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What is the impact of bankrupt and restructured loans on Japanese bank efficiency?

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ABSTRACT

The Japanese banking system provides a distinctive platform for the examination of the long-lasting effect of problem loans on efficiency. We measure technical efficiency by modifying a translog enhanced hyperbolic distance function with two undesirable outputs, identified as problem loans and problem other earning assets. Our unique database allows us to distinguish between bankrupt and restructured loans to investigate the underlying causality between these loans and efficiency. From the flexible panel vector autoregression specification, primary results reveal that bankrupt loans have a positive impact on efficiency related to the "moral hazard, skimping" hypothesis, with the causality originating from bankrupt loans. In contrast, findings for the relationship between restructured loans and efficiency support the "bad luck" hypothesis.

1. Introduction

An unprecedented escalation of nonperforming loans in the Japanese banking sector during the 1990s triggered a prolonged economic downturn. During the turmoil, the government undertook its stabilisation scheme by providing deposit insurance, injecting public capital, and bailing out troubled banks (Hoshi and Kashyap, 2010; Montgomery and Shimizutani, 2009). The expensive bailouts and intervention policies helped banks to reduce the volume of nonperforming loans from ¥30 trillion in 1997 to ¥11.6 trillion in 2008. However, the Japanese government was criticised for its procrastination, in particular earlier in the banking crisis, as some considerable lags in response were recorded. Moreover, before 1997, banks had been struggling to deal with the increase in problem loans whilst indecisive government exacerbated the situation (Giannetti and Simonov, 2013; Hayashi and Prescott, 2002; Hoshi and Kashyap, 2010). Overall, government intervention has been effective in pulling troubled banks out of the turmoil and relaxing the financial distress, yet it is factual that earlier indecisiveness prolonged the period of disruption, thereby hindering bank performance recovery. These unique features of the Japanese banking system make the investigation of the detrimental effect of problem loans on efficiency worthwhile.

Unlike most studies on Japanese banking which consider nonperforming loans as a control variable or a proxy for risk (Altunbas et al., 2000; Drake and Hall, 2003; Liu and Tone, 2008), this paper follows a new strand of the literature by treating nonperforming loans as an undesirable output in bank efficiency measurement (Barros et al., 2012; Fukuyama and Weber, 2008; Glass et al., 2014). We explore how nonperforming loans affect bank technical efficiency, as well as the causality of the relationship between risks (identified as bankrupt and restructured loans) and efficiency.

This study is different from previous empirical research on bank efficiency in Japan in the following ways. First, we propose an innovative way of estimating bank efficiency by using a translog enhanced hyperbolic output distance function as introduced by Cuesta et al., 2009. The advantage of deploying this parametric approach is to allow for a simultaneous expansion of desirable

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outputs and contraction of inputs and undesirable outputs. Second, we modify the model with a vector of two undesirable outputs (problem loans and problem other earning assets[1]) using semi-annual data. In this paper, we use the term "problem loans" instead of nonperforming loans to be consistent with the classification of problem assets under the Financial Reconstruction Law. We argue that while problem loans are by-products of loans, problem other earning assets are by-products of other earning assets. Beside conventional banking operations, Japanese commercial banks also invest in government bonds, corporate bonds and securities, as well as offer non-traditional banking services such as guarantees and acceptances. Thus, the inclusion of problem other earning assets in the undesirable output vector would control for the effect of these problem assets on bank efficiency. Such an analysis has not yet been conducted because of the limitation of previous models and data unavailability. Third, our semi-annual data range covers a long time span from 2000 to 2012, embracing the restructuring period, the global financial crisis, as well as the aftermaths of the crisis.

In addition, we investigate the impact of bankrupt loans and restructured loans on bank efficiency. No previous studies explored this particular issue. These types of loans are disaggregated from our data of risk-monitored loans of Japanese commercial banks.[2] Bankrupt loans are loans to borrowers in legal bankruptcy and past due loans by 6 months or more. Restructured loans are named after the sum of past due loans by 3 months but less than 6 months and restructured loans. We argue that bankrupt loans and restructured loans measure the level of risk held within Japanese banks. The increase of these loans could be attributed to both bank managers and exogenous shocks. Given endogeneity concerns, we further examine the underlying dynamic relationship between bankrupt loans/restructured loans, bank specific and macroeconomic variables, and technical efficiency within a panel Vector Autoregression (VAR) model. This method grants the opportunity to explore important causality hypotheses between bankrupt, restructured loans and efficiency. Following Berger and DeYoung (1997) and Koutsomanoli-Filippaki and Mamatzakis (2009), we address four renowned hypotheses: "bad luck", "bad management", "skimping/moral hazard", and "risk-averse management". Our results show that the relationship between bankrupt loans and technical efficiency resembles the "moral hazard" and "skimping" hypothesis, with the causality running from bankrupt loans to efficiency. Restructured loans, on the other hand, affect technical efficiency in line with the "bad luck" hypothesis.

The remainder of this paper is organised as follows. Section 2 provides an overview of the restructuring process and problem loans in Japan. Section 3 summarises the literature on Japanese banking efficiency with an incorporation of problem loans. Methodology is presented in section 4. Section 5 describes our data set and variable selection. Results are discussed in section 6. Finally, concluding remarks and policy implications are offered in section 7.

2. The Japanese restructuring process and problem loans

In this section, we briefly overview the main bottlenecks in the Japanese banking sector. In particular, we focus on the restructuring process and problem loans that in our view had a crucial impact on bank efficiency.

In response to the central issue of impaired loans which were a consequence of the outburst of asset price bubble, Japanese authorities instigated several restructuring packages to restore the financial health of the banking system. First, capital injection programs were implemented five times from March 1998 to March 2009. In 1998, under the Financial Revitalisation Plan, nearly two third of public fund injected was to fully protect depositors of insolvent banks and purchase their assets (Montgomery and Shimizutani, 2009). Second, in 2002, the Financial Services Agency forced banks to liquidate poorly performing companies' shares. However, the Bank of Japan eventually had to buy those bank-held shares directly. Third, the government approved accounting changes which permitted banks to record either book or market values for their holdings of stocks in other firms and real estate holdings. This procedure raised the value of bank assets at that time when market values were reported, even though those market prices were far below their highest records. Nevertheless, in 2001, the government required those values to be switched back to their book ones (Hoshi and Kashyap, 2010).

Apart from the abovementioned schemes, the wave of bank consolidation evolved among large banks to strengthen their resistance to financial severity. Mergers between City Banks (Mitsui Bank and Taiyo-Kobe Bank to form Sakura; Fuji, Dai-Ichi Kanyo, and Industrial Bank of Japan to form Mizuho Bank; Sanwa and Tokai Banks to form UFJ Banks; UFJ Banks and Bank of Tokyo-Mitsubishi; Sumitomo and Sakura (Nakamura, 2006)) led a strong incentive for weaker banks to be consolidated. Yet, the effects of mergers and acquisitions in the Japanese banking industry appeared unsuccessful in stabilising the financial market and reducing the probability of failure (Harada and Ito, 2011; Hosono et al., 2006).

Nonetheless, the government has been criticised for their lending facilitation policies. The (misdirected) lending to unprofitable firms ("zombie lending") was blamed to encumber the effort to diminish problem loans. The fact that Main banks (City Banks) rescued poorly performing firms at the expense of their well performing counterparts (Lincoln et al., 1996) led to an emergence of "zombie lending". Banks could also have the perverse incentive not to write off bad debts to avoid the loss of capital, which could result in a failure to comply with Basel I capital adequacy standards (Watanabe, 2010). Thus, the financing to these "zombies" borrowers weakened the restructuring process in Japan and deterred healthy firms and banks from recovering. On the other hand, after 1998, the Japanese government promoted lending to small and medium sized enterprises (SMEs), hoping to mitigate the turbulent situation and resurrect the economy. This policy particularly called for banks rescued by public capital, even the weakest financial institutions (Hoshi and Kashyap, 2010). Hence, the core of problem loans shifted from real estate lending to small and medium enterprise financing. The fact that problem loans to assets ratios in Regional Banks I and II are somewhat higher than in City Banks over time (see Fig. 1) provides further support for this argument as SMEs are Regional Banks' target customers. Regional Banks, by channelling credit to SMEs, are supposed to support the local development of their prefectures where their head offices are situated. In addition, credit risk for those banks is a non-trivial concern despite the crisis-related interventions, which may underestimate the true magnitude of SMEs' problem loans (Hoshi, 2011; International Monetary Fund, 2012). These developments led to changes in the regulatory framework so as to adjust problem loans' definition in an attempt to redeem some credits for bad loans of SMEs. Along these lines, more than 50% the amount of problem loans held by Regional Banks between September 2008 and March 2009 were reclassified as normal (Hoshi, 2011). It is argued that a large number of bad debts were in disguise until the end of March 2012. About 3–6% of total credit in Regional Banks was reclassified under the SME Financing Facilitation Act, compared to 1.7% for City Banks and Trust Banks (International Monetary Fund, 2012).

[1] The names and definitions are in accordance with the Financial Reconstruction Law. Problem loans are bankrupt, quasi-bankrupt, doubtful, and substandard loans. Problem other earning assets are bankrupt, quasi-bankrupt and doubtful other earning assets (please see Data section and Appendix A for more details).

[2] See Data section and Appendix A for more details.

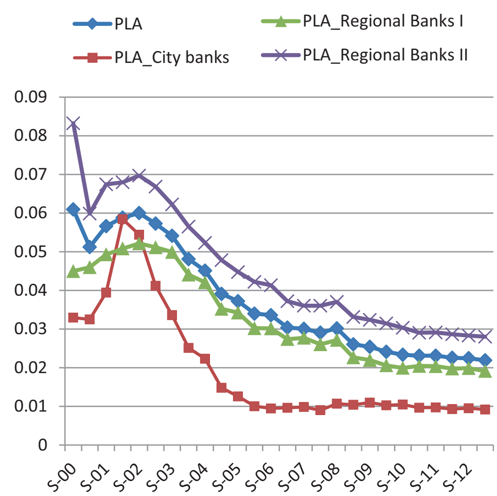

Fig. 1. Problem loans to assets ratios in Japanese commercial banks 2000–2012. Notes: This Figure illustrates the ratio of problem loans to assets of Japanese commercial banks during 2000–2012. PLA: Problem loans to assets; S: September; 00–12: 2000–2012.

It is worth mentioning the impact of macroeconomic performance on the banking system.[3] High public sector indebtedness and slow growth are amongst the most important factors accumulating the latent risk within financial institutions (International Monetary Fund, 2012). Fewer profitable investment projects, limited credit demand, economic stagnation characterised by long-term deflation and sluggish growth are all obstacles to a sound financial system, slowing down the recovery process of the economy. Hence, robust growth is a necessary condition of a successful bank recapitalisation. Yet, the causality could also be of the reverse nature as the dysfunction of the financial system retards macroeconomic rebound (Hoshi and Kashyap, 2010). Besides, existing problematic firms would find themselves struggling to overcome the bottlenecks and face high accumulative operating costs. To deal with this long-lasting effect and the threat of deterioration, the Bank of Japan introduced quantitative easing as a monetary policy tool to stimulate aggregate demand and boost the country's productivity (Bank of Japan statement, 19 March 2001[4]). Virtually zero interest rate had been maintained until 2006. At times, although GDP growth was not adequate to defeat deflation, the stimulating effect of quantitative easing on aggregate demand could not be denied (Bowman et al., 2011). The monetary easing policy was extended in 2010 due to major concerns about heightened price instability arisen from negative spill over effects from slowdown overseas economies. Aggressive monetary easing has been launched ever since to support the *Abenomics*[5] – the strategic economic policy proposed by the newly appointed Prime Minister in 2012.

3. Literature review

For a review of the literature, we revise bank efficiency studies where problem loans play an important part in the analysis. A number of studies use problem loans as covariates to identify their impact on bank efficiency among other independent variables. For instance, problem loans are treated as a proxy for asset quality (Berger and DeYoung, 1997; Mester, 1993, 1996; Uchida and Satake, 2009) or a measure of risk (Lensink et al., 2008). Hughes and Mester (1993) find that inefficiency is positively correlated to problem loans. Berger and DeYoung (1997), however, do not control for loan quality in the cost function. They assume that problem loans may be considered exogenous for a given bank if these loans are unexpected results of "bad luck", or endogenous if they are due to "bad management" or "skimping" (actions taken by management). Under the "bad luck" hypothesis, an increase in nonperforming loans (which is considered exogenous for the bank) would lead to a decrease in efficiency. The rise in bad loans is caused by unforeseen shocks (for example natural disasters) that affect the repayment ability of debtors. In contrast, for all other hypotheses that Berger and DeYoung (1997) address, the heightened level of problem loans stems from the bank itself. "Bad management" refers to the incompetence of bank managers regarding credit screening, collateral evaluating, and loan monitoring as they are also cost-inefficient managers. On the other hand, for ambitious managers, the fact that abnormal returns could help secure their position and bring on more bonuses could induce them to take on risky projects. It could also be a transfer of lower short-term costs to forthcoming risks so as to maximize long-term profit. To achieve their goals, bank managers could skip some management practices in the loan screening-monitoring process, causing the bank to appear more efficient due to fewer operating costs. That is how the "skimping" hypothesis explains the rise in problem loans from an increase in efficiency. Magnifying the outcomes of these three hypotheses, the "moral hazard" hypothesis expresses that banks with relatively low capital may have the incentives to involve in risky loan portfolios as the risk is partly shifted to another party. Empirical results of Berger and DeYoung (1997) deliver support for the "bad luck" hypothesis, but for the whole industry, the results tend to favour the "bad management" one.

Berger and Mester (1997) also include problem loans ratio as an environmental variable in the Fourier-flexible model. The findings support the "bad management" hypothesis of Berger and DeYoung (1997) and reveal a statistically significant positive relationship between problem loans and total cost. Also testing these hypotheses, Koutsomanoli-Filippaki and Mamatzakis (2009) convey the "moral hazard" hypothesis in a similar aspect to the "skimping" one by emphasising the link between efficiency and risk. To pursue expansionary strategy, it could be tempting for an efficient bank to take on more risks which might not be paid off eventually. This study also introduces the "risk-averse management" hypothesis, which refers to risk-intolerant bank managers whose prudential supervision could cause large operating costs in the short-term (subsequently, higher inefficiency) but prevent a high rate of default in the future.

In our study, we will consider the relation of these aforementioned hypotheses and problem loans in Japan. On top of that, we argue that problem loans should be treated as an undesirable output vector in bank production process. Berg et al. (1992) introduce this concept for Norwegian banks. (Negative) loan loss is included in the output vector to measure the quality of loans in two benchmark years. Park and Weber (2006) argue that these loans should be treated as an undesirable output rather than an input in a bank's production. A number of banking research then has accounted for problem loans directly in their methodology (Assaf et al., 2013; Barros et al., 2012; Fujii et al., 2014; Fukuyama and Weber, 2008).

Since the Japanese banking system has been chronically clogged by problem loans, it has become an exclusive laboratory for investigating the impact of these loans on bank efficiency. There is also a variety of methods in addressing problem loans in Japanese bank literature. Considering loan-loss provision as a control factor for output quality, Altunbas et al. (2000) examine

[3] The authors thank an anonymous referee for this helpful suggestion.

[4] Bank of Japan's statements, 2001 (http://www.boj.or.jp/en/announcements/release_2001/k010319a.htm/).

[5] The priority aims are: (i) reconstruction and disaster prevention; (ii) creation of wealth through growth; (iii) securing safety of livelihood of regional revitalisation. The priority areas are documented on the Prime Minister website, January 11, 2013.

the effects of risk factors in Japanese banks' cost during 1993–1996. Overall inefficiency scores appear to be between 0.05–0.069 for all 4 years whether or not risk and quality factors are controlled for. Problem loans, in this study, are found to have little effect on scale economies and X-efficiency. Liu and Tone (2008) also include the ratio of problem loans as a bank characteristic variable in a cost frontier analysis.

Unlike other studies, Drake and Hall (2003) choose to include problem loans as an uncontrollable input when estimating Japanese banking efficiency by DEA model. Following Berger and Humphrey (1997), they consider bad loans as a result of "bad luck" rather than "bad management". Loan-loss provision is used as an indicator of the extent of problem loans. It is emphasised that although in the DEA model, uncontrollable inputs are held fixed, in effect; it is somewhat under the bank's discretion as the management board is able to adjust the level of provision. After the basic DEA model is modified for the inclusion of non-discretionary input, the associated findings imply a reward for banks with good control of problem loans as mean pure technical efficiency increases from 72.36 to 89.38 for financial year 1997.

In contrast to Drake and Hall (2003), Fukuyama and Weber (2008) argue that problem loans should be treated as an undesirable output as they appear only after a loan has been made. Data for Japanese banks are pooled over a three-year period (2002–2004), with an assumption that a common technology exists for all banks. The findings present that the null-jointness hypothesis between good output and bad output is satisfied, indicating that problem loans are a by-product of the loan generating process. Similarly, Barros et al. (2012) measure technical efficiency of Japanese banks (2000–2007) with the appearance of problem loans as an undesirable output. They apply a non-radial directional methodology, which involves the expansion of good outputs and the contraction of inputs and bad outputs directionally by the nonzero vector $g = (-g_x,\ g_y,\ -g_b)$. The finding suggests that the problem of nonperforming loans was not completely wiped out, although the process of revitalisation had been taken place.

To this end, our paper contributes to the existing efficiency literature about Japanese banks in terms of methodology employed and data used to measure bank efficiency. The translog enhanced hyperbolic distance function proposed by Cuesta et al. (2009) allows us to directly estimate the impact of problem loans on efficiency. In addition, the introduction of problem other earning assets in the undesirable output vector is innovative and accounts for the non-traditional operations of Japanese banks.

4. Methodology

Our methodology is underpinned by Cuesta et al.'s (2009) model. The enhanced hyperbolic distance function[6] takes the form of:

$$D(x, y, b) = \inf\{\phi > 0 : (x\phi, y/\phi, b\phi) \in T\} \tag{1}$$

with input vector $x_i = (x_{1i}, x_{2i}, \ldots, x_{ki}) \in R^K_+$, desirable output vector $y_i = (y_{1i}, y_{2i}, \ldots, y_{mi}) \in R^M_+$, and undesirable output vector $b_i = (b_{1i}, b_{2i}, \ldots, b_{ri}) \in R^R_+$

The technology T represents the production possibility set:

$T = \{(x, y, b) : x \in R^K_+, (y, b) \in R^P_+, x \text{ can produce}\,(y, b)\}$ such that R^P_+ expresses the set of all $u = (y, b)$ output vectors obtainable from x.

Subscript $i = (1, 2, \ldots, N)$ denotes a set of observed producers.

Eq. (1) expresses a simultaneous expansion in good outputs y and shrinkage in inputs x and bad outputs b, generating a hyperbolic path. If $D(x, y, b) = 1$, the production of the observed unit lies on the production frontier and is efficient. Thus, if $D(x, y, b) < 1$, the producer is inefficient and could improve their performance by increasing desirable outputs and cutting undesirable outputs and inputs.

Applying a translog specification for $D(x, y, b)$, it yields:

$$\begin{aligned}
\ln D = {} & \alpha_0 + \sum_{k=1}^{K}\alpha_k \ln x_{ki} + \sum_{m=1}^{M}\beta_m \ln y_{mi} + \sum_{r=1}^{R}\chi_r \ln b_{ri} \\
& + \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K}\alpha_{kl}\ln x_{ki}\ln x_{li} + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M}\beta_{mn}\ln y_{mi}\ln y_{ni} \\
& + \frac{1}{2}\sum_{r=1}^{R}\sum_{s=1}^{R}\chi_{rs}\ln b_{ri}\ln b_{si} + \sum_{k=1}^{K}\sum_{m=1}^{M}\delta_{km}\ln x_{ki}\ln y_{mi} \\
& + \sum_{k=1}^{K}\sum_{r=1}^{R}\gamma_{kr}\ln x_{ki}\ln b_{ri} + \sum_{m=1}^{M}\sum_{r=1}^{R}\eta_{mr}\ln y_{mi}\ln b_{ri}
\end{aligned} \tag{2}$$

Imposing the almost homogeneity condition and choosing the Mth desirable output for normalising purpose $\mu = 1/y_M$, we obtain:

$$D\left(xy_M, \frac{y}{y_M}, by_M\right) = \frac{D(x, y, b)}{y_M} \tag{3}$$

with $x^*_{ki} = x_{ki} * y_{Mi}, y^*_{mi} = y_{mi}/Y_{Mi}, b^*_{ri} = b_{ri} * y_{Mi}$, the translog function takes the form:

$$\begin{aligned}
\ln(D/y_{Mi}) = {} & \alpha_0 + \sum_{k=1}^{K}\alpha_k \ln x^*_{ki} + \sum_{m=1}^{M-1}\beta_m \ln y^*_{mi} + \sum_{r=1}^{R}\chi_r \ln b^*_{ri} \\
& + \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K}\alpha_{kl}\ln x^*_{ki}\ln x^*_{li} + \frac{1}{2}\sum_{m=1}^{M-1}\sum_{n=1}^{M-1}\beta_{mn}\ln y^*_{mi}\ln y^*_{ni} \\
& + \frac{1}{2}\sum_{r=1}^{R}\sum_{s=1}^{R}\chi_{rs}\ln b^*_{ri}\ln b^*_{si} + \sum_{k=1}^{K}\sum_{m=1}^{M-1}\delta_{km}\ln x^*_{ki}\ln y^*_{mi} \\
& + \sum_{k=1}^{K}\sum_{r=1}^{R}\gamma_{kr}\ln x^*_{ki}\ln b^*_{ri} + \sum_{m=1}^{M-1}\sum_{r=1}^{R}\eta_{mr}\ln y^*_{mi}\ln b^*_{ri}
\end{aligned} \tag{4}$$

We can write Eq. (4) in a simplifying form of:

$$\ln(D/y_{Mit}) = TL(x^*_{it}, y^*_{it}, b^*_{it}; \alpha, \beta, \chi, \delta, \gamma, \eta) + v_{it} \quad i = (1, 2, \ldots, \mathrm{N}) \tag{5}$$

As $\ln D$ corresponds to the one-sided distance component u_i, by rearranging it we get:

$$-\ln(y_{Mit}) = TL(x^*_{it}, y^*_{it}, b^*_{it}; \alpha, \beta, \chi, \delta, \gamma, \eta) + v_{it} - u_{it} \quad i = (1, 2, \ldots, \mathrm{N}) \tag{6}$$

where $-\ln(y_{Mit})$ is the log of the Mth desirable output, v_{it} is the stochastic error which follows a normal distribution, u_{it} is the inefficiency term.[7]

The stochastic frontier approach enables researchers to decompose the usual error term, ε_{it}, into two components: the two-sided random error, and the one-sided inefficiency term to capture inefficiency. We assume that the inefficiency term follows a half normal distribution $N(0,\sigma^2{}_u)$. It reflects the distribution of non-negative u values drawn from a population which is normally distributed with zero mean.

Thus, the translog enhanced hyperbolic distance function takes the form[8]:

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[6] The enhanced hyperbolic distance function has a range $0 < D(x, y, b) \leqslant 1$, assuming inputs and outputs are weakly disposable. It has the following properties: (i) it is almost homogeneous $D(\mu^{-1}x, \mu y, \mu^{-1}b) = \mu D(x, y, b), \mu > 0$, (ii) it is non-decreasing in desirable outputs $D(x, \lambda y, b) \leqslant D(x, y, b), \lambda \in [0, 1]$ (iii) it is non-increasing in undesirable outputs $D(x, y, \lambda b) \leqslant D(x, y, b), \lambda \geqslant 1$ (iv) it is non-increasing in inputs $D(\lambda x, y, b) \leqslant D(x, y, b), \lambda \geqslant 1$.

[7] We can now estimate Eq. (6) with various methods, e.g. maximum likelihood estimation (Battese and Coelli, 1988) where the technical efficiency of each observed unit is expressed as $TE_{it} = \exp(-u_{it})$ (Battese and Coelli, 1992; Greene, 2005).

[8] We specify model (7) for three inputs, two desirable outputs, and two undesirable outputs (see Data section). y_2 (net earning assets) normalises other output and input variables.

$$
\begin{aligned}
-\ln(y_{2i}) = {} & \alpha_0 + \sum_{k=1}^{3}\alpha_k \ln x_{ki}^* + \sum_{m=1}^{1}\beta_m \ln y_{mi}^* + \sum_{r=1}^{2}\chi_r \ln b_{ri}^* \\
& + \frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3}\alpha_{kl} \ln x_{ki}^* \ln x_{li}^* + \frac{1}{2}\sum_{m=1}^{1}\sum_{n=1}^{1}\beta_{mn} \ln y_{mi}^* \ln y_{ni}^* \\
& + \frac{1}{2}\sum_{r=1}^{2}\sum_{s=1}^{2}\chi_{rs} \ln b_{ri}^* \ln b_{si}^* + \sum_{k=1}^{3}\sum_{m=1}^{1}\delta_{km} \ln x_{ki}^* \ln y_{mi}^* \\
& + \sum_{k=1}^{3}\sum_{r=1}^{2}\gamma_{kr} \ln x_{ki}^* \ln b_{ri}^* + \sum_{m=1}^{1}\sum_{r=1}^{2}\eta_{mr} \ln y_{mi}^* \ln b_{ri}^* + at \\
& + \frac{1}{2}bt^2 + \sum_{k=1}^{3}c_{kt} \ln x_{ki}^* t + \sum_{m=1}^{1}d_{mt} \ln y_{mi}^* t + \sum_{r=1}^{2}f_{rt} \\
& \times \ln b_{ri}^* t + v_{it} - u_{it} \qquad (7)
\end{aligned}
$$

It is very unlikely that technology is constant over time; therefore, we incorporate time variable t to capture neutral technical change. We estimate Eq. (7) using time-varying decay technique, following Battese and Coelli (1992).

5. Data

Our dataset is drawn from semi-annually financial reports of Japanese commercial banks during 2000–2012, published on the Japanese Bankers Association website. We obtain an unbalanced panel data with 3036 observations, embracing City Banks, Regional Banks I, and Regional Banks II.

Being the largest commercial banks in Japan, City Banks comprise of nationwide branching institutions. Their primary funding sources vary from the Bank of Japan to the deposit and short-term financial markets. They also involve in securities–type operations domestically and internationally (Drake and Hall, 2003; Tadesse, 2006). In contrast, Regional Banks I are smaller than City Banks and operate only in the principal cities of the prefectures where their head offices are situated. They have a strong commitment with the local development through financing small and medium business activities. Regional Banks II[9] are similar to Regional Banks I in terms of business features, but smaller than Regional Banks I in size. They also offer financial services for customers within their immediate geographical regions.

In the data set, six banks report negative shareholders' equity in 2000–2007. Three of those banks (Ashikaga Bank, Kinki Osaka Bank, and Tokyo Sowa Bank) were bailed out to continue operating. On 12/6/1999, the Bank of Japan announced to provide necessary funds to assist the business continuation of Tokyo Sowa Bank.[10] Tokyo Sowa Bank only had negative equity and net income in September 2000. Ashikaga Bank also received liquidity support for undercapitalisation and income loss in September 2003.[11] Unlike Tokyo Sowa Bank, Ashikaga Bank could not raise enough capital at the end of the first halves of fiscal years 2004–2007. After September 2007, Ashikaga Bank operation was restored. On the other hand, Kinki Osaka Bank suffered from capital loss only in September 2003. The Bank of Japan did not intervene in the case of Kinki Osaka Bank as it gained positive equity in the following period. Unlike these three banks which have successfully recovered from the banking turbulence and continued their normal operation, the other three banks (Kofuku Bank, Ishikawa Bank, and Chubu Bank) were unable to survive through the crisis and had to terminate their business after September 2002 and 2003.

With respect to input and output definitions of Japanese commercial banks used in Eq. (7),[12] we follow the widely used intermediation approach (Sealey and Lindley, 1977). We characterise three proxies for inputs: x_1 interest expenses (Glass et al., 2014; Liu and Tone, 2008), x_2 fixed assets (Assaf et al., 2011; Fukuyama and Weber, 2008), and x_3 general and administrative expenses[13] (Drake and Hall, 2003; Liu and Tone, 2008). We define our outputs in line with Barros et al. (2009), Assaf et al. (2011), Barros et al. (2012) as y_1 net loans and bills discounted, and y_2 net earning assets which include net investments, securities, and other earning assets. Data are adjusted for inflation using semi-annual GDP deflator (2005 = 100). Table 1 describes the summary statistics of key variables in our panel data.

Turning to problem loans, a loan is defined as non-performing if payment of interests and principal are past due by 90 days or more, or if there are doubts that debt payments can be made in full. The availability of data allows us to distinguish the two classifications of problem assets in Japan. They are "risk-monitored loans" disclosed in accordance with the Banking Law, and "problem assets" disclosed under the Financial Reconstruction Law. According to the Financial Reconstruction Law, problem other earning assets (claims related to securities lending, foreign exchanges, accrued interests, suspense payments, customers' liabilities for acceptances and guarantees, and bank-guaranteed bonds sold through private placements) are subject to the disclosure of problem assets. We follow the problem assets definition based on the Financial Reconstruction Law to define undesirable outputs in our efficiency estimation (please see Appendix A). The first undesirable output is problem loans b_1, the second one is problem other earning assets b_2. Problem loans are bankrupt, quasi-bankrupt loans, doubtful loans, and substandard loans. Problem other earning assets are bankrupt, quasi-bankrupt and doubtful other earning assets.[14] The disclosed information from our data set is quite novel as it is for the first time that undesirable outputs are disaggregated into problem loans and problem other earning assets. The only study that we are aware of is Barros et al. (2012) but they did not disaggregate the data.

To represent the level of risk, we employ data of risk-monitored loans disclosed subject to the Banking Law (see Appendix A). Another innovation of this paper is that we further disaggregate risk-monitored loans into two components: the first one is the sum of bankrupt loans and non-accrual loans,[15] the second one is the sum of past due loans by 3 months or more but less than 6 months, and restructured loans.[16] To facilitate the analysis and the exposition of results, we name the first class of risk-monitored loans as bankrupt loans, whereas the second class is the restructured loans. These two types of risk-monitored loans contain information about the level of risk held in each bank, and partly reflect the exogenous impact of problem loans on bank operation. In the short-run, banks somewhat rely on their borrowers to reduce the level of these risk-monitored loans. This disaggregation permits us to further examine the relationship between bankrupt loans, restructured loans and bank efficiency.

To account for bank specific characteristics, we opt for performance variables which are represented by return on assets

[9] Regional Banks II are also called members of the Second Association of Regional Banks (Japanese Bankers Association website – Principle Financial Institutions).

[10] Bank of Japan's statements (https://www.boj.or.jp/en/announcements/press/danwa/dan9906b.htm/).

[11] Bank of Japan's statements (https://www.boj.or.jp/en/announcements/press/danwa/dan0311a.htm/).

[12] Our inputs and outputs specification is similar to Fukuyama and Weber (2008, 2009), Barros et al. (2009, 2012).

[13] As data for number of employees are not available semi-annually.

[14] The values of problem other earning assets = Problem assets − Risk-monitored loans (see Appendix A for more details).

[15] Reported in Japanese commercial banks' balance sheets, these loans are loans to borrowers in the state of legal bankruptcy, and past due loans in arrears of six months or more.

[16] The Japanese Bankers Association originally defined restructured loans as loans for which interest rates were lowered. In 1997, the definition was extended to loans with any amended contract conditions and loans to corporations under ongoing reorganisation (Montgomery and Shimizutani, 2009).

Table 1
Descriptive statistics.

Variable	Name	Mean	Std.Dev	Min	Max
y_1	Net loans	3,182,876	7,867,099	109898.9	69,541,992
y_2	Net earning assets	2,178,294	7,419,522	1296.512	78,517,385
b_1	Problem loans	143582.6	371639.3	5207.246	6,060,743
b_2	Problem non-loan assets	4294.59	16352.12	0	280,278
x_1	Interest expenses	17093.14	80852.25	45.966	1,379,955
x_2	Fixed assets	60392.48	141052.1	2463.104	1,278,986
x_3	General and administrative expenses	37441.04	88237.43	1438.638	1,086,994
	Total assets	5,833,343	16,390,968	172,320	151,697,392
cap	Capital ratio	0.04324	0.02552	−0.78823	0.12787
NIM	Net interest margin	0.01329	0.00553	0.00076	0.03794
ROA	Return on assets	0.00013	0.0084	−0.29452	0.05886

Notes: y_1, y_2, x_1, x_2, x_3, b_1, b_2, total assets are in million Yen. Net loans = Loans and bills discounted-Problem loans. Net earning assets = (call loans, receivables under resale agreement, receivables under securities borrowing transactions, bills bought, monetary claims bought, foreign exchanges, customers' liabilities for acceptances and guarantees, investment securities, and other assets) – problem other earning assets. Problem loans are bankrupt, quasi-bankrupt, doubtful, and substandard loans. Problem other earning assets are bankrupt, quasi-bankrupt, and doubtful other earning assets. Capital ratio = shareholders'equity/total assets. Net interest margin = (interest income–interest expense)/(interest-earning assets). Std.Dev: standard deviation.

(ROA), and net interest margin (NIM) (Glass et al., 2014). NIM is defined by the difference between interest incomes and interest expenses to total interest-earning assets (Nguyen, 2012). To control for the leverage effect which is the higher the leverage ratio, the more volatile the return (Saunders et al., 1990), we use the capital to assets ratio, which also accounts for bank capitalisation.

In terms of macroeconomic variables, we select the Nikkei 225 index as a proxy for the stock market performance, the industrial production index as a measure of business activity (Officer, 1973), and the total reserves held by the Bank of Japan at the end of each period as a proxy for quantitative easing policy (Lyonnet and Werner, 2012; Voutsinas and Werner, 2011). The inclusion of quantitative easing takes into account the effect of monetary policy in promoting bank lending and adjusting the performance of contemporary financial institutions. During the observed period, the Bank of Japan applied quantitative easing from March 2001 to March 2006 in order to maintain the target inflation rate and the level of current account balances held by depository institutions at the Bank (Berkmen, 2012). In addition, the purchase of long-term Japanese government bonds – the main instrument of quantitative easing - and other asset purchase programs reduced yields (Lam, 2011; Ueda, 2012; Ugai, 2007) and assisted the Bank of Japan to maintain the "zero interest rates" policy.[17] However, in terms of economic activity and inflation, whether or not the quantitative easing policy in Japan was effective remains ambiguous. Baumeister and Benati (2010) and Girardin and Moussa (2011) find it effective, whereas Ugai (2007) finds little evidence. Bowman et al. (2011) suggest that the stimulus to economic growth from quantitative easing might be undermined by excessive spending on the weak banking system and firm balance sheet problems.

To account for market concentration, we use the Herfindahl–Hirschman Index (HHI) (Bikker, 2004). However, as concentration ratio is a rather crude indicator which measures the actual market shares disregarding inferences about bank competitiveness (Beck, 2008), we also use the Boone indicator as a proxy for competition.[18] Regarding risk variables, because most banks in our sample are not listed, we opt for accounting measures rather than market-based measures to compute risk. The most common risk proxy for banks is the Z-score, which is the number of standard deviations below the mean by which bank returns would have to fall so as to dry up capital (Boyd and Runkle, 1993; Hannan and Hanweck, 1988). The higher Z-score indicates bank stability or lower insolvency risk. More importantly, we introduce risk-monitored loans as another proxy for risk in our model. As discussed above, the disaggregation of risk-monitored loans into bankrupt loans and restructured loans allows us to measure their exogenous effects on bank efficiency and ROA. In the short-run, bankrupt loans and restructured loans are not subject to the control of bank management but the recovery of debtors and their compliance with the loan contracts.

6. Results

6.1. Technical efficiency

Regarding input and desirable output elasticities, all the parameters are statistically significant and consistent with the monotonic condition. All three inputs exhibit expected negative signs, satisfying the property of non-increasing in inputs of $D(x,y,b)$, and indicating a smaller distance to the frontier when input usage is reduced. The magnitude of these coefficients suggests that the contribution of fixed assets ($\alpha_2 = -0.379$) to the production process outnumbers the other two. More specifically, the elasticities of interest expenses and general and administrative expenses are quite small and similar. The small magnitude of the coefficient of interest expenses ($\alpha_1 = -0.0173$) could be explained by the implementation of the virtually zero interest rate during 2000–2006. The reported coefficient of y_1 (0.465) is positively significant, confirming the non-decreasing characteristic in good outputs. This is what we could expect as loans are the main products of banking operation. Our findings also suggest that Japanese commercial banks experience decreasing returns to scale (0.8427, with associated standard error of 0.0102 significantly different from one at the 1% level). Previous studies have found that decreasing returns to scale is valid in the case of City Banks (Altunbas et al., 2000; Azad et al., 2014; Drake and Hall, 2003; Tadesse, 2006); while Regional Banks exhibit increasing returns to scale (Altunbas et al., 2000). Therefore, results are rather mixed (see also Fukuyama, 1993; McKillop et al., 1996).

In terms of undesirable output elasticity, problem loans ($\chi_1 = -0.0261$) are found to have a significant negative impact on bank performance, in line with findings from Glass et al. (2014) for credit cooperatives. The finding suggests that problem loans

[17] Examples of other asset purchase programs: the purchase of asset-backed securities from July 2003 to March 2006; and the program under the Comprehensive Monetary Easing in October 2010, which expanded the types of assets purchased into private sector financial assets.

[18] The authors gratefully acknowledge the suggestion of an anonymous referee in choosing a better proxy for competition such as the Boone indicator, as HHI is a poor indicator of competition compared to non-structural ones. Please see Appendix C for the methodology used to derive the Boone indicator.

are more important than interest expenses and general and administrative expenses in affecting bank efficiency. The coefficient of problem other earning assets – the second bad output in our undesirable output vector, however, is insignificant. The results might imply that problem other earning assets are not the main source of bank inefficiency.

Table 2 exhibits technical efficiency (TE) scores for three groups of Japanese commercial banks over each observed period. The average technical efficiency of all banks over the entire period is 0.612, suggesting that Japanese commercial banks can improve their performance by increasing their desirable outputs by $[(1/0.612) - 1] = 63.4\%$, whereas simultaneously reducing inputs and bad outputs by $[1–0.612] = 38.8\%$. Overall, the time varying technical efficiency scores of all banks expose a slight downward trend over time. This is consistent with our finding of no presence of technical progress over years. Within each group of banks, there is a minor variation in the decreasing trend of mean technical efficiency. For example, scores of Regional Banks II dropped after rising in March 2002, while that of City Banks climbed from 32.93% in September 2007 to 33.99% in March 2008.

Illustrated in Fig. 2 is kernel density graph mapping the distribution of technical efficiency scores by bank type. We find that City Banks are the least efficient banks with average technical efficiency at 34.55% compared to their counterparts, whereas Barros et al. (2012) find a high level of efficiency for City Banks. Being the smallest in bank size, Regional Banks II seem to be the most efficient with mean TE at 70.49%. A potential explanation for the high TE of Regional Banks could be that under the Temporary Measures to Facilitate Financing for SMEs, banks are encouraged not only to supply loans in favour of SMEs, but also to relax the conditions of these loans. Under certain conditions, a loan to an SME debtor about to be classified as nonperforming could be considered as performing, as long as the borrower could provide a promising business reconstruction plan within one year from the date the loan was due to be nonperforming (Hoshi, 2011).

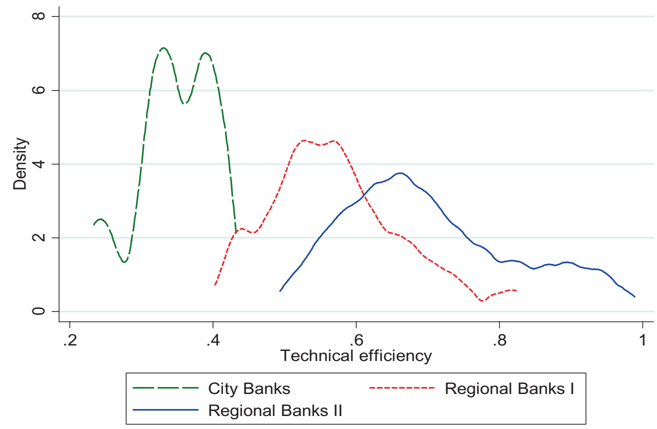

Fig. 2. Technical efficiency scores by bank type. Notes: This Figure illustrates kernel density plots of technical efficiency scores by each type of banks.

6.2. The impact of bankrupt loans and restructured loans on bank performance

In this section, we perform baseline regressions to investigate the relationship between risk-monitored loans and performance (technical efficiency and return on assets), taking into consideration the impact of bank specific and macroeconomic variables. We present results for both a fixed effect model to account for the unobserved heterogeneity across banks, and a two-stage least squares model to control for endogeneity. The dependent variables are: (i) technical efficiency TE; and (ii) return on assets ROA. As discussed in Section 5, we treat bankrupt loans and restructured loans as measures of risk. The analysis is also conducted for Z-score to test the robustness of the results. Risk proxies are respectively incorporated with alternative instruments. The results are reported

Table 2
Technical efficiency scores by bank type over time.

Bank type	City banks					Regional banks I					Regional banks II				
Period	Obs	Mean	Std.dev	Min	Max	Obs	Mean	Std.dev	Min	Max	Obs	Mean	Std.dev	Min	Max
Sep-00	8	0.3700	0.0412	0.3218	0.4325	64	0.5807	0.0922	0.4256	0.8231	55	0.7274	0.1212	0.5150	0.9890
Mar-01	8	0.3691	0.0412	0.3209	0.4316	64	0.5811	0.0926	0.4247	0.8227	55	0.7221	0.1202	0.5142	0.9889
Sep-01	8	0.3682	0.0412	0.3200	0.4307	64	0.5835	0.0923	0.4238	0.8223	55	0.7194	0.1205	0.5133	0.9889
Mar-02	7	0.3697	0.0439	0.3191	0.4298	64	0.5805	0.0918	0.4229	0.8219	55	0.7210	0.1206	0.5125	0.9889
Sep-02	7	0.3555	0.0625	0.2518	0.4289	64	0.5788	0.0930	0.4220	0.8215	55	0.7166	0.1186	0.5116	0.9889
Mar-03	7	0.3474	0.0551	0.2509	0.4065	64	0.5769	0.0927	0.4211	0.8211	52	0.7113	0.1186	0.5108	0.9888
Sep-03	7	0.3465	0.0551	0.2501	0.4056	64	0.5764	0.0936	0.4202	0.8207	50	0.7070	0.1194	0.5099	0.9888
Mar-04	7	0.3456	0.0550	0.2492	0.4047	64	0.5756	0.0937	0.4193	0.8203	49	0.7089	0.1195	0.5091	0.9888
Sep-04	7	0.3447	0.0550	0.2483	0.4038	64	0.5718	0.0914	0.4184	0.8199	48	0.7087	0.1209	0.5082	0.9888
Mar-05	7	0.3438	0.0550	0.2475	0.4029	64	0.5710	0.0915	0.4175	0.8195	47	0.7085	0.1224	0.5073	0.9887
Sep-05	7	0.3429	0.0550	0.2466	0.4020	64	0.5730	0.0933	0.4166	0.8191	47	0.7079	0.1227	0.5065	0.9887
Mar-06	6	0.3435	0.0601	0.2458	0.4011	64	0.5723	0.0934	0.4157	0.8187	46	0.7028	0.1202	0.5056	0.9887
Sep-06	6	0.3426	0.0600	0.2449	0.4002	64	0.5715	0.0935	0.4148	0.8183	46	0.7022	0.1204	0.5048	0.9886
Mar-07	6	0.3417	0.0600	0.2441	0.3993	64	0.5707	0.0936	0.4139	0.8179	45	0.7000	0.1214	0.5039	0.9886
Sep-07	6	0.3293	0.0592	0.2432	0.3972	64	0.5699	0.0937	0.4130	0.8175	44	0.6957	0.1205	0.5031	0.9886
Mar-08	6	0.3399	0.0600	0.2423	0.3974	64	0.5692	0.0939	0.4121	0.8171	44	0.6951	0.1207	0.5022	0.9886
Sep-08	6	0.3390	0.0600	0.2415	0.3965	64	0.5684	0.0940	0.4111	0.8166	44	0.6945	0.1209	0.5013	0.9885
Mar-09	6	0.3381	0.0599	0.2406	0.3956	64	0.5676	0.0941	0.4102	0.8162	43	0.6959	0.1218	0.5005	0.9885
Sep-09	6	0.3373	0.0599	0.2398	0.3947	64	0.5668	0.0942	0.4093	0.8158	43	0.6953	0.1220	0.4996	0.9885
Mar-10	6	0.3364	0.0599	0.2389	0.3938	64	0.5661	0.0943	0.4084	0.8154	41	0.6961	0.1242	0.4988	0.9884
Sep-10	6	0.3355	0.0599	0.2381	0.3929	63	0.5665	0.0946	0.4075	0.8150	41	0.6955	0.1244	0.4979	0.9884
Mar-11	6	0.3346	0.0598	0.2373	0.3920	63	0.5657	0.0948	0.4066	0.8146	41	0.6949	0.1246	0.4970	0.9884
Sep-11	6	0.3337	0.0598	0.2364	0.3911	63	0.5649	0.0949	0.4057	0.8142	41	0.6943	0.1248	0.4962	0.9884
Mar-12	6	0.3328	0.0598	0.2356	0.3902	63	0.5642	0.0950	0.4048	0.8138	41	0.6937	0.1250	0.4953	0.9883
Sep-12	6	0.3319	0.0598	0.2347	0.3892	63	0.5634	0.0951	0.4039	0.8133	40	0.6942	0.1266	0.4945	0.9883
Mar-13	6	0.3310	0.0598	0.2339	0.3883	63	0.5626	0.0952	0.4030	0.8129	40	0.6936	0.1268	0.4936	0.9883
All	169	0.3455	0.0530	0.2339	0.4325	1646	0.5715	0.0930	0.4030	0.8231	1203	0.7050	0.1209	0.4936	0.9890

Notes: This Table reports average scores of technical efficiency in each period for each type of banks. The scores are obtained from estimating Eq. (7), using time-varying decay technique (Battese and Coelli, 1992). Obs: number of observations; Std.dev: standard deviation; Mar: March; Sep: September; 00–13: 2000–2013.

in Tables 3 and 4, whereas robustness checks with the Boone indicator as a proxy for competition are provided in Tables 5 and 6.

For fixed effect models, generally, bankrupt loans and restructured loans do not affect technical efficiency and ROA in a similar way. The relationship is found positive for these risk-monitored loans and TE, whereas an inverse one applies for ROA. The influences are statistically significant but small in magnitude. When we replace risk-monitored loans by Z-score, the same conclusion can be drawn for the risk - efficiency/ROA nexus. Specifically, while Z-score shows a negative, insignificant effect on TE, its influence on ROA is positively significant. These initial evidences reveal that the less involvement in risky projects of the bank, the higher the level of its ROA. Regarding other control variables, higher capital to assets ratio would increase bank profitability. In a similar aspect, when the stock price and industrial indices rise, Japanese banks' performance would be improved. The measure of market concentration, the HHI index, is significant in most cases, but the effect varies. We obtain quite a similar pattern for the influence of total reserves.

Given endogeneity concerns, we proceed with a two-stage least square regression. We examine the model with the same two dependent variables and alternative instrumental variables for risk proxies (see Table 4). The impacts of almost all variables are consistent with findings from the fixed effect models. In terms of bank characteristics, capitalisation appears to have a positive significant effect on performance, suggesting that banks with lower leverage ratio operate more efficiently, in line with Pasiouras (2008). It is also well-known in the literature that well-capitalised banks will have higher ROA than their under-capitalised counterparts (Demirgüç-Kunt and Huizinga, 1999). Net interest margin also comes consistently positively significant in relation with TE. On the other hand, the relationship between NIM and ROA is negative, in accordance with Goldberg and Rai (1996) who argue that more efficient banks are flexible to offer depositors and borrowers attractive interest rates. Even though the spread is smaller for those banks than that of less efficient banks, they could still be able to generate higher profit thanks to the larger quantity of loans.

Regarding the influence of macroeconomic variables, the Nikkei index and industrial production index yield equivalent impact on TE. A rise in the stock price index would positively affect the efficiency level of Japanese banks. Investment prospects signified by a rise in the stock price index could bring promising loan portfolios to commercial banks. Similar is the case of escalating manufacturing output which denotes an expansion period of the economy. In addition, the likelihood of nonperforming loans would be expected to be relatively small. Put differently, financial institutions could be able to expand their good outputs and lessen their bad outputs, which then help to improve their technical efficiency. In terms of ROA, the results are mixed. An increase in the stock price index is not necessarily associated with higher ROA. As not many banks in our sample are listed, the benefit they would acquire from the difference in stock prices might be negligible compared to the mounting fund required to purchase those securities. Regional Banks, in particular, invest mostly in government bonds and local government bonds, which are less volatile than other securities, and thus might be indifferent to market volatility.

Another influential variable is the degree of concentration which is significant and negatively correlated with TE. This finding is related to Homma et al. (2014) who report that market concentration dampens cost efficiency of large Japanese banks. Coming to ROA, our evidence suggests a positive impact of HHI. Regardless the causality, this somehow supports the efficient-structure hypothesis (Demsetz, 1973; Smirlock, 1985) that banks with larger market share have greater profitability. Differently phrased, our findings could be expressed as heightened competition resulting in higher likelihood of default, which supports the results of Fu et al. (2014). Using the Lerner index as a proxy for market power of Asia Pacific banks (Japanese banks inclusive), they find a presence of the "competition-fragility" hypothesis. Employing the 3-bank concentration ratio, Liu et al. (2012) also report that South East Asian banks in more concentrated market are less exposed to systemic risk. With respect to the coefficients of total reserves, we find mixed results for the effect of quantitative easing on bank performance.

Table 3
Impact of bankrupt loans and restructured loans on performance – fixed effect models.

Model Dependent variable	Model 1 TE	Model 2 TE	Model 3 TE	Model 4 ROA	Model 5 ROA	Model 6 ROA
Capital ratio	−0.00265	0.00384	−0.00135	0.245***	0.241***	0.251***
	(0.0028)	(0.00258)	(0.00248)	(0.00488)	(0.00483)	(0.00472)
Net interest margin	0.135***	0.122***	0.108***	−0.109***	−0.0859***	−0.0877***
	(0.0098)	(0.0096)	(0.0095)	(0.0217)	(0.0216)	(0.022)
Nikkei index	0.000321	0.000710**	0.000331	0.00155**	0.00122*	0.00185***
	(0.000321)	(0.000309)	(0.000301)	(0.000713)	(0.000695)	(0.000698)
Industrial production	0.00381***	0.00361***	0.00082	0.00317**	0.00366**	0.00551***
	(0.000724)	(0.000704)	(0.000713)	(0.00161)	(0.00158)	(0.00165)
Herfindahl–Hirschman Index	−0.353***	−0.331***	−0.298***	0.0772***	0.0343***	0.0323***
	(0.0041)	(0.00429)	(0.00504)	(0.00909)	(0.00962)	(0.0117)
Quantitative easing	−0.00129***	−0.00129***	−0.00140***	0.000643***	0.000709***	0.000790***
	(9.58E-05)	(9.22E-05)	(9.06E-05)	(0.000212)	(0.000207)	(0.00021)
Z-score	-5.89E-07			7.27E-05**		
	(1.41E-05)			(3.08E-05)		
Bankrupt loans		0.00170***			−0.00283***	
		(0.000137)			(0.000308)	
Restructured loans			0.00113***			−0.000820***
			(6.81E-05)			(0.000158)
Constant	0.632***	0.609***	0.632***	−0.0536***	−0.0180**	−0.0565***
	(0.00338)	(0.00373)	(0.00318)	(0.00749)	(0.00839)	(0.00736)
R-sq	0.0149	0.0162	0.0089	0.4384	0.3872	0.4456
p value (*F*-test)	0.00	0.00	0.00	0.00	0.00	0.00

Notes: This Table reports results of the fixed effect models examining the impact of control variables on technical efficiency and return on assets. The proxy for risk (Z-score, bankrupt and restructured loans) is alternatively incorporated in the models. Quantitative easing is proxied by the natural logarithm of total reserves; Z-score = (ROA + capital ratio)/σROA. Bankrupt loans = Bankrupt loans + Non-accrual loans; Restructured loans = past due loans over 3 months but less than 6 months + Restructured loans. Standard errors in parentheses, $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 4
Impact of bankrupt loans and restructured loans on performance – two-stage least squares models.

Model Dependent variable	Model 1 TE	Model 2 TE	Model 3 TE	Model 4 TE	Model 5 ROA	Model6 ROA	Model 7 ROA	Model 8 ROA
Capital ratio	0.0756***	0.366**	−0.00255	−0.00261	0.142***	0.00942	0.235***	0.242***
	(0.012)	(0.156)	(0.00425)	(0.0032)	(0.0187)	(0.119)	(0.00902)	(0.00911)
Net interest margin	0.141***	0.164**	0.135***	0.133***	−0.124***	−0.145**	−0.0741***	0.0977
	(0.017)	(0.0669)	(0.0118)	(0.0389)	(0.0313)	(0.058)	(0.0261)	(0.128)
Nikkei index	0.00491***	0.0219**	0.000327	0.000319	−0.00580***	−0.0150*	0.000859	0.00169*
	(0.000853)	(0.00936)	(0.000375)	(0.000315)	(0.00158)	(0.00844)	(0.000828)	(0.000956)
Industrial production	0.00700***	0.0188**	0.00381***	0.00363	−0.00201	−0.00845	0.00384**	0.0263*
	(0.00133)	(0.00798)	(0.00073)	(0.00425)	(0.00246)	(0.00704)	(0.00161)	(0.0141)
Herfindahl–Hirschman Index	−0.427***	−0.699***	−0.353***	−0.350***	0.199***	0.352**	0.0133	−0.348
	(0.0126)	(0.149)	(0.0124)	(0.0773)	(0.0237)	(0.138)	(0.0276)	(0.256)
Quantitative easing	−0.000156	0.00406*	−0.00130***	−0.00130***	−0.00116***	−0.00341	0.000707***	0.00153***
	(0.000231)	(0.00235)	(9.46E-05)	(0.000174)	(0.000422)	(0.00208)	(0.000208)	(0.000574)
Z-score	−0.00107***	−0.00503**			0.00178***	0.00392**		
	(0.000153)	(0.00212)			(0.000282)	(0.00192)		
Bankrupt loans			3.66E-05				−0.00441**	
			(0.000877)				(0.00197)	
Restructured loans				6.67E-05				−0.00865
				(0.00159)				(0.00527)
Constant	0.590***	0.436***	0.632***	0.632***	0.012	0.0942	0.00326	−0.0585***
	(0.00829)	(0.0859)	(0.0123)	(0.00334)	(0.0151	(0.0758)	(0.0275)	(0.0101)
R-sq	0.0175	0.0137	0.0136	0.0119	0.0428	0.0255	0.3113	0.0883
p value (*F*-test)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: This Table reports results of the two-stage least squares models examining the impact of control variables on technical efficiency and return on assets. The proxy for risk (Z-score, bankrupt and restructured loans) is alternatively incorporated in the models with different instruments. Quantitative easing is proxied by the natural logarithm of total reserves. Z-score = (ROA + capital ratio)/σROA. Bankrupt loans = Bankrupt loans + Non-accrual loans; Restructured loans = past due loans over 3 months but less than 6 months + Restructured loans. Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 5
Impact of bankrupt loans and restructured loans on performance – fixed effect models – robustness check.

Model Dependent variable	Model 1 TE	Model 2 TE	Model 3 TE	Model 4 ROA	Model 5 ROA	Model 6 ROA
Capital ratio	−0.0128***	0.0245*	0.0076	0.2482***	0.2401***	0.2508***
	(0.0034)	(0.0133)	(0.0081)	(0.0691)	(0.0702)	(0.0693)
Net interest margin	0.0478***	0.0402***	0.0273**	−0.0756**	−0.0613**	−0.0642**
	(0.0117)	(0.0128)	(0.0105)	(0.0296)	(0.0278)	(0.0285)
Nikkei index	−0.0027***	−0.0003	−0.0009***	0.0021***	0.0012*	0.0019***
	(0.0002)	(0.0002)	(0.0002)	(0.0005)	(0.0006)	(0.0006)
Industrial production	0.0116***	0.0108***	0.001	0.0015	0.0029**	0.0051***
	(0.0005)	(0.0007)	(0.001)	(0.0015)	(0.0011)	(0.0013)
Boone indicator	−0.1003***	−0.0824***	−0.0551***	0.0272***	0.0154**	0.0134*
	(0.0033)	(0.0037)	(0.0035)	(0.0076)	(0.0064)	(0.008)
Quantitative easing	−0.0055***	−0.0046***	−0.0039***	0.0017***	0.0012***	0.0012***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Z-score	0.0003***			0.0000		
	(0.0000)			(0.0001)		
Bankrupt loans		0.0046***			−0.003***	
		(0.0005)			(0.0006)	
Restructured loans			0.0031***			−0.0009***
			(0.0003)			(0.0002)
Constant	0.6378***	0.5655***	0.6298***	−0.0546***	−0.0149	−0.0558***
	(0.0031)	(0.0079)	(0.0039)	(0.008)	(0.0106)	(0.0065)
R-sq	0.004	0.2767	0.1971	0.4805	0.3764	0.092
p value (*F*-test)	0.00	0.00	0.00	0.00	0.00	0.00

Notes: This Table reports results of the fixed effect models examining the impact of control variables on technical efficiency and return on assets. We replace HHI with the Boone indicator as a proxy for competition. The proxy for risk (Z-score, bankrupt and restructured loans) is alternatively incorporated in the models. Quantitative easing is proxied by the natural logarithm of total reserves; Z-score = (ROA + capital ratio)/σROA. Bankrupt loans = Bankrupt loans + Non-accrual loans; Restructured loans = past due loans over 3 months but less than 6 months + Restructured loans. Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Corresponding to findings of the fixed effect estimation, two-stage least square models confirm the impact of bankrupt loans and restructured loans on performance. The results represent a positive relationship between risk-monitored loans and TE, though the impact is statistically insignificant. In contrast, these loans negatively affect ROA, with restructured loans being negligible compared to bankrupt loans. Our findings are reinforced when Z-score is used, and support the results from fixed effect models.

When HHI is replaced by the Boone indicator as a robustness exercise, the impact stemming from most control variables on TE/ROA is confirmed. Noteworthy, the effects of capitalisation, the stock price index, and Z-score vary compared to prior results. In model 1 reported in Table 5, capital ratio is found to be negatively associated with TE, whilst the relationship turns out positive in the other models. There is an ambiguous picture for the effect of stock price index on performance as the Nikkei index consistently becomes negative in affecting TE. Z-score, previously found insignificant in model 1-Table 3, appears positive and significant. Yet, the magnitude of the effect is approximately zero, similar to the former result. We also find the same variation for these variables in our two-stage least square analysis, except the effect of capital ratio which is convincingly positive and significant.

Table 6
Impact of bankrupt loans and restructured loans on performance – two-stage least squares models – Robustness check.

Model Dependent variable	Model 1 TE	Model 2 TE	Model 3 TE	Model 4 TE	Model 5 ROA	Model6 ROA	Model 7 ROA	Model 8 ROA
Capital ratio	0.1152**	−0.0583	0.0685***	0.0254***	0.1453***	0.184***	0.1859***	0.2065***
	(0.0483)	(0.0371)	(0.0076)	(0.0067)	(0.0295)	(0.0282)	(0.0103)	(0.0104)
Net interest margin	0.1098***	0.0854***	0.0667***	0.0471***	−0.0931***	−0.0559***	−0.0622***	−0.0639***
	(0.0197)	(0.0178)	(0.016)	(0.0142)	(0.0224)	(0.0202)	(0.0218)	(0.0222)
Nikkei index	−0.0028***	−0.0048***	−0.0016***	−0.002***	0.0018**	0.0031***	0.0014**	0.002***
	(0.0008)	(0.0006)	(0.0005)	(0.0004)	(0.0008)	(0.0007)	(0.0007)	(0.0007)
Industrial Production	0.0181***	0.0139***	0.0132***	0.0015***	−0.0008	0.0025	0.0028*	0.006***
	(0.0017)	(0.0014)	(0.0011)	(0.001)	(0.0017)	(0.0015)	(0.0015)	(0.0016)
Boone indicator	−0.0962***	−0.0964***	−0.0757***	−0.0458***	0.0227***	0.021***	0.0124***	0.0073*
	(0.0031)	(0.0028)	(0.0028)	(0.0027)	(0.0036)	(0.0032)	(0.0038)	(0.0042)
Quantitative easing	−0.0042***	−0.0049***	−0.0038***	−0.0031***	0.0011***	0.0014***	0.001***	0.0009***
	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Z-score	−0.0003	0.0005***			0.0003**	−0.0001		
	(0.0002)	(0.0002)			(0.0002)	(0.0001)		
Bankrupt loans			0.0054***				−0.0032***	
			(0.0003)				(0.0003)	
Restructured loans				0.0035***				−0.0012***
				(0.0001)				(0.0001)
Constant	0.6031***	0.6357***	0.5464***	0.6235***	−0.0397***	−0.0603***	−0.0105	−0.0539***
	(0.0106)	(0.0086)	(0.0059)	(0.0043)	(0.0097)	(0.0085)	(0.008)	(0.0068)
R-sq	0.0207	0.006	0.3267	0.2337	0.0792	0.1156	0.092	0.14
p value (chi2-test)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: This Table reports results of the two-stage least squares models examining the impact of control variables on technical efficiency and return on assets. We replace HHI with the Boone indicator as a proxy for competition. The proxy for risk (Z-score, bankrupt and restructured loans) is alternatively incorporated in the models with different instruments. Quantitative easing is proxied by the natural logarithm of total reserves. Z-score = (ROA + capital ratio)/σROA. Bankrupt loans = Bankrupt loans + Non-accrual loans; Restructured loans = past due loans over 3 months but less than 6 months + Restructured loans. Standard errors in parentheses, $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Our robustness exercise reveals firm evidence to portray a negative relationship between quantitative easing and TE, whereas it is positive in the case of ROA. A potential explanation could lie on fewer interest expenses due to the virtually zero interest rate policy that could results in higher returns on assets. However, expansionary policy which stimulates investments and funding, especially when aiming to channelling credit to SMEs, could create a latent problem of adverse selection and decelerate the progress of contracting problem loans (International Monetary Fund, 2003). Low interest rates could also heighten banks' risk-tolerance through higher asset prices and collateral values (Altunbas et al., 2010). Given the adverse effect of the banking crisis in Japan, a contrast experience of risk-aversion could also prevail, causing banks which had undergone the tough period to hesitate to extend credit. In fact, although ample liquidity was provided by quantitative easing, bank lending did not rise proportionately during 1999–2005 (Ito, 2006).

The results are robust for the impact of competition on performance. Indicated in Boone et al. (2007), the larger the Boone indicator in absolute value signifies the higher the degree of competition. The reported coefficient of the Boone indicator in Tables 5 and 6 confirm the competition – efficiency nexus hypothesising that heightened competition would stimulate banks to minimise costs and maximise outputs (Andrieş and Căpraru, 2014; Schaeck and Cihák, 2008). In contrast, we find that intensified competition would refine returns on assets of Japanese banks. This finding somewhat supports the "competition-fragility" hypothesis in the sense that tougher degree of competition puts more pressure on profit and eventually could lead to financial instability (Keeley, 1990). On the other hand, as the Boone indicator conveys bank market power, our result is more robust in supporting findings of Fu et al. (2014) previously mentioned. Evidence of this hypothesis is also confirmed for Japanese banking in Liu and Wilson (2013).

In terms of risk variables, both bankrupt and restructured loans significantly affect TE, which support the "moral hazard" and "skimping" hypotheses. It is worth noting that until this stage, we have not been able to assess the causality relationship between risk-monitored loans and efficiency. These findings should be treated with some caution and it is the analysis of the panel VAR model that would shed light into their underlying relationships.

6.3. Panel VAR analysis

To capture the underlying dynamics, we apply panel Vector Autoregression (VAR) methodology. A VAR model allows us to relax any priori assumptions about the relationship between variables in the model. Instead, all variables entering the model are considered endogenous within a system of equations. We also account for unobserved individual heterogeneity in our panel data by specifying individual specific terms (Love and Zicchino, 2006).[19] Figs. 3 and 4 illustrate the impulse responses (IRFs) for 1 lag VAR technical efficiency, net interest margin, quantitative easing, bankrupt loans and restructured loans. The variance decompositions (VDCs) are reported in Tables 7 and 8.[20]

IRFs diagram describes the response of each variable in the VAR system to its own innovations and to innovations of other variables. The last diagram on the first row of Fig. 3 shows that the response of TE to a shock in bankrupt loans is positive but small

[19] To relax the restriction that all cross-sectional units in our panel data are the same, we incorporate the fixed effect μ_i, which is correlated with lags of the dependent variable. To remove the fixed effect in estimation without eliminating the orthogonality between the transformed variables and lagged regressors, we use forward mean-differencing, referred as the "*Helmert procedure*" (Arellano and Bover, 1995). The standard errors of the impulse response functions and their confidence intervals are estimated by Monte Carlo simulations. To illustrate the percent of variation in one variable explained by the shock in another variable, we perform the variance decompositions (VDCs). We report the accumulated total effects through 10 and 20 periods ahead. Please see Appendix B for the model specification.

[20] It is essential to select the optimal lag order j of the right-hand side variables in the equation system before estimation (Lütkepohl, 2007). It is constructed using the Arellano-Bover GMM estimator for the lags of $j = 1$, 2 and 3 and the Akaike Information Criterion (AIC) to decide the optimal lag order. The lag order 1 is proposed by the AIC, which is confirmed by the Arellano-Bond AR tests. More lags were added to detect evidence of autocorrelation. The null hypothesis of no autocorrelation for lag ordered one is not rejected in Sargan tests. According to the results from those tests, we estimate VAR of order one, also not to lose information and reduce degrees of freedom. Additionally, we perform normality tests for the residuals, employing the Shapiro-Francia W-test. The results confirm that there is no violation of the normality.

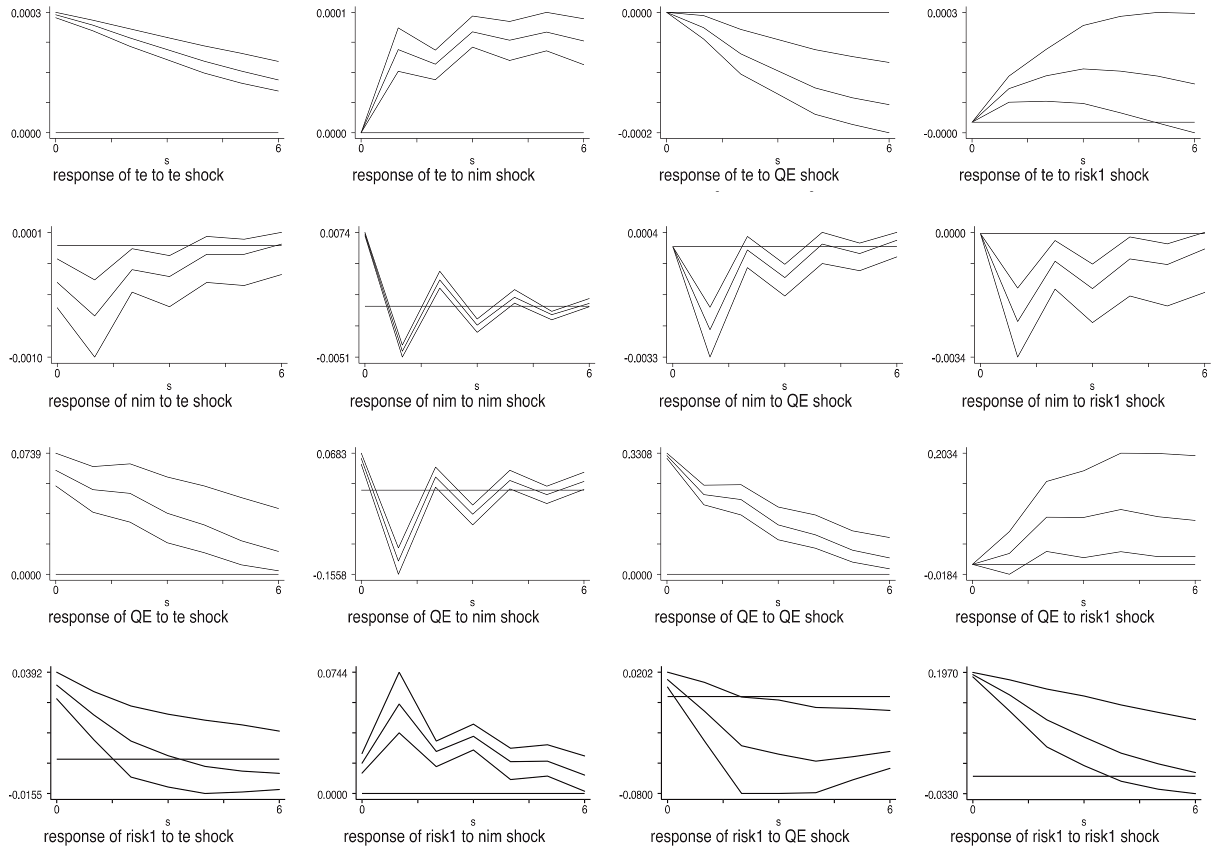

Fig. 3. IRFs for TE, NIM, QE, Bankrupt loans. Notes: This figure illustrates the impulse-response functions (IRFs) of each endogenous variable with respect to one standard deviation shock in other variables. TE: technical efficiency; NIM: net interest margin; QE: quantitative easing, proxied by the natural logarithm of total reserves; Risk 1: Bankrupt loans = Bankrupt loans + Non-accrual loans, s: number of periods. Errors are 5% on each side generated by Monte-Carlo simulation.

in magnitude. Put differently, a one standard deviation shock to bankrupt loans will raise technical efficiency visibly in the first three periods. After the first two periods, the confidence interval becomes wider. Hence, we could deduce that in the short-run, the relationship initiates from bankrupt loans to efficiency. This finding is related to the "moral hazard" and "skimping" hypothesis, in line with Koutsomanoli-Filippaki and Mamatzakis (2009) who report similar causality. Altunbas et al. (2007) also find that more efficient European banks take on more risk. Under the "moral hazard, skimping" hypothesis, bank efficiency could be improved because of less inputs used corresponding to credit screening, loan monitoring and management. Banks might also be induced to involve in more credit screening relaxation to offset the loss of problem loans (Fiordelisi et al., 2011). This particular finding for Japan in terms of reverse causality could reflect the effect of quantitative easing through bank lending. Previously discussed in Section 2, apart from the central period of quantitative easing, the Bank of Japan has pursued aggressive unconventional monetary policy since December 2012 in accordance with the *Abenomics*. On the other hand, the potential "moral hazard" problem could also arise from government support and SMEs financing facilitation. The fact that bank lending expands could increase the likelihood of problem loans, followed by the rise of efficiency due to the attempt to "skip" management practices of bank managers.

The first diagram in the last row of Fig. 3 provides evidence of the reverse causal relationship between efficiency and bankrupt loans. In the short-run of the first two years, the response of bankrupt loans to a one standard deviation shock in technical efficiency is positive. The relationship might be explained under the "bad management" hypothesis. The magnitude of the response of bankrupt loans to a shock in TE (estimated at about 0.025 in the first period) is larger than the magnitude of the response of efficiency to bankrupt loans' innovations. The response of bankrupt loans turns out to be negative thereafter, reaching a value around −0.006 in the last observed period. We treat this finding with caution as the confidence interval expands after the first period. This case would imply that the "risk-averse management" hypothesis might come into play.

Interestingly, the causal relationship between restructured loans and efficiency lends support to the "bad luck" hypothesis. The last diagram on the first row of Fig. 4 reveals that a one standard deviation shock in restructured loans would generate a negative response in efficiency. The magnitude of the effect is small but statistically significant in the short-run. The reverse causality is rejected as indicated in the first diagram on the last row of Fig. 4 where we observe an insignificant response of restructured loans to a shock in efficiency. In line with the "bad luck" hypothesis, the relationship runs from restructured loans to efficiency, and carries a negative sign. When unexpected events lead to a rise in restructured loans, bank managers divert their focus to deal with delinquencies and loan supervision rather than daily operation. Additional operating costs associated with credit screening, loan monitoring, collateral liquidating, and writing-off bad debts would lessen bank efficiency.

In Fig. 3, we observe a positive reaction of technical efficiency to a shock on net interest margin. A one standard deviation shock of net interest margin induces a positive response of technical efficiency, though the overall magnitude is small. In contrast, in Fig. 4, the response of efficiency to a shock in net interest margin is negative after the first period. Regarding the response of technical efficiency to a one standard deviation shock in monetary policy as measured by quantitative easing, the results suggest a negative

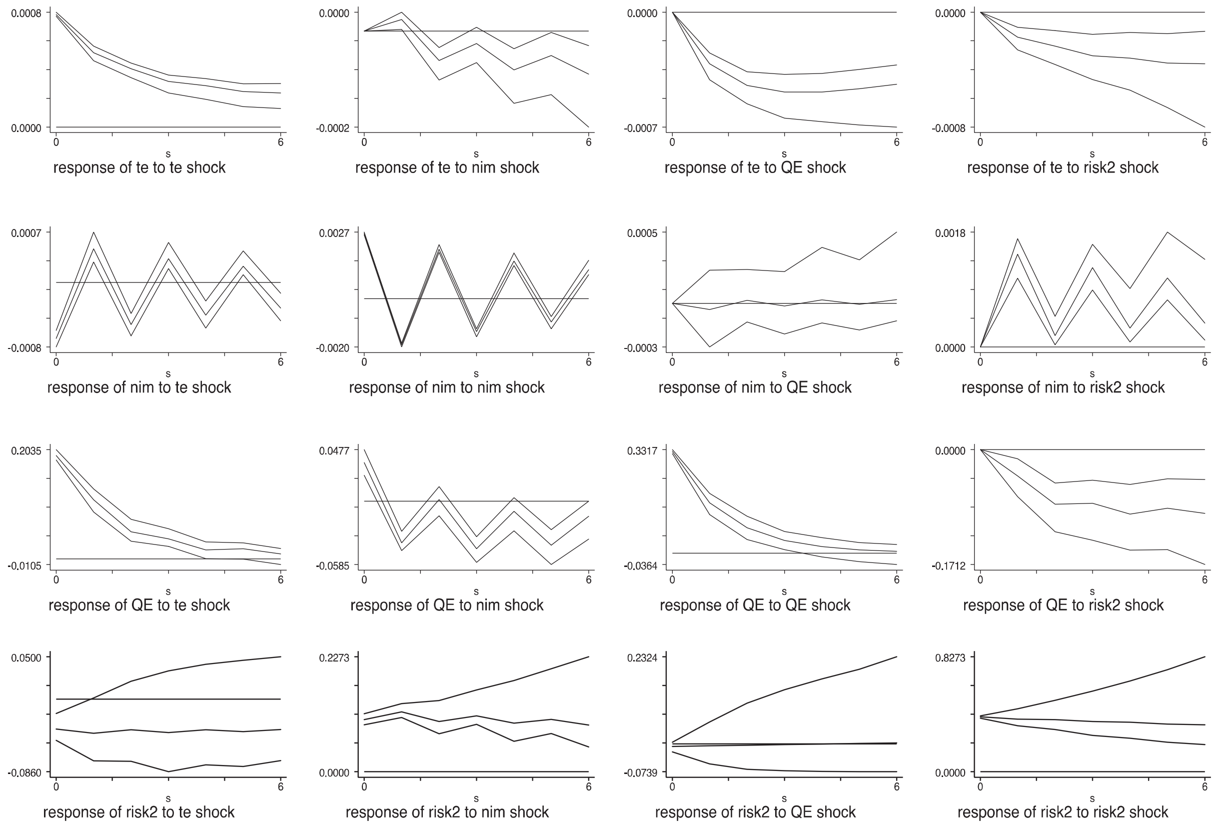

Fig. 4. IRFs for TE, NIM, QE, Restructured loans. Notes: This figure illustrates the impulse-response functions (IRFs) of each endogenous variable with respect to one standard deviation shock in other variables. TE: technical efficiency; NIM: net interest margin; QE: quantitative easing, proxied by the natural logarithm of total reserves; Risk 2: Restructured loans = past due loans over 3 months but less than 6 months + Restructured loan; s: number of periods. Errors are 5% on each side generated by Monte-Carlo simulation.

Table 7
VDCs for TE, NIM, QE, and bankrupt loans.

	s	TE	NIM	QE	Risk 1
TE	10	0.46662	0.08145	0.31208	0.13985
NIM	10	0.00584	0.8225	0.07089	0.10076
QE	10	0.03862	0.07714	0.73385	0.1504
Risk 1	10	0.01693	0.06092	0.14121	0.78094
TE	20	0.39274	0.08014	0.41575	0.11137
NIM	20	0.00596	0.82179	0.0714	0.10085
QE	20	0.03881	0.07709	0.73088	0.15322
Risk 1	20	0.01693	0.06018	0.1454	0.77749

Notes: This Table reports the Variance Decompositions for the panel VAR with Bankrupt loans as a proxy for risk level. VDCs illustrate the percent of variation in one variable explained by the shock in another variable. We report the accumulated total effects through 10 and 20 periods ahead. TE: technical efficiency; NIM: net interest margin; QE: quantitative easing, proxied by the natural logarithm of total reserves; Risk 1: Bankrupt loans = Bankrupt loans + Non-accrual loans; s: number of periods.

effect which is significant up to the second period in both Figures. These findings also further defend those reported in Tables 5 and 6.

Both Figs. 3 and 4 indicate a significant impact of a shock in net interest margin on the response of quantitative easing. This implies total reserves which act as a proxy for quantitative easing would decline if there is a shock to net interest margin. In terms of the effect of a shock in technical efficiency on quantitative easing, we find a positive and significant response of quantitative easing (though only in the first two periods when bankrupt loans are included in the model). The positive response gradually declines over time, with greater magnitude when restructured loans are in the equation system.

The effect of a shock in net interest margin on bankrupt loans and restructured loans is found to be positively important. There is no specific pattern as the response of bankrupt loans to a shock in net interest margin varies over time, but overall exhibits a diminishing trend. The peak response takes place after period 1, with a large magnitude of about 0.05; while that magnitude is relatively stable around 0.1 for the response of restructured loans. Turning to the macroeconomic shock, the impact of a shock in quantitative easing on bankrupt loans is positively significant only in the first period; while it is insignificant on restructured loans. A weak implication here is, in the short-run, if the Bank of Japan reduces their asset purchase, interest rates might rise and borrowers would face extra costs associated with their future repayments. The probability that bankrupt loans increase would be more likely.

Table 8
VDCs for TE, NIM, QE, and restructured loans.

	s	TE	NIM	QE	Risk 2
TE	10	0.33457	0.01407	0.37134	0.28003
NIM	10	0.04916	0.7348	0.00017	0.21587
QE	10	0.20278	0.03459	0.52593	0.23671
Risk 2	10	0.0103	0.07479	0.00011	0.91481
TE	20	0.22804	0.02697	0.29995	0.44504
NIM	20	0.04616	0.67761	0.00029	0.27593
QE	20	0.16634	0.04224	0.42544	0.36598
Risk 2	20	0.01131	0.07448	0.0004	0.91381

Notes: This Table reports the Variance Decompositions for the panel VAR with Restructured loans as a proxy for risk level. VDCs illustrate the percent of variation in one variable explained by the shock in another variable. We report the accumulated total effects through 10 and 20 periods ahead. TE: technical efficiency; NIM: net interest margin; QE: quantitative easing, proxied by the natural logarithm of total reserves; Risk 2: Restructured loans = past due loans over 3 months but less than 6 months + Restructured loans; s: number of periods.

The variance decompositions (VDCs) presented in Tables 7 and 8 enlighten our IRFs results. We report the total effect accumulated over 10 and 20 periods ahead. In Table 7, quantitative easing is found to explain 31.2% the forecast error variance of efficiency, followed by bankrupt loans which account for approximately 14% of the variance after 10 periods. The percent of variation in TE attributed to a shock in quantitative easing is higher for 20 periods ahead (increases to 41.6%). In contrast, TE's variation described by a shock in bankrupt loans decreases to 11.1%. On the other hand, a small part of nearly 1.7% forecast error variance 10 and 20 periods ahead in bankrupt loans is due to the shock in technical efficiency. This implies the causality runs from bankrupt loans to efficiency, suggesting that the "bad luck" hypothesis could be valid. If we also take into account the findings from the IRFs, the "moral hazard" and "skimping" hypothesis is more appropriate to explain the relationship between risk and efficiency. Note that risk triggers the causal chain as indicated by the VDCs estimations.

In the case of restructured loans (Table 8), quantitative easing is also important in explaining 37.1% the forecast error variance of efficiency over 10 periods. Disturbances in restructured loans account for 28% of efficiency's variation, and become more prominent in explaining up to 44.5% after 20 periods. In contrast, efficiency's innovations account for only about 1% variation of restructured loans. These results reinforce findings from the IRFs in the sense that the causality runs from restructured loans to efficiency, in line with the "bad luck" hypothesis.

Bankrupt loans and restructured loans are found to elucidate a large percent of the variation on net interest margin and quantitative easing. In contrast, the shock in net interest margin accounts for a small percent of variation in bankrupt loans (about 6%) and restructured loans (about 7.5%), confirming the causality would run from bankrupt and restructured loans to net interest margin. In the case of restructured loans,[21] this finding supports the argument in Angbazo (1997), Wong (1997), Demirgüç-Kunt and Huizinga (1999). Net interest margin would increase in response to a higher degree of risk as banks require a higher rate of return to offset the potential loss from risky portfolios. Interestingly, the causal relation between quantitative easing and bankrupt loans is not persuasively confirmed as being run from bankrupt loans. A shock in bankrupt loans explains slightly more variation in the forecast error of quantitative easing (15%) in comparison with a shock in quantitative easing interpreting bankrupt loans' variation (14%). Either way, the relationship carries a positive sign. However, it is evident that the relationship would run from restructured loans to quantitative easing. In general, our analysis indicates that bankrupt and restructured loans cause the changes of TE and other variables, rather than being affected.

7. Conclusion

This paper provides an additional angle of how to model bank production process so as to include undesirable outputs. We cover a large period that allows us to extensively analyse the changes in bank efficiency and its response to shocks. We report that Japanese banks' efficiency remains rather low with a mean technical efficiency level of 0.612. The slight downward trend of efficiency also implies that banks do not seem to fully revive or perform more efficiently after overcoming the crisis. We further find that Regional Banks II operate more efficiently than their counterparts do. Unlike Barros et al. (2012), our findings show that City Banks are less efficient than Regional Banks. Regarding the impacts of undesirable outputs, problem loans are more influential in efficiency estimation than problem other earning assets. The model suggests that Japanese banks could increase their good outputs by 63.4%, whilst simultaneously reducing bad outputs and inputs by 38.8%. To enhance efficiency, Japanese banks could also diversify their loan and investment portfolios to achieve the optimal desirable output mix. Additionally, investing in technology innovation would assist a bank to be ahead of their peers in attracting customers. Although short-run costs would rise, the benefits for customers and long-term cost savings could generate higher efficiency in the long-run.

In the latter stage analysis, we explore the impact of bankrupt loans and restructured loans on bank efficiency. We report that the response of technical efficiency is positive to a shock in bankrupt loans, but negative to a shock in restructured loans. There are evidences showing that bankrupt and restructured loans significantly explain the variation in technical efficiency, net interest margin, and quantitative easing. The relationship between bankrupt loans and efficiency resembles the "moral hazard" and "skimping" hypotheses, with the causality originating from bankrupt loans to efficiency. Banks would appear to be more efficient in the short-run because of fewer inputs associated with the loan-issuing process, and the motivation to compensate the loss from bankrupt loans. However, restructured loans are revealed to affect efficiency under the "bad luck" hypothesis. When restructured loans arise due to unexpected events, banks might face excessive operating costs to defend their financial health. We also examine the impact of quantitative easing on bank efficiency. We argue that changes in monetary policy diminish technical efficiency in the short-run, but with a small magnitude. This finding implies that quantitative easing tool might not be useful in strengthening bank performance. Among the panel VAR variables, a shock in net interest margin - a bank specific factor - does not greatly explain the variation of efficiency.

Our analysis sheds light for regulators and supervisors in terms of maintaining financial stability. There is evidence to convince that the favourable appearance of bank efficiency corresponds to more risky portfolios which are represented by the level of bankrupt loans. Regulators might need to prudently control the level of risk-taking in commercial banks as well as their loan issuance process. On the other hand, based on findings from the impact of restructured loans on efficiency, effective regulatory procedures to preserve and enhance financial stability would help lessen bank default risk and improve performance. Both highly efficient banks and worst performers should be supervised thoroughly as their efficiency scores act as a warning for heightened uncertainty.

In light with the ongoing *Abenomics* policy to drive Japan out of the deflation cycle, our finding for the impact of quantitative easing on technical efficiency and bankrupt loans could be supportive for future research in the Bank of Japan monetary easing policy. As there is no consensus evidence in the literature about the effectiveness of quantitative easing during March 2001-March 2006, the continuation of the zero interest rate policy and asset purchase programs from 2012 could provide an interesting platform for investigating their impact on bank productivity and financial stability. Not exclusively, one could directly control for the effect of bankrupt and restructured loans in measuring Japanese bank productivity growth. Departing from this study, we would conjecture a detrimental impact of these risk-monitored loans on bank productivity. Moreover, future research could decompose total factor productivity growth into different components which account for the particular effect of bankrupt and restructured loans.

Acknowledgement

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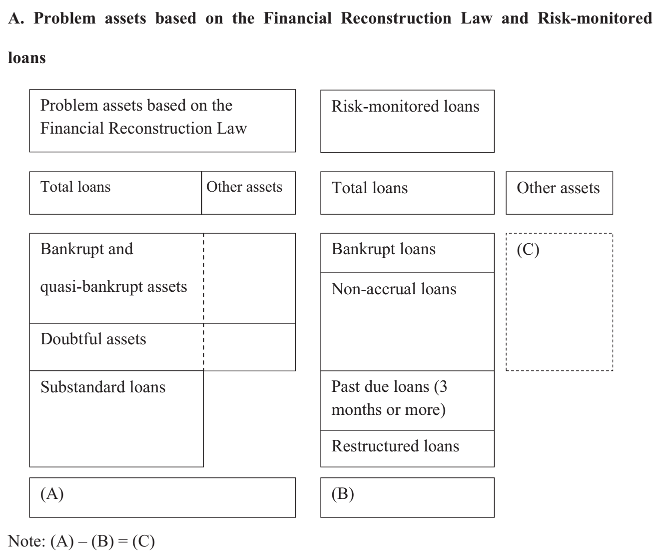
[21] Please refer to Fig. 4, second row, last diagram.

Appendix A. Problem assets based on the Financial Reconstruction Law and Risk-monitored loans



Notes: This Appendix presents the two classifications of problem assets in Japan. The difference between the two is other assets which are problem other earning assets (claims related to securities lending, foreign exchanges, accrued interests, suspense payments, customers' liabilities for acceptances and guarantees, and bank-guaranteed bonds sold through private placements). Risk-monitored loans are disclosed in accordance with the Banking Law, which we use to represent the potential risk. In this paper, Bankrupt loans are named after the sum of Bankrupt loans and Non-accrual loans; Restructured loans are named after the sum of past due loans over 3 months but less than 6 months and Restructured loans. Problem loans are the sum of bankrupt, quasi-bankrupt, doubtful loans and substandard loans. Problem other earning assets are the sum of bankrupt, quasi-bankrupt, and doubtful other earning assets. Source: Interim report 2010-Sumitomo Mitsui Financial group.

Appendix B. Panel VAR model

The first order VAR model takes the form of:

$$w_{it} = \mu_i + \Phi w_{it-1} + e_{i,t} \quad i = 1,\dots,N; \quad t = 1,\dots,T \tag{B.1}$$

where w_{it} is a vector of four random variables, technical efficiency Ef, net interest margin NIM, quantitative easing QE, and risk R (bankrupt and restructured loans), Φ is a 4x4 matrix of coefficients, μ_i is a vector of m individual effects, μ_{0t} is a time dummy, and $e_{i,t}$ is a multivariate white-noise vector of m residuals. The equation system to be estimated is as follows:

$$\begin{aligned}
Ef_{it} &= \mu_{1i0} + \mu_{10t} + \sum_{j=1}^{J} a_{11} Ef_{it-j} + \sum_{j=1}^{J} a_{12} NIM_{it-j} + \sum_{j=1}^{J} a_{13} QE_{it-j} + \sum_{j=1}^{J} a_{14} R_{it-j} + e_{1i,t}\\
NIM_{it} &= \mu_{2i0} + \mu_{20t} + \sum_{j=1}^{J} a_{21} Ef_{it-j} + \sum_{j=1}^{J} a_{22} NIM_{it-j} + \sum_{j=1}^{J} a_{23} QE_{it-j} + \sum_{j=1}^{J} a_{24} R_{it-j} + e_{2i,t}\\
QE_{it} &= \mu_{3i0} + \mu_{30t} + \sum_{j=1}^{J} a_{31} Ef_{it-j} + \sum_{j=1}^{J} a_{32} NIM_{it-j} + \sum_{j=1}^{J} a_{33} QE_{it-j} + \sum_{j=1}^{J} a_{34} R_{it-j} + e_{3i,t}\\
R_{it} &= \mu_{4i0} + \mu_{40t} + \sum_{j=1}^{J} a_{41} Ef_{it-j} + \sum_{j=1}^{J} a_{42} NIM_{it-j} + \sum_{j=1}^{J} a_{43} QE_{it-j} + \sum_{j=1}^{J} a_{44} R_{it-j} + e_{4i,t}
\end{aligned} \tag{B.2}$$

The residuals $e_{i,t}$ captures the exogenous shocks to the endogenous variables in the VAR system. The moving average (MA) representation equates Ef_{it}, NIM_{it}, QE_{it} and R_{it} on present and past residuals e_1, e_2, e_3 and e_4 from the VAR estimation:

$$\begin{aligned}
Ef_{it} &= a_{10} + \sum_{j=1}^{\infty} b_{11j} e_{1it-j} + \sum_{j=1}^{\infty} b_{12j} e_{2it-j} + \sum_{j=1}^{\infty} b_{13j} e_{3it-j} + \sum_{j=1}^{\infty} b_{14j} e_{4it-j}\\
NIM_{it} &= a_{20} + \sum_{j=1}^{\infty} b_{21j} e_{1it-j} + \sum_{j=1}^{\infty} b_{22j} e_{2it-j} + \sum_{j=1}^{\infty} b_{23j} e_{3it-j} + \sum_{j=1}^{\infty} b_{24j} e_{4it-j}\\
QE_{it} &= a_{30} + \sum_{j=1}^{\infty} b_{31j} e_{1it-j} + \sum_{j=1}^{\infty} b_{32j} e_{2it-j} + \sum_{j=1}^{\infty} b_{33j} e_{3it-j} + \sum_{j=1}^{\infty} b_{34j} e_{4it-j}\\
R_{it} &= a_{40} + \sum_{j=1}^{\infty} b_{41j} e_{1it-j} + \sum_{j=1}^{\infty} b_{42j} e_{2it-j} + \sum_{j=1}^{\infty} b_{43j} e_{3it-j} + \sum_{j=1}^{\infty} b_{44j} e_{4it-j}
\end{aligned} \tag{B.3}$$

The composite error term in the underlying structural model contains no economic implication, unless the equation is transformed. The orthogonalisation of impulse responses enables us to interpret the reaction of one variable to a shock in another variable in the system. Love and Zicchino (2006) opt for this technique in order to separate the influence of different variables in one variable of interest by holding other shocks constant. Because it is very unlikely that the covariance matrix of the error terms is diagonal, it is required that the residuals are decomposed following a procedure (such as Cholesky decomposition) to become orthogonal. A particular ordering is specified according to the degree of endogeneity of each variable. It is assumed that the variables appear first are more exogenous, and the ones appear later are more endogenous. The orthogonalised, or structural, MA representation is:

$$\begin{aligned}
Ef_{it} &= \alpha_{10} + \sum_{j=1}^{\infty} \beta_{11j} \varepsilon_{1it-j} + \sum_{j=1}^{\infty} \beta_{12j} \varepsilon_{2it-j} + \sum_{j=1}^{\infty} \beta_{13j} \varepsilon_{3it-j} + \sum_{j=1}^{\infty} \beta_{14j} \varepsilon_{4it-j}\\
NIM_{it} &= \alpha_{20} + \sum_{j=1}^{\infty} \beta_{21j} \varepsilon_{1it-j} + \sum_{j=1}^{\infty} \beta_{22j} \varepsilon_{2it-j} + \sum_{j=1}^{\infty} \beta_{23j} \varepsilon_{3it-j} + \sum_{j=1}^{\infty} \beta_{24j} \varepsilon_{4it-j}\\
QE_{it} &= \alpha_{30} + \sum_{j=1}^{\infty} \beta_{31j} \varepsilon_{1it-j} + \sum_{j=1}^{\infty} \beta_{32j} \varepsilon_{2it-j} + \sum_{j=1}^{\infty} \beta_{33j} \varepsilon_{3it-j} + \sum_{j=1}^{\infty} \beta_{34j} \varepsilon_{4it-j}\\
R_{it} &= \alpha_{40} + \sum_{j=1}^{\infty} \beta_{41j} \varepsilon_{1it-j} + \sum_{j=1}^{\infty} \beta_{42j} \varepsilon_{2it-j} + \sum_{j=1}^{\infty} \beta_{43j} \varepsilon_{3it-j} + \sum_{j=1}^{\infty} \beta_{44j} \varepsilon_{4it-j}
\end{aligned} \tag{B.4}$$

and

$$\begin{pmatrix} \beta_{11j}\beta_{12j}\beta_{13j}\beta_{14j}\\ \beta_{21j}\beta_{22j}\beta_{23j}\beta_{24j}\\ \beta_{31j}\beta_{32j}\beta_{33j}\beta_{34j}\\ \beta_{41j}\beta_{42j}\beta_{43j}\beta_{44j} \end{pmatrix} = \begin{pmatrix} b_{11j}b_{12j}b_{13j}b_{14j}\\ b_{21j}b_{22j}b_{23j}b_{24j}\\ b_{31j}b_{32j}b_{33j}b_{34j}\\ b_{41j}b_{42j}b_{43j}b_{44j} \end{pmatrix} P \begin{pmatrix} \varepsilon_{1it}\\ \varepsilon_{2it}\\ \varepsilon_{3it}\\ \varepsilon_{4it} \end{pmatrix} = P^{-1} \begin{pmatrix} e_{1it}\\ e_{2it}\\ e_{3it}\\ e_{4it} \end{pmatrix} \tag{B.5}$$

where P is the Cholesky decomposition of the covariance matrix of the residuals:

$$\begin{pmatrix} Cov(e_{1it}, e_{1it})Cov(e_{1it}, e_{2it})Cov(e_{1it}, e_{3it})Cov(e_{1it}, e_{4it}) \\ Cov(e_{2it}, e_{1it})Cov(e_{2it}, e_{2it})Cov(e_{2it}, e_{3it})Cov(e_{2it}, e_{4it}) \\ Cov(e_{3it}, e_{1it})Cov(e_{3it}, e_{2it})Cov(e_{3it}, e_{3it})Cov(e_{3it}, e_{4it}) \\ Cov(e_{4it}, e_{1it})Cov(e_{4it}, e_{2it})Cov(e_{4it}, e_{3it})Cov(e_{4it}, e_{4it}) \end{pmatrix} = PP^{-1} \tag{B.6}$$

Appendix C. The Boone indicator

Derived from the log-linear relationship between marginal cost mc and profit π in equation C.1, the Boone indicator should be generally negative (Boone et al., 2007). The larger the Boone indicator in absolute value, the more intensified the competition.

$$\ln \pi_i = \alpha + \beta \ln mc_i \tag{C.1}$$

In order to obtain time-varying Boone indicator, we add a time dummy d_t and run the following regression (Schaeck and Cihák, 2014; Van Leuvensteijn et al., 2011):

$$\ln \pi_{it} = \alpha_i + \sum_{t=1}^{T} \beta_t d_t \ln mc_{it} + \sum_{t=1}^{T-1} \gamma_t d_t + u_{it} \tag{C.2}$$

In line with Fiordelisi and Mare (2014), marginal cost is obtained from the translog cost function:

$$\begin{aligned} \ln TC_{it} = {} & \alpha_0 + \alpha_1 \ln Q + \frac{\alpha_2}{2} \ln Q^2 + \sum_{j=1}^{2} \beta_j \ln P_j + \frac{1}{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \delta_{jk} \\ & \times \ln P_j \ln P_k + \sum_{j=1}^{2} \gamma_j \ln Q \ln P_j + \varphi_1 t + \frac{1}{2} \varphi_2 t^2 + \varphi_3 t \\ & \times \ln Q + \sum_{j=1}^{2} \varphi_j t \ln P_j + \varepsilon_{it} \end{aligned} \tag{C.3}$$

where TC_{it} is total costs which are the sum of interest and investment expenses, and general and administrative expenses; Q is total earning assets (loans, investments, and securities) (Delis, 2012). Price of funds P_1 is defined as interest and investment expenses/deposits and borrowed funds. Due to data unavailability, we are unable to extract data from general and administrative expenses which include personnel expenses and non-personnel expenses associated to physical capital. Hence, in line with Hensel (2006) and Fu et al. (2014), we define the second input price as price of overhead P_2 as general and administrative expenses divided by the number of employees. Time trend is t, and ε_{it} is a two-component error term capturing inefficiency and a two-sided error term.

The marginal costs can be derived from Eq.(C.3) as follows (Fu et al., 2014):

$$MC_{it} = \frac{TC_{it}}{Q_{it}} (\alpha_1 + \alpha_2 \ln Q + \sum_{j=1}^{2} \gamma_j \ln P_j + \varphi_3 t) \tag{C.4}$$

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