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DEREGULATION, FINANCIAL CRISIS, AND BANK EFFICIENCY IN TAIWAN: AN ESTIMATION OF UNDESIRABLE OUTPUTS

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ABSTRACT

Purpose- This study investigates the undesirable impacts of outputs on bank efficiency and contributes to the literature by assessing how regulation policies and other events impact bank efficiency in Taiwan in regards to deregulation, financial crisis, and financial reform from 1993 to 2011.

Methodology- In order to effectively deal with both undesirable and desirable outputs, this study follows Seiford and Zhu (2002), who recommend using the standard data envelopment analysis model to measure performance by increasing the desirable outputs and decreasing the undesirables.

Findings- Empirical findings indicate that bank efficiency with undesirable outputs is more prevalent than bank efficiency without undesirable outputs, which implies that undesirable outputs play a key role in hampering bank efficiency. This study result show that the effect of deregulation on bank efficiency decreased during the initial financial reform period. Nevertheless, our empirical evidence shows that financial reform significantly improved bank efficiency in emerging countries in the long run.

Conclusion- First, in accounting for both desirable and undesirable output while evaluating and analyzing bank efficiency, it assumes that undesirable outputs operate as non-performing loans and offers a comparison of different results from perspectives that either consider undesirable output within the classical DEA model or do not. The second contribution stems from the fact that the processes of rapid growth and recovery in recent years have given emerging Asian countries undoubtedly key roles in world economics, and studies have responded by analysing data of emerging Asian countries, such as Taiwan. Thirdly, this study contributes to the literature by assessing how regulation policies and other events impact bank efficiency in Taiwan in regards to deregulation, financial crisis, and financial reform.

Keywords: Undesirable outputs, deregulation, financial crisis, data envelopment analysis, banks efficiency
JEL Codes: G21, G34, L51

1. INTRODUCTION

The idea of bank efficiency has long been a chief research topic for scholars and regulators who want to assess how well banks serve as pivotal intermediary institutions between finance and currency. In general, these scholars and regulars have found that bank operation efficiency is significantly relative to a nation's economic growth and its development of financial institutions. Studies in the literature can be categorized into two distinct scopes of research. On the one hand, scholars have focused on how to more effectively evaluate bank performance by providing new methods or revising pre-existing models to measure banks efficiency (Chiu et al., 2009; Koutsomanoli-Filippaki et al., 2009; Liu (2010); Ray & Das, 2010). On the other hand, scholars have also focused on specifying the determinants of bank efficiency. For instance, risk factors in the banking industry of developed and emerging countries have major impacts on bank efficiency, asset quality, and bank soundness. Recent scholars have analyzed individual risk indicators on bank performance (Chiu & Chen, 2009; Liu & Liao, 2013; Sun & Chang, 2011).

This study thus provides an interesting case study of efficiency regarding one basic problem with undesirable outputs. In doing so, it aims to extend the literature examining bank efficiency vis-à-vis undesirable outputs by reflecting true efficiency instead of excluding undesirable outputs in the DEA model. In conclusion, it offers three important contributions. First, in accounting for both desirable and undesirable output while evaluating and analyzing bank efficiency, it assumes that undesirable outputs operate as non-performing loans (NPL) and offers a comparison of different results from perspectives that either consider undesirable output within the classical DEA model or do not. The second contribution stems from the fact that the processes of rapid growth and recovery in recent years have given emerging Asian countries undoubtedly key roles in world economics, and studies have responded by analysing data of emerging Asian countries, such as Taiwan, and gathered results for various management, economics, and financial management topics. However, if NPLs are not accounted for in estimates, the DEA model could operate with severe bias, especially by neglecting how NPLs significantly interfere with bank development in emerging countries. By continuing the trend of examining emergent Asian economies, this study provides additional empirical evidence regarding how undesirable outputs affect bank efficiency outside the United States and European countries. Thirdly, this study contributes to the literature by assessing how regulation policies and other events impact bank efficiency in Taiwan in regards to deregulation, financial crisis, and financial reform. In this sense, it provides empirical evidence from a longitudinal analysis of financial reform's impact on bank efficiency in Taiwan from 1993 to 2011. It does so by comparing bank efficiency in three periods: pre-first financial reform (pre-FFR), financial reconstruction before the subprime mortgage crisis (FR), and post-subprime mortgage crisis (post-SMC). By comparison, then, this study offers a more comprehensive analysis of deregulation in regards to emerging countries than have previous studies, such as Zhao et al. (2010) in the Indian context, Berger et al. (2009) in the Chinese context, and Hsiao et al. (2010) in the Taiwanese context. Altogether, this study aims to examine how undesirable outputs affect bank efficiency for Taiwan. After implementing a DEA to estimate bank efficiency and productivity changes during the first stage, Tobin regression was used to further investigate the determinants of bank efficiency during the second stage.

This paper is organized as follows: section one contains the introduction; section two describes the model specification, data source, and empirical design; and section three presents the empirical results, while conclusions are drawn in section four.

2. LITERATURE REVIEW AND METHODOLOGY SPECIFICATIONS

2.1 Bank Efficiency by Data Envelopment Analysis

Many studies have acknowledged that any data envelopment analysis (DEA) model relies on the assumption that inputs must be minimized and outputs maximized. From the point of view of the classical model, ignoring undesirable output is a major oversight that will likely result in biased conclusions. In general, most scholars have thus assumed that non-performance loans (NPLs) are an undesirable output for the DEA model.

More specifically, Seiford and Zhu (2002) have described five possibilities for dealing with undesirable outputs while using the DEA-BCC framework. The first possibility is to simply delete undesirable outputs; the second, to treat undesirable outputs according to the non-linear DEA model; the third, to treat undesirable outputs as simply outputs and adjust the distance in order to restrict the expansion of undesirable outputs;[1] the fourth, to treat the undesirable outputs as inputs, though doing so does not reflect the true production process; and the first, to apply a monotone that decreases shifts to the undesirable outputs and to then use the adapted variables as outputs. Additionally, Fernandez et al. (2002) have illustrated that a production process must be clearly defined based on both desirable and undesirable outputs, for using desirable outputs only will fail to credit banks for their efforts to reduce undesirable outputs. Following Seiford and Zhu (2002), this study used a linear monotone to decrease the shift to undesirable outputs within the classical DEA model.

2.2 Data Envelopment Analysis (DEA) using an Undesirable Output Model

A popular stochastic frontier approach used in the literature to estimate bank efficiency indicates that bank efficiency measures the extent to which a bank's costs approach those of banks with the best practices. In effect, this approach produces an identical output bundle under the same conditions. Following this approach, the best-practice production frontier for a sample of firms is constructed through a piecewise linear combination of an actual input-output correspondence set that envelopes the input-output correspondence of all firms in the sample (Thanassoulis, 2001).

The classical DEA model assumes that inputs must be minimized and outputs maximized. Seiford and Zhu (2002), however, have developed an alternative approach to treat both desirable and undesirable factors differently in the standard linear BCC DEA model provided by Banker et al. (1984). They suppose a DEA data domain can be characterized by data matrix

[1] For more details illustrating directional distance function, see the weak dispoasbility model in Fare et al. (1989).

$$P = \begin{bmatrix} Y \\ -X \end{bmatrix} = \left[P_1, \mathrm{L} \;\; P_n \right] \qquad (1)$$

with $s + m$ rows and *n* columns. Each column corresponds to one of the DMUs. The j th column can be written as

$$P_j = \begin{bmatrix} Y_j \\ -X_j \end{bmatrix} \qquad (2)$$

Supposing, however, that some outputs are undesirable, the output matrix Y can be better represented by following the model of Seiford and Zhu (2002) who write the DEA data domain as

$$\begin{bmatrix} Y \\ -X \end{bmatrix} = \begin{bmatrix} Y^g \\ Y^b \\ -X \end{bmatrix} \qquad (3)$$

which Y^g and Y^b indicate the desirable and undesirable outputs, respectively.

In general, we wish to increase desirable outputs and decrease the undesirables in order to improve performance. However, since the standard BCC model excludes undesirable outputs, all outputs are supposed to be improving performance. Fare et al. (1989) modified the traditional BCC model to the non-linear programming problem

$$\begin{aligned} &\max \qquad \Theta \\ &s.t. \qquad \sum_{j=1}^{n} z_j x_j + s^- = x_o \\ &\sum_{j=1}^{n} z_j y_j^g - s^+ = \Theta y_o^g \\ &\sum_{j=1}^{n} z_j y_j^b - s^+ = \frac{1}{\Theta} y_o^b \\ &\sum_{j=1}^{n} z_j = 1 \\ &z_j \geq 0, \quad j = 1, \mathrm{K}\,, n. \end{aligned} \qquad (4)$$

Based upon classification invariance, Seiford and Zhu (2002) show that an alternative to model (1) can be developed to preserve the linearity and convexity in DEA. They first multiply each undesirable outpour by -1 and then find a proper translation vector *w* to let all negative undesirable outputs be positive. The model (1) can thus be rewritten as the linear program model (2)

$$\begin{aligned} &\max \; \Pi \\ &s.t. \qquad \sum_{j=1}^{n} z_j y_j^g \geq \Pi y_0^g \end{aligned}$$

$$\sum_{j=1}^{n} z_j \overline{y}_j^b \geq \Pi \overline{y}_o^b$$

$$\sum_{j=1}^{n} z_j x_j \leq x_0$$

$$\sum_{j=1}^{n} z_j = 1$$

$$z_j \geq 0, \quad j = 1, \mathrm{K}\ , n. \qquad (5)$$

The theorem ensures that the optimized undesirable output of $y_0^b = (w - \Pi^* \overline{y}_0^b)$ cannot be negative.

Seiford and Zhu (2002) also assume that some inputs must be increased instead of decreased to improve performance. They thus rewrite the DEA date

$$\begin{bmatrix} Y \\ -X \end{bmatrix} = \begin{bmatrix} Y \\ -\overline{X}^I \\ -X^D \end{bmatrix} \qquad (6)$$

which X^I and X^D represent inputs to be increased and decreased, respectively. The jth column of translated input to be increased is now $\overline{x}_j^I = -x_j^I + k > 0$. They therefore used (6) and model (2) to rewrite the DEA model as follows

$$\max \qquad \upsilon$$

$$s.t. \quad \sum_{j=1}^{n} z_j x_J^D + s^- = \upsilon x_0^D$$

$$\sum_{j=1}^{n} z_j x_j^I - s^- = \upsilon \overline{x}_o^I$$

$$\sum_{j=1}^{n} z_j y_j - s^+ = y_o$$

$$\sum_{j=1}^{n} z_j = 1$$

$$z_j \geq 0, \quad j = 1, \mathrm{K}\ , n. \qquad (7)$$

in which X^I is increased and X^D is decreased to allow any decision-making unit (DMU) to improve performance.

The input-output specification of the present study is based on the intermediation approach suggested by Berger (1995), Hsiao et al. (2010), and Sun and Chang (2011). Like most studies, this study follows the intermediation approach definition of input-output variables, in which employee expense, physical capital expense, and fund expense are the input factors used to produce earning assets, labor, capital, and interest price.[2] The price of labor is defined as the total salary of all

[2] Sun and Chang (2011) used only two input variables to establish cost function and omitted labor input, which perhaps caused bias. With respect to input prices, the price of labor, capital, and funds are conventional input prices in previous studies, such as Berger (1995).

employees; the price of physical capital is defined as operating expense minus employee expense divided by fixed assets; and the price of funds is defined as the interest paid to all funding. Meanwhile, the two outputs are total loans and investment, which are commonly used in the literature (Berger, 1995; Bonin et al., 2005; Hsiao et al., 2010). For this study, the primary data source was Taiwan Economics Journal (TEJ). The unbalance panel data samples included 36 banks during 1993 to 2011. The total observation included 750 full samples.

2.3 Empirical Regression Design

This study relied on regression analysis to investigate the determinants of bank efficiency. Though many studies have explored the determinants of bank efficiency, this present study refers primarily to those that used the bank efficiency estimate derived from DEA estimations as the dependent variable. From there, a Tobin regression model was constructed for the determinants of bank efficiency. The empirical equation can thus be written

$$EFF_{it} = \beta_0 + \beta_1 Risk_{it} + \beta_2 SIZE_{it} + \beta_3 BRCH_{it} + \beta_4 RGR_{it} + \beta_5 EQAS_{it} + \beta_6 DV_{it}\varepsilon_{it} \quad (8)$$

which *EFF* indicates banks efficiency, *risk* indicates risk lever of banks measured by standard deviation of each bank's annual return on assets (ROA), *size* indicates the natural logarithm of bank assets, *BRCH* indicates the natural logarithm number of bank branches, *RGR* indicates revenue growth ratio, *EQAS* indicates the total equity divided by total assets, and *DV* indicates the dummy variable, which equals one if the bank is state-owned and zero if otherwise.

To further investigate the determinants of bank efficiency, a Tobin regression model was implemented to determine whether bank efficiency derived from the pooled sample is related to bank-specific factors. Following other studies, this study attempts to establish an empirical regression equation. Following Liu et al. (2012) and Liao (2013), *risk* was measured by ROA volatility. This rate is an accounting-based volatility indicator measured by standard deviation of each bank's yearly ROA. *Size* indicates bank scale and is measured by the natural logarithm of bank assets, with which empirical studies have found mixed relationships between bank size and efficiency. *BRCH* indicates number of branches and is measured by a natural logarithm. This variable is important since widespread networks of branches can provide more services for more customers; this study thus expected that the impact of a widespread network of branches on bank efficiency is positive. *RGR* indicates bank operating revenue growth rate; efficient banks should show more profitability and higher operating revenue growth rates. *EQAS* indicates the total equity divided by total assets. Results from studies by Hsiao et al. (2010) and Liu and Liao (2013) show that the capital ratio is positively associated to bank efficiency. *DV* indicates the dummy variable, which equals one if the bank is state-owned and zero if otherwise. Table 1 provides descriptive statistics of the empirical variables.

Table 1: Descriptive Statistics

	Mean	**Std.**
Output items		
Investment	848,015	1,282,238
Loans	3,753,923	4,160,833
NPL	3,393,025	2,131,694
Input items		
Salary	32,735	31,433
Interset expense	134,382	159,396

Phyical expense	29,122	26,793
Regression variables		
RISK	0.0113	0.0116
BRCH	3.925	0.7579
ORG	0.083	0.294
EQAS	0.064	0.088
SIZE	19.5091	1.136

Note: the primary data source for this study was the Taiwan Economics Journal (TEJ). The input-output variables unit measure by millions, fund and Capital price measure by percent.

3. EMPIRICAL RESULTS

3.1. Results of Efficiency with Undesirable Outputs

This section reports estimations of the banks' average efficiency, which we ascertained using a DEA model. Our three-part efficiency index includes overall technical efficiency (TE), pure technical efficiency (PTE), and scale efficiency (SE). Table 2 presents the results of the banks' efficiency.

The mean technical efficiency, pure technical efficiency, and scale efficiency scores were 0.61, 0.845, and 0.706, respectively, which suggests that these banks improved their efficiency by 39%, 15.5%, and 29.4%, respectively. This result indicates that nearly 40% of banks' costs are wasted according to the best-practice frontier when facing the same output within samples. This result is consistent with both Sun and Chang (2011) and Liu and Liao (2013), whose results both report a general bank efficiency of approximately 0.6 for Taiwan. This figure reflects a generally low efficiency level for banks over the present study's data collection period. One possible reason for this phenomenon is that the Taiwanese government allowed new banks to enter into the financial market to increase competition as a measure to improve efficiency after deregulation, but over-competition deteriorated the quality of assets, reduced profitability, and even led some banks to bankruptcy.

Regarding bank efficiency sources, the mean pure technical efficiency is higher than the scale efficiency, which indicates that scale inefficiency is a major source of bank inefficiency. A bank's inefficiency can in turn be attributed to returns of scale diseconomies. The government encouraged banks to perform merger activities in order to increase bank efficiency because the government believed that larger banks would have better efficiency than smaller banks. Dark (2001) has suggested that the minimum efficient scale of operation in the United Kingdom is at an asset size ranging from GBP 18 to 23 billion. Liao (2009) has pointed out that regulators should not blindly merge to expand their asset base, for it is uncertain whether doing so improves efficiency and profitability. It was thus suggested that Taiwanese banks should promote scales of optimal operation.

We compared the results of bank efficiency scores estimated both with undesirable outputs and without undesirable outputs. Results show that the efficiency score estimated with undesirable output was slightly higher than that without undesirable outputs. Test results showed the same outcome, though overall technical efficiency and pure technical efficiency were significantly different.[3] This result is thus consistent with Assaf et al. (2012), who found that excluding crediting banks from their production of bad outputs resulted in misspecification, which appears as an underestimation of both efficiency and productivity change. This result also provides significant evidence suggesting that not accounting for undesirable output while estimating the evolution of the model may seriously distort efficiency results.

Table 2: Results of Efficiency With Undesirable Outputs

Year	OTE	PTE	SE
1993	0.724	0.853	0.834
1994	0.735	0.89	0.801
1995	0.634	0.82	0.741

[3] For brevity, this section excludes the results of these tests. For the TE test, the t value was -3.081 and the F value was 9.493 for the TE test. For the PTE test, the t value was -6.161 and the F value was 37.953.

1996	0.394	0.803	0.464
1997	0.581	0.832	0.668
1998	0.546	0.811	0.653
1999	0.519	0.84	0.592
2000	0.62	0.78	0.764
2001	0.726	0.904	0.788
2002	0.604	0.796	0.722
2003	0.578	0.824	0.677
2004	0.465	0.714	0.602
2005	0.636	0.812	0.763
2006	0.583	0.852	0.654
2007	0.685	0.919	0.729
2008	0.636	0.817	0.747
2009	0.647	0.859	0.717
2010	0.688	0.857	0.792
2011	0.666	0.879	0.754
Mean	0.61	0.845	0.706

Note: the banks efficiency score that range from 0 to1.

Table 3: Results of Efficiency without Undesirable Outputs

Year	OTE	PTE	SE
1993	0.607	0.733	0.8
1994	0.398	0.674	0.567
1995	0.589	0.736	0.775
1996	0.415	0.603	0.673
1997	0.534	0.693	0.749
1998	0.404	0.597	0.634
1999	0.212	0.454	0.457
2000	0.5	0.665	0.733
2001	0.465	0.662	0.696
2002	0.506	0.625	0.799
2003	0.48	0.683	0.658
2004	0.468	0.656	0.7
2005	0.544	0.698	0.764
2006	0.652	0.803	0.787

2007	0.698	0.854	0.791
2008	0.5	0.67	0.731
2009	0.464	0.652	0.659
2010	0.658	0.788	0.813
2011	0.624	0.829	0.728
Mean	0.5115	0.6882	0.7113

Note: the banks efficiency score that range from 0 to1.

3.2. Comparing Three Stages of Bank Efficiency

This study compared bank efficiency over three periods from 1993 to 2011: pre-first financial reform from 1993 to 2001 (pre-FFR), financial reconstruction from 2002 to 2007 (FR), and post-subprime mortgage crisis from 2008 to 2011 (post-SMC). Table 5 presents the test results for the three periods. The mean overall technical efficiency was 0.6095, 0.5882, and 0.6543 for pre-FFR, FR, and post-SMC, respectively. These results show that the financial reconstruction period was lower during our study period, which is consistent with Hsiao et al. (2010) and Burki and Niazi (2010).[4] Although the U.S. banking industry faced a shocking subprime mortgage crisis in 2008, this event did not significantly impact bank efficiency in Taiwan. One reason may be that financial reform significantly improves bank efficiency. During FFR, the main objective was to improve the bank capital structure and quality of assets, thus the effect of FFR for bank efficiency offset the shock caused by the subprime mortgage crisis. However, mean technical efficiency has still existed, as 34 percent of bank costs are wasted according to best-practice frontier.

The success of meeting primary goals during deregulation in emerging countries has been mixed (Kumbhakar & Sarkar, 2003). The present study's results suggest that deregulation has improved bank efficiency in emerging countries, which is consistent with literature arguing that the effects of financial reform have significantly positive impacts on bank efficiency in emerging countries, such as Hsiao et al. (2010) has found with Taiwan, Ataullah and Le (2006) have found with India, and Burki and Niazi (2010) have found with Pakistan. Furthermore, Bertrand et al. (2007) suggest that less state intervention in the banking sector is accompanied by a more efficient allocation of bank loans across firms, as well as an increase in restructuring activities. This study's results show that improved efficiency after the period of financial reform was possibly due to enhanced bank efficiency, improved risk management practices, and the benefits obtained from complying with the First Financial Reform for Taiwan (Hsiao et al., 2010). Hsaio et al. also suggest that deregulation enticed more banks to cultivate a more competitive market environment in order to raise bank efficiency and profitability. In theory, this idea suggests that a higher of level of competition improved bank efficiency and incentivized the creation of new financial businesses' service skills and operating logistics but also produced banks with higher risk levels. Thus, the effect of deregulation may decrease bank efficiency during the initial stages of financial reform period. Nevertheless, most studies have found that financial reform significantly improved bank efficiency in emerging countries over a longer period of time.[5]

Table 4: Comparison Among Different Periods

	T test	One way ANOVA	Mann-Whitney-Wilcoxon Test	Kolmogorov-Smirnov Test
		Period_1 vs. 2		
OTE	0.812	0.66	-0.745	0.82
PTE	-0.505	0.255	-0.55	0.679
SE	0.822	0.675	-0.55	0.95
		Period_2 vs. 3		
OTE	-1.927*	3.712*	-2.018**	1.106

[4] Burki and Niazi (2010) found that bank efficiency falls during initial reform periods in Pakistan.

[5] Hsiao et al. (2010) found that efficiency improves after the implementation of financial reform due to continuing the enhanced banking and risk management practices that were employed to satisfy new policy requirements. At the same time, they suggest that more time might be needed to reap the long-term benefits of restructuring.

PTE	0.127	0.016	-1.576	1.105
SE	-2.015**	4.062**	-1.951*	1.177
	OTE	PTE	SE	
Period_1	0.6095	0.8368	0.7055	
Period_2	0.5882	0.8561	0.6868	
Period_3	0.6543	0.8481	0.7434	

Note: the banks efficiency score that range from 0 to 1. Period_1 indicates Pre-first financial reform (1993-2001), Period_2 indicates financial reconstruction (2002-2007), and Period_3 indicates post-subprime mortgage crisis (2008-2011). This study test whether has a gap with each other countries, as follows T test, one-way ANOVE test with F-statistics, Mann-Whitney-Wilcoxon Test with Z-statistic. Kolmogorov-Smirnov Test with Z-statistic.

* Significant level at the α=0.1, **at α=0.05 and ***at α=0.01

3.3. Results of Productivity Changes

In line with previous studies that isolate the components of productivity changes, this study uses the acronyms TFPCH (Malmquist index of total factor productivity), TECHCH (technical change), EFFCH (efficiency change), PECH (pure technical efficiency change), and SECH (scale efficiency change). Table 5 presents the total factor productivity change indexes of banks. These data demonstrate that the mean values of TFPCH and TECHCH are greater than one, which indicates that banks experience positive productivity growth and technical progress. The mean values of EFFCH, PECH, and SECH are less than one, which demonstrates that they are unable to manage resourcing problems and the lack of scale efficiency. The mean value of TFPCH is 1.027, which indicates that bank productivity slightly improved over the study period. This result is consistent with Chen and Yen (2000) and Chiu et al. (2009), the former showing that the mean TFPCH is 1.013 and the latter showing a mean TFPCH of 1.049.

These results suggest that TFPCH has only slightly improved, mainly due to the frontier shift effect rather than the catch-up effect, which implies that deregulation policies can enhance bank productivity growth. At the same time, banks have generally experienced the benefits of technological progress since many new banks have entered the market and have provided many new ideas, cultures, and operating strategies. As for the idea that bank inefficiency is due to not "catching–up" to the efficient frontier (i.e., falling behind the best-practice), the mean EFFCH of 0.99 implies that banks require more in order to save on management costs or more utilized input resources.

The same holds for EFFCH and PECH, which are respectively 0.99 and 0.995. On the whole, this study suggests that banks increase productivity by more effectively utilizing input resources or management factors. This result is consistent with prior studies (Chen & Yen, 2000; Chiu et al., 2009; and Liao, 2009), which report a lesser influence of the catch-up effect for banks. The mean value of SECH is less than one, which indicates that the banks have not moved toward their optimal size and thus implies that banks must gradually adjust their operating scales. Hsiao et al. (2010) have found that the relationship between bank assets and efficiency is not insignificant. Shen (2005) has showed that the optimal fixed assets size is around NT 10 billion, which suggests that government encouraged banks to activate mergers and acquisitions (M&A) in order to increase profitability and competitiveness. In mergers and acquisitions theory, large banks exercise a wider array of resources, such as brand image and branch networks, to increase profitability more than smaller banks. While this study does not support the idea that grant banks are best for Taiwan, its resultant SECH value shows that banks have not come close to achieving optimal size.

Table 5: Total Factor Productivity Changes

	Average annual change				
	EFFCH	**TECHCH**	**PECH**	**SECH**	**TFPCH**
1994-95	0.216	1.871	0.893	0.242	1.704
1995-96	4.837	0.14	1.108	4.367	0.675
1996-97	1.065	1.162	1.018	1.046	1.237
1997-98	0.838	1.028	0.873	0.959	0.861
1998-99	0.677	0.918	1.029	1.021	0.965
1999-00	1.051	1.581	0.946	0.715	1.071
2000-01	1.452	0.06	1.045	1.39	0.88

2001-02	0.868	1.289	0.993	0.87	1.119
2002-03	0.723	1.651	1.022	0.708	1.194
2003-04	1.585	0.479	0.984	1.611	0.759
2004-05	1.03	1.247	1.09	0.944	1.285
2005-06	1.029	1.026	0.98	1.05	1.056
2006-07	0.883	0.845	0.911	0.969	0.747
2007-08	1.063	1.068	1.057	1.006	1.136
2008-09	0.584	1.979	0.966	0.605	1.157
2009-10	1.886	0.488	1.071	1.761	0.92
2010-11	0.794	1.424	0.963	0.825	1.131
mean	0.99	1.038	0.995	0.995	1.027

Note: The "mean" indicates the average the entire sample value over the period 1994 to 2011. TFPCH indicates the total factor productivity index and EFFCH the catch-up indicates the insurers efficiency change, Frontier-shift indicates the technology change, THCHCH, PECH are pure technical efficiency change, and SECH is the scale efficiency change.

3.4. Results of Baseline Regression

This section explains the determinants of bank efficiency estimates derived from the DEA model with undesirable outputs for Taiwan. First, a Variance Inflation Factor (VIF) was implemented to test whether the collinearity problem is significant. As shown in column 6 of Table 5, all variables of VIF were less than 10, which implies that there were no collinearity problems in the regression analysis. As can be seen in Table 6, the coefficient of *risk* is positive and significant in all columns. A higher operation uncertainty is seen when banks have a high ROA volatility, which indicates that banks with higher ROA volatility should be more inefficient than other banks. Strong evidence supports the idea that efficiency is associated with operating risk; banks still experience high efficiency even if they have high operating uncertainty. One possible reason for this phenomenon is that bureaucratic power and regulator interference still play important roles in improving efficiency in emerging countries, even for banks with higher operation uncertainty.[6]

The coefficient of BRCH is insignificant in all columns, implying that a greater number of branches does not improve bank efficiency. Regulations restricting banks from establishing new branches simultaneously encouraged merger activities among banks who assumed that a widespread network of branches would increase bank services, scope, and profitability. This study's results, however, show that an increased number of branches cannot significantly improve bank efficiency, Burki and Niazi (2010) have pointed out that delivery systems in rural areas are very costly, thus banks operating in a rural branch network are expected to maintain several loss-making branches. For this reason, banks prefer to establish new branches in urban areas, though doing so costs more and causes more competition than in rural areas. Therefore, only with great uncertainty can banks increase efficiency by cultivating a large network of branches.

The coefficient of RGR was significantly positive, which fulfills this study's expectations. This implies that banks with a higher operating revenue growth rate show better efficiency. The coefficient of *size* is positive and significant, indicating that managers could improve their bank's efficiency by increasing asset size. This result is consistent with Kwan (2006) and Liu and Liao (2013). As Ataullah and Le (2006) have shown, a positive relationship between size and efficiency is attributed to larger banks' market power and their ability to diversify credit risk in an uncertain macroeconomic environment.

The coefficient of *EQAS* was insignificant. The equity-to-assets ratio as a proxy of the external corporate governance indicator implies that equity stakes could put pressure on management to reduce efficiency shortfalls. The coefficient of *DV* was positive and significant, which indicates that state-owned banks experience greater efficiency than non-state-owned banks, which in turn implies that bureaucratic power still plays an important role for bank efficiency for emerging countries, as the regulator often intervenes on the financial market and on bank operating management. In short, most public policies to protect the benefits of state-owned banks.

[6] Bonin et al. (2005) and Liao (2013) have illustrated that state-owned banks continue to enjoy the advantages of government policies in emerging countries, as evidenced by their efficiency and profitability compared to private banks.

Table 6: Results of Baseline Regression

	Full sample				
	OTE		SE		
	OLS	TB	OLS	TB	VIF
RISK	1.495	4.8457	1.542	5.791	1.221
	(1.967)**	(1.985)**	(2.361)**	(2.371)**	
BRCH	-0.029	-0.0932	-0.035	-0.132	4.896
	(-0.866)	-0.8734	(-1.221)	(-1.236)	
ORG	0.078	0.2529	0.074	0.2784	1.377
	(1.723)*	(1.733)*	(1.904)*	(1.907)*	
EQAS	0.081	0.2676	-0.032	-0.1197	1.198
	(0.577)	(0.5916)	(-0.236)	(-0.2646)	
SIZE	0.048	0.1564	0.04	0.1515	5.0
	(2.15)**	(2.17)**	(2.089)**	(2.1036)**	
DV	0.081	2.597	0.068	0.2573	1.427
	(2.686)***	(2.69)***	(2.653)***	(2.6648)***	
R^2	0.036		0.033		
Log-likelihood function		-188.907		-75.3778	

Notes: EFF indicates banks efficiency, Risk indicates risk lever of banks measured by standard deviation of each bank's yearly ROA, SIZE indicates the natural logarithm of bank assets, BRCH indicates natural logarithm of bank branches, RGR indicates revenue growth ratio, EQAS indicates the total equity divided by total assets and DV indicates dummy variable, which equals one if the banks is state-owned banks including actual-control power by government, and zero otherwise.

OLS is ordinary least square, TB is Tobit regression model.

* Significant level at the α=0.1, **at α=0.05 and ***at α=0.01

3.4. Results of robustness test

Following previous studies, this section evaluates firm performance as measured by accounting variables, such as return of equity and return of asset. To further investigate the various dependent variables in our empirical equation and to decide whether to change our results, we re-estimated regression and used return of asset (ROA) as the dependent variable. Table 7 reports the results. It is found that the effect of ROA volatility on the banks performance is inconsistent with result of efficiency, meaning that a bank with higher ROA volatility is lower profitability than other banks. ROA regression has a higher R-square than efficiency regression, however these results still remain qualitatively similar, which implies that efficiency and performance regression are consistent.

Table 7: Results of ROA Regression

	OLS	TB	VIF
RISK	-0.24 (-8.637)***	-21.669 (-7.9856)***	1.212
BRCH	-0.054 (-0.963)	-0.1798 (-1.6286)	4.896
ORG	0.05 (1.688)*	0.4548 (3.0546)***	1.377
EQAS	0.733 (26.583)***	11.625 (20.207)***	1.198
SIZE	0.21 (3.736)***	0.374 (4.9174)***	5.0
DV	-0.07 (-0.224)	-0.041 (-0.4409)	1.427

R^2	0.528	
Log-likelihood function		1376.18

Notes: EFF indicates banks efficiency, Risk indicates risk lever of banks measured by standard deviation of each bank's yearly ROA, SIZE indicates the natural logarithm of bank assets, BRCH indicates natural logarithm of bank branches, RGR indicates revenue growth ratio, EQAS indicates the total equity divided by total assets and DV indicates dummy variable, which equals one if the banks is state-owned banks including actual-control power by government, and zero otherwise.
OLS is ordinary least square, TB is Tobit regression model.
* Significant level at the α=0.1, **at α=0.05 and ***at α=0.01

4. CONCLUSIONS

This study provides an interesting case study of efficiency for one basic problem concerning undesirable output. It has aimed to expand the literature examining bank efficiency by including undesirable outputs to reflect true efficiency instead of excluding undesirable output in the DEA model. Overall, this study's results indicate that nearly 40% of banks' costs are wasted according to the best-practice frontier while facing the same output within samples. This also shows that bank operated at a lower efficiency level over our study period. One possible reason for this is that the government allowed new banks to enter the financial market after deregulation in order to increase competition, which eventually improved bank efficiency. At the same time, over-competition deteriorated the quality of their assets, dropped their profitability, and even led to bankruptcy. Comparing the results of bank efficiency estimated either with undesirable outputs or without undesirable outputs shows that efficiency estimated with undesirable output was slightly higher than that of models without undesirable outputs. This result provides significant evidence that not accounting for undesirable outputs in the classical DEA model might seriously distort efficiency results.

The results of comparing three stages during 1993 to 2011 suggest that deregulation encouraged more banks to foster a more competitive market environment in order to raise bank efficiency and profitability. As such, this study suggests a higher of level of competition improved bank efficiency and incentivized the creation of new financial businesses with service skills and operating logistics but also produced banks with higher risk levels. Thus, the effect of deregulation on bank efficiency decreased during the initial financial reform period. Nevertheless, our empirical evidence shows that financial reform significantly improved bank efficiency in emerging countries in the long run.

Though most studies argue that banks with higher ROA volatility should be more inefficient than other banks, our study does not support this viewpoint. Instead, there is strong evidence to support the idea that efficiency is associated with operating risks, for banks still have high efficiency even when operating with high uncertainty. One possible reason for this is that bureaucratic power and interference from regulators still play important roles in improving efficiency in emerging countries, even for banks with higher operating uncertainty. State-owned banks have the duty to assist government enforcement of relative policies and obtain franchise value from bureaucratic power.

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REFERENCES

Assaf, A.G., Matousek, R., & Taionas, E., 2013, "Turkish bank efficiency: Bayesian estimation with undesirable outputs", *Journal of Banking and Finance*, vol.37, pp.506-517.

Ataullah, A., & Le H.,2006, "Economic reforms and bank efficiency in developing countries: the case of the Indian banking industry", *Applied Economics*, vol.16, pp.653-663.

Berger, A. N., 1995, "The profit-structure relationship in banking-tests of market-power and efficient-structure hypothesis", *Journal of Money, Credit and Banking,* vol.27, pp.404-431.

Berger, A.N., Hasan, L. & Zhou, M.,2009, "Bank ownership and efficeincy in China: what will happen the world's largest nation?", *Journal of Banking and Finance*, vol.33, pp.113-130.

Bertran. M., Schoar, A. & Thesmar, D., 2007, "Banking Deregulation and industry structure: evidence from the French banking reforms of 1985", *Journal of Finance*, vol.62, no.2, pp.597-628.

Bonin, J.P., I, Hasan & P. Wachtel, 2005, "Bank performance, efficiency and ownership in transition countries", *Journal of Banking and Finance*, vol.29, pp.31-53.

Burki, A.A., & G.S. Niazi, 2010, "Impact of financial reforms on efficiency of state-owned, private and foreign banks in Pakistan", *Applied Economics*, vol.42, pp.3147-3160.

Chen, T. Y., & Yeh, T.L.,2000, "A measurement of bank efficiency, ownership and productivity changes in Taiwan", *Service Industries Journal*, vol.20, pp.95-109.

Chiu Y.H., & Y.C. Chen, 2009, "The analysis of Taiwanese bank efficiency: incorporating both external environment risk and internal risk", *Economic Modelling*, vol.26, pp.456-463.

Chiu, Y.H., Y.C. Chen & X. J. Bai, 2011, "Efficiency and risk in Taiwan banking: SBM super-DEA estimation", *Applied Economics*, vol.43, pp.587-602.

Drake, L., 2001, "Efficiency and productivity change in UK banking". *Applied Financial Economics*, vol.11, pp.557-571.

Fare, R., Grosskopf, S., Norris, M., & Zhang Z., 1994, "Productivity growth, technical progress, and efficiency change in industrialized countries", *American Economics Review*, vol. 84,pp. 66-83.

Fernansez, C., Koop, G., & Steel, M., 2002, "Multiple-output production with undesirable outputs: an application to nitrogen surplus in agriculture", J*ournal of the American Statistical Association*, vol.97, pp.432-442.

Filippaki, A.K., D. Margaritis, & C. Staikiuras, 2009, "Efficiency and productivity growth in the banking industry of Central and Eastern Europe", *Journal of Banking and Finance*, vol.33, pp.557-567.

Hsiao, H.C., H. Chang, A.M. Cianci, & L.H. Huang, 2010, "First financial restructuring and operating efficiency: evidence from Taiwanese commercial banks", *Journal of Banking and Finance*, vol.34, pp.1461-1471.

Liao, C.S., 2009, "Efficiency and productivity change in the banking industry in Taiwan: domestic versus foreign banks", *Banks and Bank systems*, vol.4, pp.75-84.

Liao, C.S.,2013, "Risk-taking and Efficiency of Banks for Emerging Eastern Asian Countries", Graduate Institute of Finance, National Taiwan University of Science and Technology ,Working paper.

Liu, D.Y., & Liao, C.S., 2013, "Executive turnover, risk-taking, and efficiency among banks in emerging Asian countries", *International Research journal of Finance and Economics*, vol.103, pp.6-24.

Liu, S.T., 2010, "Measuring and categorizing technical efficiency and productivity change of commercial banks in Taiwan," *Expert System and Application*, vol. 37, pp.2783-2789.

Liu, H., P. Molyneuz, & L.H. Nguyen, 2012, "Competition and risk in South East Asian commercial banking", *Applied Economics*, vol.44, pp.3627-3644.

Kumbhakar, S.C. & Sarkar, S., 2003, "Deregulation, ownership and productivity growth in the banking industry: evidence from India", *Journal of Money, Credit and banking*, vol.35, pp.403-423.

Kwan, S.H,2006, "The X-Efficiency of Commercial Banks in Hong Kong", *Journal of Banking and Finance*, vol.30, pp.1127-1147

Ray, S.C., & Das, A., 2010, "Distribution of cost and profit efficiency: evidence from Indian banking", *European Journal of Operational Research*, vol.201, pp. 297-307.

Rezvanian, R., R.T. Ariss & S. M. Mehdian, 2011, "Cost efficiency, technological progress and productivity growth of Chinese banking pre- and post- WTO accession", *Applied Financial Economics*, vol.21, pp.437-454.

Seiford, L., & Zhu, J., 2002, "Modeling undesirable factors in efficiency evaluation", European *Journal of Operatiom Research*, vol.142, pp.16-20.

Shen, C.H., 2005, "Cost efficiency and banking performance in a partial universal banking system: An application of the panel smooth threshold model", *Applied Economics*, vol.37, pp. 993-1009.

Sun, L. & T.P. Chang, 2011, "A comprehensive analysis of the effects of risk measures on bank efficiency: Evidence from emerging Asian countries", *Journal of Banking and Finance*, vol.35, pp.1727-1735.

Thanassoulis, E., 2001, Introduction to the theory and application of Data envelopment analysis: a foundation text with integrated software, Kluwer academic publishers, Boston, Hardbound.

Zhao, T., B. Casu, & A. Ferrari, 2010, "The impact of regulatory reforms on cost structure, ownership and competition in Indian banking", *Journal of Banking and Finance*, vol.34, pp.246-254.