).

Following the methodology described previously, Table 3 presents banks' mean efficiency estimates and their standard deviation values over the period from 2003 to 2012, both for full and robust measures.[15] The results reveal that there are differences between the mean efficiencies values between the *VRS* and the *Order-α* estimates (with $\alpha = 0.5$). Specifically, for *Hudson City Bancorp Inc*, *Bank of New York Mellon Corp, Astoria Financial Corp, New York Cmnty Bancorp Inc, Washington Federal Inc, Cathay General Bancorp, First Bancorp P R, Bank of Hawaii Corp, Westamerica Bancorporation* and *United Bankshares Inc/WV* the results between the robust and full frontiers indicate high efficiency differences (on average terms). Moreover, in the case of full frontiers 12 banks report the standard deviation efficiency values greater than 0.1. Similarly, when we examine the results of the robust frontiers also 12 banks report the standard deviation efficiency values greater than 0.1. That suggests that in both cases we have higher efficiency fluctuations over the examined period.

[Table 3 about here]

Figure 1 presents diachronically the number of banks with efficiency values above the sample's mean efficiency value, both for the full and robust frontiers. As we observe for the case of full frontiers (solid line), the number of banks that have technical efficiency scores above the sample's average value increases till 2007. This result changes after 2007, when the US banks were affected by the global financial crisis. We can observe that the number of banks with the technical efficiency scores over the average value decreases. We can also see that in the case of the robust frontiers (dashed

[15]The analytical results of the estimated efficiencies both for the conditional and unconditional measures for the full and robust frontiers are available upon request.

line), this phenomenon is even more pronounced. We can further observe a decrease in the number of banks that have technical efficiency scores above the sample's average value from 2005 and as we move towards the initiation period of the global financial crisis this number reduces considerably. However, after 2008 the results reveal that the number of banks having technical efficiency score above the sample average value increases but with some fluctuations (especially during the period from 2008 to 2011). In both cases, the results emphasize the negative effect of the global financial crisis on bank performance levels.

[Figure 1 about here]

Figure 2 then illustrates graphically the effect of CEO compensation on banks' performance levels. More analytically, sub-figures 2a, 2c and 2e present the effect of time and CEO salaries on banks' technological change (shift of the frontier) and technological catch-up (distribution of efficiencies). In addition sub-figures 2b, 2d and 2f present the effect of time and CEO bonus payments on banks' technological change and technological catch-up. As we have already explained, we use input oriented efficiency measures and an increasing nonparametric regression line indicates a negative effect of the external variables (time, salary and bonus). A decreasing line indicates a positive effect. When analyzing the effect of time and salary on banks' technological change (sub-figure 2a), we observe that for lower CEO salary levels the effect is negative. On the other hand, for higher salary values, we observe that the effect is positive.

If we examine the effect of CEO bonuses and time on banks' technological change (sub-figure 2b), we observe a different effect. For lower bonus levels the effect is positive that is represented as a decreasing nonparametric regression line, up to a certain bonus level. However, as we move towards the end of the period the effect from neutral turns to negative, which is indicated by an increasing nonparametric line.

Furthermore, when we examine the dynamic effect of CEO salary and bonus levels on banks' technological catch–up (subfigures 2c and 2d), we observe a similar behaviour. As we have already mentioned, we set $\alpha = 0.5$ in order to observe the effect of time, bonus and salary payments on the middle of the distribution of banks' efficiencies. Our 3-dimensional picture reveals that for lower salary levels the effect is negative – an increasing nonparametric line. We observe that after a certain threshold salary level the effect becomes then positive, a decreasing nonparametric line. When we examine the behaviour of salary on banks' efficiency levels, we observe that as we move towards and away from the global financial crisis period, the effect described previously becomes more emphatic. Similarly, when we examine the effect of bonus on banks' distribution of efficiencies again we observe that for small levels of bonus payments the effect on banks' efficiency levels is positive but for higher bonuses the effect becomes negative. When we move towards the end of the period this effect becomes more pronounced.

The 3-dimensional pictures 2e and 2f provide us with the same information of the effect of bonuses and payments on banks' technological change as in sub-figures 2a and 2b. However, as has been suggested by Bădin et al. (2012) when we apply the *Order-α* frontiers and we set α near to 1 (in our case $\alpha = 0.95$), then we can have a robust visualization of the examined effects since in some cases some extreme data points can mask over some effect of bonus, salaries and time. If we compare our four 3-dimensional pictures (i.e. 2a with 2e and 2b with 2f), we can observe differences in the effect on banks' technological change levels. These differences are attributed to the extreme data points. Specifically, when we examine the effect of salary and time on banks' technological change levels (sub-figure 2e), we observe that for lower salary levels the effect is negative up to a certain salary level. After that level, and for the largest part of salary levels, the effect becomes positive. Furthermore, when we compare the 3-dimensional picture from the partial frontier in subfigure 2e with the one for the full frontier (subfigure 2a), we can conclude that the effect of salary on banks' technological change is the same throughout the examined period and does not change. Thus it is evident that extreme data point can mask over the examined effect and therefore the need to apply robust frontiers with α values near to 1 proven to be essential for our case. In the same way subfigure 2f presents the effect of bonus payment and time on countries' technological change levels using robust frontiers. In contrast to subfigure 2b, the 3-dimensional picture presented on subfigure 2f provides us with a robust view of the effect avoiding the influence of extreme data points. The results reveal a clear positive effect on banks' technological change levels for lower levels of bonus payments, however, for larger levels of bonus payments the effect become negative. It is also evident that this effect is observed throughout the entire period. However, this was not the case when we examine the same effect under the full frontiers (subfigure 2b), suggesting that the extreme data points mask over the examined effect.

The overall results suggest that higher levels of CEO salaries affect positively banks' technological change and technological catch-up, whereas higher levels of CEO bonuses affect them negatively. According to Crawford et al. (1995) the deregulation of banks provides the framework for riskier investments. In our setting risk-taking involves the over-investment in risky loans and securities (Kupiec and O'Brien, 1997). As a result shareholders use performance-pay schemes to encourage risk-taking by CEOs. The positive correlation between CEO compensation and corporate risk is well documented in the relative literature (Aggarwal and Samwick, 1999a; Gormley et al., 2013),[16] this in turn justifies our findings regarding the negative effect of higher levels of CEO bonus payments. Since the CEO bonus payments are associated with risk investments, this in turn reflects negatively on banks' technological change and technological catch-up levels. On the other hand, since technological change investments are regarded as a source of systematic risk (Papanikolaou, 2008), the positive effect of higher levels of CEO salary payments on banks' technology change and technological catch-up can be attributed to the positive correlation between riskier investments and CEO incentives.

[Figure 2 about here]

5. Conclusions

In our study, we apply an innovative methodological framework to explore the effect of CEO salary and bonus payments on banks' efficiency levels. We find that the effect of CEO cash compensation on bank performance has a nonlinear form. These results challenge the findings presented by studies that apply the traditional pay-for-performance relationship investigated in a parametric setup, eg. Ang et al., 2002; John and Qian, 2003; Anderson et al. 2004; Cuñat and Guadalupe, 2009; among other studies that assume *ex-ante* a linear relation. We also argue that higher CEO compensation levels do not necessarily improve bank efficiency. Our results indicate that CEO salary and bonus payments affect differently bank technological change and technological catch-up levels. We show that lower salaries have a negative effect on bank technological change and technological catch-up levels. That means CEOs have to be

[16] Additionally, Brissimis et al. (2008) suggest that capital and credit risk have a negative relationship on banks' efficiency levels.

paid above a certain threshold level in order to affect bank performance positively. We also show that higher bonuses as a performance related part of the total CEO remuneration package do not have the expected effect on bank technological change and technological catch-up levels. These results correspond to previous research studies that explore the CEO payment incentives and risk investments, eg. Aggarwal and Samwick, 1999a; Gormley et al., 2013; among others. Riskier investments have a negative effect on bank efficiency levels (Brissimis et al., 2008), and therefore CEO payment incentives that are interrelated with such investments (loans and securities) also have a negative effect. This is supported by our empirical findings that indicate that higher levels of CEO bonus payments can lead to risk taking involving the over-investment in risky loans and securities (Kupiec and O'Brien, 1997). This consequently negatively affects bank technological change and technological catch-up levels.

A logical extension of this study might be to further explore the effect of time and CEO compensation on bank performance levels in other geographical locations, and in particular in Europe. In terms of methodological framework it would be worth investigating the probabilistic characterization of directional distance functions, as proposed by Simar and Vanhems, 2012 and the new developments involved in the conditional directional distances, as discussed by Daraio and Simar, 2014. However, the proposed research extensions are beyond the scope of our paper and are left for future research.

Acknowledgements

We would like to thank Professor Robert G. Dyson and three anonymous reviewers for their helpful and constructive comments on an earlier version of our manuscript. Any remaining errors are solely the authors' responsibility.

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Table 1: Descriptive statistics of the variables

		Property Plant and Equipment USD (000' s)	**Deposits USD (000' s)**	**Number of Employees (000' s)**	**Securities USD (000' s)**	**Loans USD (000' s)**	**Salary USD (000' s)**	**Bonus USD (000' s)**
2003	*Mean*	276.784	31926.882	12.679	9765.726	25606.215	531.370	775.988
	Std	859.676	66985.126	27.734	18509.018	51543.541	214.180	1445.749

	Min	2.463	869.553	0.332	382.479	703.184	129.808	0.000
	Max	4305.000	326492.000	140.000	102078	244705	1000.000	7498.232
2004	*Mean*	270.422	39185.947	14.777	10983.952	32893.404	583.401	922.024
	Std	832.522	95081.974	35.077	24223.132	74135.695	220.248	1405.517
	Min	1.898	1239.532	0.395	568.23	980.281	249.615	0.000
	Max	3835.000	521456.000	160.968	141940	365051	1000.000	6500.000
2005	*Mean*	306.669	43121.738	15.551	10876.794	35895.247	621.519	1072.474
	Std	964.719	102621.554	36.836	21538.155	77810.279	215.704	1653.746
	Min	2.334	1726.401	0.397	268.657	1340.065	259.014	0.000
	Max	4318.000	554991.000	168.847	122204	375237	1000.000	8400.000
2006	*Mean*	261.529	46310.102	15.890	11725.839	38677.679	662.560	510.022
	Std	773.399	114149.688	37.936	28087.04	83999.715	214.137	2135.407
	Min	1.265	1729.659	0.409	215.515	1453.185	298.438	0.000
	Max	3577.000	638788.000	174.360	165663	418040	1108.654	13000.000
2007	*Mean*	237.131	53012.157	16.986	13869.301	44533.101	705.853	518.208
	Std	672.927	131736.926	39.110	30901.526	98705.354	219.677	2388.781
	Min	2.334	1713.684	0.414	235.968	1617.669	314.423	0.000
	Max	3821.000	740728.000	180.667	169634	488888	1240.385	14500.000
2008	*Mean*	260.338	78139.174	22.358	21322.389	67194.305	745.134	52.575
	Std	767.939	205429.857	58.211	59394.906	175603.576	227.761	228.237
	Min	1.265	1989.197	0.453	243.475	1708.452	324.450	0.000
	Max	4406.000	1009277.000	281.000	329943	827988	1390.385	1345.000
2009	*Mean*	294.335	78711.920	21.864	26945.321	61287.678	996.923	103.899
	Std	776.758	200698.566	56.218	82448.481	153680.18	902.506	305.148
	Min	1.265	2082.282	0.433	192.005	1673.207	346.662	0.000
	Max	3833.000	938367.000	267.300	480020	744044	5600.000	1531.250
2010	*Mean*	305.683	79964.461	22.471	26597.173	61962.104	1129.034	160.032
	Std	870.004	202513.046	58.618	77110.919	156809.806	758.887	824.669
	Min	1.051	2142.702	0.442	91.494	1670.698	334.183	0.000
	Max	4965.000	930369.000	272.200	439923	721151	3239.847	5000.000
2011	*Mean*	321.306	92017.030	23.019	31011.683	64781.445	1069.532	156.465
	Std	909.725	234728.807	59.906	90323.817	163094.293	573.319	743.931
	Min	0.837	2086.125	0.435	178.272	1517.724	334.183	0.000
	Max	5105.000	1127806.000	264.200	507255	737142	3141.667	4500.000
2012	*Mean*	355.023	99109.989	23.332	31603.69	68070.474	1053.962	127.059
	Std	963.470	251729.886	60.461	88964.382	169046.634	464.920	444.510
	Min	0.624	1779.537	0.034	132.909	292.562	371.000	0.000
	Max	5147.000	1193593.000	269.200	490169	770090	2800.000	2600.000

Figure 1: Diachronic representation of the number of banks with efficiency scores above samples' average efficiency value.

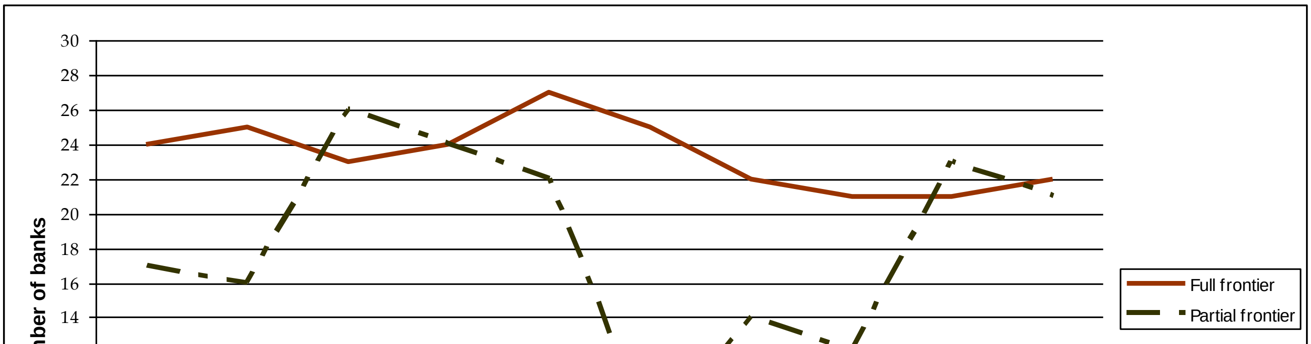

Figure 2: The effect of time and CEO's compensation on banks' performance levels

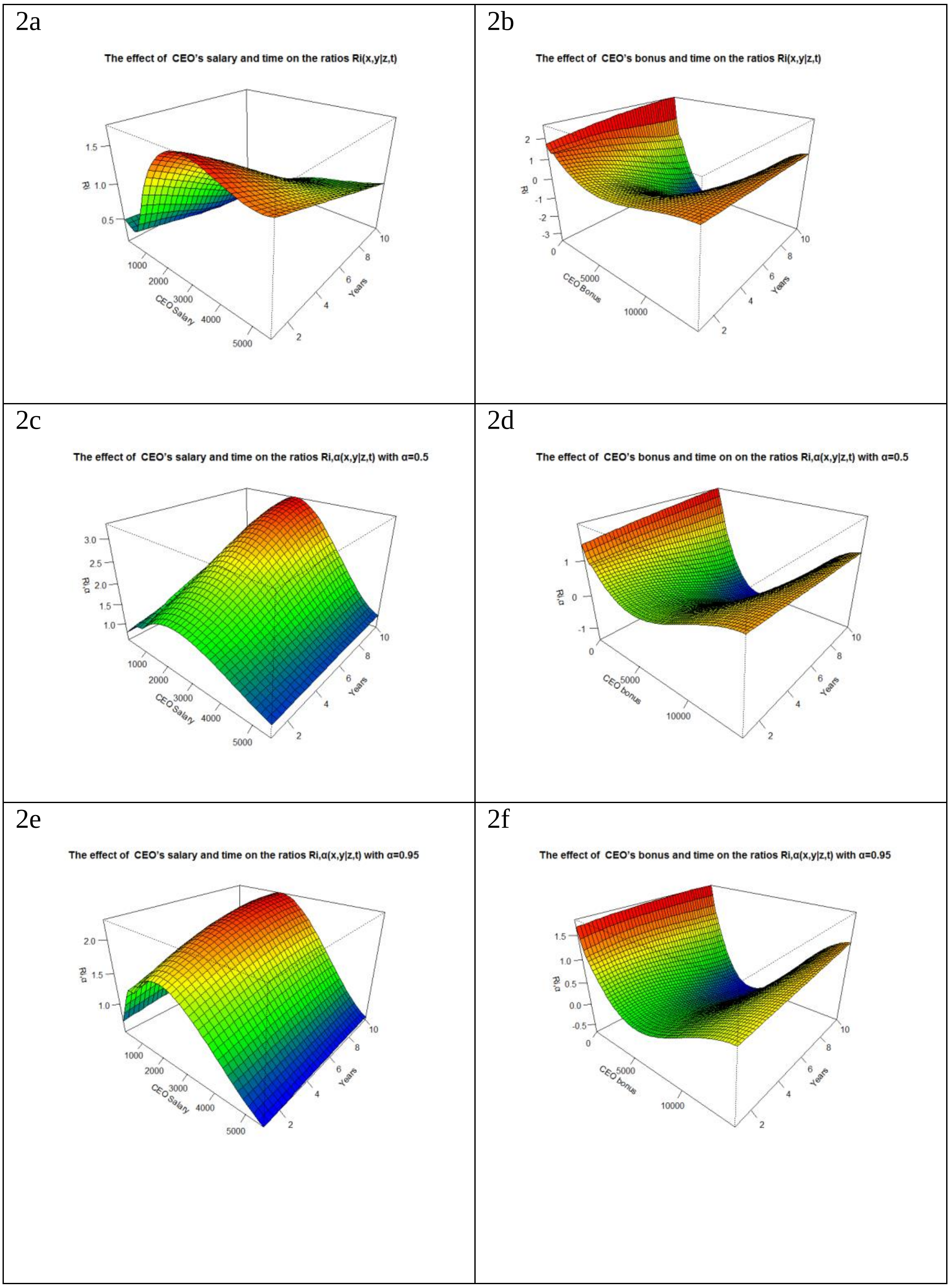

Table 2: Descriptive statistics of the variables per bank

Bank Name	Property Plant and Equipment USD (000' s)		Deposits USD (000' s)		Number of Employees (000' s)		Securities USD (000' s)		Loans USD (000' s)		Salary USD (000' s)		Bonus USD (000' s)	
	Mean	*Std*	*Mean*	*Std*	*Mean*	*Std*	*Mean*	*Std*	*Mean*	*Std*	*Mean*	*Std*	*Mean*	*Std*
ASTORIA FINANCIAL CORP	14.633	1.772	12217.450	1030.143	1.701	0.124	4945.381	2444.113	14346.086	1394.315	713.587	148.690	67.088	142.095
BANK OF HAWAII CORP	16.848	4.822	8848.355	1424.773	2.512	0.136	4422.476	1957.832	5466.727	406.691	486.510	183.469	204.500	415.942
BANK OF NEW YORK MELLON CORP	700.500	248.083	126507.300	68294.493	36.608	11.860	49080.800	27619.673	37813.500	5647.043	818.128	76.218	2311.347	2833.392
BB&T CORP	306.660	64.547	94787.292	24981.168	29.470	3.243	26244.336	8336.623	85731.733	19207.246	726.264	197.292	150.669	249.831
BBX CAPITAL CORP	14.961	0.000	3582.476	451.175	1.994	1.012	846.951	350.338	3578.606	1374.419	535.686	47.670	461.380	793.865
CATHAY GENERAL BANCORP	10.304	2.964	6183.922	1194.274	1.011	0.086	2303.554	758.892	5855.593	1486.230	973.100	233.012	247.500	402.528
CITY NATIONAL CORP	28.797	7.220	15115.614	4400.923	2.880	0.377	4797.738	2695.059	11220.276	2327.291	960.508	38.237	351.232	565.972
COMERICA INC	101.361	11.117	43608.300	3865.653	10.307	1.051	6720.800	2581.179	42533.100	4038.636	1153.591	567.055	353.810	592.425
COMMUNITY BANK SYSTEM INC	15.956	1.790	3701.862	917.896	1.562	0.302	1643.247	493.000	2864.473	526.844	390.462	137.084	21.843	36.223
CULLEN/FROST BANKERS INC	31.413	5.928	12179.421	3802.801	3.655	0.259	4697.616	2257.020	7050.826	1500.542	729.500	102.265	3968.116	2177.108
DIME COMMUNITY BANCSHARES	2.079	1.611	2257.085	194.314	0.421	0.019	330.571	141.886	2982.415	480.173	668.360	31.903	289.600	134.430
EAST WEST BANCORP INC	36.327	31.901	10314.091	5652.229	1.639	0.672	1987.836	1032.675	9571.999	4081.668	1235.167	994.658	445.071	716.663
FIFTH THIRD BANCORP	211.542	140.256	74737.300	11350.834	20.950	0.943	17742.800	5992.474	66701.200	10970.438	1185.119	869.029	96.360	167.356
FIRST BANCORP P R	22.163	4.395	10673.788	2086.209	2.621	0.345	4177.913	1379.604	10853.198	1910.458	673.528	161.739	261.240	295.010
FIRST MIDWEST BANCORP INC	13.257	2.521	5794.833	675.951	1.751	0.098	1890.972	582.700	4835.472	523.592	531.229	296.100	83.317	94.835
GLACIER BANCORP INC	10.453	3.404	3432.426	1269.596	1.409	0.374	1654.237	1077.487	3024.959	901.144	309.661	48.712	75.000	81.650
HUDSON CITY BANCORP INC	6.677	2.803	17909.024	6268.871	1.407	0.242	17021.537	7537.830	22635.720	8488.961	1279.885	353.118	363.529	637.208
INDEPENDENT BANK CORP/MI	6.288	1.906	2237.848	337.859	1.268	0.136	330.653	162.904	2059.814	443.217	372.462	123.957	24.568	45.469
JPMORGAN CHASE & CO	4210.800	696.319	798186.700	285502.711	198.453	52.342	294882.900	170798.285	520798.500	179300.106	1091.667	194.246	5690.000	5148.344
M & T BANK CORP	187.699	10.211	45166.357	10550.391	13.994	0.769	7694.540	821.780	46239.191	9461.579	954.289	575.406	247.000	237.711

NEW YORK CMNTY BANCORP INC	37.164	12.131	16418.203	5687.833	2.883	0.744	6263.829	1375.776	21821.579	6973.153	1000.000	98.601	855.127	739.820
NORTHERN TRUST CORP	104.270	6.507	53984.910	19473.290	11.143	2.343	16833.520	8547.157	23546.230	4957.106	715.500	236.665	135.000	284.849
PNC FINANCIAL SVCS GROUP INC	627.400	399.377	127206.700	70289.702	39.871	16.051	39237.900	20047.073	99617.900	59490.300	1234.423	569.420	38003.477	19732.318
POPULAR INC	97.904	36.397	24928.184	3450.359	10.631	1.968	8567.755	2634.964	24902.303	3000.725	861.594	273.319	187.796	358.414
PROSPERITY BANCSHARES INC	12.947	5.694	5773.209	3083.762	1.337	0.549	3279.954	2061.739	2767.856	1368.731	567.911	149.554	149.040	132.417
STERLING BANCORP/NY	6.367	1.669	1890.086	606.929	0.535	0.083	858.096	219.778	1491.381	398.459	845.249	171.380	237.500	383.379
SUSQUEHANNA BANCSHARES INC	22.253	3.601	7949.963	2698.096	2.835	0.516	1819.003	602.271	7425.704	2685.460	691.424	134.751	57.965	123.635
TCF FINANCIAL CORP	72.247	16.903	10368.001	1994.846	8.176	1.111	1877.010	446.147	12233.915	2391.950	800.192	289.341	573.500	623.824
TRUSTCO BANK CORP/NY	3.574	1.142	3086.476	508.225	0.645	0.114	1020.755	176.103	1915.059	536.054	561.500	275.056	317.225	310.896
U S BANCORP	655.010	127.981	164774.100	49172.426	55.632	5.778	49042.500	13074.551	154097.000	36633.802	803.139	206.342	375.000	644.313
UNITED BANKSHARES INC/WV	10.798	0.955	5417.991	940.846	1.479	0.100	1180.033	318.567	5294.160	817.096	648.050	54.377	140.900	183.648
WASHINGTON FEDERAL INC	6.154	2.167	6641.302	1766.046	0.984	0.217	2072.868	818.626	7429.562	1725.951	479.088	151.960	7.348	12.426
WEBSTER FINANCIAL CORP	68.183	19.114	12269.978	1806.106	3.052	0.222	4333.308	1409.762	11405.047	1066.744	991.256	324.034	175.110	282.280
WELLS FARGO & CO	2811.700	984.377	586780.500	310607.366	211.070	63.334	122644.400	84146.436	530519.500	245521.347	1828.922	1722.262	827.500	1429.960
WESTAMERICA BANCORPORATION	9.045	1.592	3744.587	416.711	0.950	0.058	1664.453	374.559	2487.083	288.530	372.500	5.874	135.000	217.371
WINTRUST FINANCIAL CORP	17.460	4.861	8688.478	3233.712	2.138	0.707	1415.336	372.386	7496.434	2915.105	792.500	167.984	188.300	282.524
ZIONS BANCORPORATION	178.928	95.120	36183.663	8426.848	10.061	1.137	4869.333	749.005	32722.011	7174.098	986.916	350.782	3882.417	1001.227

Table 3: Mean efficiency values and standard deviations (Std) for full and partial frontiers over 2003-2012.

Bank Name	**Mean (VRS)**	**Mean (Order-α)**	**Std (VRS)**	**Std (Order-α)**
ASTORIA FINANCIAL CORP	0.396	0.951	0.043	0.003
BANK OF HAWAII CORP	0.485	0.937	0.035	0.008
BANK OF NEW YORK MELLON CORP	0.190	0.759	0.190	0.612
BB&T CORP	0.497	0.290	0.364	0.205
BBX CAPITAL CORP	0.547	0.856	0.006	0.197
CATHAY GENERAL BANCORP	0.495	0.978	0.020	0.005
CITY NATIONAL CORP	0.452	0.889	0.054	0.033
COMERICA INC	0.237	0.510	0.113	0.031
COMMUNITY BANK SYSTEM INC	0.535	0.961	0.007	0.006
CULLEN/FROST BANKERS INC	0.495	0.882	0.040	0.023
DIME COMMUNITY BANCSHARES	0.533	0.753	0.003	0.235
EAST WEST BANCORP INC	0.501	0.920	0.021	0.065
FIFTH THIRD BANCORP	0.091	0.197	0.177	0.113
FIRST BANCORP P R	0.450	0.927	0.034	0.018
FIRST MIDWEST BANCORP INC	0.520	0.960	0.011	0.009
GLACIER BANCORP INC	0.528	0.952	0.016	0.058
HUDSON CITY BANCORP INC	0.147	0.948	0.140	0.033
INDEPENDENT BANK CORP/MI	0.552	0.479	0.005	0.067
JPMORGAN CHASE & CO	0.711	0.865	0.236	0.145
M & T BANK CORP	0.224	0.327	0.137	0.080
NEW YORK CMNTY BANCORP INC	0.331	0.882	0.027	0.058
NORTHERN TRUST CORP	0.262	0.428	0.196	0.161
PNC FINANCIAL SVCS GROUP INC	0.558	0.196	0.342	0.114
POPULAR INC	0.372	0.610	0.081	0.070
PROSPERITY BANCSHARES INC	0.507	0.916	0.034	0.095
STERLING BANCORP/NY	0.539	0.615	0.004	0.167
SUSQUEHANNA BANCSHARES INC	0.522	0.920	0.020	0.019
TCF FINANCIAL CORP	0.589	0.756	0.031	0.023
TRUSTCO BANK CORP/NY	0.536	0.823	0.004	0.221
U S BANCORP	0.699	0.208	0.175	0.030
UNITED BANKSHARES INC/WV	0.524	0.965	0.005	0.007
WASHINGTON FEDERAL INC	0.485	0.984	0.020	0.009
WEBSTER FINANCIAL CORP	0.478	0.860	0.016	0.027
WELLS FARGO & CO	0.562	0.776	0.252	0.138
WESTAMERICA BANCORPORATION	0.527	0.979	0.006	0.005
WINTRUST FINANCIAL CORP	0.521	0.934	0.011	0.028
ZIONS BANCORPORATION	0.539	0.465	0.208	0.159