BANK COMPETITION, EFFICIENCY, PRODUCTIVITY, AND THE IMPACT OF QUANTITATIVE EASING IN JAPAN.

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SUMMARY

The Japanese banking system provides a distinctive platform for the examination of the long-lasting effect of problem loans on bank performance. Japan is also known for an extended quantitative easing programme of unprecedented scale. Yet the links between risk-taking activities, quantitative easing, and bank competition are largely unexplored. This thesis employs a unique database, which allows us to distinguish between bankrupt and restructured loans. The aim of the thesis is to investigate the impact of these loans on Japanese bank efficiency and productivity growth, as well as their relationship with bank competition and quantitative easing policy.

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. Further analyses reveal that bankrupt loans affect efficiency in a manner related to the "moral hazard, skimping" hypothesis, with the causality originating from bankrupt loans. In contrast, the relationship between restructured loans and efficiency supports the "bad luck" hypothesis. We also follow the parametric approach to quantify the impact of bankrupt and restructured loans on productivity growth of the

Japanese banking system. We further perform convergence cluster analysis to examine convergence in productivity growth between regions, where limited convergence is reported. Additionally, this thesis employs, for the first time, the bank-level Boone indicator to measure bank competition in Japan to examine the underlying linkages between quantitative easing, competition, and risk. Given the scale of problem loans, we measure bank risk-taking based on bankrupt and restructured loans. Our analyses show that enhancing quantitative easing and competition would reduce bankrupt and restructured loans, but it would negatively affect financial stability. In light of the ongoing negative interest rates and quantitative and qualitative easing policy to enhance economic growth in Japan, this thesis would provide insightful implications for policymakers and regulators.

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Abbreviations

BRL:	Bankrupt loans
DEA:	Data Envelopment Analysis (DEA)
e.g.:	for example
Fig.:	Figure
FSA:	Japan's Financial Services Agency
GDP:	Gross Domestic Product
i.e.:	that is
IRFs:	Impulse Response Functions
JPY:	Japanese Yen
NIM:	Net interest margin
QE:	Quantitative easing
QQE:	Qualitative and quantitative easing
ROA:	Return on Assets
ROE:	Return on Equity
RSL:	Restructured loans
SFA:	Stochastic Frontier Approach
SMEs:	Small and Medium-sized enterprises
TE:	Technical efficiency
VAR:	Vector Autoregression
VDCs:	Variance decompositions

Chapter 1. Introduction

Japan is one of the most important economies in Asia, serving as a unique research setting due to its regional significance, the economic shocks it has faced, and the policies set out to deal with those challenges. Among the outstanding economic features of Japan is its banking system, which had been struck by the asset bubble burst in the early 1990s before being restructured through a variety of central banking policies and government interventions. There are a number of distinctive reasons why the Japanese banking sector is an interesting research platform for academics and policymakers. Briefly, they are the protracted nonperforming loan problem, the controversial government responses, and the aggressive quantitative easing policy.

It is worth mentioning an overview of Japan's macroeconomic conditions and performance pre-crisis so that the overall economic developments of the country can be linked with the issues in subsequent discussions. In the late 1980s, Japan was characterised as a country with high economic growth, low risk premium, and nearly zero inflation (Yamaguchi, 1999). The real GNP per adult growth was at a rate much higher than the 2% benchmark which was the long run growth rate of the United States (Hayashi and Prescott, 2002). During the whole decade of the 1980s, strong GDP growth was witnessed, starting from 2.82% in 1980 and ending at 5.37% in 1989. GDP growth at its peak was recorded at 7.15% in 1988. As a result of the then booming economy, asset prices increased and credit expansion was rapidly under way. Besides, the accelerated financial deregulation and liberalisation catalysed the expansion of bank lending. In some detail, relaxation of interest rate controls, capital market deregulation, lifting of restrictions on banking activities were the typical examples (Kanaya and Woo, 2000). Banks increased their consumer and real estate lending, which was the riskier loan segment in their portfolios. As real estate prices were soaring at the time, the fact that banks' lending decisions were mainly made on the basis of collateral led to lax credit standards. In 1989, the Japanese stock market witnessed a record high, contributing to significantly overvalued stocks. Typically, the eighties in Japan was characterised as a decade of inflating an asset bubble. When, eventually, the asset bubble burst in the early nineties, Japan's GDP growth dropped significantly from 3.32% in 1991 to 0.82% in 1992, followed by deflation in 1998 (-1.13%) and 1999 (-0.25%). The slowdown of economic growth subsequent to 1991 and the plummet of stock and asset prices marked the start of the so-called *Japanese lost decade* and the banking crisis.

Nonperforming loans were a central issue shattering financial stability post the Japanese banking crisis. The unprecedented amount of nonperforming loans endangered the banking system, forcing banks and financial firms to declare bankruptcy. In the aftermath of the land and asset price bubble, problem loans rose dramatically since a vast number of firms went bankrupt or experienced business difficulties. A number of high profile banks had to file for bankruptcy because the majority of collaterals were real estate, or they held stocks and land directly (Giannetti and Simonov, 2013). The first financial institutions that got into troubles and triggered the banking crisis were the *jusen*[1], which were eventually liquidated in 1996 (Hoshi and Kashyap, 2010). The first listed failed bank in 1995 was Hyogo Bank. The Deposit Insurance Corporation at times was allowed to insure up to 10 million JPY per depositor, which meant that by 1996 all deposits in Japan were under guarantee. Following *jusen*, Sanyo Securities declared bankruptcy in early November 1997, which led to the first interbank loan default and the soar of the relative borrowing rate for Japanese banks. The first major bank failure post-

[1] The *jusen* financial institutions were housing loans companies in 1970s and involved in high risk real estate lending in 1980s (Hoshi and Kashyap, 2010).

war in Japan, Hokkaido Tokushoku, took place two weeks after that. Afterwards, regional bank Tokuyo City Bank collapsed in 1997, and two major banks (the Long-Term Credit Bank of Japan, and the Nippon Credit Bank) were nationalised in 1998. It is worth noting that the cost of bankrupt and restructured loans in 1997 was 30 trillion JPY (Hoshi and Kashyap, 2000). However, the actual value could be in excess of 100 trillion JPY (Hoshino, 2002). The level of bad loans fell after March 2002, reflecting the effort of banks to reduce problem loans under the reform program by Heizo Takenaka (the Minister in charge of the Financial Services Agency). Along the line, nonperforming loans gradually declined. However, from the governance perspective, the weak corporate governance stemming from the system of "relationship banking" was also among the causes for the prolonged distress of the banking sector (Hanazaki and Horiuchi, 2003; Kanaya and Woo, 2000). Japan's financial system is bank-centered (i.e. horizontal *keiretsu* or *main* bank system), characterised by cross-shareholdings and the monopolisation of information from the banks. Banks are able to exploit information from borrower firms and conceal firms' management information from their rivals. As a consequence, third parties may find it difficult to evaluate firms' creditworthiness. *Main* banks were supposed to identify troubled borrowers and rectify the problems that their borrowers had been facing, thus reducing the likelihood of insolvency. However, when the *main* banks themselves were in distress, allowing borrowers to default would have an adverse effect on their reputation. The fact that *main* banks are required to cover some of the losses that the firms in question would cause to other creditors would add extra costs to their operations. Therefore, instead of disposing nonperforming loans, they were prone to forbearance (Kanaya and Woo, 2000).

In addition, government intervention as a whole was not without controversies. Indecisive government responses worsened the then chaotic situation. Instead of acting promptly to stabilise the financial turmoil, initially, the government denied to admit the nonperforming loan problem, unnecessarily prolonging the disruption period. Before 2002, although the government had enacted the rescue schemes by injecting capital and bailing out troubled banks, it was blamed to delay the much needed restructuring period (Caballero et al., 2008). In detail, before 1997, the then Ministry of Finance refused to use public fund to assist banks as they considered it unnecessary. In February 1999, the Vice Minister of International Finance said the banking crisis "would be over within a matter of weeks". In addition, their attempts to rescue insolvent banks also faced criticism for legislation changes regarding *zombie* lending (i.e. loan financing to unprofitable borrowers) and restructuring bad loans of Small and Medium-sized enterprises (SMEs). Under the basis of this policy, the then government required banks to carry on funding to SMEs to assist them in regaining their financial health. As indicated in Kanaya and Woo (2000), the Japanese unnecessarily lengthy financial distress was characterised by regulatory weakness and forbearance. After 1998, the government encouraged banks, especially those received financial aid through public capital, to increase their lending to SMEs in order to ease the "credit crunch" (Hoshi, 2011; Hoshi and Kashyap, 2010). However, the fact that the government subsidised these unprofitable borrowers inhibited the entry and investment of productive firms, leading to fewer good lending opportunities for solvent banks (Caballero et al., 2008). Thus, during the 1999-2003 period, the core of problem loans shifted from real estate lending to SME financing. Hoshi (2011) emphasises the hidden risks in the SME sector because the Japan's Financial Services Agency (FSA) acted in favour of these enterprises. Among the changes of the regulatory framework, the adjustment of nonperforming loans' definition redeemed some credits for bad loans of SMEs. More than 40% the amount of nonperforming loans held by Regional Banks between September 2008 and March 2009 were reclassified as normal. Although in 2007, Japanese banks' capital was claimed to be restored (Hoshi and Kashyap, 2010), in the basis of the Act of Temporary Measures to Facilitate Financing for SMEs, Hoshi (2011) argues that a large amount of nonperforming loans are in disguise until the end of March 2012.

Third, Japan's poor macroeconomic performance in the sense of sluggish growth and long-term deflation has influenced the latent risk within financial institutions. As indicated in International Monetary Fund (2003), protracted economic slowdown hindered bank profitability and magnified the nonperforming loan problem. Meanwhile, the continued deflationary environment exacerbated the bad loan issue by increasing the likelihood of corporate bankruptcy, raising the real value of debts, and deteriorating collateral values. An additional effect of deflation, the "debt deflation" process, whereby the real value of nominal debt obligations increases because of the fall in prices, can reduce borrowers' net worth (Bernanke and James, 1991). This in turn could aggravate potential principal-agent problems in the borrower-lender relationship and could lead to a full-scale banking crisis. This proved to be the case in Japan. As a result, the then distressed Japanese banking system was systematically weakened by risks related to problem loans. Monetary expansion, quantitative easing in particular, was the underlying policy exercised as the solution for the Japanese sluggish growth performance and deflationary puzzle.

Being the pioneer in enacting quantitative easing policy, Japan provides the unique case to assess its impact on the banking system, especially in terms of its relationship with risk. Japan had a long history of virtually zero interest rates in the 1990s. In March 2001, the Bank of Japan initiated quantitative easing policy to stimulate aggregate demand and boost the country's productivity. Ending in March 2006, although deflation was not fully pushed away, there was evidence for the effectiveness of quantitative easing in stimulating demand (Bowman et al., 2015). The policy was reactivated in October 2010 due to concerns regarding the spill over effect of economic downturn in other countries. This time the Bank of Japan has been strongly committed to fighting against deflation. Tremendous amounts of asset purchases were set out in addition to extending the types of financial assets eligible for purchase. Given the extensive quantitative easing program, we could not rule out its potential impact on bank performance, competition, and risk.

This thesis aims to highlight the aforementioned reasons in relation to the prevailing research topics in the banking literature, namely bank competition, efficiency, productivity, and quantitative easing policy. Bank performance is a well-established research field which seeks to compute efficiency scores and productivity growth, as well as identify the impact of determinants. It is of importance as information on efficiency scores and productivity growth can be used for comparison purposes, e.g. between banks or between different measures of performance such as accounting ratios (Return on Assets ROA and Return on Equity ROE). Furthermore, performance rankings can be revealed, thus allowing bank managers and policymakers to pinpoint the best and worst performers. Based on efficiency studies, areas of input overuse or output underproduction can be detected so that managers can adjust banking operations accordingly (Berger and Humphrey, 1997). For regulators and supervisors, they are provided with useful information to assess the impact of government policies. Productivity growth is also of interest to managers to determine the driving forces of growth. The methods employed in bank performance studies also vary. Among the nonparametric techniques, Data Envelopment Analysis (DEA) is the most popular method. Numerous bank efficiency and productivity studies are DEA applications, for example Berg et al. (1992), Miller and Noulas (1996), Grifell-Tatjé and Lovell (1997), Alam (2001), Drake and Hall (2003), Sturm and Williams (2004), Pasiouras (2008), Fiordelisi and Molyneux (2010), Kao and Liu (2014). Stochastic Frontier Approach is the widely-used parametric method. While nonparametric techniques are assumption-free about the distribution of inefficiency and random error, and relax the specification form of the underlying production relationship, parametric techniques require explicit assumptions (Berger and Humphrey, 1997). The distribution of inefficiency can follow a normal, half-normal, or truncated distributions. As no random error exists in DEA, Berger and Humphrey (1997) argue that efficiency measurement could be problematic if there are measurement errors in constructing the frontier, or luck that may bring better performance, or inaccuracy created by accounting rules. Berger and Mester (1997), Berger and DeYoung (1997), Bonin et al. (2005), Fries and Taci (2005), Lensink et al. (2008), Koutsomanoli-Filippaki and Mamatzakis (2009), Fiordelisi et al. (2011), and Glass et al. (2014) are among studies that apply parametric methods to estimate bank efficiency. For bank productivity growth, typical studies include Kumbhakar et al. (2001), Orea (2002), Berger and Mester (2003), Boucinha et al. (2013), Casu et al. (2013), and Lozano-Vivas and Pasiouras (2014) among others. It is worth emphasising that in the Japanese bank performance literature, parametric studies are rather limited (Altunbas et al., 2000; Assaf et al., 2011; Barros et al., 2009; Fukuyama et al., 1999; Glass et al., 2014; Uchida and Satake, 2009).

Alongside performance, bank competition is another interesting research topic. Banks are the central nodes in the economy, channelling funds from surplus areas to deficit sectors. Anticompetitive behaviour may result in additional costs for households and firms in their banking business, in turn affecting productive efficiency, economic welfare, and economic growth (Shaffer, 2004). Banking studies have examined in depth market structure (Claessens and Laeven, 2004; Demsetz, 1973; Lloyd-Williams et al., 1994; Molyneux et al., 1994), as well as the impact of competition on bank performance

(Fu et al., 2014; Homma et al., 2014; Liu et al., 2012). With regard to the banking system per se, whether competition is good or bad remains a debatable issue (Berger et al., 2009; Fiordelisi and Mare, 2014; Fu et al., 2014; Liu and Wilson, 2013; Schaeck and Cihák, 2008; Stiroh and Strahan, 2003). In this thesis, the role of bank competition is assessed in its impact on bank risk and efficiency. As competition can stimulate banks to minimise costs and maximise outputs (Andrieş and Căpraru, 2014; Schaeck and Cihák, 2008), it is among the determinants of efficiency. In a similar vein, competition may reduce bank risk through the efficiency channel. Yet, it could put bank stability at risk, e.g. through improper credit screening in the loan issuance process (Allen and Gale, 2004). The degree of bank competition in its relationship with bank risk would assist bank managers in assessing their risk management practices given the current competitive stance. Policymakers could also derive information to evaluate government interference as well as anti-competitive behaviours.

Quantitative easing, as aforementioned, is an important monetary policy in Japan. Its implications are also of interest to other countries, especially the US, UK, and European economies. Following Japan, the central banks of these countries have implemented quantitative easing, which is also known as an unconventional monetary policy tool. Its impacts on aggregate demand, supply of credit, and economic growth through interest rates, government bond yields, and credit default swap have enlightened the substantial role of quantitative easing among macroeconomic policies (Bowman et al., 2015; Glick and Leduc, 2012; Schenkelberg and Watzka, 2013). The international transmission effect of unconventional monetary policy triggered by advanced economies such as the US, UK, Germany, and Japan could channel some contagion influences to other economies, for example, in terms of variations in bond yields, exchange rates, or stock price indices (Bauer and Neely, 2014; Bredin et al., 2010; León and Sebestyén, 2012). At the microeconomic level, what effects that quantitative easing has imposed on the Japanese banking system would also have significant policy implications to other countries. Hence, this thesis aims to investigate these impacts at the bank-level.

More importantly, in this thesis, the abovementioned research topics are studied with a particular focus on their relationship with risk which is characterised by problem loans. Lengthy disruptions for over a decade caused by problem loans warrant the need to examine their detrimental effect on the stability of the banking industry. The body of the thesis consists of three main chapters, beside chapter two which overviews the Japanese banking structure. We focus on commercial banks rather than the whole banking sector due to data unavailability and differences in business features. Chapter three addresses the question of how bankrupt loans and restructured loans affect bank efficiency. As research activities for this chapter were carried out first, the time span of our data ranges from financial years 2000 to 2012. For the remaining chapters, the data are updated until March 2015, which represents the ending financial year of 2014. Chapter four measures bank productivity, taking into account the impact of problem loans and further investigating the integration process in terms of productivity growth. Chapter five examines the interplay between quantitative easing, risk, and competition. Although each chapter has its own contributions to the literature, in general we can summarise the overall contributions of the thesis in the following ways. First, we apply the parametric approach to estimate bank efficiency and productivity, enriching this literature in Japanese banking, which has been dominated by studies using non-parametric approaches. Second, we employ data on bankrupt loans and restructured loans as proxies for risk. Data on these loans are reported under the Banking Law and have not been used in the literature. Third, we estimate bank-level Boone indicator of competition. This indicator is superior compared to other competition measures and mostly calculated at the industry level in banking studies. Fourth, we take into account the impact of quantitative easing in our analyses, especially in its relationship with bank risk. Finally, our data are at semi-annual frequency from financial years 2000 to 2014. This provides us with a rich set of information, as well as covering the milestones in Japan economic history. In particular, they are the restructuring period, the global financial crisis, the two time frames of quantitative easing, and the Tohoku earthquake. The overview and contributions of each main chapter are detailed in the following paragraphs.

Chapter three measures technical efficiency by modifying a translog enhanced hyperbolic distance function with two undesirable outputs, identified as problem loans and problem other earning assets. Unlike most studies on Japanese banking which consider problem loans as a control variable or a proxy for risk (Altunbas et al., 2000; Drake and Hall, 2003; Liu and Tone, 2008), we follow a new strand of the literature by treating problem loans as an undesirable output in bank efficiency measurement (Barros et al., 2012; Fukuyama and Weber, 2008; Glass et al., 2014). We apply the parametric approach introduced by Cuesta et al. (2009). This methodology allows for a simultaneous expansion of desirable outputs and contraction of inputs and undesirable outputs. The model is adjusted for a vector of two undesirable outputs, namely problem loans and problem other earning assets. We use the term "problem loans" instead of nonperforming loans to be consistent with the classification of problem assets under the Financial Reconstruction Law. It is necessary to include problem other earning assets as a second undesirable output. Similar to problem loans being by-products of loans, problem other earning assets are by-products of other earning assets. Beside conventional activities, 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. They are an output component of banking operations. Thus, accounting for problem other earning assets 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. The next stage of our analysis investigates the impact of bankrupt loans and restructured loans on bank efficiency. Our unique database allows us to distinguish between bankrupt and restructured loans to investigate the underlying associations between these loans and efficiency. These types of loans are disaggregated from our data of risk-monitored loans of Japanese commercial banks and have not been used in the literature regarding Japanese bank performance. These loans measure the level of risk held within Japanese banks. The variation of these loans can be due to management issues 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 enables causality hypothesis testing 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”.

Chapter four examines for the first time the impact of problem loans, categorised as bankrupt and restructured loans, on productivity growth. Our parametric methodology quantifies the impact of these loans on productivity growth of the Japanese banking system. We decompose bank productivity growth into different components, namely the effects of problem loans, quasi-fixed input, returns to scale, and technological change. Given the extensive volume of bankrupt and restructured loans in Japan, we expect that they have an impact on bank productivity. In this chapter, we also consider bankrupt and restructured loans as undesirable outputs. These overdue loans in turn would raise bank’s operating costs in the short-run. Hence, one would expect these loans to deteriorate bank productivity. Beside bankrupt and restructured loans, we also employ equity as a quasi-fixed input (Berger and DeYoung, 1997; Hughes et al., 2001; Ray and Das, 2010). Unequivocally, equity plays a significant role in banking production as a buffer against risks (Boucinha et al., 2013). Equity is the shock absorber for unexpected operating losses, preventing banks from temporary illiquidity and insolvency (Diamond and Rajan, 2000). Beside embracing the risks incurred, the level of equity should also facilitate future growth of the bank's assets (Boucinha et al., 2013). In the banking literature, treating equity as a quasi-fixed input has been a typical practice (Berger and Mester, 1997; Hughes and Mester, 1993; Hughes et al., 2001; Ray and Das, 2010; Weber and Devaney, 2002). In the short-term, altering a significant level of equity would be impossible (Lozano-Vivas and Pasiouras, 2014). In other words, banks benefit from equity but do not need to pay for it in the short-run. Equity would also serve as a cost-reducing factor due to less interest paid for debt financing (Hughes and Mester, 2013). Beside these benefits of equity, neglecting the impact of equity in the Japanese banking system would result in biased estimators. The reason is that during the banking crisis in the late 1990s – early 2000s, the shortage of equity jeopardised Japanese banks' stability, leading to the need of recapitalisation from the government (Hoshi and Kashyap, 2010; Montgomery and Shimizutani, 2009). Further, we perform convergence cluster analysis to examine the presence of convergence between and within regions and over time. We employ the club convergence test developed by Phillips and Sul (2007) to test for convergence in total factor productivity growth and its components. This method is flexible as it can detect convergence in sub-groups, even though convergence is rejected at the whole sample.

Chapter five studies the interplay between quantitative easing, risk, and competition. Along with the initiation of quantitative easing policy in March 2001, Japan is also known for an extended quantitative easing program of unprecedented scale since October 2010. Yet the links between risk-taking activities, quantitative easing and bank competition are largely unexplored. This chapter employs, for the first time, the Boone indicator to measure bank competition in Japan to examine these underlying linkages. This competition proxy is valid under different situations that could lead to more intense competition in the market. For instance, an increase in the number of market participants, a lift in entry barriers, a decrease in costs for other incumbents, or more aggressive interactions between firms can result in heightened competition. Other competition proxies, both structural and non-structural ones, have limitations (Beck, 2008). Taking concentration ratio as an example, it rises following a decrease in the number of firms. Higher concentration ratio is interpreted as less competition. However, this interpretation could be misleading if firms are forced to exit the market because of higher competition. We further add to the literature by providing bank-level Boone indicators, as existing studies usually compute either industry/country-level scores, or time-varying ones at most. Given the scale of nonperforming loans, we explicitly measure bank risk-taking based on our new data set of bankrupt and restructured loans. We apply the dynamic panel threshold and panel Vector Autoregression analyses to identify the threshold values for our variables of interest and tackle endogeneity concerns. Following the literature, we test the *competition-stability* (Schaeck and Cihák, 2008; Stiroh and Strahan, 2003), *competition-fragility* (Fu et al., 2014; Liu and Wilson, 2013), and quantitative easing-risk (Buch et al., 2014; Ioannidou et al., 2015; Jiménez et al., 2014) hypotheses. Given the recent adoption of negative rates in January 2016 by the Bank of Japan, our study provides new insights, as clearly there is a trade-off between quantitative easing and financial stability beyond a certain threshold. Therefore, caution regarding further scaling up quantitative easing is warranted.

The remaining chapter of the thesis, chapter six, summarises the findings of the thesis. Policy implications, limitations, and directions for further research are also included in the conclusion.

Chapter 2. Overview of the Japanese Banking System.

2.1. The horizontal *keiretsu* network

The Japanese banking sector is special in the long-term relationship between manufacturing firms and financial institutions under the so-called horizontal *keiretsu* network. This strong tie arose on the dissolution of *zaibatsu*, which stands for a large, diversified, family-centered conglomerate prior to the war. These corporations held more than a quarter of the economy's capital assets and much larger shares in heavy, modern industries (Hadley, 1970). Horizontal *keiretsu* indicates a business connection between various industries through a common *main* bank which holds a certain amount of equity of network firms. After the redistribution of shareholdings from individuals to corporations in the fifties, descendants of the big three former *zaibatsu*, namely Mitsubishi, Mitsui, and Sumitomo, constituted one type of the horizontal groups. The other type was bank-centered by Fuyo, Sanwa, and Dai-Ichi Kangyo banks. Being the "big-six" horizontal groups post-war, these *keiretsu* groups benefited from stable funding thanks to the lending ties established between diversified member firms and the central financial institution (McGuire and Dow, 2009). The certainty in access to available funds is built on close relationships with banks and other debt providers, whereas equity financing is ready from reciprocal shareholdings. On the other hand, the fact that lending ties reinforced by interlocking board membership and equity holdings are coupled with personnel exchanges reduces market pressures for member firms in the sense of short-term performance (McGuire and Dow, 2009; Yafeh, 2000). Being in a horizontal *keiretsu* network, member firms are protected from being controlled by external shareholders. Schaede (2006) argues that these groups act as an insurance against foreign hostile takeover and volatility in the stock market as the reciprocal equity would not be sold.

However, these benefits could also be regarded as costs which we will revisit at a later point.

With regard to the aforementioned personnel exchange and reciprocal monitoring, horizontal *keiretsu* affiliations bring a risk-lowering advantage and mutual assistance (Khanna and Yafeh, 2005). Additionally, information asymmetry among horizontal connected participants is lessened as mutual shareholdings create the incentives for the president's councils to effectively manage member firms' activities, as well as to assist each other in achieving profit goals or encountering operating challenges. One favourable consequence from this characteristic is the reduction in transaction and agency costs associated with trading, managing, and obtaining information (Gedajlovic and Shapiro, 2002; Lincoln et al., 1996). As a result, affiliation profitability could be improved or less exposed to exogenous shocks (Wang et al., 2005). Particularly, weak or distressed firms attain greater benefits from being within the network. Beside financial assistance from the *main* banks, they are protected from bankruptcy at the expense of the well-performing counterparts. This, however, could become a severe burden for the rescue team in the short-term (Lincoln et al., 1996).

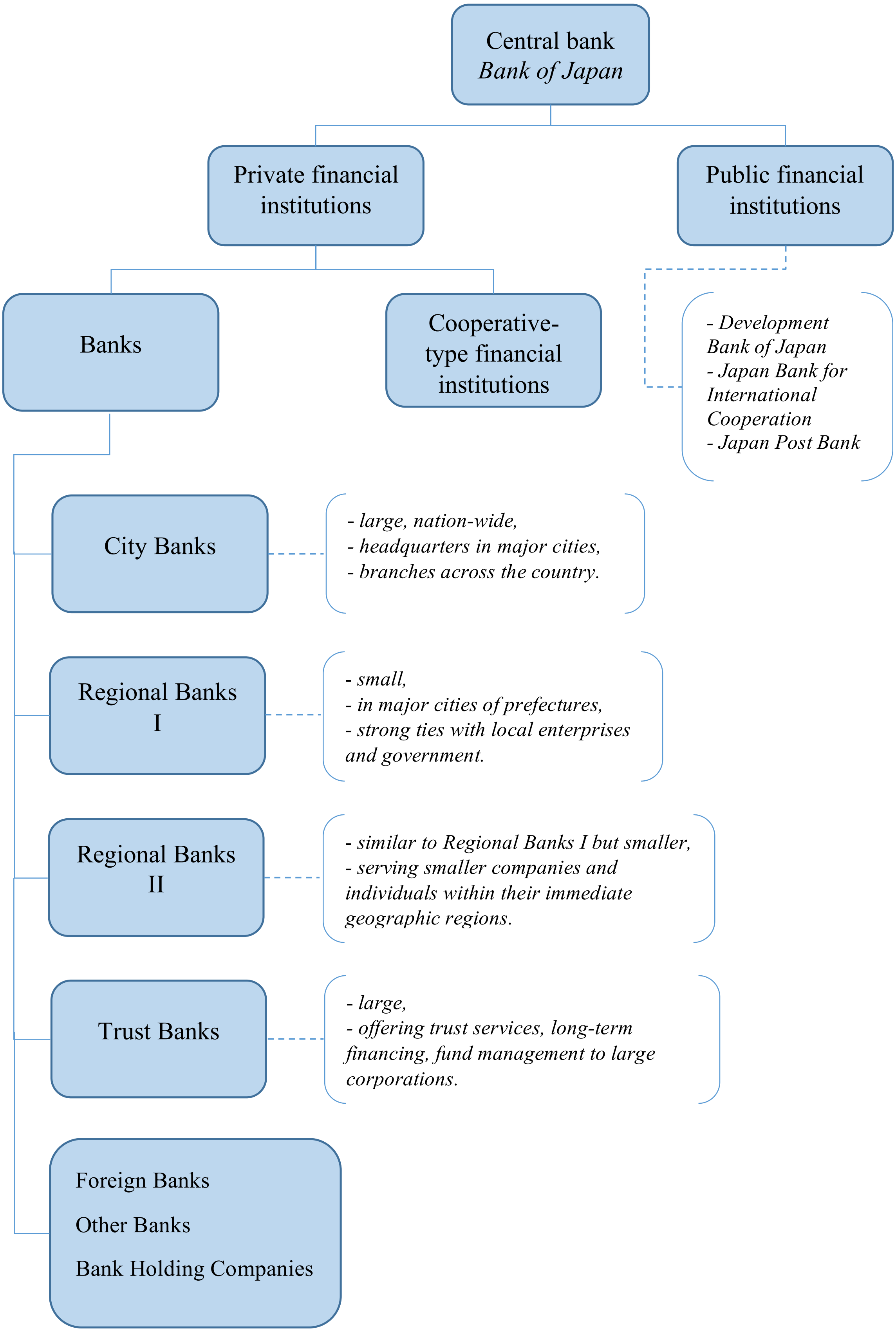
The costs of horizontal *keiretsu* could turn the appealing features of theses enterprise conglomerates into a dilemma for affiliated firms and a threat of uncertainty for the economy. The list and references of the disadvantages that financial *keiretsu* may embrace are comprehensively discussed in Lincoln et al. (1996), Weinstein and Yafeh (1998), McGuire and Dow (2009), and Brouthers et al. (2014). With regard to the central firm, overwhelming responsibility could make its monitoring of the network and its own operation inefficient. *Main* banks have come under heavy criticism for their financing to unprofitable firms, although, apparently as the crucial linkage of the network, they are entitled to assist and rescue troubled firms. These firms, in fact, *have paid* for this protection when joining the affiliation as mentioned in the *keiretsu* main purpose of insurance above. Nevertheless, taking into consideration the cost of capital between member firms and independent firms, it appears that the protection from the network could be a burdensome expense for the former. Weinstein and Yafeh (1998) argue that if easy access to ready loans from the *main* banks serves as a great comparative advantage for client firms, their performance should be superior. Yet, research has come to show the opposite (Lincoln et al., 1996; Weinstein and Yafeh, 1998). Explanations could rest on the borrowing encouragement of the *main* bank, which considers its creditor role more important than the ownership stake, consequently aiming for less risky tactics and asset protection (Suto and Toshino, 2005). Weinstein and Yafeh (1998) also regard this debate as one of the two main reasons for the lower profitability of firms relying on *main* bank financing compared against non-affiliated firms. The other cause lies on the bank's ability to extract rents from client firms in exchange for its financial services. Thus, *main* banks' clients could eventually incur relatively high interest expenses under the exertion of their *main* banks' monopoly power.

If information transparency appears as one of the great benefits internally, heightened information asymmetry between affiliated incumbents and outsiders could hinder *keiretsu* members from obtaining external investments (McGuire and Dow, 2009). This issue in turn also augments the monopoly power of *main* banks previously discussed. Another cost of affiliation is attributed to the joint monitoring and assistance that the group provides, resulting in intervention, bailout, and turnaround which affect the destiny of troubled affiliates (Lincoln et al., 1996). To reverse the adverse conditions pressuring problematic firms, the conglomerate may set favourable terms to support the purchase of their products. In addition, existing debts are rolled over, new loans are issued, and directors of the spearheaded bank and principal trading partners are dispatched to the target firms. Nonetheless, how effective are these interventions? The costs to the group, in particular the *main* bank and highly performing firms, could seriously impede their growth in the short run. Besides, overall performance of the group can be worse if all the hard work does not pay back in the long term. In fact, what came into light after the financial crisis in the late 1990s reveals the harm of continuous financing for unprofitable firms. Caballero et al. (2008) call this phenomenon *zombie* lending which is found to distort competition, lower industry productivity and deprive healthy firms' profits. Gedajlovic and Shapiro (2002) also report that financially healthy firms suffer impaired profit in concentrated ownership structure, while weaker peers seem to absorb the benefits of inter-organisational framework.

2.2. The Japanese banking structure

Private Japanese financial institutions are classified into two main categories: depository institutions (commercial banks and cooperative banks) and other financial institutions (insurance companies and securities firms). City Banks, Regional Banks I, and Regional Banks II constitute half the number of commercial banks in the former classification. The other half consists of Trust Banks, Foreign Banks, Bank holding companies, and others. City Banks operate across the nation while Regional Banks are geographical restricted. However, Regional Banks compete among each other, although less aggressively compared to how City Banks do, especially before the banking crisis (Uchida and Tsutsui, 2005). Harimaya (2008) suggest that Regional Banks engage in non-traditional banking activities because of increased competition, while findings from Kano and Tsutsui (2003) imply that Regional Banks compete within prefectures. There is no legal distinction between City Banks, Regional Banks I, and Regional Banks II. As stated in the Japanese Banker Association's website, these banks are classified into the three types for the purpose of administration and statistics. They do differ in terms of size and business functions, which are described in the following sub-sections. Figure 1 illustrates the overview of the Japanese banking structure.

Figure 1. The Japanese banking structure.



Source: Japanese Bankers Association

2.2.1. City Banks

As introduced in the previous section, members of City Banks were the *main* banks in the post-war horizontal *keiretsu* networks. The big-six horizontal *keiretsu* groups (Mitsui Nimoku-kai, Mitsubishi Kinyokai, Sumitomo Hakusui-kai, Fuyo Fuyo-kai, Sanwa group, and DKB Sankuin-kai) had City banks as the leaders that organised presidents' council meetings and backed up member firms' business through funding and board connections. Those *main* banks constituted the core of the corporate groups, functioning as an "internal capital market" and servicing the insurance mechanism between corporate businesses (Nakatani, 1983). In exceptional circumstances, management personnel assistance and financial aid from *main* banks to their customers going through business difficulties were significantly recognised, revealed by the increased proportion of lending to these specific companies (Horiuchi et al., 1988). Under their power, the large six banks used to bailout their affiliated firms by rescuing their members from the event of bankruptcy or intervening to mitigate circumstances that might destroy the member firms' reputation. The cases of Sumitomo Bank and Mazda Motors, Mitsui Bank and Mitsukoshi department stores are representative evidence. Towards the late 1990s, bank consolidation tendency diminished the number of *main* banks. The remaining City Banks at present are still among the largest commercial banks in Japan, comprising of nationwide branching institutions. Their funding resources vary from the Bank of Japan to the deposit and short term financial market, as well as securities–type operations domestically and internationally (Drake and Hall, 2003).

City Banks have been extensively studied in relation to the effectiveness of bank bailouts, the wave of mergers and acquisition, and the persistence of *zombie lending* (Caballero et al., 2008; Harada and Ito, 2011). For the two capital injection programs in

March 1998 and March 1999, nine City Banks were involved, namely Dai-ichi Kangyo, Fuji, Sakura, Sanwa, Sumitomo, Tokyo Mitsubishi, Asahi, Daiwa, and Tokai (Hoshi and Kashyap, 2010) (see Appendix A). The famous deals regarding mergers are as follows: Mitsui Bank and Taiyo-Kobe Bank to form Sakura Bank; 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; and Sumitomo Bank and Sakura Bank (Nakamura, 2006). It was expected that consolidation could strengthen bank financial health to withstand the critical situation at times. Nevertheless, mergers did not seem to improve bank performance, even in a decade later (Harada and Ito, 2011). Criticism also arose based on the misdirected lending of the government in encouraging banks to provide liquidity for troubled borrowers despite their insolvency (Caballero et al., 2008).

2.2.2. Regional Banks

Regional Banks (I and II) are smaller than City Banks. They are restrictedly operating in the principle cities of the prefectures where their head offices are situated. The loan markets of Regional Banks, however, are not segmented by prefecture. Kano and Tsutsui (2003) show that Regional Banks also operate in adjacent prefectures, revealed by similar loan interest rates across neighbouring prefectures. Over 50% of Regional Banks' time deposits are from individuals, specialised from one year or more. They have strong commitment with the local development by financing SMEs' activities. Local stock and money markets are also important sources for their investment portfolios. Regional Banks II are basically member banks of the Second Association of Regional Banks, which are categorised mainly for administration and statistical purposes, and smaller than the first category. Similar to Regional Banks I in business activities, Regional Banks II offer financial services for customers within their immediate geographical region.

Although their scope of business is rather limited compared to City Banks, the financial deregulation starting in 1993 has encouraged Regional Banks to expand their activities to nonconventional banking services. However, Harimaya (2008) argues that engaging in non-traditional activities, in particular Trust business, yields no cost benefit for Regional Banks. First, not all Trust activities were allowed. Only land trusts, charitable trusts, special donation trusts, and movable property trusts are authorised. Second, the ones approved are not very profitable to Regional Banks because of limited demand within the operating areas.

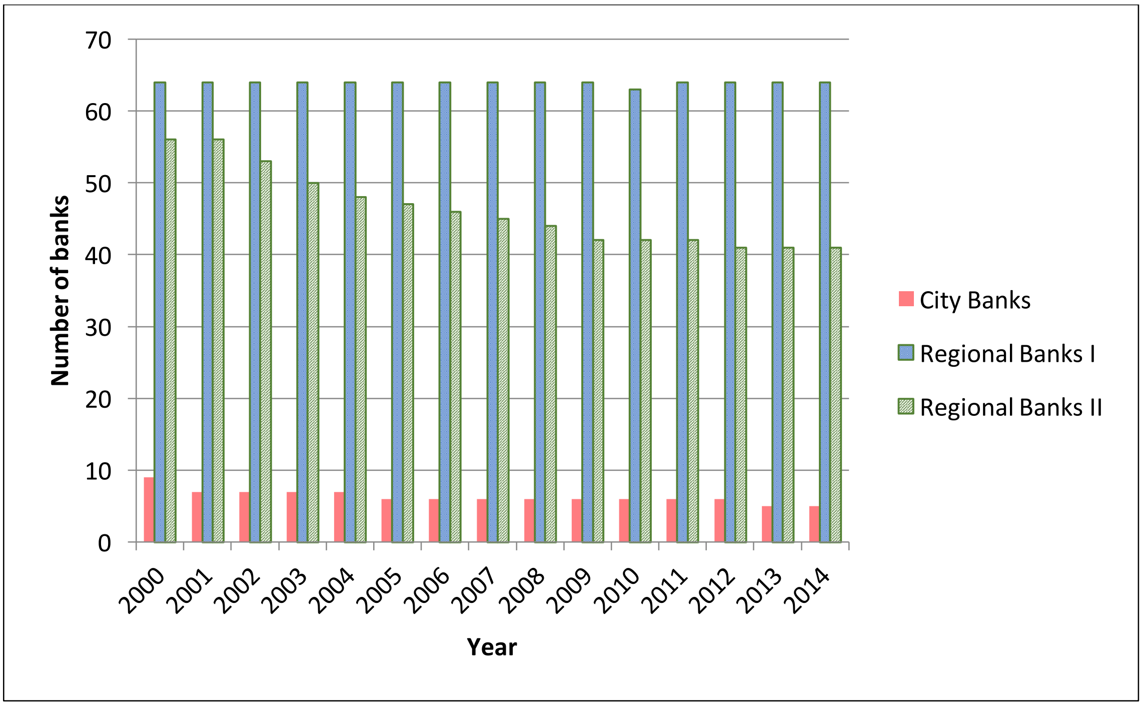
Linked to Regional Banks is the problem of SME financing which is argued to be associated to political interests of local governments (Choe, 2007). As SMEs constitute a large part of employment creators, taxpayers and voters, their growth goes along with the development of the prefecture. Consequently, unavoidably, Regional Banks incur the political influences on financing SMEs. Discussed in Choe (2007), government supports vary from special loan programs, credit guarantee to credit insurance schemes. Subsequently, portfolio risk arises within Regional Banks, also as a result of insufficient regional diversification. Baba and Inada (2009) also highlight the incentives of Regional Banks in issuing subordinated debts, which in their view should be controlled for by appropriate disciplinary tools. Banks that encounter difficulties in maintaining capital requirement levels under Basel are more likely to issue subordinated debts. Nevertheless, during the disruption period 2000-2003, investors diverted their focus to nonperforming loan ratios to distinguish between good and bad banks. This screening behaviour, which acts as a market discipline, somehow hindered financially unhealthy banks from issuing subordinated debts.

2.2.3. Trust Banks and Cooperative Banks

In contrast to conventional banks, Trust Banks are specialised long-term banking institutions, which combine financing services (offering deposits and savings account, and financing large Japanese corporations) with asset management services. Their funding sources are mainly from trusts (Drake and Hall, 2003), while their business operations spread over stock transfers, real-estate broking, securities underwriting, and securitisation. Differently, target clients of Cooperative Banks are households, local small and medium enterprises whose business operations are facilitated to improve the development of the local community. Each customer is allowed to borrow up to a specific amount of loan. Restrictions on membership are applied on the number of workers and the amount of capital. In addition, management practices must be approved in general representatives' meetings (Barros et al., 2009). Cooperative banks are subject to the same regulatory rules imposed on commercial banks and the deposit protection scheme. However, as they operate in rural areas characterised by segmented loan markets, the lack of competition can result in unfavourably high loan interest rates (Kano and Tsutsui, 2003).

Based on data availability and for comparative purposes across commercial banks, we choose to include City Banks and Regional Banks in our study. Figure 2 illustrates the number of commercial banks over time, which indicates a downward trend in the numbers of City Banks and Regional Banks II as a result of the financial crisis and bank consolidation. The number of Regional Banks II varies mostly among the three categories, gradually decreasing from 56 at the end of financial year 2000 to 41 at the end of financial year 2014. Regional Banks I, overall, remain stable with 64 banks, except in 2010. Although the number of City Banks over time does not seem to signify a significant reduction, based on their systemic importance, the fall in their number from 9 in 2000 to 5 in 2014 does indicate a remarkable change in the banking system.

Figure 2. The number of Japanese commercial banks over time.



Source: Japanese Bankers Association.

Appendix A. List of banks received capital injections.

Bank name	*Type*	*Amount injected in March 1998*	*Amount injected in March 1999*
Dai-ichi Kangyo	City Bank	99	900
Fuji	City Bank	100	1000
Sakura	City Bank	100	800
Sanwa	City Bank	100	700
Sumitomo	City Bank	100	501
Tokyo Mitsubishi	City Bank	100	
Asahi	City Bank	100	500
Daiwa	City Bank	100	408
Tokai	City Bank	100	600
Industrial Bank of Japan	Long Term Credit Bank	100	600
Long Term Credit Bank of Japan	Long Term Credit Bank	177.6	
Nippon Credit Bank	Long Term Credit Bank	60	
Mitsubishi Trust	Trust Bank	50	300
Sumitomo Trust	Trust Bank	100	200
Mitsui Trust	Trust Bank	100	400
Chuo Trust	Trust Bank	60	150
Toyo Trust	Trust Bank	50	200
Bank of Yokohama	Regional Bank	20	200
Hokuriku Bank	Regional Bank	20	
Ashikaga Bank	Regional Bank	30	

Source: Hoshi and Kashyap (2010). Unit: billion JPY.

Chapter 3. What is the Impact of Bankrupt and Restructured Loans on Japanese Bank Efficiency?

3.1. 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 JPY in 1997 to 11.6 trillion JPY 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 surge of problem loans whilst indecisive government, back then, deteriorated a rather critical 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. It becomes apparent that in effect the Japanese banking industry is unique worldwide and provides an interesting case to investigate the detrimental effect of problem loans on the stability of the industry.

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 chapter 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 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[2]) using semi-annual data. In this chapter, 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.

[2] 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).

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[3]. 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 chapter is organised as follows. Section 3.2 provides an overview of the restructuring process and problem loans in Japan. Section 3.3 summarises the literature on Japanese banking efficiency with an incorporation of problem loans. Methodology is presented in section 3.4. Section 3.5 describes our data set and variable

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

selection. Results are discussed in section 3.6. Finally, concluding remarks and policy implications are offered in section 3.7.

3.2. 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).

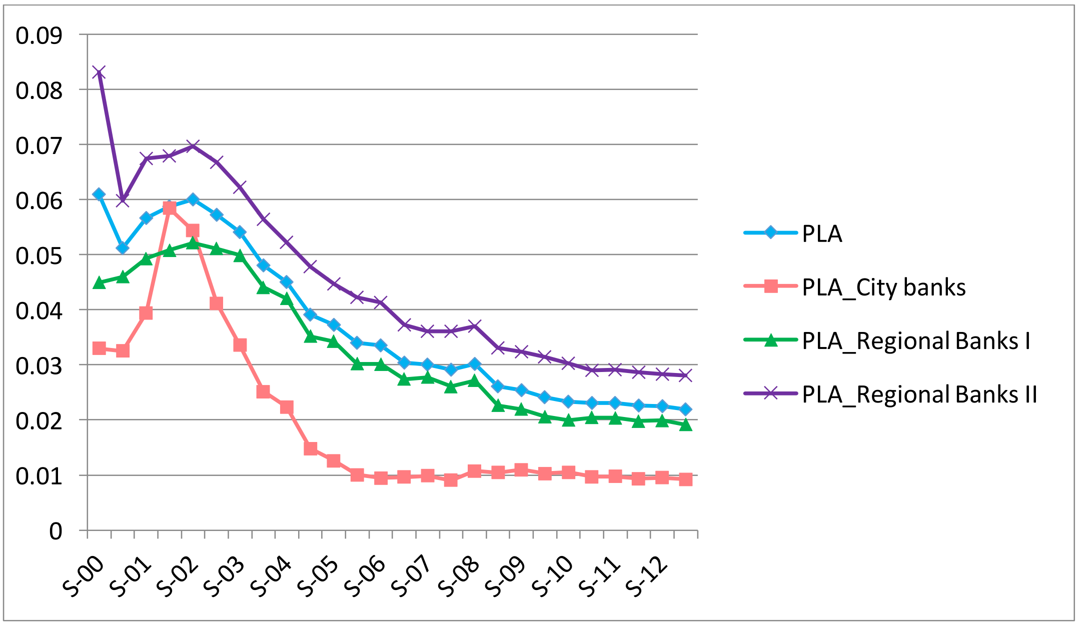
Apart from the abovementioned schemes, the wave of bank consolidation evolved among large banks to strengthen their resistance to financial severity. Mergers between City Banks (Mitsui Bank and Taiyo-Kobe Bank to form Sakura; Fuji, Dai-Ichi Kanyo, and Industrial Bank of Japan to form Mizuho Bank; Sanwa 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, 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 Figure 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% to 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).

Figure 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[4]. 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[5]). 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., 2015). The monetary easing policy was extended in 2010 due to major concerns about heightened price instability arising from negative spill over effects from slowdown overseas economies. Aggressive monetary easing has been launched ever since to support the *Abenomics* [6]– the strategic economic policy proposed by the newly appointed Prime Minister in 2012.

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[4] We thank an anonymous referee for this helpful suggestion.

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

[6] 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.

3.3. 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 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 loan 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 between 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 the effects of risk factors in Japanese banks' cost during 1993-1996. Overall inefficiency scores appear to be between 0.05 and 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. Glass et al. (2014) also consider nonperforming loans as an undesirable output when estimating technical efficiency of Japanese cooperative banks (*Shinkin* and *Shinkumi*) in 1998-2009.

It is worth noting that the literature on Japanese banking efficiency shows that studies applying nonparametric approach, in particular DEA, outnumber those using parametric method (for example, Fukuyama (1993), Fukuyama (1996), Fukuyama et al. (1999), Fukuyama and Weber (2002), Drake and Hall (2003), Fukuyama and Weber (2008), Loukoianova (2008), Liu and Tone (2008), Drake et al. (2009), Barros et al. (2009), and Yang and Morita (2013)). Altunbas et al. (2000), Uchida and Satake (2009), Assaf et al. (2011), and Glass et al. (2014) are among few parametric studies.

The first DEA study on Japanese bank efficiency is Fukuyama (1993), examining technical and scale efficiency of 143 Japanese commercial banks between 1990 and 1991. The average technical efficiency and scale efficiency for all banks in the sample are 0.8645 and 0.9844 respectively. Fukuyama (1995) includes also Trust banks and Long-Term Credit banks in the sample. These banks are found to be more technically efficient than commercial banks between 1989 and 1991. Efficiency scores for 435 Japanese credit associations in 1992 reported in Fukuyama (1996) are similar to those of commercial banks reported in Fukuyama (1993). Ownership is also taken into consideration when measuring efficiency of credit cooperatives and commercial banks in Fukuyama et al. (1999). During 1992-1996, foreign-owned banks performed better than Japanese-owned counterparts. Studying the same period for all active Japanese commercial banks, Fukuyama and Weber (2002) utilise Russell and Farrell input technical efficiency measures. Efficiency scores obtained from Farrell methodology are 0.91, significantly greater than Russell measure (0.53). It is in line with Altunbas et al. (2000) as they report X-inefficiency scores ranging from 5% to 7% in 1993-1996. Fukuyama and Weber (2005) estimate the Luenberger and Farrell output efficiency measure for Japanese banks during 1992-1999. The results entail a greater gain in outputs by reallocating inputs than reducing technical inefficiency.

Focusing on credit cooperative banks, Barros et al. (2009) report that on average, Japanese credit banks had negative technical efficiency change in 2000-2006. Assaf et al. (2011) find that between 2000 and 2006, only about 28% and 43% of the number of *Shinkin* banks experienced productivity and efficiency, respectively. Average efficiency score of *Shinkin* banks was around 86%, consistent during the study period. Other studies employ a slack-based measure for technical inefficiency, e.g. Liu and Tone (2008), Drake et al. (2009), Fukuyama and Weber (2009), and Fukuyama and Weber (2010).

In the strand of parametric efficiency studies, Tachibanaki et al. (1991) estimate output translog cost functions for 61 banks during 1985-1987. There is evidence for a presence of economies of scale (from 1.03 to 1.24) in City Banks and Regional Banks. McKillop et al. (1996) obtain similar values for economies of scale (from 1.08 to 1.28) and confirm the presence of increasing returns to scale in five giant Japanese Banks during 1978-1991. Proposed explanations for lower costs in giant banks are: i) they are able to hold shares of corporate firms instead of various bonds, ii) the long-term interrelationship between banks and firms can result in cheaper information costs.

Uchida and Satake (2009) was the first study incorporating market discipline in their efficiency estimation. They argue that depositors and market investors play a significant role in monitoring bank behaviours, thus motivating sound management and cost efficiency. Inefficiency measures are obtained from a translog cost function using stochastic frontier approach method and controlling for nonperforming loans. Tadesse (2006) also estimates the translog cost function for commercial banks and Trust Banks. Findings suggest that from 1974 to 1994, smaller banks appeared to benefit from increasing returns to scale.

Glass et al. (2014) apply the enhanced hyperbolic output distance function proposed by Cuesta et al. (2009) on cooperative banks. The results reveal that Japanese credit cooperative banks are operating under increasing returns to scale, as they are too small on average. Banks with lower return on assets and capital adequacy ratio are found to be more efficient. This is explained by the fact that the business nature of those banks is for the sake of small businesses and individuals, and to increase financial welfare of their members. Therefore, the surplus generated may not be high in the first place. Regarding the capital adequacy ratio, because all banks reported their compliance during this period, the authors suggest that banks holding excess capital requirements are locking funds on non-earning or low-earning assets, which strongly affects their efficiency level.

To this end, our study 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.

3.4. Methodology

Our methodology is underpinned by Cuesta et al.'s (2009) model. They introduce a new specification and estimation procedure of the traditional distance function to take into account the undesirable output vector. The benefits of this methodology compared to other techniques are as follows. First, the traditional distance functions do not distinguish between desirable outputs and undesirable outputs. They measure performance radially to the extent of expanding all outputs (or contracting all inputs) in the same proportion (Cuesta et al., 2009). The enhanced hyperbolic distance function of Cuesta et al. (2009) can treat desirable outputs and undesirable outputs asymmetrically, replicating the theoretical and nonparametric techniques of Färe et al. (1989). In particular, Cuesta et al. (2009)'s model reveals the proportion by which desirable outputs can be increased, and undesirable outputs and inputs can be reduced in a multiplicative manner. Second, the model enables us to estimate efficiency scores in a parametric stochastic environment. Using nonparametric techniques, e.g. DEA, to estimate the directional or hyperbolic distance function encounters the shortcomings of non-constant returns to scale which lead to a nonlinear program and deterministic models where inferences can only be drawn by bootstrapping (Simar and Wilson, 2004). Employing stochastic frontier techniques to estimate a hyperbolic distance function can overcome these problems.

The enhanced hyperbolic distance function[7] takes the form of:

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

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

The technology T represents the production possibility set:

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

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

Equation (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:

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

[7] The enhanced hyperbolic distance function has a range $0<D(x,y,b)\le 1$, 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 $D(x,\lambda y,b)\le D(x,y,b),\lambda\in[0,1]$
(iii) it is non-increasing in undesirable outputs $D(x,y,\lambda b)\le D(x,y,b),\lambda\ge 1$
(iv) it is non-increasing in inputs $D(\lambda x,y,b)\le D(x,y,b),\lambda\ge 1$

Imposing the almost homogeneity condition and choosing the M^{th} desirable output for normalising purpose $\mu = 1/y_M$, we obtain:

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

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:

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

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

$$\ln(D/y_{Mit}) = TL\left(x_{it}^*, y_{it}^*, b_{it}^*; \alpha, \beta, \chi, \delta, \gamma, \eta\right) + v_{it} \qquad i = (1, 2, \ldots, N) \qquad (5)$$

As *lnD* corresponds to the one-sided distance component u_i, by rearranging it we get:

$$-\ln(y_{Mit}) = TL\left(x_{it}^*, y_{it}^*, b_{it}^*; \alpha, \beta, \chi, \delta, \gamma, \eta\right) + v_{it} - u_{it} \qquad i = (1, 2, \ldots, N) \qquad (6)$$

where $-ln(y_{Mit})$ is the log of the M^{th} desirable output, v_{it} is the stochastic error which follows a normal distribution, u_{it} is the inefficiency term[8].

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

[8] We can now estimate equation (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).

population which is normally distributed with zero mean. It is worth mentioning that stochastic frontier techniques are extensively utilised to measure bank efficiency in Europe, US, and other countries where the banking systems are structured differently from Japan. The banking literature also reveals a considerable number of studies using this method for European banks compared to papers using similar stochastic techniques for Japanese banks (e.g. Altunbas et al., 2000; Liu and Tone, 2008; Uchida and Satake, 2009). For the Japanese context, the application of the frontier techniques to estimate bank efficiency for the whole banking industry (which means Trust Banks, Cooperative Banks, Foreign Banks, and others are also included in the sample) should account for heterogeneous production technologies (Mester, 1997). One strategy is to estimate different frontiers for different sub-samples, especially when it comes to terms with the ownership structure (Altunbas, 2001). However, doing so may not yield comparable efficiency scores across sub-samples as they are relative values. One way to address this drawback is to simultaneously estimate different technology regimes by using one latent stochastic frontier (e.g. cost function) (Orea and Kumbhakar, 2004; Green, 2005; Koetter and Wedow, 2010). In our study, the presence of the Japanese *keiretsu* (although not as important as it used to be in the 1990s), relationship banking, and the business features of different bank types may raise concern over the existence of different technologies. However, we only focus on commercial banks (City, Regional I, and Regional II), not mutual banks and others. Additionally, although Regional Banks are smaller than City Banks and not acting as the central node of the horizontal *keiretsu*, their relationship with clients are somewhat similar to the role of City Banks in the *keiretsu*. Moreover, government policies regarding banking operations usually concern all these three bank types. Besides, the application of efficiency techniques has been documented in the Japanese banking literature, both in DEA (Barros et al., 2012) and SFA (Altunbas et al., 2000; Liu and Tone, 2008; Uchida and Satake, 2009). Hence, it is feasible to apply the parametric distance function of Cuesta et al. (2009) to our sample.

Thus, the translog enhanced hyperbolic distance function takes the form[9]:

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

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

3.5. 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.

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

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 [10] 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[11]. 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[12]. 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

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

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

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

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 equation (7)[13], 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[14] (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.

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

[14] as data for number of employees are not available semi-annually.

Table 1. Descriptive statistics

Variable	Name	Mean	Std.Dev	Min	Max
y_1	Net loans	3,182,876	7,867,099	109,898.9	69,541,992
y_2	Net earning assets	2,178,294	7,419,522	1,296.512	78,517,385
b_1	Problem loans	143,582.6	371,639.3	5,207.246	6,060,743
b_2	Problem non-loan assets	4,294.59	16,352.12	0	280,278
x_1	Interest expenses	17,093.14	80,852.25	45.966	1,379,955
x_2	Fixed assets	60,392.48	141,052.1	2,463.104	1,278,986
x_3	General and administrative expenses	37,441.04	88,237.43	1,438.638	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 JPY. 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.

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[15]. 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 study is that we further disaggregate risk-monitored loans into two components: the first one is the sum of bankrupt loans and non-accrual loans[16], the second one is the sum of past due loans by 3 months or more but less than 6 months, and restructured loans[17]. 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 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.

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

[16] 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.

[17] 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).

To account for bank specific characteristics, we opt for performance variables which are represented by return on assets (ROA), and net interest margin (NIM) (Glass et al., 2014). NIM is defined as the difference between interest incomes and interest expenses, divided by total interest-earning assets (Nguyen, 2012; Williams and Nguyen, 2005). 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).[18] 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, 2012a; Ugai, 2007) and assisted the Bank of

[18] In terms of the macroeconomic variables, the Nikkei index can also represent aggregate demand, although not directly. The Nikkei index reflects stock prices whereby higher values could indicate high economic activity. In detail, I take into account an increase in consumption by households, an increase in real investment through higher Tobin's q, and an increase in real investment through the credit channel (bank lending) as firms having higher net worth positions would benefit from lower external finance premium (Miyao, 2002). Hence, the Nikkei index can capture the effect of consumption and investment which are the components of aggregate demand. With regard to the Industrial Production index, it represents industrial output or real economic activity (Miyao, 2002) rather than aggregate demand. Please note that, however, output gap, or the gap between real Gross National Product and the potential output, and de-trended output (Gordon et al., 1975; Nelson, 2002) are the common indicators for aggregate demand in the economics/growth literature.

Japan to maintain the "zero interest rates" policy[19]. However, in terms of economic activity and inflation, whether or not 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. (2015) 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[20]. 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

[19] 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.

[20] We 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. The Panzar-Rosse indicator, although non-structural, requires restrictive assumptions such as the existence of a long-run equilibrium banking market (Panzar and Rosse, 1987). The Boone indicator is more appealing, given no such assumption needed and being robust in accounting for different forces that can lead to an increase in competition (e.g. lower entry costs, relaxation of entry barriers, more aggressive interactions between firms/banks). Please see Appendix C for the methodology used to derive the Boone indicator.

subject to the control of bank management but the recovery of debtors and their compliance with the loan contracts.

3.6. Results

3.6.1. 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 (α_2 = -0.3793) 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 (α_1 = -0.0173) could be explained by the implementation of the virtually zero interest rate during 2000-2006. The reported coefficient of y_1 (0.4650) is positive and 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 and McKillop et al., 1996).

In terms of undesirable output elasticity, problem loans (χ_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 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 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.

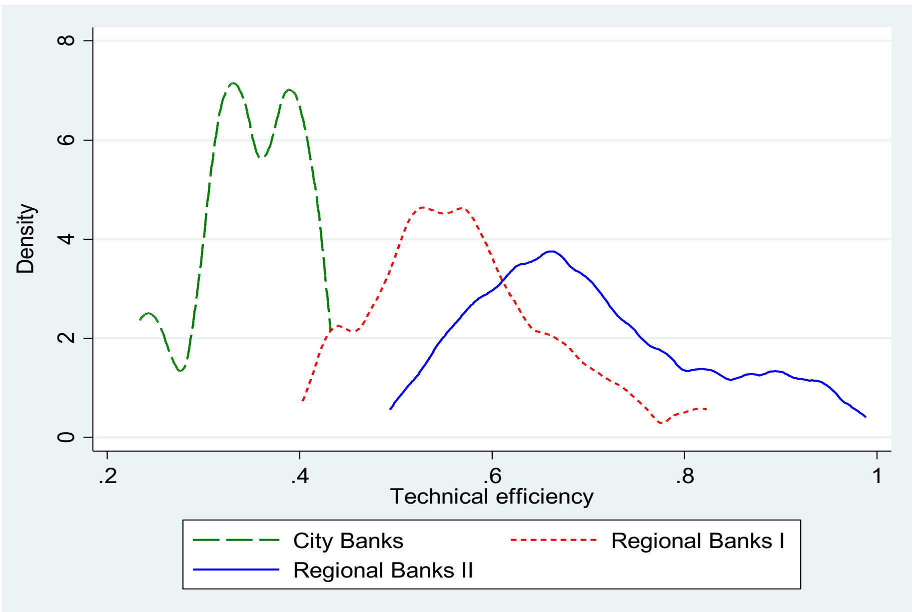
Table 2. Technical efficiency scores by bank type over time

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 equation (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.

Illustrated in Figure 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).

Figure 2. Technical efficiency scores by bank type



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

3.6.2. 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 3.5, 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 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 to be positive for these risk-monitored loans and TE, whereas an inverse one applies to 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.

Table 3. Impact of bankrupt loans and restructured loans on performance - Fixed effect models

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Dependent variable	**TE**	**TE**	**TE**	**ROA**	**ROA**	**ROA**
Capital ratio	-0.0027	0.0038	-0.0014	0.2450***	0.2410***	0.2510***
	(0.0028)	(0.0026)	(0.0025)	(0.0049)	(0.0048)	(0.0047)
Net interest margin	0.1350***	0.1220***	0.1080***	-0.1090***	-0.0859***	-0.0877***
	(0.0098)	(0.0096)	(0.0095)	(0.0217)	(0.0216)	(0.0220)
Nikkei index	0.0003	0.0007**	0.0003	0.0016**	0.0012*	0.0019***
	(0.0003)	(0.0003)	(0.0003)	(0.0007)	(0.0007)	(0.0007)
Industrial production	0.0038***	0.0036***	0.0008	0.0032**	0.0037**	0.0055***
	(0.0007)	(0.0007)	(0.0007)	(0.0016)	(0.0016)	(0.0017)
Herfindahl-Hirschman Index	-0.3530***	-0.3310***	-0.2980***	0.0772***	0.0343***	0.0323***
	(0.0041)	(0.0043)	(0.0050)	(0.0091)	(0.0096)	(0.0117)
Quantitative easing	-0.0013***	-0.0013***	-0.0014***	0.0006***	0.0007***	0.0008***
	(0.0000)	(0.0000)	(0.0000)	(0.0002)	(0.0002)	(0.0002)
Z-score	0.0000			0.0000		
	(0.0000)			(0.0000)		
Bankrupt loans		0.0017***			-0.0028***	
		(0.0001)			(0.0003)	
Restructured loans			0.0011***			-0.0008***
			(0.0000)			(0.0002)
Constant	0.6320***	0.6090***	0.6320***	-0.0536***	-0.0180**	-0.0565***
	(0.0034)	(0.0037)	(0.0032)	(0.0075)	(0.0084)	(0.0074)
R-sq	0.0149	0.0162	0.0089	0.4384	0.3872	0.4456
p value (F-test)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Notes: This Table reports results of the fixed effect models examining the impact of control variables on technical efficiency and return on assets (ROA). 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.

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 and 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 positive and 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.

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

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model6	Model 7	Model 8
Dependent variable	**TE**	**TE**	**TE**	**TE**	**ROA**	**ROA**	**ROA**	**ROA**
Capital ratio	0.0756***	0.3660**	-0.0026	-0.0026	0.1420***	0.0094	0.2350***	0.2420***
	(0.0120)	(0.1560)	(0.0043)	(0.0032)	(0.0187)	(0.1190)	(0.0090)	(0.0091)
Net interest margin	0.1410***	0.1640**	0.1350***	0.1330***	-0.1240***	-0.1450**	-0.0741***	0.0977
	(0.0170)	(0.0669)	(0.0118)	(0.0389)	(0.0313)	(0.0580)	(0.0261)	(0.1280)
Nikkei index	0.0049***	0.0219**	0.0003	0.00032	-0.0058***	-0.0150*	0.0009	0.0017*
	(0.0009)	(0.0094)	(0.0004)	(0.0003)	(0.0016)	(0.0084)	(0.0008)	(0.0010)
Industrial Production	0.0070***	0.0188**	0.0038***	0.0036	-0.0020	-0.0085	0.0038**	0.0263*
	(0.0013)	(0.0080)	(0.0007)	(0.0043)	(0.0025)	(0.0070)	(0.0016)	(0.0141)
Herfindahl-Hirschman Index	-0.4270***	-0.6990***	-0.3530***	-0.3500***	0.1990***	0.3520**	0.0133	-0.3480
	(0.0126)	(0.1490)	(0.0124)	(0.0773)	(0.0237)	(0.1380)	(0.0276)	(0.2560)
Quantitative easing	-0.0002	0.0041*	-0.0013***	-0.0013***	-0.0012***	-0.0034	0.0007***	0.0015***
	(0.0002)	(0.0024)	(0.0000)	(0.0002)	(0.0004)	(0.0021)	(0.0002)	(0.0006)
Z-score	-0.0011***	-0.0050**			0.0018***	0.0039**		
	(0.0002)	(0.0021)			(0.0003)	(0.0019)		
Bankrupt loans			0.0000				-0.0044**	
			(0.0009)				(0.0020)	
Restructured loans				0.0000				-0.0087
				(0.0016)				(0.0053)
Constant	0.5900***	0.4360***	0.6320***	0.6320***	0.0120	0.0942	0.0033	-0.0585***
	(0.0083)	(0.0859)	(0.0123)	(0.0033)	(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)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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 (ROA). 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.

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 three-bank concentration ratio, Liu et al. (2012) also report that South East Asian banks in more concentrated markets 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.

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. It is noteworthy that 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 5. Impact of bankrupt loans and restructured loans on performance - Fixed effect models – Robustness check

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Dependent variable	TE	TE	TE	ROA	ROA	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***			-0.0030***	
		(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	0.0040	0.2767	0.1971	0.4805	0.3764	0.0920
p value (F-test)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Notes: This Table reports results of the fixed effect models examining the impact of control variables on technical efficiency and return on assets (ROA). 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.

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

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model6	Model 7	Model 8
Dependent variable	**TE**	**TE**	**TE**	**TE**	**ROA**	**ROA**	**ROA**	**ROA**
Capital ratio	0.1152**	-0.0583	0.0685***	0.0254***	0.1453***	0.1840***	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)	(0.0160)	(0.0142)	(0.0224)	(0.0202)	(0.0218)	(0.0222)
Nikkei index	-0.0028***	-0.0048***	-0.0016***	-0.0020***	0.0018**	0.0031***	0.0014**	0.0020***
	(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*	0.0060***
	(0.0017)	(0.0014)	(0.0011)	(0.0010)	(0.0017)	(0.0015)	(0.0015)	(0.0016)
Boone indicator	-0.0962***	-0.0964***	-0.0757***	-0.0458***	0.0227***	0.0210***	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***	0.0010***	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)	(0.0080)	(0.0068)
R-sq	0.0207	0.006	0.3267	0.2337	0.0792	0.1156	0.0920	0.1400
p value (chi2-test)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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 (ROA). 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 return 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 distressed 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 return 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.

3.6.3. 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)[21]. Figures 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[22].

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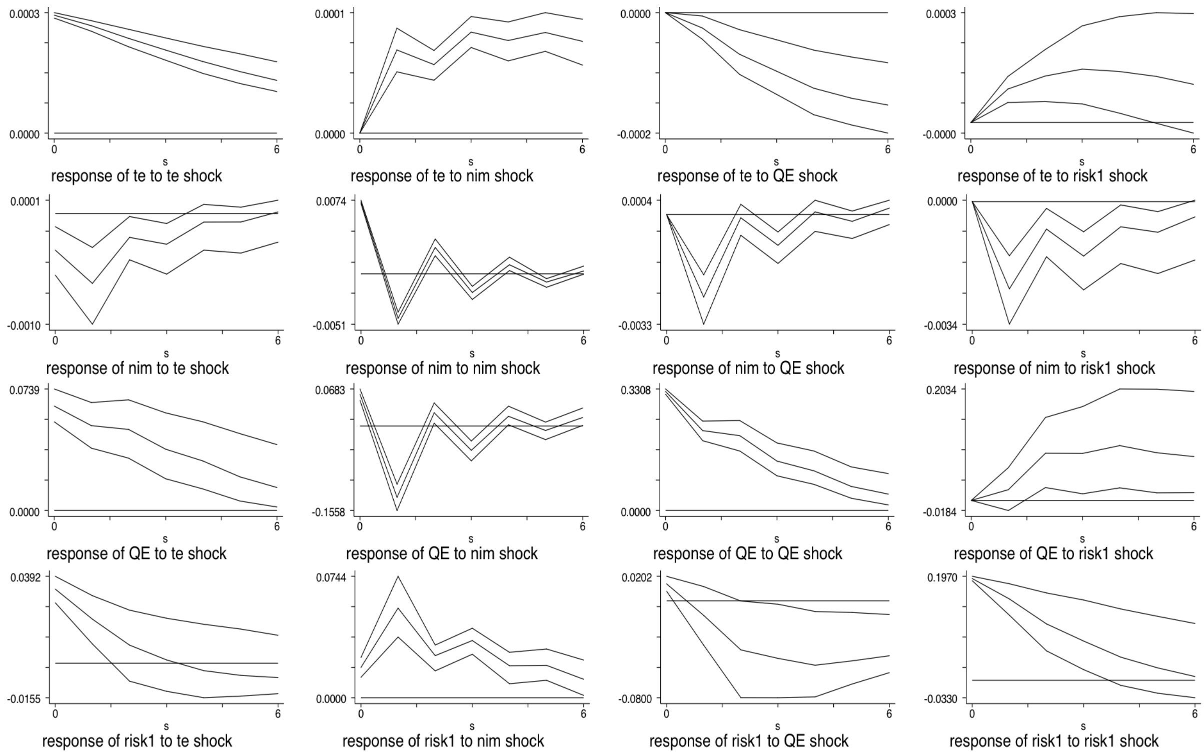
[21] To relax the restriction that all cross-sectional units in our panel data are the same, we incorporate the fixed effect μ_i, which is correlated with lags of the dependent variable. To remove the fixed effect in estimation without eliminating the orthogonality between the transformed variables and 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 the 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.

[22] 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

Figure 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.

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 Figure 3 shows that the response of TE to a shock in bankrupt loans is positive but small 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

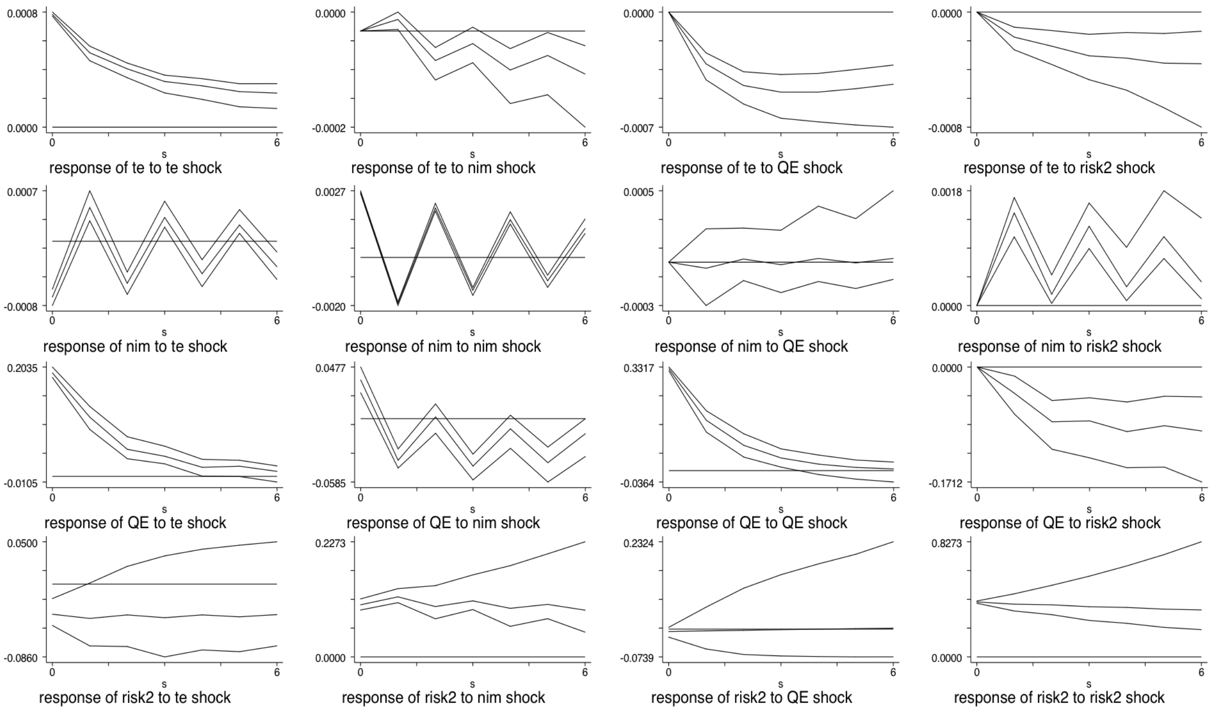
to lose information and reduce degrees of freedom. Additionally, we perform normality tests for the residuals, employing the Shapiro-Francia W-test. The results confirm that there is no violation of the normality.

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 SME 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 Figure 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 Figure 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 Figure 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.

Figure 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 loans; s: number of periods. Errors are 5% on each side generated by Monte-Carlo simulation.

In Figure 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 Figure 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 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 Figures 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 positive and significant. 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.

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% of 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.

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

	s	TE	NIM	QE	Risk 1
TE	10	0.4666	0.0814	0.3121	0.1399
NIM	10	0.0058	0.8225	0.0709	0.1008
QE	10	0.0386	0.0771	0.7339	0.1504
Risk 1	10	0.0169	0.0609	0.1412	0.7809
TE	20	0.3927	0.0801	0.4157	0.1114
NIM	20	0.0060	0.8218	0.0714	0.1008
QE	20	0.0388	0.0771	0.7309	0.1532
Risk 1	20	0.0169	0.0602	0.1454	0.7775

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.

In the case of restructured loans (Table 8), quantitative easing is also important in explaining 37.1% of 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.

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

	s	TE	NIM	QE	Risk 2
TE	10	0.3346	0.0141	0.3713	0.2800
NIM	10	0.0492	0.7348	0.0002	0.2159
QE	10	0.2028	0.0346	0.5259	0.2367
Risk 2	10	0.0103	0.0748	0.0001	0.9148
TE	20	0.2280	0.0270	0.2999	0.4450
NIM	20	0.0462	0.6776	0.0003	0.2759
QE	20	0.1663	0.0422	0.4254	0.3660
Risk 2	20	0.0113	0.0745	0.0004	0.9138

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.

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 that the causality would run from bankrupt and restructured loans to net interest margin. In the case of restructured loans[23], 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

[23] Please refer to Figure 4, second row, last diagram.

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.

3.7. 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.

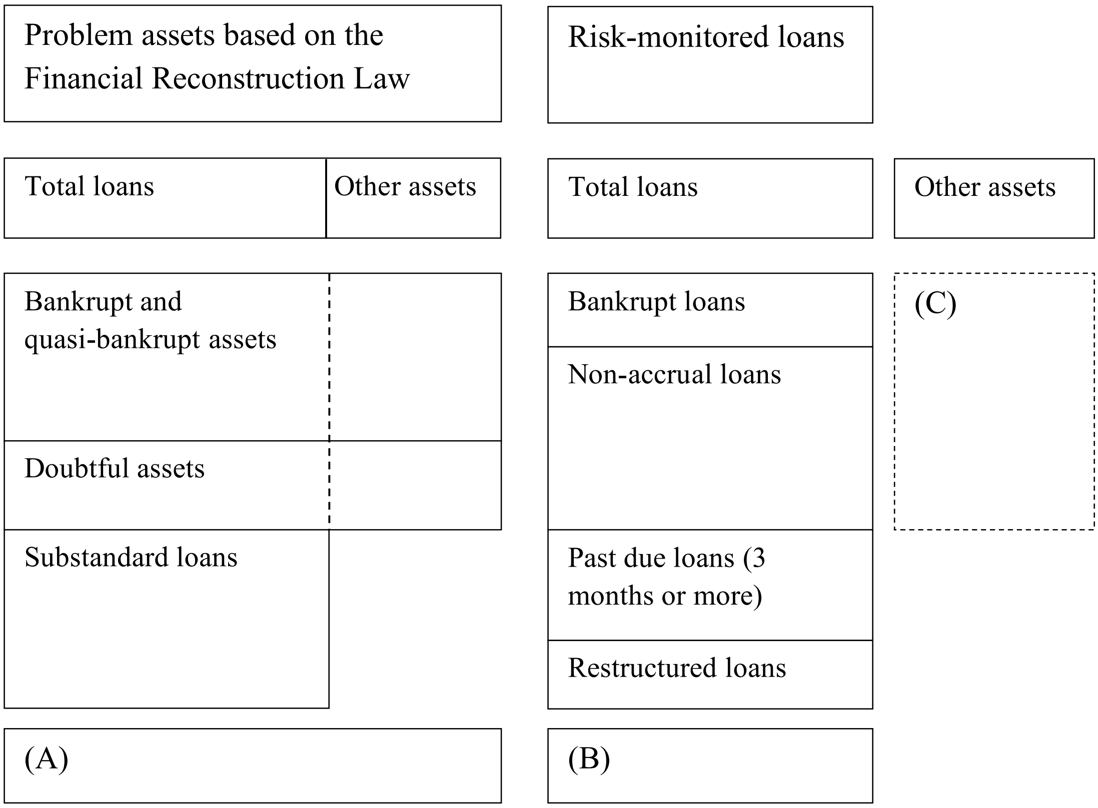
In the latter stage analysis, we explore the impact of bankrupt loans and restructured loans on bank efficiency. We report that the response of technical efficiency is positive to a shock in bankrupt loans, but negative to a shock in restructured loans. There is evidence showing that bankrupt and restructured 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 would need to prudently control the level of risk-taking in commercial banks as well as their loan issuance process. Lending standards, the screening process, and management practices are the potential areas to be examined so that the compliance with these procedures is ensured. 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. In detail, for instance, an early warning system for the potential macroeconomic disturbances could be helpful for bank risk management. Alongside the minimum capital requirement, encouraging higher level of capital to be kept by banks can enhance their resilience to economic shocks. In addition, promoting diversification or a lower proportion of loans in the components of assets can reduce banks' exposure to uncontrollable events. Besides, prompt responses of the government to natural disasters, such as the Tohoku earthquake/tsunami in 2011, should be acknowledged for assisting banks and firms in encountering unexpected events, hence mitigating the adverse effects which can lead to a rise in restructured loans. To sum up, both highly efficient banks and worst performing banks should be supervised thoroughly as their efficiency scores act as a warning for heightened uncertainty.

In light of 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.

Appendices – Chapter 3

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



Note: (A) – (B) = (C)

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.

B. Panel VAR model

The first order VAR model takes the form of:

$$w_{it} = \mu_i + \Phi w_{it-1} + e_{i,t} \quad i = 1,...,N; \qquad t = 1,...,T \qquad \text{Eq. (B.1)}$$

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:

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

Eq. (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:

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

Eq. (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:

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

Eq. (B.4)

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

Eq. (B.5)

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

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

Eq. (B.6)

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.

$$\ln \pi_i = \alpha + \beta \ln mc_i \qquad \text{Eq. (C.1)}$$

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):

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

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

$$\ln TC_{it} = \alpha_0 + \alpha_1 \ln Q + \frac{\alpha_2}{2} \ln Q^2 + \sum_{j=1}^{2} \beta_j \ln P_j + \frac{1}{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \delta_{jk} \ln P_j \ln P_k + \sum_{j=1}^{2} \gamma_j \ln Q \ln P_j$$
$$+ \varphi_1 t + \frac{1}{2} \varphi_2 t^2 + \varphi_3 t \ln Q + \sum_{j=1}^{2} \varphi_j t \ln P_j + \varepsilon_{it}$$

Eq. (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):

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

Chapter 4. What is the Impact of Problem Loans on Japanese Bank Productivity Growth?

4.1. Introduction

There has been extensive theoretical and empirical research into the field of firm efficiency and productivity (Heshmati et al., 2014; Kumbhakar and Tsionas, 2016; Sun et al., 2015). In terms of bank efficiency and productivity, the outbreak of the global financial crisis has driven a surge of banking studies (Matousek et al., 2015; Tsionas et al., 2015), unfolding the paramount importance of financial intermediaries within the economic system. In terms of productivity growth, evidence is rather limited with studies that apply parametric methods to evaluate bank productivity (Boucinha et al., 2013; Feng and Serletis, 2010; Feng and Zhang, 2012, 2014). As indicated in a review of non-parametric productivity applied in banking by Fethi and Pasiouras (2010), the majority of studies adopt a non-parametric approach (Fukuyama and Weber, 2005, 2010; Liu and Tone, 2008).

Our study extends the literature on bank productivity by opting for a parametric estimation technique. We decompose bank productivity growth into different components, namely the effects of problem loans, which are essentially undesirable outputs, quasi-fixed input, returns to scale, and technological change. The Japanese banking system is of interest as its performance has been undermined by an unprecedented volume of bankrupt and restructured loans. These loans are referred as risk-monitored loans disclosed in accordance with the Japanese Banking Law. Moreover, in Japanese banking literature, bank efficiency studies have dominated the research field of bank performance, for example Drake and Hall (2003), Fukuyama and Weber (2005), Fukuyama and Weber (2010), Barros et al. (2012), Yang and Morita (2013). Japanese bank productivity has been rather neglected (Assaf et al., 2011; Fukuyama, 1995; Fukuyama et al., 1999).

We, thus, fill a gap in the literature and apply for the first time a productivity growth decomposition to Japanese banks, where problem loans' impact would be revealed.[24] Previous literature has considered nonperforming loans as uncontrollable inputs (Drake and Hall, 2003; Hughes and Mester, 2010), a quality variable (Hughes and Mester, 1998), or undesirable outputs in the banking production process (Assaf et al., 2013; Barros et al., 2012; Berg et al., 1992; Fukuyama and Weber, 2008; Glass et al., 2014; Mamatzakis et al., 2015; Park and Weber, 2006). We follow the last stream of literature to treat bankrupt and restructured loans as undesirable outputs in our productivity decomposition. Given the extensive volume of bankrupt and restructured loans in Japan, we expect that they have an impact on bank productivity. Arguably, banks may receive payments of the principal and interest on these loans subject to borrowers' financial health. These overdue loans in turn would raise bank's operating costs in the short-run. Hence, one would expect these loans to deteriorate bank productivity.

Alongside bankrupt and restructured loans, we also employ equity as a quasi-fixed input (Berger and DeYoung, 1997; Hughes et al., 2001; Ray and Das, 2010). Within a short period, it would be unfeasible to adjust the level of equity considerably and quickly (Lozano-Vivas and Pasiouras, 2014). In the event of unexpected losses, the level of equity is of utmost importance to ensure bank safety and soundness, preventing banks from temporary illiquidity and insolvency (Diamond and Rajan, 2000). Equity would also

[24] The decomposition is similar to decomposing productivity growth with respect to public infrastructure in agriculture (Mamatzakis, 2003; Morrison and Schwartz, 1996) or branch growth in banking (Kim and Weiss, 1989).

serve as a cost-reducing factor due to less interest paid for debt financing (Hughes and Mester, 2013). Finally, the inclusion of equity in our productivity decomposition is of importance for Japan. The reason is that during the banking crisis in the late 1990s, there was a prolonged period of undercapitalisation until the early 2000s. The Japanese authorities responded by injecting public capital four times between March 1998 and June 2003 (Hoshi and Kashyap, 2010), hoping to stabilise the financial market and revive the banking industry.

The contribution of this study can be summarised in the following ways. First, we expand the parametric methodological literature of bank productivity growth (Boucinha et al., 2013; Casu et al., 2013; Lozano-Vivas and Pasiouras, 2014) as opposed to the broadly applied nonparametric one (Alam, 2001; Berg et al., 1992; Delis et al., 2011; Fiordelisi and Molyneux, 2010; Grifell-Tatjé and Lovell, 1997; Kao and Liu, 2014; Wheelock and Wilson, 1999). Our paper refers to Japan, which serves as an excellent case study given the trouble of its banking industry (Barros et al., 2009; Fukuyama, 1995; Fukuyama and Weber, 2002). Second, we exploit a new data set of bankrupt and restructured loans, which are disaggregated from "risk-monitored loans" disclosed subject to the Japanese Banking Law. The adopted approach enables a comprehensive analysis by allowing for the impact of these loans on total factor productivity growth. Finally, we test for convergence – catching up effect – among Japanese banks and geographic regions by using club convergence analysis proposed by Phillips and Sul (2007).

Our results show that productivity growth in Japanese commercial banks is impaired by the impact of bankrupt loans. The destructive effect of these loans varies over time, appearing to capture events such as government interventions, the global financial crisis, and the Tohoku tsunami/earthquake. Interestingly, restructured loans are among the drivers of productivity growth, as they are found to lower costs. With regard to the club convergence analysis, we find divergence in productivity growth across regions over time. However, some integration, and thus convergence, is identified for Regional Banks I, whereas there exist some clubs of convergence within City Banks, and within the regions of Hokkaido, Tohoku, Kanto, Chubu, Chugoku, and Shikoku.

The remainder of this chapter is structured as follows. Section 4.2 provides an overview of the literature in bank productivity. Section 4.3 presents the methodology, followed by the data description in section 4.4. Empirical results are provided in section 4.5, and convergence tests are discussed in section 4.6. Finally, section 4.7 concludes.

4.2. Literature review

This section highlights the literature in bank productivity with a particular focus on nonparametric and parametric techniques used to decompose total factor productivity (TFP) growth. According to Kumbhakar and Lovell (2003), both approaches need calculation or estimation of a representation of production technology to answer: i) how productivity change can be measured and ii) what the sources of measured productivity change are (page 279). However, only the parametric approach is able to provide the answers to both questions in a stochastic environment. In what follows, we survey the studies that apply both methodologies to measure bank productivity.

4.2.1. Non-parametric studies

As indicated in a comprehensive review for bank efficiency and productivity (Fethi and Pasiouras, 2010), the majority of productivity studies conducted before 2010 apply Data Envelopment Analysis (DEA) to decompose the Malmquist productivity index

(Malmquist, 1953). This Malmquist TFP index measures the change in TFP between two data points by computing the ratio of the distances between each data point relative to a common technology (Casu et al., 2004). If an output distance function is utilised to derive the index, the Malmquist (output oriented) TFP change index taking a value greater than one (less than one) will indicate positive (negative) TFP growth between the base period and the following period. Banking applications which apply and adjust the Malmquist productivity index include Berg et al. (1992), Grifell-Tatjé and Lovell (1997), Wheelock and Wilson (1999), Alam (2001), Mukherjee et al. (2001), Casu et al. (2004), Lozano-Vivas and Pastor (2006), Tortosa-Ausina et al. (2008), Fiordelisi and Molyneux (2010), Delis et al. (2011), and Kao and Liu (2014).

A number of studies examine bank productivity growth during the deregulation period in the 1980s. Berg et al. (1992) obtain the productivity index for Norwegian banking between 1980 and 1989. The largest banks are found to be strongly productive after deregulation. The worst performing banks also experienced productivity growth. Examining US banking, Wheelock and Wilson (1999) and Alam (2001) show that the driving factor for productivity growth was advances in technology during 1980s-1990s. Evidenced in Alam (2001), banks in states with limited branching obtained productivity growth through the incorporation of new technology into operation. Differently, banks in states allowing state-wide branching achieved productivity gain from catching up with the best performing banks. In unit-banking states, banks suffered from a decline in productivity growth due to the confined regulatory environment. Similarly, Tirtiroglu et al. (2005) show that intrastate branching deregulation had a pronounced and long-run effect on bank productivity growth. Wheelock and Wilson (1999) also report a presence of technological progress. However, there was a decline in average productivity growth during 1984-1993, when the majority of banks failed to keep up with the innovative technology. Banks of all size also experienced an increase in inefficiency. Deregulation is also reported to enhance productivity growth of Portuguese banks which were created and transformed post-deregulation period 1990-1995 (Canhoto and Dermine, 2003). Significant growth as a result of financial deregulation is also found for Turkish banks between 1981 and 1990 (Isik and Hassan, 2003).

Grifell-Tatjé and Lovell (1997) replace the Malmquist productivity index by a generalised Malmquist productivity index, allowing for the measurement of the contribution of scale economies on productivity growth. In more details, for Spanish commercial banks and fast-growing saving banks over the 1986-1993 period, Grifell-Tatjé and Lovell (1997) report greater productivity growth for the former (2.6% compared to 2.1% annually). Both categories benefited from the improvement of best-practice banks, while the scale effect had little contribution to productivity growth. Also examining Spanish banks, Tortosa-Ausina et al. (2008) use a bootstrapping technique to derive the Malmquist index in order to draw statistical inferences with regard to the significance of the index. By using this technique, one is able to obtain confidence intervals which are subsequently used to test whether the Malmquist productivity index is significantly greater or less than one at a given significance level. The results indicate that during 1992-1998, the majority of Spanish saving banks experienced productivity growth, statistically significant at 5% level. Kao and Liu (2014) is a recent study proposing that the Malmquist productivity index should be probabilistic as banking operations are subject to high externalities. A probabilistic analysis is carried out on data of Taiwanese banks after the second financial restructuring 2004. Kao and Liu (2014) argue that this type of analysis provides managers with probability information alongside average values, thus, strengthening information reliability.

Studies computing and comparing bank productivity growth in European banking also prevail in the literature, e.g. Casu et al. (2004), Fiordelisi and Molyneux (2010), and Delis et al. (2011). Based on the nonparametric approach, Casu et al. (2004) find different trends in productivity change of European banks (1994-2000). Modest productivity growth is reported for British, French, and German banks, while strong growth is found for Spanish and Italian banks. Fiordelisi and Molyneux (2010) obtain TFP growth of European banking by using similar techniques. Focusing on the impact of each component of the Malmquist productivity index, Fiordelisi and Molyneux (2010) further examine the role of productivity growth in explaining shareholders' value. Technological change was the most productive component which contributed to shareholder's value. Delis et al. (2011) examine bank productivity growth of 22 new EU members between 1999 and 2009, in light of the regulation for transition countries in Europe. Covering also Japan and the US, Lozano-Vivas and Pastor (2006) also suggest that technological progress is a driving factor for the convergence of productivity growth.

A development of the Malmquist index is the Luenberger productivity indicator (Chambers, 2002; Luenberger, 1992), which measures productivity in difference form. Unlike the Malmquist index, the Luenberger indicator can account for an expansion in outputs and a contraction in inputs simultaneously. Studies that compute the Luenberger indicator for banking industries are Park and Weber (2006) (Korean banks 1992-2002), Epure et al. (2011) (Spanish banks 1998-2006), Williams et al. (2011) (saving banks in 10 European countries 1996-2003), Chang et al. (2012) (Chinese banks 2002-2009), and Fujii et al. (2014) (Indian banks 2004-2011).

4.2.2. Parametric studies

Bank productivity in parametric studies is mainly derived from estimating cost, profit, or distance functions. There is extensive research on productivity growth of US and European banking industries, such as Stiroh (2000), Berger and Mester (2003), Feng and Serletis (2010), Feng and Zhang (2012), and Feng and Zhang (2014) among others. European banking systems also attract research interest, e.g. Chaffai et al. (2001) Kumbhakar et al. (2001), Orea (2002), Casu et al. (2004), Koutsomanoli-Filippaki et al. (2009), and Boucinha et al. (2013). Empirical research focusing on banks in other countries includes Kim and Weiss (1989), Kumbhakar and Sarkar (2003), and Casu et al. (2013). In what follows, we review the studies based on the underlying functional form employed.

For the use of the cost function, Kim and Weiss (1989) estimate an equation system consisting of the translog cost function and cost shares of inputs to examine the effect of branches on TFP growth of Israeli banks during 1979-1982. The results show that during three years, TFP of Israeli banks increased at an average of 7.79% per year. The contribution of branch growth is found to be less than that of technical change, although they were both significant drivers of TFP growth, especially for small banks. For the Indian banking sector from 1985 to 1996, Kumbhakar and Sarkar (2003) estimate a translog shadow cost function together with one equation of the shadow cost share of one input, using seemingly unrelated regression. TFP growth is decomposed into three components: a scale factor, a technological change, and a miscellaneous part. All three factors depend on regulation via shadow prices of inputs which are a product of actual input prices and a function component defined as the distortion function of labour relative to capital. Results show a decreasing trend of productivity growth around the deregulation period, followed by an upward trend after deregulation. Regardless of the ownership structure, the scale component was the main force of TFP growth in all banks. Estimating a cost function on its own by using stochastic frontier analysis, Boucinha et al. (2013) obtain the estimated parameters and compute total factor productivity change for Portuguese banks. Their results suggest that technological progress was the main driver of total factor productivity change from 1992 to 2006.

Also utilising the cost function, Stiroh (2000) examines productivity in US bank holding companies during the 1990s using several econometric approaches: i) pooling annual data and estimate the shift from the cost function; ii) incorporating bank holding companies' specific effects in panel data, and estimating the shift in a common cost function; and iii) decomposing total cost changes into changes in business conditions and in productivity. They find quite consistent results (0.4% yearly in average) across different techniques with different specifications of outputs.

Berger and Mester (2003) estimate cost and profit functions for US banks during 1991-1997 to obtain cost productivity change and profit productivity change. Productivity change in this study is defined as changes in best practice and changes in inefficiency. Focusing on off-balance sheet variables, Lozano-Vivas and Pasiouras (2014) also obtain productivity change by applying this parametric decomposition on an international sample for the period 1999-2006. Using a translog profit function, Kumbhakar et al. (2001) measure productivity change as the sum of technical change which is defined as shifts in the profit frontier, and variation in the components of profit technical efficiency. For Spanish saving banks during 1986-1995, there was evidence for high technical inefficiency, but significant technical progress.

Chaffai et al. (2001) use a stochastic output distance function to decompose the Malmquist index into pure technological effect and environmental effect. During 1993-1997, among the banking industries in France, Germany, Italy, and Spain, the environmental effect was more significant than the other factor in explaining the productivity gaps between countries. Orea (2002) also opts for the distance function to introduce a parametric decomposition of a generalised Malmquist productivity index. The TFP index in Orea (2002) is contributed by the Malmquist productivity index and a returns to scale term. Applying the parametric decomposition for Spanish saving banks (1985-1998), Orea (2002) finds that TFP growth was mainly attributed to technical progress, although the scale effect also revealed a positive impact on productivity change. Koutsomanoli-Filippaki et al. (2009) parameterise the directional distance function to examine Luenberger productivity indicator for banking industries in Central and Eastern European countries (1998-2003). Their finding suggests that the dominant factor driving productivity growth was technological change. Feng and Zhang (2012) and Feng and Zhang (2014) adopt a true random stochastic distance frontier model to allow for unobserved heterogeneity among US banks. The "output-distance-function-based-Divisa" productivity index proposed in Feng and Serletis (2010) is used in these studies to measure TFP growth of large US banks.

Following the parametric technique in Berger and Mester (2003), Casu et al. (2004) obtain productivity growth of European banking sectors to compare with findings from the Malmquist index. Their results confirm the strong productivity growth for Italian and Spanish banks, whereas mixed evidence is reported for the German and French banking sectors. Productivity growth is found to mostly stem from technical change rather than the catching up of non-best-practice financial institutions. Casu et al. (2013) also use both Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) to estimate productivity change of Indian banks 1992-2009. They further conduct a metafrontier analysis to account for technology heterogeneity amongst banks with different ownership structures.

It is noteworthy to emphasise that a semi-parametric approach has emerged in the efficiency and productivity literature (Sun and Kumbhakar, 2013; Sun et al., 2015). Flexibility is the main feature of this approach that attracts research interest. This methodology to measure productivity, however, has been mainly applied in nonbanking research (Heshmati et al., 2014). Sun et al. (2015) propose a semiparametric cost frontier of which the slope coefficients are a nonparametric function of the time trend. The semiparametric cost function is estimated first, followed by a decomposition of inefficiency into time-varying and time-invariant components. Finally, productivity is decomposed based on the estimated cost frontier. Although the authors use Norwegian farming data set as an example, this methodology could also be of interest for banking applications.

4.2.3. Productivity growth in Japanese banking

This section reviews the productivity literature with regard to the Japanese banking industry. As Barros et al. (2009) point out, there are limited studies examining productivity growth in Japanese banks in general. Productivity growth studies in Japanese banking are also dominated by those adopting nonparametric methodologies (Assaf et al., 2011; Barros et al., 2009; Fukuyama, 1995; Fukuyama et al., 1999; Fukuyama and Weber, 2002). Fukuyama et al. (1999), Barros et al. (2009), Assaf et al. (2011) are among a few studies publishing on cooperative banks. Fukuyama (1995) is a typical study investigating TFP growth of all commercial banks 1989-1991.

Estimating the Malmquist productivity index, Fukuyama (1995) finds evidence indicating that the collapse of the bubble economy resulted in lower productivity change index. Productivity loss is found to be attributed to reduction in efficiency. Similar technique of decomposition is applied in Fukuyama et al. (1999), following Färe and Grosskopf (1994). For both foreign and Japanese credit cooperatives, productivity had improved slowly during 1992-1994 before declining in 1995 due to the fall in efficiency. However, the number of credit cooperatives experiencing a greater fall in overall efficiency reduced over time, while the number of banks having technical progress increased. Foreign cooperative banks are found to have greater productivity growth (slower decline) than their Japanese counterparts. Fukuyama and Weber (2002) estimate a number of different specifications of the Malmquist productivity index, namely the indirect Malmquist–Russell productivity index, the indirect Malmquist–Farrell productivity index, and the indirect Malmquist output-based productivity index. All measures give evidence for a significant decline in productivity growth on average for Japanese banks operating between 1992 and 1996.

Barros et al. (2009) employ the Malmquist productivity index and DEA to investigate the productivity growth and biased technological change in Japanese credit banks (*Shinkin* banks) in 2000-2006. The Malmquist index is disentangled into efficiency change and technological change composition. Technological change index then can be decomposed into three different component indices: output biased technological change, input biased technological change, and the magnitude of technological change. The results show that on average, *Shinkin* banks experienced negative productivity and technical efficiency change. The majority of them had a bias in using labour and fixed assets. Securities are also found to illustrate the bias in the production of relative outputs of most *Shinkin* banks. Similarly, Assaf et al. (2011) confirm that *Shinkin* banks do not experience significant improvement in productivity growth during 2000-2006. They analyse productivity by using a bootstrapped Malmquist index, and further regress the scores on market share of deposits, number of branches, return on assets, net interest margin, and concentration ratio of deposits for the five largest banks. Except net interest margin, all other variables are significant in the contribution of productivity growth.

To this end, the aim of our study in filling a gap in Japanese banking productivity growth literature is twofold. First, we enhance the literature in parametric productivity studies. Second, our parametric methodology allows for the impact of undesirable outputs and a quasi-fixed input on TFP growth, exploring further the principal effects of bankrupt and restructured loans on productivity growth of Japanese banks.

4.3. Methodology

4.3.1. Decomposing productivity growth

The starting point is to minimise total cost given a production function *F*. This optimisation is:

$$C(w, Y, b, E, t) = \min_{X}\left\{\sum wX : F(X, Y, b, E, t) = 0\right\} \quad (1)$$

or $C \equiv \sum_{k=1}^{K} w_k X_k$ (2)

where *F* denotes the production function with output quantity *Y*, input quantity *X*, input prices *w* (with *k* being the number of input prices), undesirable outputs *b*, equity *E*, and technology *t*. We treat equity *E* as quasi-fixed as it is difficult to adjust the quantity of equity quickly in the short-run (Lozano-Vivas and Pasiouras, 2014). Hughes and Mester (2010) indicate that nonperforming loans can also be treated in the manner of accounting for a quasi-fixed "input" by including the level of nonperforming loans rather than the price. In addition, reducing these loans, to some extent, is not under bank managers' control, but the financial ability of borrowers and their willingness of repayment, as argued in Drake and Hall (2003). To derive the impact of undesirable outputs on productivity growth, we adopt the methodology proposed by Morrison and Schwartz (1996).

The total differentiation of equation (1) with respect to time yields:

$$\frac{dC}{dt} = \sum_{k=1}^{K} \frac{\partial C}{\partial w_k} \frac{\partial w_k}{\partial t} + \sum_{m=1}^{M} \frac{\partial C}{\partial Y_m} \frac{\partial Y_m}{\partial t} + \sum_{j=1}^{J} \frac{\partial C}{\partial b_j} \frac{\partial b_j}{\partial t} + \frac{\partial C}{\partial E} \frac{\partial E}{\partial t} + \frac{\partial C}{\partial t} \tag{3}$$

Dividing both sides of equation (3) by total cost C, multiplying and dividing the terms in the right hand side of equation (3) (except the last term) with input prices, outputs, undesirable outputs, and equity respectively, we obtain:

$$\frac{\dot{C}}{C} = \sum_{k=1}^{K} \frac{\partial C}{C} \frac{w_k}{\partial w_k} \frac{\dot{w}_k}{w_k} + \sum_{m=1}^{M} \frac{\partial C}{C} \frac{Y_m}{\partial Y_m} \frac{\dot{Y}_m}{Y_m} + \sum_{j=1}^{J} \frac{\partial C}{C} \frac{b_j}{\partial b_j} \frac{\dot{b}_j}{b_j} + \frac{\partial C}{C} \frac{E}{\partial E} \frac{\dot{E}}{E} + \frac{1}{C} \frac{\partial C}{\partial t} \tag{4}$$

with a dot above variables denoting derivative with respect to time[25]; $S_k = \frac{\partial C}{C} \frac{w_k}{\partial w_k} \equiv \frac{w_k X_k}{C}, k = 1,\ldots,K$ being the cost share of input *k*; $\varepsilon_{CY_m} = \frac{\partial C}{C} \frac{Y_m}{\partial Y_m}, m = 1,\ldots,M$ being the cost elasticity with respect to output *m*; $\varepsilon_{Cb_l} = \frac{\partial C}{C} \frac{b_j}{\partial b_j}, j = 1,\ldots,J$ being the cost elasticity with respect to undesirable output *j*; $\varepsilon_{CE} = \frac{\partial C}{C} \frac{E}{\partial E}$ being the cost elasticity with respect to equity; and $\varepsilon_{Ct} = \frac{1}{C} \frac{\partial C}{\partial t}$ being the technical change.

25 $\dot{w}_k = \partial w_k / \partial t; \dot{Y}_m = \partial Y_m / \partial t; \dot{b}_j = \partial b_j / \partial t; \dot{E} = \partial E / \partial t$. Our data consist of K = 2 input prices, M = 2 outputs, J = 2 undesirable outputs (bankrupt and restructured loans).

Thus, we can obtain equation (5):

$$\frac{\dot{C}}{C}=\sum_{k=1}^{K}S_k\frac{\dot{w}_k}{w_k}+\sum_{m=1}^{M}\varepsilon_{CY_m}\frac{\dot{Y}_m}{Y_m}+\sum_{j=1}^{J}\varepsilon_{Cb_l}\frac{\dot{b}_j}{b_j}+\varepsilon_{CE}\frac{\dot{E}}{E}+\varepsilon_{Ct} \tag{5}$$

Rearranging equation (5) with respect to ε_{Ct}, we get:

$$\varepsilon_{Ct}=\frac{\dot{C}}{C}-\sum_{k=1}^{K}S_k\frac{\dot{w}_k}{w_k}-\sum_{m=1}^{M}\varepsilon_{CY_m}\frac{\dot{Y}_m}{Y_m}-\sum_{j=1}^{J}\varepsilon_{Cb_l}\frac{\dot{b}_j}{b_j}-\varepsilon_{CE}\frac{\dot{E}}{E} \tag{6}$$

From equation (6), we can obtain equation (11) by totally differentiating equation (2) with respect to time and with some arrangements detailed as below:

▪ The total differentiation of equation (2) with respect to time is:

$$\frac{dC}{dt}=\sum_{k=1}^{K}X_k\frac{\partial w_k}{\partial t}+\sum_{k=1}^{K}w_k\frac{\partial X_k}{\partial t} \tag{7}$$

▪ Dividing both sides of equation (7) by total cost, we get:

$$\frac{\dot{C}}{C}=\sum_{k=1}^{K}\frac{X_k}{C}\dot{w}_k+\sum_{k=1}^{K}\frac{w_k}{C}\dot{X}_k \tag{8}$$

▪ For the right-hand side of equation (8), multiplying and dividing the first term and second term with w_k and X_k respectively, we get:

$$\frac{\dot{C}}{C}=\sum_{k=1}^{K}\frac{w_kX_k}{C}\frac{\dot{w}_k}{w_k}+\sum_{k=1}^{K}\frac{w_kX_k}{C}\frac{\dot{X}_k}{X_k} \tag{9}$$

▪ As $S_k=w_kX_k/C$, rearranging (9), we obtain:

$$\sum_{k=1}^{K}\frac{w_kX_k}{C}\frac{\dot{X}_k}{X_k}=\frac{\dot{C}}{C}-\sum_{k=1}^{K}S_k\frac{\dot{w}_k}{w_k} \tag{10}$$

▪ Thus, substituting the first two terms in the right-hand side of equation (6) by the left-hand side of equation (10), we obtain equation (11):

$$\varepsilon_{Ct} = \sum_{k=1}^{K} \frac{w_k X_k}{C} \frac{\dot{X}_k}{X_k} - \sum_{m=1}^{M} \varepsilon_{CY_m} \frac{\dot{Y}_m}{Y_m} - \sum_{j=1}^{J} \varepsilon_{Cb_j} \frac{\dot{b}_j}{b_j} - \varepsilon_{CE} \frac{\dot{E}}{E} \tag{11}$$

The total factor productivity growth (if constant returns to scale, $\varepsilon_{CY} = 1$), the Solow residual, showing the difference between the rate of change of outputs and the rate of change of inputs is:

$$\dot{TFP} = \sum_{m=1}^{M} \frac{\dot{Y}_m}{Y_m} - \sum_{k=1}^{K} \frac{w_k X_k}{C} \frac{\dot{X}_k}{X_k} \tag{12}$$

In the case of nonconstant returns to scale, the traditional measure of productivity growth needs to be adjusted. Combining equations (11) and (12), we get:

$$\varepsilon_{Ct} = \sum_{m=1}^{M} \frac{\dot{Y}_m}{Y_m} - \dot{TFP} - \sum_{m=1}^{M} \varepsilon_{CY_m} \frac{\dot{Y}_m}{Y_m} - \sum_{j=1}^{J} \varepsilon_{Cb_l} \frac{\dot{b}_j}{b_j} - \varepsilon_{CE} \frac{\dot{E}}{E} \tag{13}$$

Rearranging equation (13), we obtain equation (14):

$$\dot{TFP} = -\varepsilon_{Ct} + \left(\sum_{m=1}^{M} \frac{\dot{Y}_m}{Y_m} - \sum_{m=1}^{M} \varepsilon_{CY_m} \frac{\dot{Y}_m}{Y_m} \right) - \sum_{j=1}^{J} \varepsilon_{Cb_j} \frac{\dot{b}_j}{b_j} - \varepsilon_{CE} \frac{\dot{E}}{E} \tag{14}$$

The terms in the right-hand side of equation (14) are the impact of technological change $(-\varepsilon_{Ct})$, the scale effect $\left(\sum_{m=1}^{M} \frac{\dot{Y}_m}{Y_m} - \sum_{m=1}^{M} \varepsilon_{CY_m} \frac{\dot{Y}_m}{Y_m} \right)$, the impact of undesirable outputs (bankrupt and restructured loans) $\left(-\sum_{j=1}^{J} \varepsilon_{Cb_j} \frac{\dot{b}_j}{b_j} \right)$, and the impact of equity $\left(-\varepsilon_{CE} \frac{\dot{E}}{E} \right)$.

4.3.2. The translog function

The specification of our translog cost function is as follows[26]:

$$\ln C = \alpha_0 + \sum_{k=1}^{K}\alpha_k \ln w_k + \sum_{m=1}^{M}\beta_m \ln Y_m + \sum_{j=1}^{J}\phi_j \ln b_j + \lambda \ln E + \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{L}\alpha_{kl} \ln w_k \ln w_l$$
$$+\frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{N}\beta_{mn} \ln Y_m \ln Y_n + \frac{1}{2}\sum_{j=1}^{J}\sum_{s=1}^{S}\phi_{js} \ln b_j \ln b_s + \frac{1}{2}\lambda_e \ln E \ln E$$
$$+\sum_{k=1}^{K}\sum_{m=1}^{M}\delta_{km} \ln w_k \ln Y_m + \sum_{k=1}^{K}\sum_{j=1}^{J}\gamma_{kj} \ln w_k \ln b_j + \sum_{k=1}^{K}\mu_k \ln w_k \ln E + \sum_{m=1}^{M}\sum_{j=1}^{J}\varphi_{mj} \ln Y_m \ln b_j$$
$$+\sum_{m=1}^{M} o_m \ln Y_m \ln E + \sum_{j=1}^{J}\varsigma_j \ln b_j \ln E + \theta_t t + \frac{1}{2}\theta_{tt} t^2 + \sum_{k=1}^{K}\alpha_{kt} \ln w_k t + \sum_{m=1}^{M}\beta_{mt} \ln Y_m t$$
$$+\sum_{j=1}^{J}\phi_{jt} \ln b_j t + \lambda_t \ln E t + \varepsilon \tag{15}$$

where w_k, Y_m, b_j, E denote k^{th} input price, m^{th} output, j^{th} undesirable output, and equity respectively.

Applying Shephard's lemma for equation (15), we obtain the shares of cost attributed to input price k^{th}:

$$Sw_k = \alpha_k + \alpha_{kk} \ln w_k + \sum_{l=1}^{L}\alpha_{kl} \ln w_l + \sum_{m=1}^{M}\delta_{km} \ln Y_m + \sum_{j=1}^{J}\gamma_{kj} \ln b_j + \mu_k \ln E + \alpha_{kt} t \tag{16}$$

Total differentiating equation (15) with respect to output m^{th}, undesirable output j^{th}, and equity, we obtain:

$$\varepsilon_{CY_m} = \beta_m + \beta_{mm} \ln Y_m + \sum_{n=1}^{N}\beta_{mn} \ln Y_n + \sum_{k=1}^{K}\delta_{km} \ln w_k + \sum_{j=1}^{J}\varphi_{mj} \ln b_j + o_m \ln E + \beta_{mt} t \tag{17}$$

$$\varepsilon_{Cb_j} = \phi_j + \phi_{jj} \ln b_j + \sum_{s=1}^{S}\phi_{js} \ln b_s + \sum_{k=1}^{K}\gamma_k \ln w_k + \sum_{m=1}^{M}\varphi_m \ln Y_m + \varsigma_j \ln E + \phi_t t \tag{18}$$

[26] Subscripts *i* for banks (*i=1,..., N*) and *t* for time (*t=1,..., N*) are omitted for simplification.

$$\varepsilon_{CE} = \lambda + \lambda_e \ln E + \sum_{k=1}^{K} \mu_k \ln w_k + \sum_{m=1}^{M} o_m \ln Y_m + \sum_{j=1}^{J} \varsigma_j \ln b_j + \lambda_t t \quad (19)$$

The cost function requires a monotonic condition of non-decreasing in *w*. We impose the usual symmetry restrictions $\alpha_{kl} = \alpha_{lk}, \beta_{mn} = \beta_{nm}, \phi_{js} = \phi_{sj}$ and linear homogeneity restriction on the cost function (15) with respect to input prices:

$$\sum_{k=1}^{K} \alpha_k = 1; \sum_{k=1}^{K} \alpha_{kl} = 0 \ \forall l; \sum_{k=1}^{K} \delta_{km} = 0 \ \forall m; \sum_{k=1}^{K} \gamma_{kj} = 0 \ \forall j; \sum_{k=1}^{K} \mu_k = 0; \sum_{k=1}^{K} \alpha_{kt} = 0 \quad (20)$$

There are two input prices: price of fund, and price of physical capital and labour.[27] We estimate the model as specified from equations (15) to (20). The results obtained are then used to compute the impact of each component on productivity growth.

4.4. Data

This study employs a new data set of problem loans in Japan, providing new information of a critical bank undesirable output. Moreover, we disaggregate problem loans disclosed in accordance with the Japanese Banking Law into two categories. The first one consists of loans to borrowers in legal bankruptcy, and past due loans in arrears by six months or more. The second component comprises loans in arrears by 3 months or more but less than 6 months, and restructured loans. For simplicity, we name these two types of problem loans as bankrupt loans (*BRL)* and restructured loans (*RSL)* thereafter. Such disaggregation of problem loans has not been employed widely in the Japanese banking productivity literature (Mamatzakis et al., 2015). This disaggregation allows us to explore the extent to which each undesirable output, namely bankrupt loans and restructured loans, affects bank productivity.

[27] Please refer to Data section. The price of fund can be used to normalise.

In the aftermath of the asset price bubble that burst late 1990s in Japan, problem loans rose dramatically since a vast number of firms went bankrupt or experienced business difficulties. The cost of bankrupt and restructured loans in 1997 was 30 trillion JPY (Hoshi and Kashyap, 2000). However, some estimate the actual value in excess of 100 trillion JPY (Hoshino, 2002). After 1998, the government encouraged banks to increase their lending to small- and medium-sized firms (SMEs) in order to ease the "credit crunch" (Hoshi, 2011; Hoshi and Kashyap, 2010). However, the fact that the government subsidised these unprofitable borrowers dampened the entry and investment of productive firms, leading to fewer good lending opportunities for solvent banks (Caballero et al., 2008). Prior to 2002, the government had deployed rescue schemes by injecting capital and bailing out troubled banks, but it had been claimed that there was delay of much-needed restructuring at the banking industry (Caballero et al., 2008). Furthermore, misdirected bank lending augmented the accumulated level of bankrupt and restructured loans. In 2002, the level of these loans fell, reflecting the effort of banks to reduce problem loans under the reform program introduced by Heizo Takenaka, who was in charge of the Financial Services Agency. After the recovering period, the global financial crisis 2007-2008 somewhat increased further the level of bankrupt and restructured loans.

We employ a unique semi-annual data set provided by the Japanese Bankers Association. Our panel data consist of 3484 observations for Japanese commercial banks - 10 City Banks, 65 Regional Banks I, and 56 Regional Banks II - from financial years 2000 to 2014. City Banks are the largest banks amongst the three types. Apart from conventional banking activities, their operation spreads widely from security investment to ancillary services (Tadesse, 2006). Regional Banks, in contrast, strongly commit to the local development in their scope of business. They cater the financial need of SMEs within their geographic regions. Regional Banks II are the smallest with a more prefectural focus.

To define outputs and input prices, we follow the widely accepted intermediation approach (Sealey and Lindley, 1977). In our cost function, in line with Fukuyama and Weber (2009), Barros et al. (2012), Assaf et al. (2011), we specify two outputs: y_1 net loans and bills discounted, and y_2 earning assets which include investments, securities, and other earning assets. Because of data constraints, we are unable to extract data for personnel expenses or to obtain their share from noninterest expenses. Therefore, we define two input prices: price of fund, and price of physical capital and labour, in line with Fu et al. (2014). Price of fund w_1 is the ratio of interest expenses divided by total deposits and borrowed funds. Price of physical capital and labour w_2 is the ratio of noninterest expenses divided by fixed assets. Equity is included in the cost function as a quasi-fixed input (Hughes and Mester, 2013). Table 1 describes the summary statistics of key variables in our panel data.

Table 1. Descriptive statistics

Variable	Name	Mean	Std.Dev	Min	Max
TC	Total costs	57,055	172,876	153	2,267,130
Y_1	Net loans and bills discounted	3,342,342	8,387,483	124,016	76,700,336
Y_2	Earning assets	2,205,550	7,692,617	783	78,602,674
w_1	Price of fund	0.0012	0.0014	0.0001	0.0261
w_2	Price of physical capital and labour	0.7572	0.4241	0.0034	7.5558
BRL	Bankrupt loans	89,107	197,591	2,698	3,522,077
RSL	Restructured loans	43,424	154,252	48	2,701,164
E	Equity	242,010	678,690	2,845	7,425,766

Notes: This Table reports summary statistics of main variables used in the translog cost function. Apart from w_1 and w_2, all other variables are in Million JPY. Total cost = interest expenses + noninterest expenses. Net loans and bills discounted = loans and bills discounted – bankrupt loans – restructured loans. Earning assets are 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. Price of financial capital = interest expenses/(deposits + borrowed funds). Price of overhead = noninterest expense/fixed assets. Bankrupt loans = loans to borrowers in legal bankruptcy + past due loans in arrears by 6 months or more. Restructured loans = past due loans in arrears by 3 months but less than 6 months + restructured loans. Std.Dev: Standard Deviation.

4.5. Empirical results

4.5.1. Cost elasticities with respect to undesirable outputs and equity

Estimated parameters satisfy the monotonic condition and linear homogeneity constraints of the cost function.[28] The coefficients are statistically significant with appropriate signs as expected. Bankrupt loans are found to have a slightly stronger impact on cost than restructured loans (the parameters are 0.0384 and 0.0203 respectively). The impact of equity on cost is positive and significant (0.0533). We report the elasticities of cost with respect to bankrupt loans, restructured loans, and equity in Table 2. Overall, for all banks in the sample, these variables expose a cost-augmenting effect. The average cost elasticities with respect to bankrupt loans, restructured loans, and equity are reported at

[28] Please see Appendix A of this chapter.

0.0385, 0.0201, and 0.0537 respectively. In sub-periods, while the cost elasticity with respect to bankrupt loans appears to vary over time, the cost elasticity with respect to restructured loans decreases monotonically, turning out negative in the last two sub-periods (-0.0002 and -0.0106). This negative cost elasticity is attributed to the negative values found for City Banks and Regional Banks I. In terms of equity, there is variability in cost elasticities. The largest magnitudes for cost elasticities with respect to equity are in the first two sub-periods, 0.0721 in September 2000-March 2003 and 0.0998 in September 2003-March 2006. This could reflect the high cost of equity prevailing during the acute phase of the banking crisis and the restructuring period. Afterwards, the cost elasticity with respect to equity declines to 0.0415 in September 2006-March 2009, and thereafter, further down to 0.0194 in September 2009-March 2012. This finding is in line with King (2009). King (2009) reports that the magnitude of the cost of equity incurred by Japanese banks is higher compared to that in other countries such as Canada, France, Germany, UK, and US.

Table 2. The elasticity of cost with respect to undesirable outputs and equity.

	All banks			City			Regional I			Regional II		
Time	BRL	RSL	Equity	BRL	RSL	Equity	BRL	RSL	Equity	BRL	RSL	Equity
Sep 2000-Mar 2003	0.0527	0.0510	0.0721	0.0286	-0.0166	-0.0959	0.0476	0.0456	0.0810	0.0619	0.0659	0.0834
Sep 2003-Mar 2006	0.0313	0.0462	0.0998	0.0265	-0.0156	0.0265	0.0252	0.0395	0.1067	0.0399	0.0636	0.1012
Sep 2006-Mar 2009	0.0470	0.0086	0.0415	0.0226	-0.0410	-0.0047	0.0405	0.0044	0.0453	0.0592	0.0212	0.0423
Sep 2009-Mar 2012	0.0447	-0.0002	0.0194	0.0011	-0.0551	-0.0045	0.0386	-0.0022	0.0302	0.0601	0.0106	0.0067
Sep 2012-Mar 2015	0.0148	-0.0106	0.0303	-0.0468	-0.0601	-0.0268	0.0103	-0.0133	0.0411	0.0296	0.0000	0.0210
Sep 2000-Mar 2015	*0.0385*	*0.0201*	*0.0537*	*0.0088*	*-0.0359*	*-0.0221*	*0.0325*	*0.0148*	*0.0608*	*0.0507*	*0.0349*	*0.0541*

Notes: This Table reports the elasticity of cost with respect to bankrupt loans (BRL), restructured loans (RSL), and equity for all banks and per type of banks. The figures are averaged per 6 semi-annual periods. Figures may not sum due to averaging and rounding. Mar: March, Sep: September.

Breaking up the cost elasticities according to bank types, we observe a decreasing trend of the cost elasticities with respect to undesirable outputs for City Banks. Note that these values are negative in the case of restructured loans in all sub-periods and in the case of bankrupt loans during the September 2012-March 2015 period. For Regional Banks I and II, there is also a downward trend of the cost elasticities with respect to restructured loans. In the September 2009-March 2012 period and September 2012-March 2015 period, there are negative cost elasticities with respect to restructured loans in Regional Banks I. These findings show that restructured loans do not always raise cost. This is an interesting finding, revealing that restructuring the industry through legislation changes referring to restructured loans benefits the industry. A component of our restructured loan data relates to loans of which interest rates have been lowered, contracts have been amended, and/or loans to corporations under ongoing reorganisation (Montgomery and Shimizutani, 2009). Without this process, these loans would be more likely to become nonperforming loans, raising further bank costs. Furthermore, to deal with restructured loans, banks have received government support through the Act on Special Measures for Strengthening Financial Functions (August 2004-March 2008). Under this Act, capital injections ensure that financial institutions overcome difficulties in funding so that "*the financial sector can voluntarily commit to risk taking and function as financial intermediaries in the regional economy*" (Endo, 2013). In the aftermath of the collapse of Lehman Brothers, this Act was reactivated in December 2008. From March 1999 to March 2009, there were four capital injection programs, involving 37 financial institutions (Hoshi and Kashyap, 2010). Banks rescued by public capital were then required to increase lending to SMEs. In the Policy Statement on 12/03/2009, Kaoru Yosano (Minister of Finance and Minister of State for Financial Services and Economic and Fiscal Policy) announced that various measures had been enforced to allow financial institutions to supply funds with confidence, "*including prompt enforcement of the amended Act on Special Measures for Strengthening Financial Functions, partially relaxing the capital adequacy requirements of banks, and expanding the scope of cases in which restructured loans to SMEs are not classified as nonperforming loans*". [29] Besides, in the basis of the SME Financing Facilitation Act (2008-2013), there were changes in the regulatory framework which allowed bad loans of SMEs to be reclassified. These legislation amendments appear to be effective, as shown in our findings of negative cost elasticities with respect to restructured loans.

Apart from government support measures, the nature of business might also explain for the cost-saving impact of restructured loans. Regional Banks are committed to the development of the local regions where their headquarters are situated. SMEs are among their target clients. Therefore, Regional Banks are motivated to support SMEs through amending bad loans. As a result, 3-6% total credit was reclassified under the SME Financing Facilitation Act (International Monetary Fund, 2012).[30]

Another noteworthy finding is the cost-saving impact of equity for City Banks, on average at -0.0221. While the cost elasticity with respect to equity remains positive in all

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[29] http://www.fsa.go.jp/en/announce/state/20090312.html

[30] City Banks were strongly engaged in a so-called *main bank* system (Hoshino, 2002), in which they had strong ties with their clients. After the second half of the 20th century, this business network has gradually shrunk (Lincoln and Shimotani, 2010). In this type of relationship, there exist interlocking shareholdings among banks and their client firms. Apart from funding, banks provide member firms with management assistance. If restructured loans were disposed, banks would terminate their financial relation with the firms in question, and force them to declare bankruptcy. Hence, City Banks might have incentives to carry on funding troubled firms to assist them in regaining their financial health. In addition, as City Banks are the largest commercial bank group, they may have available resources to withstand restructured loans and recover these loans within the time frame set out in the regulatory framework. Furthermore, since October 2012, the Bank of Japan has pursued aggressive quantitative easing and committed to provide unlimited funding to match the net increase in loans to households and non-financial sectors (Bank of Japan's announcement on 30/10/2012). Although this *Stimulating Bank Lending Facility* benefits financial institutions in terms of funding, this may discourage proper credit screening. These countervailing effects might be reflected in the negative cost elasticities with respect to bankrupt loans from September 2012 to March 2015. Note that the Japanese economy has been struggling to strive from deflation since 2009, notably indicated by the implementation of negative interest rate in January 2016. If the economic slump is not attributed to banks not willing to lend (due to the fear of bad loans), but the lack of borrowers, there could be less incentive for banks to accelerate the disposal of bankrupt loans.

sub-periods for Regional Banks I and II, it is positive only in September 2003 to March 2006 for City Banks. Hence, equity financing might benefit City Banks in terms of mitigating the interest burden from debt financing, supporting the argument of Hughes and Mester (2013). These negative elasticities could also be interpreted as how much banks are willing to pay for equity as it would result in cost saving (Boucinha et al., 2013). Boucinha et al. (2013) also report a desirable impact of equity in lessening costs for Portuguese banks during 1992-2006. In contrast, this may not apply for Regional Banks. Their cost elasticities with respect to equity appear to have variability over time. On average, a more pronounced magnitude is found for Regional Banks I (0.0608 compared to 0.0541 for Regional Banks II).

4.5.2. Total factor productivity growth over time

In Table 3, we report the average values (semi-annually) of TFP growth over time. On average, the productivity growth of Japanese banks during the years 2000-2014 is at 1.52%. In the first sub-period March 2001-March 2003, Japanese banks experienced negative productivity growth, which could be expected since they were undergoing major reforms to restore financial stability post-crisis. In the second sub-period September 2003-March 2006, TFP exhibited strong growth at an average of 3.53%, thanks to the decline in bankrupt loans and restructured loans. This could also be attributed to the effect of quantitative easing in stimulating economic activity (Girardin and Moussa, 2011).[31] In the third sub-period September 2006-March 2009, TFP growth dropped markedly to 0.17%, possibly because of the onset of the global financial crisis 2007-2008. The destructive effect of the crisis seems short-lived, as TFP growth bounced back and peaked at 3.64% during the September 2009-March 2012 period, followed by a decrease to 2.29%

[31] Japanese annual GDP growth rate in 2004 was 2.4%, highest since 2000 (source: OECD statistics).

in the last sub-period September 2012-March 2015. With reference to the Japanese banking literature, there are a few studies which estimate bank productivity growth, though not very recent. Using the indirect Malmquist–Russell productivity index, Fukuyama and Weber (2002) report a 2% decline per year on average for Japanese banks operating between 1992 and 1996. Studying Japanese credit cooperative banks and using the bootstrapped Malmquist index, Assaf et al. (2011) find that their productivity growth did not rise significantly during 2000-2006.

Table 3. Average total factor productivity growth

Time	All banks	City	Regional I	Regional II
Mar 2001-Mar 2003	-2.3660	9.6486	-1.6734	-4.6385
Sep 2003-Mar 2006	3.5314	4.7213	3.7549	3.0757
Sep 2006-Mar 2009	0.1681	-0.6270	-0.2066	0.7982
Sep 2009-Mar 2012	3.6375	4.0606	3.8651	3.2369
Sep 2012-Mar 2015	2.2884	-1.6154	2.8062	1.9943
Mar 2001-Mar 2015	*1.5197*	*3.2803*	*1.8179*	*0.8747*

Notes: This Table reports average total factor productivity growth every three fiscal years for all banks and for each type of banks. The figures are averaged per 6 semi-annual periods, except the first time frame which includes 5 semi-annual periods. All values are in % and may not sum due to averaging and rounding.

Among bank categories, City Banks were the most productive, on average at 3.28%, followed by Regional Banks I (1.82%). The smallest banks in size, Regional Banks II, performed the lowest growth of 0.87% on average. Fukuyama (1995) also reports that between 1989 and 1991, City Banks were more productive than Regional Banks. In a similar vein, Barros et al. (2012) find that City Banks were the most efficient among the three types during 2000-2007. During the restructuring and the first quantitative easing period (March 2001-March 2006), City Banks experienced substantial growth in their productivity, notably at 9.65% during March 2001-March 2003 and 4.72% during September 2003-March 2006. The other two types, in contrast, underwent negative productivity growth in the restructuring period, -1.67% for Regional Banks I and -4.64% for Regional Banks II. Like City Banks, their productivity growth increased significantly during the initial quantitative easing period September 2003-March 2006 (3.75% and 3.08%). In the third sub-period September 2006-March 2009, which covers the duration of the global financial crisis 2007-2008, City Banks and Regional Banks I bore a loss in productivity growth. The decline was more prominent in City Banks, -0.63%. On the contrary, Regional Banks II appeared to survive the crisis, though their growth dropped to 0.798%. Afterwards, productivity growth rose to 4.06% in City Banks, 3.87% in Regional Banks I, and 3.24% in Regional Banks II. The last sub-period September 2012-March 2015, which embraces the aggressive quantitative easing time frame, witnessed a considerable decline in productivity growth of City Banks (down to -1.62%). Other bank types also saw a fall in their productivity growth.

4.5.3. Total factor productivity growth decomposition

To shed more light into the contribution of each component to TFP growth, we report the average values of the effect of each component in Table 4, according to equation (14) of our model. From March 2001 to March 2003, bankrupt loans dampened TFP growth by -0.45. Nevertheless, their negative effect was smaller compared to the impact of restructured loans, -0.49, and the impact of returns to scale, -2.17. Equity and technological change positively contributed to productivity growth by 0.11 and 0.65 respectively. In the second sub-period September 2003-March 2006, large productivity growth was a result of the decline in bankrupt and restructured loans, the rise in the scale effect, and technological progress.

Table 4. Total factor productivity growth decomposition

Time	BRL	RSL	Equity	Scale	Technology
Mar 2001-Mar 2003	-0.4509	-0.4947	0.1060	-2.1719	0.6453
Sep 2003-Mar 2006	0.0408	0.3915	-0.2250	2.6708	0.6532
Sep 2006-Mar 2009	-0.0562	0.2117	0.1371	-0.4791	0.3546
Sep 2009-Mar 2012	0.0492	0.2341	0.0704	3.1515	0.1322
Sep 2012-Mar 2015	0.0177	0.1181	-0.0570	1.9418	0.2679
Mar 2001-Mar 2015	*-0.0735*	*0.1044*	*0.0030*	*1.0751*	*0.4108*

Notes: This Table reports the effects of bankrupt loans (BRL), restructured loans (RSL), equity, scale, and technological change on TFP growth for all banks. The figures are averaged per 6 semi-annual periods, except the first time frame which includes 5 semi-annual periods. All values are in % and may not sum due to averaging and rounding. The sum of each row equals total factor productivity growth reported in Table 3 for all banks.

In the third sub-period September 2006-March 2009, on average, bankrupt loans constrained productivity growth with a magnitude of -0.06. In contrast, from September 2009 onwards, they in fact contributed to productivity gain because there was a drop in the level of bankrupt loans for the whole banking system (gradually down from 8458 billion JPY in September 2009 to 5896 billion JPY in March 2015). Using nonperforming loan ratio as a control variable in the cost function, Altunbas et al. (2000) find a positive relationship between nonperforming loans and inefficiency. Mamatzakis et al. (2015) also report a negative impact of problem loans on Japanese bank performance. Like bankrupt loans, restructured loans had imposed a negative effect on TFP growth (-0.49) before the implementation of the Takenaka plan. From September 2003 to March 2006, the effectiveness of the rehabilitation program was revealed by the fall in restructured loans, consequently contributing to productivity growth by 0.39%. From September 2006 to March 2015, the positive impact of restructured loans on TFP growth remained. Note that there was an increase in restructured loans in the last two sub-periods. It could be the case that the US credit crunch imposed a destructive effect on Japanese bank productivity growth with a lag, which was reflected in the rise of restructured loans after the crisis. The Tohoku-Pacific Ocean earthquake in March 2011, which has been the most powerful earthquake ever in Japan, might also be among the reasons for the rising of restructured loans afterwards.

Equity was among the growth drivers, although its average impact on productivity growth was small (0.003) for the whole sample period. In the initial sub-period March 2001-March 2003, 0.11% was the contribution of equity to TFP growth. This could stem from the fact that banks were undercapitalised post-crisis, and during that time of uncertainty, the cost of equity financing was high. Nevertheless, banks that failed to raise enough equity were eventually rescued by public capital (Montgomery and Shimizutani, 2009). Therefore, they benefited from government subsidisation and could make use of the bailout capital. In the second and the last sub-periods, equity put more weight on the cost burden, thus eroding productivity growth, -0.23 during September 2003-March 2006 and -0.06 during September 2012-March 2015. Between September 2006 and March 2012, equity positively contributed to productivity growth.

Overall, technical progress was consistently the driving force of TFP growth. Over the whole period, technology accounted for the increase in TFP growth on average at 0.41. Tadesse (2006) also reports evidence for technological progress in Japanese banks between 1974 and 1991. The scale effect, although fluctuating over time, on average was the major contributor to productivity growth (1.08). Boucinha et al. (2013) also find a significant contribution of returns to scale to increased productivity growth of Portuguese banks. Feng and Serletis (2010) find a moderate positive effect of returns to scale on productivity growth of large US banks, on average about 0.44%. Yet, the scale effect is the second largest component (after technical change) of US banks' productivity growth. Computing technical and scale efficiency for Japanese commercial banks in 1990, Fukuyama (1993) reports that scale inefficiency is negligible compared to pure technical inefficiency. Regarding the quasi-fixed input, the magnitude of the contribution of equity over time is not considerable, 0.003. In terms of undesirable outputs, bankrupt loans, on average, showed a detrimental impact on TFP growth, -0.07. Restructured loans, in contrast, was among the main driving forces for productivity growth, 0.104. There is evidence to support that the increase in TFP growth during September 2003-March 2006 was partly attributed to the fall in bankrupt loans and restructured loans. The reverse is true for the initial sub-period, when the loss in TFP growth was also mainly explained by the scale effect.

4.5.4. Total factor productivity decomposition per type of banks

Table 5 reports the decomposition of TFP growth for each bank type. In terms of the effects of undesirable outputs, on average bankrupt loans exhibit a destructive effect on productivity growth of all banks. The magnitude of the impact is greater for City Banks, -0.23, than for Regional Banks I, -0.04, and Regional Banks II, -0.09. In the first sub-period March 2001-March 2003, except City Banks, Regional Banks suffered a negative effect of bankrupt loans on TFP growth. This finding could indicate that the restructuring scheme had helped City Banks to cut their bankrupt loan level. Afterwards, Regional Banks had to bear that impairment again during September 2006-March 2009. From September 2003-March 2015, City Banks endured a negative impact of bankrupt loans on productivity growth. It could be that the global financial crisis worsened the likelihood of recovery of bankrupt loans and downgraded restructured loans to bankrupt loans. The effect could be more pronounced in City Banks than in the others because of their size and business structure. Regional Banks are more geographical focus, thus, could be less exposed to the contagion effect of the US credit crunch.

Table 5. Total factor productivity growth decomposition per bank type.

	City					Regional I					Regional II				
Time	BRL	RSL	Equity	Scale	Time	BRL	RSL	Equity	Scale	Time	BRL	RSL	Equity	Scale	Time
03/2001-03/2003	0.1041	1.6966	-0.5542	7.3895	1.0127	-0.3847	-0.5047	0.1465	-1.6439	0.7134	-0.5960	-0.7488	0.1386	-3.9530	0.5207
09/2003-03/2006	-0.1983	-0.0655	0.9321	3.3261	0.7268	0.0457	0.3323	-0.3473	2.9708	0.7534	0.0680	0.5322	-0.2287	2.1910	0.5132
09/2006-03/2009	-0.6755	-0.2386	0.1311	-0.1969	0.3529	-0.0136	0.1905	0.2561	-1.0710	0.4314	-0.0339	0.3010	-0.0288	0.3126	0.2473
09/2009-03/2012	-0.1029	0.1696	0.1425	3.1549	0.6965	0.0524	0.1427	0.1531	3.3169	0.2001	0.0662	0.3799	-0.0635	2.9037	-0.0492
09/2012-03/2015	-0.2313	0.2426	0.2162	-2.5095	0.6666	0.0227	0.0782	-0.0942	2.4542	0.3452	0.0423	0.1637	-0.0350	1.7271	0.0963
03/2001-03/2015	-0.2254	0.3291	0.2062	2.2832	0.6872	-0.0448	0.0657	0.0191	1.2967	0.4811	-0.0929	0.1278	-0.0463	0.6089	0.2771

Notes: This Table reports the effects of bankrupt loans (BRL), restructured loans (RSL), equity, scale, and technological change on TFP growth for all banks. The figures are averaged per 6 semi-annual periods, except the first time frame which includes 5 semi-annual periods. All values are in % and may not sum due to averaging and rounding. The sum of five components for each bank type in each row equals total factor productivity growth reported in Table 3 per bank type.

Restructured loans appear beneficial to productivity growth of each bank type. On average, they contributed to TFP growth of all types, more considerably for City Banks, 0.33. Yet, City Banks had to face a negative effect of restructured loans from September 2003 to March 2009. In the initial sub-period, Regional Banks suffered from an adverse effect of restructured loans on their productivity growth, while the contrary is reported for City Banks. In the remaining sub-periods, restructured loans enhanced TFP growth of Regional Banks. In terms of equity, on average, equity undermined productivity growth of Regional Banks II by -0.05, while the effect is favourable for City Banks, 0.21, and Regional Banks I, 0.02. Over time, there was a volatile impact of equity on productivity growth of Regional Banks I. From September 2003 to March 2015, the impact of equity was persistently negative for Regional Banks II, but positive for City Banks.

Regarding the scale effect, the influence of the global financial crisis on all banks could be reflected in our results. The reason is that the contribution of returns to scale declined considerably in the third sub-period, which covers the crisis. It was even negative in City Banks, -0.197 and Regional Banks I, -1.07. This might be due to quantitative easing policy that the scale effect was quite large in the second and the last two sub-periods, especially for Regional Banks. Other studies also find that small Japanese banks, in particular Regional Banks, exhibit increasing returns to scale (Altunbas et al., 2000; Azad et al., 2014; Fukuyama, 1993). Interestingly, there exists decreasing returns to scale for City Banks in the last period, -2.51. Previous research on Japanese banks also reports decreasing returns to scale for City Banks (Altunbas et al., 2000; Azad et al., 2014; Drake and Hall, 2003; Tadesse, 2006).

Turning to the effect of technology, we find strong evidence for technological progress in all bank types. Within City Banks, the impact of technological change on productivity growth was greater than this of other banks, 0.69 compared to 0.48 for Regional Banks I and 0.28 for Regional Banks II. From March 2001 to March 2012, Regional Banks II experienced a downward trend of technological progress, with technological regress, -0.05, reported in the September 2009-March 2012 period. In the last sub-period, technological change contributed to productivity growth of all banks. Evaluating technical efficiency of Japanese credit cooperatives, Glass et al. (2014) also find a presence of technical progress between 1998 and 2009. Technical progress also existed for all banks in the early 1990s, although different productivity measures yield different timing for its presence (Fukuyama, 1996).

4.6. Convergence cluster analysis

The next stage of our analysis investigates whether there is a tendency of convergence in TFP growth across regions and time. During the course of bank restructuring and promoting economic growth, the Japanese government has enacted a variety of support measures, including quantitative easing policy, aiming to raise bank lending to nonfinancial sectors. Hence, if indeed the restructuring were working, we would expect a tendency of convergence in bank productivity growth among banks and across regions over time. We adopt the methodology developed by Phillips and Sul (2007) to identify the integration process in Japanese banks.[32] In the context of our data, we

[32] Appendix B provides an overview of this methodology. In banking research, two widely used methods to examine convergence are β-convergence and σ-convergence, proposed by Barro et al. (1991) for the growth literature. Banking applications include Andrieş and Căpraru (2014), Casu and Girardone (2010), Fung (2006), and Weill (2013). If β-convergence regresses the growth rate of any variable on its initial level, σ-convergence measures the cross-sectional dispersion of the level of the variable over time. $\beta < 0$ implies that there exists a negative correlation between the initial level and the growth rate, which can be expressed as the entity that has a lower starting point has a faster growing speed than their counterparts which have higher initial levels. In the long-run, all observed units would converge to the same steady state. On the other hand, if the dispersion of a cross-section declines over time, there exists σ-convergence which exhibits the speed of each unit's growth to converge with the average level of the sample. σ-convergence somehow outperforms β-convergence in terms of explanatory power. Quah (1996) indicates a few limitations of β-convergence by referring to a situation where the entity with lower departing point grows so quickly that passes the ones with higher starting points, resulting in no convergence in the long-run.

explore the process of banking integration in the convergence of TFP growth, and the effect of each component in 121 Japanese commercial banks.[33] Matousek et al. (2015) also apply this methodology for testing banking integration in the 'old' European Union using bank-level efficiency data. Rughoo and Sarantis (2012) use this approach to test the convergence of deposit and lending rates in the European retail banking market. To our knowledge, our paper would be the first to test for convergence in TFP growth and its components using Phillips and Sul (2007) methodology. The task is to find the speed of convergence *b-hat*, and then apply a one-sided *t*-test. If *t*-statistics < -1.65, the null hypothesis of convergence is rejected at the 5% level. We report the speed of convergence and associated *t*-statistics in Tables 6 to 9.

4.6.1. Results for bank types

We start the analysis by testing for convergence in TFP growth and the effects of the five underlying TFP components over the whole sample. Results from the log *t*-test indicate that there is no convergence (see Table 6). Results from the club convergence test also show an absolute absence of convergence clubs. We further repeat the analysis for each bank type. We find no club convergence for Regional Banks II. For the other two types, there exists convergence, reported in Table 6. For Regional Banks I, there is evidence of convergence for this sample in terms of productivity growth (*b-hat* = -0.122) and its components. However, the speed of convergence is slow as values of *b-hat* are negative in all data series. They are -0.137 for the effect of bankrupt loans, -0.146 for the effect of restructured loans, -0.136 for the effect of equity, -0.059 for the scale effect, and -0.174 for the effect of technological change.

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[33] After computing TFP growth, we exclude some banks from the convergence test because they have too few observations.

Table 6. Log *t*-test and club convergence test – All banks and per bank type.

Bank types	Data series	Clubs	Bank IDs	*b*-hat	*t*-statistics
All banks	TFP growth	All banks: Divergent		-1.781	-13.193*
	BRL effect	All banks: Divergent		-1.669	-12.009*
	RSL effect	All banks: Divergent		-1.686	-12.183*
	Equity effect	All banks: Divergent		-1.636	-12.207*
	Scale effect	All banks: Divergent		-1.647	-12.751*
	Technological change	All banks: Divergent		-1.684	-13.017*
City	TFP growth	All banks: Divergent		-3.458	-3.406*
		Club 1: Convergent	1, 10	-2.132	-0.693
		Club 2: Divergent		-3.978	-3.903*
	BRL effect	All banks: Divergent		-3.424	-3.354*
		Club 1: Convergent	1, 10	-1.915	-0.883
		Club 2: Divergent		-3.924	-3.873*
	RSL effect	All banks: Divergent		-3.437	-3.362*
		Club 1: Convergent	1, 10	-2.027	-1.016
		Club 2: Divergent		-3.928	-3.871*
	Equity effect	All banks: Divergent		-3.442	-3.371*
		Club 1: Convergent	1, 10	-2.029	-1.053
		Club 2: Divergent		-3.941	-3.895*
	Scale effect	All banks: Divergent		-3.468	-3.398*
		Club 1: Convergent	1, 10	-2.026	-0.789
		Club 2: Divergent		-3.999	-3.891*
	Technological change	All banks: Divergent		-3.183	-3.361*
		Club 1: Convergent	1, 16	1.832	2.307
		Club 2: Convergent	8, 17	-0.928	-0.510
		Club 3: Divergent		-5.967	-9.229*
Regional I	TFP growth	All banks: Convergent		-0.122	-0.976
	BRL effect	All banks: Convergent		-0.137	-1.021
	RSL effect	All banks: Convergent		-0.146	-1.085
	Equity effect	All banks: Convergent		-0.136	-1.001
	Scale effect	All banks: Convergent		-0.059	-0.472
	Technological change	All banks: Convergent		-0.174	-1.334
Regional II	TFP growth	All banks: Divergent		-1.851	-11.953*
	BRL effect	All banks: Divergent		-1.628	-12.520*
	RSL effect	All banks: Divergent		-1.659	-12.486*
	Equity effect	All banks: Divergent		-1.584	-12.819*
	Scale effect	All banks: Divergent		-1.746	-12.025*
	Technological change	All banks: Divergent		-1.606	-13.200*

Notes: This Table reports the log *t*-test and club convergence test for TFP growth and the effect of each component on TFP growth in all banks and each bank type. The Phillips and Sul (2007) log *t*-test and club convergence test were run in OxEdit using the Gauss code by Sul (2007). *b-hat* is the convergence coefficient or speed of convergence. If *t*-statistics<-1.65, the null hypothesis of convergence is rejected at the 5% significance level. The corresponding bank IDs are reported for each convergent club. * indicates rejection of the null hypothesis of convergence at the 5% significance level.

For the sample of seven City Banks, the tests reveal some convergence clubs. Table 6 also reports the convergence coefficients for City Banks and associated *t*-statistics obtained from the log *t*-test for six data series. The null hypothesis of convergence in TFP growth in City Banks is rejected at the 5% level (*b-hat* = -3.458). Similarly, the null hypothesis of convergence for the effect of each component on TFP growth is rejected, which reinforces the divergence of TFP growth.

The next step is to examine if there exists any cluster of convergence in TFP growth as well as in each of its underlying components. We find negative values of *b-hat* associated with almost all convergence clubs. These findings exhibit weak convergence with slow speed as the estimated *b-hat* is insignificantly different from zero. Matousek et al. (2015) also report a few negative *b-hats* in their Phillips and Sul (2007)'s convergence test for technical efficiency of the top 10 EU banks. Regarding TFP growth, we detect one convergence club which is formed of two banks (IDs 1 and 10). The same two banks are reported to constitute the club of convergence in the effect of bankrupt loans, restructured loans, equity, and the scale effect. In terms of the impact of technology, there are two clubs of convergence. Banks 1 and 16 are identified in the first club with a faster convergence speed (1.832) than banks 8 and 17 in the second club (-0.928).

4.6.2. Results by geographic regions

Given that overall there is weak evidence regarding convergence, we further investigate whether there exists any convergence across geographic regions. We classify banks into eight regions based on their headquarters' locations. These eight regions are the eight principal regions of Japan, namely Hokkaido, Tohoku, Kanto, Chubu, Kansai, Chugoku, Shikoku, and Kyushu. Their relative geographic locations are illustrated in the map of Japan in Figure 1. The results are reported in Tables 7 and 8.

Table 7. Log *t*-test and club convergence test in Hokkaido, Tohoku, Chubu, Kansai, and Kyushu.

Region	Data	*b*-hat	*t*-stat	Region	Data	*b*-hat	*t*-stat
Hokkaido	TFP	0.671	1.104	Kansai	TFP	-1.176	-4.716*
	BRL	0.888	1.476		BRL	-1.069	-4.441*
	RSL	0.867	1.446		RSL	-1.104	-4.525*
	Equity	0.897	1.494		Equity	-1.052	-4.406*
	Scale	0.742	1.217		Scale	-1.121	-4.560*
	Tech.	0.896	1.492		Tech.	-1.064	-4.472*
Tohoku	TFP	-0.088	-0.247	Kyushu	TFP	-1.578	-5.832*
	BRL	-0.083	-0.235		BRL	-1.557	-5.643*
	RSL	-0.113	-0.319		RSL	-1.562	-5.68*
	Equity	-0.11	-0.312		Equity	-1.55	-5.632*
	Scale	-0.053	-0.148		Scale	-1.562	-5.774*
	Tech.	-0.132	-0.376		Tech.	-1.568	-5.737*
Chubu	TFP	2.096	2.704				
	BRL	2.121	1.281				
	RSL	2.184	1.341				
	Equity	1.858	1.285				
	Scale	2.002	1.381				
	Tech.	2.032	1.586				

Notes: This Table reports the log *t*-test and club convergence test for TFP growth and the effect of each component on TFP growth per region. The numbers of banks are: 3 in Hokkaido, 16 in Tohoku, 21 in Chubu, 18 in Kansai, and 21 in Kyushu. The data are total factor productivity growth (TFP), the effect of bankrupt loans (BRL), restructured loans (RSL), equity, the scale effect and technological change (Tech.) on TFP growth. The Phillips and Sul (2007) log *t*-test and club convergence test were run in OxEdit using the Gauss code by Sul (2007). *b-hat* is the convergence coefficient or speed of convergence. If *t*-statistics (*t*-stat)<-1.65, the null hypothesis of convergence is rejected at the 5% significance level. If the null is rejected, we conduct club convergence test. * indicates rejection of the null hypothesis of convergence at the 5% significance level.

The log *t*-test and club convergence test denote that banks in Hokkaido, Tohoku, and Chubu converge in TFP growth. Among these regions, Chubu has the fastest convergence rate, while Tohoku is the slowest. Convergence in the five underlying components of TFP growth is also present in these three regions. There is no existence of convergence for banks in Kansai and Kyushu (see Table 7). We find some clubs of convergence for banks in Kanto, Chugoku, and Shikoku (see Table 8).

Table 8. Log *t*-test and club convergence test in Kanto, Chugoku, and Shikoku.

Data	Clubs/Bank IDs	*b*-hat	*t*-stat
	For Kanto		
TFP		-2.196	-14.75*
	5, 16, 129, 522	0.062	1.025
	133, 135, 138, 516	-0.63	-0.529
	Divergent: the rest	-0.957	-3.477*
BRL		-2.115	-14.078*
	5, 16, 129, 522	0.049	1.321
	133, 135, 138, 526, 597	0.230	3.660
	17, 130, 150, 517	2.378	1.944
	Divergent: the rest	-4.310	-5.533*
RSL		-2.093	-13.956*
	5, 16, 129, 522	0.068	1.696
	133, 135, 138, 526, 597	0.206	3.280
	130, 150	1.031	1.009
	517, 525	0.631	0.586
	131, 134	0.758	0.309
	Divergent: the rest	-3.881	-3.323*
Equity		-2.116	-13.81*
	5, 16, 129, 522	0.066	1.912
	133, 135, 138, 526, 597	0.207	3.369
	9, 150, 517	0.574	0.445
	17, 130, 525	0.173	0.249
	128, 134	-3.392	-1.505
	Divergent: the rest	-5.187	-4.985*
Scale		-2.187	-14.719*
	5, 16, 129, 522	0.133	2.395
	133, 135, 138, 516	-0.780	-0.746
	Divergent: the rest	-0.705	-3.191*
Tech.		-2.337	-14.754*
	8, 17, 130	-0.923	-1.171
	16, 128, 131, 134, 137, 150, 516, 517, 525, 530	-0.157	-1.292
	133, 135	-3.849	-1.461
	Divergent: the rest	-3.627	-5.301*

Data	Clubs/Bank IDs	*b*-hat	*t*-stat
	For Chugoku		
TFP		-3.691	-4.522*
	166, 167, 168, 169	0.266	0.339
	Divergent: the rest	-8.302	-5.063*
BRL		-3.739	-4.446*
	166, 167, 168, 169	0.287	0.237
	Divergent: the rest	-8.983	-4.928*
RSL		-3.747	-4.468*
	166, 167, 168, 169	0.298	0.281
	170, 565	-5.270	-1.188
	Divergent: the rest	-12.177	-6.211*
Equity		-3.732	-4.437*
	166, 167, 168, 169	0.307	0.258
	170, 565	-5.420	-1.630
	Divergent: the rest	-12.41	-5.893*
Scale		-3.669	-4.488*
	166, 167, 168, 169	0.284	0.358
	Divergent: the rest	-8.291	-5.029*
Tech.		-3.745	-4.457*
	166, 167, 168, 169	0.290	0.246
	Divergent: the rest	-8.938	-4.935*
	For Shikoku		
TFP		2.256	11.433
BRL		-0.959	-0.692
RSL		-1.383	-2.558*
	173, 174, 175, 578	2.297	2.126
	Divergent: the rest	-4.239	-9.634*
Equity		2.714	0.96
Scale		3.902	13.833
Tech.		-0.966	-7.838*
	172, 173, 174, 175, 573, 576, 578	-0.175	-0.835
	Divergent: 572		

Notes: This Table reports the log *t*-test and club convergence test for TFP growth and the effect of each component on TFP growth per region. The numbers of banks are: 24 in Kanto, 10 in Chugoku, and 8 in Shikoku. The data are total factor productivity growth (TFP), the effect of bankrupt loans (BRL), restructured loans (RSL), equity, the scale effect and technological change (Tech.) on TFP growth. The Phillips and Sul (2007) log *t*-test and club convergence test were run in OxEdit using the Gauss code by Sul (2007). *b-hat* is the convergence coefficient or speed of convergence. If *t*-statistics (*t*-stat)<-1.65, the null hypothesis of convergence is rejected at the 5% significance level. If the null is rejected, we conduct club convergence test. The corresponding bank IDs are reported for each convergent club. * indicates rejection of the null hypothesis of convergence at the 5% significance level.

In our sample, the number of banks in Kanto is the largest compared to the numbers of banks in other regions. There are 24 banks, among which are six City Banks having their headquarters registered in Tokyo, which belongs to Kanto region. Note that City Banks and Regional Banks differ from each other in size, business structure, and focus. Hence, we would expect to find club convergence rather than convergence at the whole sample. In fact, results indicate a few clubs of convergence in TFP growth and its components. It is noteworthy that the club of banks 5, 16, 129, 522, and the club of banks 133, 135, 138, 526, 597 appear in most of the results for the data tested.

In Chugoku, there is one convergence club, formed of four banks 166, 167, 168, and 169, for productivity growth. The club convergence test for the underlying components of TFP growth also identifies this club. There is an additional convergence club (bank IDs: 170 and 565) with slow convergence rate for the effect of restructured loans (*b-hat* = -5.27) and equity (*b-hat* = -5.42). Eight banks in the remaining region, Shikoku, converge in TFP growth (*b-hat* = 2.256). There also exists convergence in the effect of bankrupt loans (*b-hat* = -0.959), equity (*b-hat* = 2.714) and the scale effect (*b-hat* = 3.902). For the effect of restructured loans and technological change, there are convergence clubs instead. One club of convergence, constituted by banks 173, 174, 175, and 578, is reported for the effect of restructured loans (*b-hat* = 2.297). For the impact of technological change, only bank 572 is not classified in the club of convergence.

Overall, in eight principal geographic regions of Japan, there are four regions where there exists convergence in terms of productivity growth. We proceed by investigating further whether that convergence behaviour is present between regions. The data are averaged for each region and are applied for between-region convergence. Interestingly, all regions converge in terms of the impacts of bankrupt loans (*b-hat* = 0.112) and equity (*b-hat* = 2.931) on TFP growth (see Table 9). There exist clubs of convergence in other components of TFP growth. Regarding restructured loans, Tohoku, Chugoku, and Shikoku belong to one convergence club. With regard to the scale effect, there are two clubs. Club one (Tohoku, Chubu, Chugoku, and Shikoku) experiences a faster convergent process (at the rate of 1.553) compared to club two (Hokkaido and Kanto, at the rate of 0.936). Regarding technological change, the tests reveal three clubs of convergence.

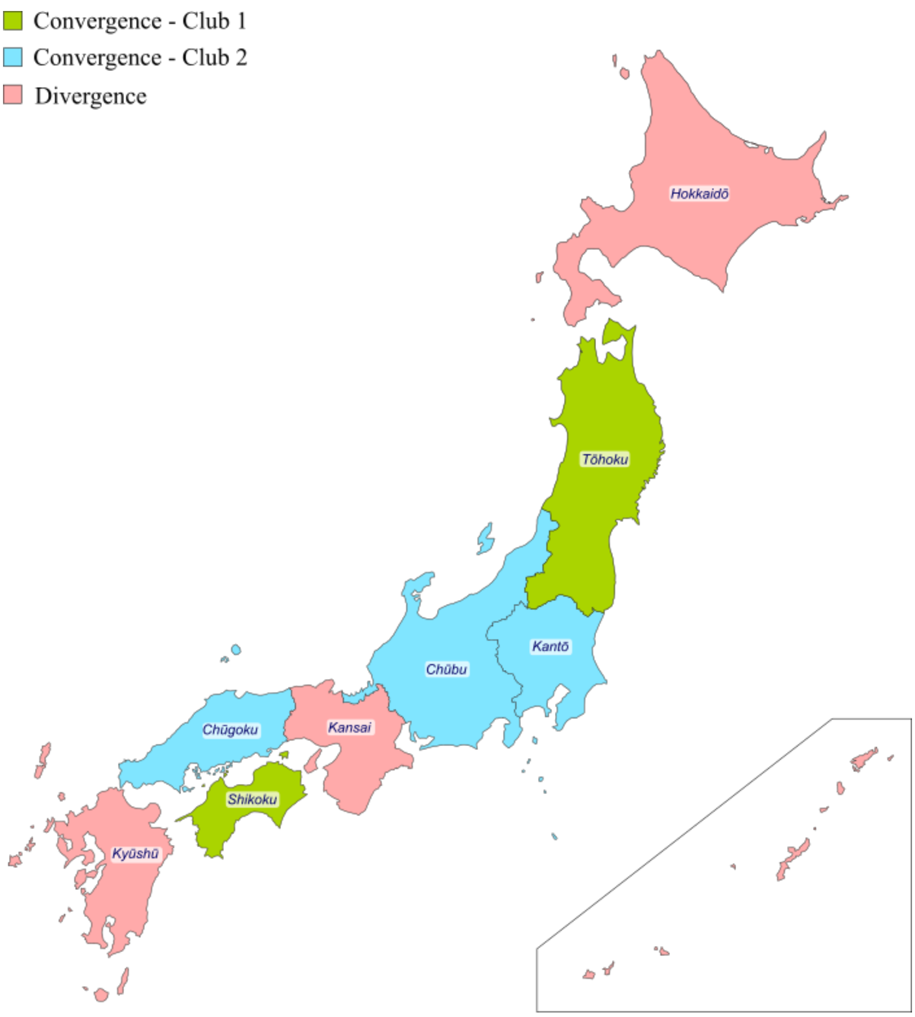
Table 9. Log *t*-test and club convergence test across regions.

Data series	Clubs	*b*-hat	*t*-statistics
TFP growth	All regions: Divergent	-2.328	-9.97*
	Club 1: Tohoku, Shikoku	5.634	3.997
	Club 2: Kanto, Chubu, Chugoku	0.789	1.666
	Club 3: Divergent	-8.016	-9.792*
BRL effect	All regions: Convergent	0.112	0.109
RSL effect	All regions: Divergent	-4.554	-9.693*
	Club 1: Tohoku, Chugoku, Shikoku	0.136	0.136
	Club 2: Divergent	-6.592	-13.244*
Equity effect	All regions: Convergent	2.931	1.5
Scale effect	All regions: Divergent	-1.439	-3.861*
	Club 1: Tohoku, Chubu, Chugoku, Shikoku	1.553	7.965
	Club 2: Hokkaido, Kanto	0.936	0.924
	Club 3: Divergent	-7.677	-9.523*
Technological change	All regions: Divergent	-4.147	-57.098*
	Club 1: Hokkaido, Kanto	-0.235	-0.402
	Club 2: Chubu, Chugoku	0.651	4.307
	Club 3: Tohoku, Kyushu	0.107	0.146
	Club 4: Divergent	-4.482	-46.464*

Notes: This Table reports the log *t*-test and club convergence test for regional average TFP growth and the effect of each component on TFP growth of banks across regions. The data are total factor productivity growth (TFP), the effect of bankrupt loans (BRL), restructured loans (RSL), equity, the scale effect and technological change on TFP growth. The Phillips and Sul (2007) log *t*-test and club convergence test were run in OxEdit using the Gauss code by Sul (2007). *b-hat* is the convergence coefficient or speed of convergence. If *t*-statistics<-1.65, the null hypothesis of convergence is rejected at the 5% significance level. If the null is rejected, we conduct club convergence test. The corresponding regions are reported for each convergent club. * indicates rejection of the null hypothesis of convergence at the 5% significance level.

Alas, convergence in TFP growth is not present between regions. The club convergence test uncovers two convergence clubs, which are illustrated in Figure 1 by the green and blue areas. The first club consists of two regions: Tohoku and Shikoku. The second club includes three regions, namely Kanto, Chubu, and Chugoku. There are 73 Regional Banks and 6 City Banks in these five regions, constituting 65.3% of the number of banks in our sample. The null hypothesis of convergence in productivity growth is rejected for the remaining regions, which are displayed in reddish areas in Figure 1. This finding lends some support for limited convergence.

Figure 1. Convergence in total factor productivity growth – Japan map.



Notes: This map illustrates the convergence in total factor productivity growth between regions.

Note from the map that Kanto and Chubu, two regions classified in convergence club two, are adjacent. This finding may suggest that apart from City Banks, Regional Banks, which have their head offices in one region, may also operate in adjacent regions through their local branch network. This is in line with findings from Kano and Tsutsui (2003) who investigate the geographic segmentation in the loan market of Japanese banks. They provide evidence for an absence of loan market segmentation within Regional Banks as these banks can operate through their branches in adjacent prefectures. Kano and Tsutsui (2003) show that about 18.9% of Regional Banks in their sample had branches outside their head offices' prefectures. Hence, partially overlapping operational areas exist among Regional Banks. Kanto is well known as Japan's economic heart, with Tokyo being one of the most important economic centres. Based on regional economic data in 2012, Kanto's gross regional product and income (1,886,166 and 1,439,151 hundred million JPY) were the highest among eight regions.[34] As previously mentioned, the majority of City Banks have their headquarters registered in Kanto. It could be the impact of their branch network that results in the integration process existing in these regions. In addition, Chugoku, which is also in this convergence club, is similar to Chubu in terms of economic activities. Chubu, where Toyota - Japan's largest company is based, is specialised in transportation equipment and textiles. Shipbuilding, automobile (Mazda's head office is based in Hiroshima), and textile are also the dominant industries in Chugoku.

Interestingly, although being classified in the same convergence club, Tohoku and Shikoku are in fact geographically distant from each other. However, there are similarities in terms of economic features between the two. First, they are the "poorer" regions compared to others in terms of gross regional product and income. Tohoku was

[34] Source: Social Indicators by Prefectures, available from Statistics Bureau, Ministry of International Affairs and Communications, Japan.

traditionally the poorest, least developed part in Japan. The 2012 statistics for Tohoku and Shikoku are 181,241 and 134,789 (hundred million JPY) in gross regional product respectively, and 135,051 and 101,341 (hundred million JPY) in income respectively. Second, the main economic activities in both regions include agriculture, fishery, forestry, and pulp and paper.

The divergence club also consists of regions that are scattered across the country. Hokkaido and Kyushu are the two far-ends of Japan surface area, and they are not geographic neighbours with Kansai either. It could be due to the significant disparities in economic features that these regions are in the divergence group of productivity growth. Kansai is a region, beside Kanto, contributing significantly to Japan's economic wealth. Historically, Kansai developed as a major rice producing and trading area, with Osaka being the centre for economic activities. The Osaka-Kobe metropolitan area has been the modern manufacturing base for textile, machinery, metal, chemicals, and heavy industries since the 20th century. In contrast, the capital of Kyushu, Fukuoka, is specialised in services and the automobile industry, being one of the world's largest car manufacturing bases. Hokkaido, on the other hand, is a popular island for tourists, and an important food-supply region. Sapporo, its capital, apart from tourism, is also well-known for the bio and IT industries. One thing in common but probably very important reflecting on the divergence of the three regions is that they all have a regional stock exchange market. They are Sapporo in Hokkaido, Osaka in Kansai, and Fukuoka in Kyushu. These markets are characterised by distinctive regional political economies which result in significant market segmentation (Hearn, 2016). The regional-related factors that distinguish banks in these diverging regions would be an interesting issue for future research.

4.7. Conclusion

This study quantifies the impact of undesirable outputs on productivity growth of Japanese commercial banks. We adopt a parametric methodology which allows for a decomposition of TFP growth with respect to the impact of undesirable outputs, namely bankrupt and restructured loans. Our finding reports an average productivity growth of 1.52% semi-annually. Productivity growth deteriorated during the restructuring period (2001-2003) and the following global financial crisis. Alongside the downturn of the scale effect, the loss in productivity growth was attributed to the adverse effect of bankrupt loans and the negative impact of equity in a few periods. There exists evidence showing that some legislation changes have benefited the banking industry, indicated by the cost-reducing impact of restructured loans.

We further proceed with convergence tests for TFP growth and its components. The presented results have important policy implications. Over 15 years, there has been heterogeneity among banks, as they are recognised as diverging altogether. Nevertheless, within City Banks, there is some evidence of slow convergence. Regional Banks that operate in the same geographic regions appear to develop with some degree of commonality. The evidence of a banking integration process within and across some regions would assist policymakers to design appropriate schemes to promote growth. As the banking system remains the important channel to convey the economic impact of *Abenomics* – the current economic policy to combat deflation and boost growth, bank productivity growth would act as a signal for the effectiveness of this policy. It would be worth looking into the characteristics of the diverging regions so that modified versions of these policies would be more applicable.

Given the negative interest rate policy enacted in January 2016 for the first time in Japan's history, bank productivity gain could be an important indication for the efficacy of this central banking policy. However, negative interest rates should be accompanied by prudent lending standards and proper supervision in order not to increase the risk of bankrupt and restructured loans. Additionally, potential challenges associated with prolonged negative interest rates may limit bank productivity growth by, for example, lowering outputs. For instance, the fear of substantial deposit withdrawals may inhibit banks to pass the cost of negative rates on to retail depositors. Hence, if banks have to incur this cost, they may be reluctant to increase lending due to low profit margin (Bech and Malkhozov, 2016). These policy limitations are beyond the scope of this paper. It would be an interesting area for future research to observe and study the benefits and drawbacks of negative interest rate on Japanese bank productivity growth.

Appendices – Chapter 4

Appendix A. Estimated parameters for the translog cost function

Notations	Variables	Coefficient	S.e	Notations	Variables	Coefficient	S.e
α_2	w_2	0.8521***	0.004	φ_{12}	y_1*RSL	0.0381**	0.016
β_1	y_1	0.5275***	0.022	φ_{21}	y_2*BRL	0.0958***	0.015
β_2	y_2	0.1088***	0.013	φ_{22}	y_2*RSL	-0.0422***	0.008
ϕ_1	BRL	0.0384***	0.007	λ_e	E*E	0.0415	0.026
ϕ_2	RSL	0.0203***	0.004	o_1	y_1*E	-0.1036**	0.043
λ	E	0.0533***	0.015	o_2	y_2*E	0.0895***	0.027
θ_t	t	-0.0042***	0.000	μ_2	w_2*E	0.0404***	0.011
α_{22}	w_2*w_2	0.0743***	0.006	ς_1	BRL*E	-0.1127***	0.019
β_{11}	y_1*y_1	0.5465***	0.086	ς_2	RSL*E	0.0213*	0.012
β_{22}	y_2*y_2	0.0745***	0.016	λ_t	E*t	-0.0045***	0.002
β_{12}	y_1*y_2	-0.2523***	0.033	θ_{tt}	t*t	-0.0002*	0.000
ϕ_{11}	BRL*BRL	0.0280*	0.015	α_{2t}	w_2*t	-0.0002	0.001
ϕ_{22}	RSL*RSL	-0.0082*	0.005	β_{1t}	y_1*t	0.0139***	0.002
ϕ_{12}	BRL*RSL	-0.0196***	0.007	β_{2t}	y_2*t	-0.0038***	0.001
δ_{21}	w_2*y_1	-0.0563***	0.017	ϕ_{1t}	BRL*t	-0.0023**	0.001
δ_{22}	w_2*y_2	-0.0018	0.009	ϕ_{2t}	RSL*t	-0.0041***	0.001
γ_{21}	w_2*BRL	-0.0152**	0.007	α_o	Constant	-0.0903***	0.009
γ_{22}	w_2*RSL	0.0248***	0.005	R^2	0.91		
φ_{11}	y_1*BRL	-0.0172	0.031	Observations	3484		

Notes: This Appendix reports the parameters estimated and corresponding standard errors from the translog cost function with input price *w* (price of fund w_1; price of physical capital and labour w_2; w_1 is the normalising input price), output *Y* (net loans and bills discounted y_1; earning assets y_2), undesirable outputs (bankrupt loans *BRL*; restructured loans *RSL*), equity *E*, and time *t*. w_1=(interest expense)/(deposits + borrowed funds); w_2=noninterest expenses/fixed assets; y_1= net loans and bills discounted; y_2 are 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; Bankrupt loans = loans to borrowers in legal bankruptcy + past due loans in arrears by 6 months or more. Restructured loans = past due loans in arrears by 3 months but less than 6 months + restructured loans. ***, **, * indicate significant at the 1%, 5%, 10% level respectively; S.e: standard error.

Appendix B. Log t-test and club convergence test

The Phillips and Sul (2007) approach is more advanced compared to β-convergence and σ-convergence. It accounts for both common and heterogeneous components of a panel data variable. That systemic idiosyncratic element is also allowed to evolve over time. Furthermore, Phillips and Sul (2007) argue that the rejection of the null hypothesis of convergence does not always mean that there is no convergence among sub-groups of the panel. Their clustering algorithm can unfold the existence of club convergence within the panel. The transition parameter and the regression *t* test can be summarised as follows:

The variable of interest X_{it} (in our study, it is TFP growth and its components) in the context of a panel data can be decomposed into a systemic component g_{it}, and a transitory component a_{it}:

$$X_{it} = g_{it} + a_{it} \qquad \text{Eq. (A.1)}$$

To distinguish between the common and idiosyncratic components which may be embraced in g_{it} and a_{it}, equation (A.1) can be reformulated as:

$$X_{it} = \left(\frac{g_{it} + a_{it}}{\mu_t} \right) \mu_t = \delta_{it} \mu_t \qquad \text{Eq. (A.2)}$$

with μ_t is a single common component and δ_{it} is a time-varying idiosyncratic element measuring the relative share in μ_t of individual *i* at time *t*.

Phillips and Sul (2007) define the relative transition coefficient h_{it} and obtain δ_{it} as follows:

$$h_{it} = \frac{X_{it}}{\frac{1}{N}\sum_{i=1}^{N} X_{it}} = \frac{\delta_{it}\mu_t}{\frac{1}{N}\sum_{i=1}^{N} \delta_{it}\mu_t} = \frac{\delta_{it}}{\frac{1}{N}\sum_{i=1}^{N} \delta_{it}} \qquad \text{Eq. (A.3)}$$

The objective is to test whether the factor loading coefficients δ_{it} converge to δ, which means the relative transition coefficients h_{it} converge to unity. Hence, in the long run, the cross-sectional variance of h_{it} $\left(\sigma_t^2 = (1/N)\sum_{i=1}^{N}(h_{it}-1)^2 \right)$ converges to zero.

The regression test of convergence is a regression t test for the null hypothesis of convergence H$_o$: $\delta_i = \delta$ and $\alpha \geq 0$, where α is the decay rate[35], against the alternative hypothesis H$_a$: $\delta_i \neq \delta$ for all i or $\alpha < 0$. The log t regression is conducted in three steps:

i) Calculate the cross-sectional variance ratio H_1/H_t, where $H_t = (1/N)\sum_{i=1}^{N}(h_{it}-1)^2$

ii) Perform the OLS regression: $\log(H_1/H_t) - 2\log L(t) = \hat{a} + \hat{b}\log t + \hat{u}_t$ Eq. (A.4)

where the fitted coefficient of log t, *b-hat* $\hat{b} = 2\hat{\alpha}$, is the estimate of the speed of convergence, and $\hat{\alpha}$ is the estimate of α in H_o, and $L(t) = \log(t+1)$. Phillips and Sul (2007) recommend that the data for this regression start at $t = rT$, with $r = 0.3$ obtained from Phillips and Sul (2007)'s Monte-Carlo regression.

iii) Apply an autocorrelation and heteroskedasticity (HAC) robust one-sided t test of the inequality null hypothesis $\alpha \geq 0$ using *b-hat* and a HAC standard error. If t-statistics < -1.65, the null hypothesis of convergence is rejected at the 5% level. [36]

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[35] Phillips and Sul (2007) show that the formulation for δ_{it} ensures it converges to δ_i for all $\alpha \geq 0$. Refer to their paper for the derivation of the log t regression equation.

[36] For the procedure to test for club convergence, please refer to Phillips and Sul (2007), pp. 1798-1801 for more details.

Chapter 5. The Interplay between Quantitative Easing, Risk and Competition: The Case of Japanese Banking.

5.1. Introduction

The competition and bank risk-taking nexus has sparked heated debates (Beck et al., 2013; Boyd and De Nicolo, 2005; Jiménez et al., 2013; Tabak et al., 2015). There is extensive research that reveals the mixed evidence as both positive and negative relationships between bank competition and risk are reported (Berger et al., 2009; Fiordelisi and Mare, 2014; Fu et al., 2014; Liu and Wilson, 2013). One strand of the literature argues that there are benefits to be derived from enhanced competition as it promotes efficiency and prevents banks from taking excessive risk (Schaeck and Cihák, 2008; Stiroh and Strahan, 2003). On the other hand, some (Fu et al., 2014; Liu and Wilson, 2013) raise concerns due to uncertainties that could be brought by increased competition through excessive bank risk-taking. Others argue that stiff competition results in loss of high economic rents (e.g. lending opportunities and profit) associated with reduced competition, and this has an augmenting effect on risk (Allen and Gale, 2004; Keeley, 1990). Hence, whether higher competition destabilises the banking system by accumulating bank risk remains yet to reach unanimity.

In this chapter, we build on the existing literature to investigate the relationship between bank competition and risk for the Japanese banking industry that also experiences extensive quantitative easing. To this end, we bring into the framework also quantitative easing. We further innovate by using bank specific Boone indicators instead of its aggregate value or the Lerner index to capture competition.

The case of Japan is of interest as it has faced chronic problems with nonperforming loans, and is one of the first economies that an extensive and far-reaching program of quantitative easing has been initiated.[37] We tackle the former factor in our measure of bank risk-taking by opting for a new data set, whilst we explore the impact of quantitative easing through the bank risk channel. Given the significance of quantitative easing for Japan, it warrants examining its impact at bank level. The emerging of quantitative easing as a monetary policy tool to achieve price stability has raised concerns among academics and policymakers about its association with bank risk-taking (Chodorow-Reich, 2014; Claeys and Darvas, 2015). Low short-term interest rates prior to loan issuance result in banks granting more new risky loan portfolios, distorting their credit supply to favour borrowers with worse credit histories, lower ex-ante internal ratings, and weaker ex-post performance (Ioannidou et al., 2015; Jiménez et al., 2014). Less return from yields is another motive for financial institutions to accelerate their risk-taking activities (Chodorow-Reich, 2014; Rajan, 2005). Banking surveys based on credit standards in the US and the UK, on the contrary, do not suggest an excessive risk-taking by banks as a result of the enforcement of quantitative easing (Claeys and Darvas, 2015).

The Bank of Japan was the pioneer in empowering quantitative easing policy. Currently, there has been a strong record of active and aggressive quantitative easing

[37] It is well documented (Caballero et al., 2008; Imai, 2009) that there were destructive effects from the prolonged banking crisis to the first half of the 2000s as economic policies in Japan failed to recognise that the mounting nonperforming loans were an issue. Eventually, a restructuring of the whole banking industry was initiated in 2000s. However, this restructuring campaign was met with controversies as it incorporated funding for unprofitable firms, which in turn crowded out solvent firms and lengthened the revitalisation of the economy (Caballero et al., 2008). Moreover, there exists evidence of political influence, where regulators deferred solvency declaration of banks situated in prefectures supporting the then ruling party (Imai, 2009). However, the global financial crisis rather left the Japanese banking industry unaffected. Nonperforming loans of all banks increased slightly from 11.4 trillion JPY in March 2008 to 12 trillion JPY in March 2009. It is noteworthy that during 2008-2013, the government strategically aimed to assist small and medium enterprises (SMEs), which are Regional Banks' primary corporate clients, via the SME Financing Facilitation Act. One term in the Act involved reclassifying SME's nonperforming loans. This has raised concern about the accumulated hidden credit risks within the banking system (Hoshi, 2011), as about 3-6% of total credit in Regional Banks was reclassified (International Monetary Fund, 2012).

since 2010. We are interested in investigating whether the warning of heightened financial stability risks associated with this policy is supported by Japanese bank level data. We hypothesise, based on the aforementioned literature, that quantitative easing and competition affect bank risk-taking. After the acute phase of the banking crisis in Japan (1997-1999), the banking system underwent major reforms, bailout and consolidation from 1999 to 2003. Their competition stance, hence, is expected to vary over time, also in light of the global financial crisis 2007-2008. Between 2000 and 2015, quantitative easing was launched twice (during March 2001-March 2006 and from October 2010). This could be considered as a macroeconomic shock to bank competition due to the relaxation of economic conditions, which in turn may affect the competition-risk nexus. The degree of competition in the banking industry, however, could also influence the quantitative easing-risk linkage (Altunbas et al., 2014). Therefore, we control for the effect of quantitative easing when measuring the competition-risk relationship, and vice versa. We also explore in depth the underlying causality among quantitative easing, competition and risk.

Thereby, our study contributes to the literature in the following ways. First, whereas the current literature has mostly used the bank-specific Lerner index or aggregate Boone indicator as a proxy for competition (Liu and Wilson, 2013; Schaeck and Cihák, 2014), we estimate bank level Boone indicators. We use local regression techniques to calculate the Boone indicator for each bank-year observation. Second, we opt for an original data set to capture risk that has been overseen by the literature to date. Bank risk-taking, our primary focus, is represented by bankrupt loans and restructured loans. Data on bankrupt and restructured loans are available for Japanese commercial banks and have not been used extensively in the Japanese banking literature (Mamatzakis et al., 2015). We also use the classical measure of bank default risk, Z-score, to enhance the robustness of our analyses. The use of bankrupt and restructured loans at semi-annual data frequency allows an enriched information set in our modelling of competition and quantitative easing.[38] Third, we employ a bank level proxy of quantitative easing that is the bank specific lending rate. The advantages of this microeconomic measure lie on the absence of aggregation bias and the ample set of information. This bank-specific variable ensures its compatibility with the bank level Boone indicator and risks in our analyses. We also conduct the analyses with two other proxies for quantitative easing: the 10-year Japanese government bond yield and Bank of Japan total assets. To examine the risk-competition and risk-quantitative easing nexus, we employ dynamic panel threshold analysis, where Generalised Methods of Moments type estimators are used to tackle the issues of endogeneity (Kremer et al., 2013). This methodology allows us to examine whether these relationships are stable over the observed period (financial years from 2000 to 2014) which embraces quite a few important events. They are the final phase of the banking crisis (2000-2001), the restructuring period (2001-2003), the presence of quantitative easing (2001-2006 and from 2010), the global financial crisis (2007-2008), and the Tohoku earthquake (2011). Fourth, we extend our analysis by using a panel vector autoregression (VAR) approach to address the underlying causality and the potential endogeneity among competition, quantitative easing and risk.

Our results show that competition and quantitative easing appear to undermine overall bank stability. However, quantitative easing reduces problem loans. The results could entail the countervailing effects of quantitative easing on bank risk-taking (Buch et al., 2014; De Nicolò et al., 2010). Regarding the causality between the variables of

[38] 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. See Data section for more details.

interest, the panel VAR analysis suggests that quantitative easing causes bank risk and bank competition.

The chapter proceeds as follows. Section 5.2 briefly reviews the literature and associated hypotheses. Section 5.3 presents the methodologies. Section 5.4 introduces the data. Section 5.5 discusses the results. Finally, section 5.6 concludes.

5.2. Related literature and hypotheses

In this section, we establish our research hypotheses based on the literature regarding the competition-risk nexus and the relationship between quantitative easing and bank risk. The two renowned hypotheses about the impact of competition on financial stability, an important part of our main investigation objectives, have been well defined in the literature as introduced in the following sections.

5.2.1. The competition - fragility hypothesis

The underlying theory of this hypothesis poses the view of uncertainty created by a competitive banking industry. The rationale behind this is the threat of market share being reduced by the entry of newly established banks as well as stronger competence of incumbent rivals. The rise in bank competition could be attributed to, e.g., consolidation, deregulation, and technological advances (Berger and Mester, 2003; Jeon et al., 2011; Keeley, 1990). The liberalisation of geographic restriction and relaxation in unconventional banking activities have also fostered bank competition (Berger and Mester, 2003). There exists evidence suggesting that when deregulation took place (e.g. in the US during 1970s–1980s), poor performers were more vulnerable due to the incompetence in keeping pace with their counterparts and potential entrants (Stiroh and Strahan, 2003). Deregulation also fuelled bank consolidation, resulting in a large number of banks disappearing from the market due to mergers (Berger and Mester, 2003). Note that sizeable consolidation could, however, result in large banks exerting considerable market power (Yildirim and Mohanty, 2010). In developing banking markets, beside the lift in entry barriers, technological development is another catalyst for heightened competition brought by foreign bank entry (Jeon et al., 2011).

One of the main arguments for greater risks corresponding to increased competition is profit reduction. This reasonably serves as a motive for bank managers to take excessive risks to pursue business targets, to preserve market shares, and eventually to protect market power. Of course, the notion of falling profitability could also raise concerns among banks' executives and jeopardise their position. Consequently, they may have the incentive to stretch their risk tolerance ability. Keeley (1990) is among the studies laying the first bricks of the debate of an increasing level of fragility in association with intensified competition. The results lend support for the hypothesis to the extent that amplified competition lowers bank charter value, which in turn promotes extra risk-taking through either higher leverage or asset risk.

Apart from profitability, a number of factors have been put forward as arguments for the *competition-fragility* hypothesis. Boot and Greenbaum (1993) and Allen and Gale (2004) show that in a less concentrated banking market, the arising asymmetric information would discourage proper credit screening. Consequently, the rise in credit risk could accumulate the latent uncertainty within the banking system. Another fundamental factor of financial safety in association with competition is liquidity. Liquidity constraints could be better handled in a more concentrated market as information regarding the probability of withdrawal of depositors is private (Smith, 1984). Furthermore, as modelled in Allen and Gale (2000), financial distress would be less contagious as banks would be willing to provide liquidity to temporarily illiquid banks. Other proponents of these views argue that a few large banks in highly concentrated markets are easier to supervise than many small banks. Large banks are also more flexible in diversifying investment portfolios, which in turn lowers the fragility of the banking system (Allen and Gale, 2000).

5.2.2. The competition - stability hypothesis

Contrasting the previous hypothesis, Boyd and De Nicolo (2005) propose that market concentration intensifies risk. Ceteris paribus, less competition implies that banks could be granted more market power; they in turn would impose higher lending rates on loan portfolios. The rise in loan rates, thus, could increase bankruptcy probability for borrowers. On the other hand, this would magnify the moral hazard incentives within the borrowers themselves in an attempt to reap greater returns.

As opposed to the *competition-fragility* hypothesis, Caminal and Matutes (2002) present a model explaining the ambiguous relationship between market power and bank failure. They argue that it is not always valid the argument that higher probability of default is due to higher degree of competition. In fact, if investments were assumed to be subject to a large aggregate shock, at the presence of intermediate monitoring costs, a monopolistic bank would be exposed to more bankruptcy risk than a competitive bank. This arises from less credit rationing which can serve as an imperfect substitute for monitoring.

Advocates of the *competition-fragility* hypothesis dispute that it is generally easier to regulate and monitor a few incumbent banks to prevent contagion risk than many banks in a competitive banking industry (Beck, 2008; Beck et al., 2006). Financial support from the government to big banks may also prevent a distress time from turning into a crisis (Schaeck et al., 2009). Nevertheless, there are still arguments along the lines of the "too-big-to-fail" concern, especially in light of financial conglomerates emerging as a result of the consolidation trend. In view of the consolidation, internationalisation, and conglomeration trend, Nicoló et al. (2004) report that more concentrated banking systems reflect higher systemic risk potential than less concentrated ones. In the aftermath of the global financial crisis, "large, complex financial institutions" pose a great threat to the global financial system (Saunders et al., 2009). Such global banks due to the complexity of their operations require appropriate regulatory control across borders. However, it is possible that big banks are politically powerful to compromise the power of their supervisors (Johnson and Kwak, 2011). Even Basel III guidelines would probably not be adequate to account for all the potential risk-holding aspects of global banks. Other potential causes for increased riskiness associated with "large, complex financial institutions" include difficulties in controlling and monitoring operational risk, credit risk, and market risk (Jones and Nguyen, 2005). In addition, these banks are more prone to volatile and short-term non-deposit funding sources which, as a result, could expose them to higher liquidity risk. Besides, given that global banks are commonly subsidised by the government, their risk-taking motives could be twisted, hence, threatening overall financial stability.

In a similar vein, Anginer et al. (2014) address the issue of systemic risk in association with competition on 1872 published banks in 63 countries over 1997-2009. Competition is measured by the Lerner index and Panzar-Rosse *H*-statistic, whereas systemic risk is computed from the Merton distance-to-default model. More especially, Anginer et al. (2014) use the correlation in risk-taking behaviour obtained from a time series analysis. A bank's change distance-to-default is regressed on average change in distance-to-default excluding the examined bank. The results show that heightened competition leads to more diversified risk-taking activities which subsequently enhance bank resilience to shocks.

A growing body of bank competition literature of which empirical findings support the *competition-stability* has adopted the prevailing Boone indicator as a competition proxy. The evidence in Schaeck and Cihák (2008) indicates that competition (measured by the Boone indicator) stabilises the banking systems in Europe and the US (1995-2005). In a recent study examining banks in major European countries, Schaeck and Cihák (2014) confirm their previous findings of competition being stability-enhancing. It is noteworthy that the relationship is conveyed through the efficiency channel which reallocates profit from cost-inefficient banks to the cost-efficient ones.

As the literature has yet to reach a consensus over the two hypotheses, we attempt to revisit the competition-risk dispute by investigating their existence in Japanese banking using bank level Boone indicator, while taking into account the impact of quantitative easing. The next section reviews the relationship between quantitative easing and bank risk as another primarily investigatory subject in our study.

5.2.3. Quantitative easing and risk hypothesis

After a long history of nearly zero policy rates during the 1990s to avoid deflationary slump (Leigh, 2010), the Bank of Japan initiated quantitative easing policy in March 2001 through long-term government bond purchase. That central banking policy has made Japan the pioneer in introducing an unconventional monetary policy to combat deflation and sluggish growth. The initial target outstanding balance of current accounts held at the Bank (i.e. bank reserves) was 5 trillion JPY, being raised further to 30-35 trillion JPY by

January 2004. Thereafter, assets purchased were broadened to private assets held by private banks, asset-backed securities and asset-backed commercial papers (Girardin and Moussa, 2011). Officially ended in March 2006, the first quantitative easing period did not firmly prove its effectiveness in detaching the economy from the deflation circle (Bowman et al., 2015; Ueda, 2012b; Ugai, 2007).

The Bank of Japan reactivated this policy in October 2010, when a comprehensive monetary easing policy comprising of purchasing a variety of assets was announced. The financial assets included are government securities, commercial paper, corporate bonds, exchange-traded funds, and Japan real estate investment trusts. From October 2010 to March 2013, the outstanding amount of Japanese long-term government bonds nearly doubled (from 50 trillion JPY to 91 trillion JPY). From April 2013, the Bank introduced a so-called qualitative and quantitative easing (QQE), entering a new phase of monetary easing policy. To the extent of quantitative easing, the Bank has changed the target from the uncollateralised overnight call rate to monetary base, aiming to increase it at the pace of 60 to 70 trillion JPY annually. The Bank also increases its purchase of Japanese government bonds, exchange traded funds, and Japan real estate investment trusts. Beside the main courses of actions of quantitative easing, qualitative easing means that the Bank expands its purchase to all maturities of Japanese government bonds. The average remaining maturity of the Bank's Japanese government bond purchases is extended from slightly less than three years at present to about seven years, equivalent to the average maturity of the amount outstanding of Japanese government bonds issued (Bank of Japan’s announcement on 04 April 2013).

The importance of quantitative easing has been addressed in its significant impact on aggregate demand, financial markets and economic growth (Bowman et al., 2015; Glick and Leduc, 2012; Schenkelberg and Watzka, 2013). Regarding its effect on the banking system, the bank lending channel is emphasised as a main conduit (Bowman et al., 2015; Hosono, 2006). As Lucas (2014) points out, the success of quantitative easing (in the US) is partly indicated by increased risk-taking, hence more bank lending. Starting with the zero lower bound interest rate policy, Hosono (2006) investigates the different impacts of expansionary monetary policy on bank lending. This paper addresses the three important bank characteristics, namely size, liquidity and capitalisation, which could alter a bank's reaction to monetary policy stance. Results indicate that expansionary monetary policy in Japan is less effective for undercapitalised banks. Lending of small, less liquid and well-capitalised banks are more exposed to monetary policy shocks than their counterparts.

Inspired by Hosono (2006) but slightly more comprehensive is Bowman et al. (2015), which particularly focus on the first quantitative easing period. Bowman et al. (2015) show that bank lending, through the transmission of quantitative easing, appears in the liquidity channel. The results suggest that liquidity injection of the central bank was inhibited by interbank illiquidity, thus the size of credit boosted was relatively small. Unlike findings of Hosono (2006), less-capitalised banks benefit more from quantitative easing than their well-capitalised peers. Weaker banks in the sense of higher nonperforming loan to asset ratio also appear to be more sensitive to liquidity injection. Bank size is reported to be insignificant in affecting the relationship between bank lending growth and liquidity. Kobayashi et al. (2006) also find evidence to support that financially weaker banks and firms reap more benefits from quantitative easing through positive excess stock returns.

To this end, to the best of our knowledge, no study has established a clear link between quantitative easing in Japan and bank risk-taking using bank level information.

Academics and policymakers have addressed the potentially disproportionate bank risk-taking associated with the enactment of quantitative easing (Chodorow-Reich, 2014; Claeys and Darvas, 2015). Quantitative easing is supposed to encourage financial institutions to attempt socially desirable risk-taking. However, banks may be deviated from their secured path when excessive risk-taking is recorded (Claeys and Darvas, 2015). In addition, under lax lending standards and low interest rates, the likelihood that more risky borrowers being offered new loans could rise, and so could credit risk (Ioannidou et al., 2015; Jiménez et al., 2014). The countervailing effects of interest rate changes on bank risk are also addressed in Buch et al. (2014). Lower interest rates could reduce the cost burden for borrowers, increase the collateral value, and subsequently raise the likelihood of repayment. In parallel, the borrowing capacity rises as a result of higher prices of collaterals, and banks are induced to engage in riskier projects to offset lower profit associated with lower interest rates. On the contrary, Lucas (2014) argues that quantitative easing could unintentionally reduce bank risk-taking incentives. Banks benefit from the term premium in the yield curve if their asset duration exceeds their liabilities'. When the yield curve is flat, they may be discouraged in issuing long-term loans which may be more desirable by borrowers.

In this regard, we leave our quantitative easing-risk hypothesis open: *The implementation of quantitative easing could lead to either an increase or a reduction in bank risk.*

5.3. Methodology

5.3.1. Marginal cost

In order to obtain values for the Boone indicator, we need to model bank marginal cost. In line with Fiordelisi and Mare (2014) and Fu et al. (2014), marginal cost is obtained from a flexible translog cost function specification[39]:

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

with total costs TC_{it}, total earning assets Q (loans, investments, and securities) (Delis, 2012), price of inputs P_j (subject to the condition of homogeneity of degree one), time trend t and a composed error term ε_{it}. Two input prices are incorporated: i) price of funds P_1 is defined as interest expenses divided by deposits and borrowed funds; ii) price of physical capital and labour P_2 as noninterest expenses divided by fixed assets[40].

The marginal cost MC for bank i at time t can be derived from equation (1) as follows:

$$MC_{it} = \frac{\partial TC_{it}}{\partial Q_{it}} = \frac{TC_{it}}{Q_{it}} \cdot \frac{\partial \ln TC_{it}}{\partial \ln Q_{it}} = \frac{TC_{it}}{Q_{it}}\left(\alpha_1 + \alpha_2 \ln Q + \sum_{j=1}^{2}\gamma_j \ln P_j + \varphi_3 t\right) \tag{2}$$

[39] Subscripts (*it*) are omitted for simplification.

[40] 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, we define the second input price in line with Fu et al. (2014).

5.3.2. The Boone indicator

The Boone indicator of competition has quite a few advantages in comparison with others. This measure accounts for both a lift in entry barriers or more aggressive interaction between market participants (Boone, 2008b), while other indicators contain limitations or bias. As Beck (2008) argues, concentration ratios such as the Herfindahl-Hirschman index and three (five)-bank concentration ratio are rather unreliable measures of competition as they only weigh concentration levels. Concentration ratio could rise following an increase in competition, as incompetent participants would have to exit the market. Hence, if one interpreted higher concentration ratios as a proxy for uncompetitive markets, the results could be misleading (Schaeck and Cihák, 2014). Other measures of competition such as the Panzar-Rosse H-statistic and Lerner index also have some limitations. While H-statistic requires a priori assumption of long-run equilibrium operating markets (Panzar and Rosse, 1987), it is ambiguous whether the Lerner index captures the degree of product substitutability (Vives, 2008). Mirzaei and Moore (2014) argue that the H-statistic does not embrace the evolution of bank competition as there is only one score obtained over time. Even though time-varying scores are achievable (Bikker and Haaf, 2002; Jeon et al., 2011), they are either increasing or decreasing which may be inapplicable in effect.

Introduced by Boone et al. (2007) and Boone (2008b), firms' (banks') market power can be measured through profit elasticity β in a simple profit equation:

$$\ln \pi_{it} = \alpha + \beta \ln mc_{it} + u_{it} \qquad (3)$$

where π_{it} and mc_{it} are profit and marginal costs of bank i at time t. β is the Boone indicator of market power which is expected to be negative as higher marginal costs would result in lower profits. Intuitively, compared to operating in an uncompetitive market, in a competitive market, inefficient banks signified by comparatively high marginal costs are penalised more harshly since they will endure high loss in profits. Hence, the larger the absolute value of β, the more intense the degree of competition.

In our paper, we employ the non-parametric methodology used in Delis (2012) to compute the Boone indicator for individual banks in each period. This allows us to create bank level estimates of competition. We estimate equation (3) by using a local regression analysis[41], which fits the relation between log profits and log marginal costs on the neighbourhood subsample of each observation to obtain individual β_{it}.[42]

5.3.3. The Lerner index

We also use the Lerner index, another proxy of bank market power, to achieve a comprehensive analysis with different indicators of competition. The Lerner index is formulated as follows:

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[41] According to Loader (1999), a local regression $Y_i = \mu(x_i) + \varepsilon_i$ with predictor variable *x* and response variable *Y* is estimated by smoothing the unknown function $\mu(x_i)$. This is obtained through fitting a polynomial model within a sliding window of *x*. Each point in the neighbourhood of *x* is assigned a weight corresponding to its distance from *x*. In particular, the closer the point to *x*, the larger its weight. The next step is to choose an optimal bandwidth *h* which controls the smoothness of fit and a smoothing window (*x*-*h*(*x*), *x*+*h*(*x*)). In other words, for each observation x_i, all neighbour points within the sliding window *h* are used in the following locally weighted least squares criterion: $\sum_{i=1}^{n} W\left(\frac{x_i - x}{h}\right)\left(Y_i - \left(a_0 + a_1\left(x_i - x\right)\right)\right)^2$ with *W* is the weight function of the form $W(u) = \begin{cases} \left(1 - |u|^3\right)^3 & if\, |u| < 1 \\ 0 & otherwise \end{cases}$ where $u = \left(x_i - x\right)/h(x)$. In line with Delis (2012), we use the generalised cross-validation method to obtain our bandwidth. The result indicates a bandwidth of 0.42.

[42] In regression (3), the Boone indicator is averaged over the entire sample across the whole examined period. Put differently, it cannot be measured for individual banks. To overcome this drawback, empirical research has modified this model to yield values of β for each period (Schaeck and Cihák, 2014; Van Leuvensteijn et al., 2011) by adding a time dummy and its interaction with marginal costs in order to increase the frequency of the indicator. However, the number of observations achieved from this approach does not rise significantly as they are estimated values for each period.

$$Lerner_{it} = \left(P_{Q_{it}} - MC_{it}\right) / P_{Q_{it}} \tag{4}$$

where $P_{Q_{it}}$ is output price calculated as operating income divided by earning assets. This indicator captures pricing ability above marginal cost, which has been used extensively in the banking literature (Berger et al., 2009; Fiordelisi and Mare, 2014; Fu et al., 2014; Koetter et al., 2012). Values of the index are bounded between 0 and 1, with the former presenting perfect competition while the latter indicating pure monopoly. A negative Lerner index entails inability to price above marginal cost which might be a consequence of non-optimal behaviour (Fu et al., 2014).

5.3.4. Dynamic panel threshold analysis

To examine the risk-competition, risk-quantitative easing nexus, we adopt the dynamic panel threshold model introduced by Kremer et al. (2013). This methodology allows for the estimation of a threshold effect within a panel data framework involving endogenous regressors. The threshold variables of interest are the proxies of competition and quantitative easing. In our main analyses, when one of them is treated as the threshold variable, the other is included in the model as a control variable. As quantitative easing policy influences interest rates, and thereby indirectly affecting competition, potential endogeneity exists. Besides, as I use a bank-specific variable which is bank lending rate as a proxy for quantitative easing, one may argue that it can be affected by competition. The dynamic threshold model of Kremer et al. (2013) extends the original static set up of Hansen (1999) to account for endogeneity. Therefore, the model allows for an estimate of a threshold value which is free from endogeneity bias. Apart from tackling endogeneity concerns, another advantage of this methodology in the case of Japanese banking is that no priori assumption needed with regard to structural breaks. Such breaks, within the present threshold model, are endogenously determined from the underlying data generating process. The model estimates threshold values for competition and quantitative easing over time, which in turn signify regime changes. In some details, the model specification is written as:

$$y_{it} = \mu_i + \beta_1 q_{it} I(q_{it} \leq \gamma) + \delta_1 I(q_{it} \leq \gamma) + \beta_2 q_{it} I(q_{it} > \gamma) + \phi z_{it} + \varepsilon_{it} \quad i = (1,...,N), t = (1,...,T) \qquad (5)$$

where μ_i indicates bank-specific fixed effect[43]; $I(.)$ is the indicator function indicating the regime defined by the threshold variable (q_{it}) and the threshold level γ; q_{it} is both the threshold variable and the regime-dependent regressor. z_{it} is a vector of control variables, which may include both endogenous and exogenous variable. As in Kremer et al. (2013), we account for the regime intercept (δ_1) because omitting the intercept may result in biases in the threshold estimates and regression slopes (Bick, 2010). ε_{it} is the error term.[44] As in Caner and Hansen (2004) and Kremer et al. (2013), we estimate equation (5) by using GMM to account for endogeneity. The first lag of the endogenous variable is used as the instrument.

5.4. Data

Our data are extracted from semi-annual financial reports of Japanese commercial banks published on the Japanese Bankers Association website. Our sample consists of 3491 observations from financial years 2000 to 2014. Three particular types of

[43] To eliminate bank-specific fixed effects, as suggested by Kremer et al (2013), we employ the forward orthogonal deviations transformation proposed by Arellano and Bover (1995).

[44] The estimation procedure is as follows. First, a reduced-form regression is estimated for endogenous variables as a function of the instrumental variables. Second, using least squares, we estimate equation (5) for a fixed threshold with the predicted values of endogenous variables obtained from the first step regression. Third, the second step regression is repeated to find the estimator of the threshold value associated with the smallest sum of squared residuals. The critical values for the 95% confidence intervals of the threshold value are: $\Gamma = \{\gamma : LR(\gamma) \leq C(\alpha)\}$, with $C(\alpha)$ is the 95% percentile of the asymptotic distribution of the likelihood ratio statistic $LR(\gamma)$ (Caner and Hansen, 2004). The slope coefficients are estimated by GMM procedure for the formerly used instruments and estimated threshold.

commercial banks are examined in our study, namely City Banks, Regional Banks I and Regional Banks II. They form more than half the whole banking system and correspond to various types of operations. If City Banks involve more in different aspects of banking business, Regional Banks are prone to conventional banking activities. City Banks are referred as *main* banks in the *horizontal keiretsu* network – the enterprise groups consisting of one large firm for every major sector pre- and post-crisis. These banks act as the core of the business group and offer venture capital for affiliates. The number of City Banks has declined over time since the crisis occurred in the 1990s. Besides, during the restructuring period, City Banks benefited from the tendency of mergers in empowering their resistance to overcome the consequences of the crisis[45].

The operating locations of Regional Banks are refined by their scope of business, with tighter geographic region restriction for Regional Banks II. These banks are the smallest in comparison with the other two. Unlike City Banks, Regional Banks mainly invest in government bonds and originate loans for small and medium firms in their specific areas where their head offices are located. Thus, Regional Banks are more committed to the local development of their prefectures. There are other different kinds of banks currently operating in Japan, for example, Trust Banks, Long-Term Credit Banks, *Shinkin* banks (credit cooperatives), and foreign banks. Due to data unavailability or differences in business features, we do not observe non-commercial banks in our study.

In terms of dependent variables representing bank risk-taking, we opt for bankrupt loans to total assets (BRL ratio), restructured loans to total assets (RSL ratio), and the

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[45] Mitsui Bank and Taiyo-Kobe Bank to form Sakura Bank; 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 Bank and Sakura Bank (Nakamura, 2006) .

natural logarithm of Z-score[46]. The first two variables characterise credit risk, whereas the remaining variable is a proxy for overall bank stability. They are incorporated respectively in the model to analyse the highlighted hypotheses. Bankrupt and restructured loans are obtained from data of risk-monitored loans disclosed under the Banking Law. Bankrupt loans are named after the sum of bankrupt loans and non-accrual loans,[47] while restructured loans are the sum of the other two categories: past due loans by 3 months or more but less than 6 months, and restructured loans.[48] The ratios of these risk-monitored loans to assets capture credit risk, similar to nonperforming loan to asset ratio that has been widely used in the literature to test for the *competition-fragility* nexus (Beck, 2008). Bank stability indicated by the Z-score is another gauge for the likelihood of bank failure (Beck et al., 2013; Laeven and Levine, 2009). This is defined as the number of standard deviations below the mean of return on assets that would result in insolvency by evaporating capital ($Z_{it} = \left(ROA_{it} + Capital\, ratio_{it}\right) / \sigma ROA_{it}$) (Beck et al., 2013).

To ensure the robustness of our estimation, we analyse the dynamic panel threshold model with two proxies for competition, the Boone indicator and the Lerner index, with the former being our primary interest. With regard to quantitative easing, we choose the bank-specific lending rate calculated as interest income on loans divided by loans and bills discounted (Delis and Kouretas, 2011)[49]. We employ bank-specific lending rate as

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[46] Nonperforming loan ratio and Z-score are used extensively in the literature to represent bank risk (Agoraki et al., 2011; Beck, 2008; Buch et al., 2012).

[47] Reported in Japanese commercial banks' balance sheets, these loans are named loans to borrowers in legal bankruptcy, and past due loans in arrears by six months or more.

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

[49] We could also use the amount of asset purchases or Japanese government bond's yield as measures for quantitative easing (Bowman et al., 2015; Lyonnet and Werner, 2012; Voutsinas and Werner, 2011).

the threshold variable for quantitative easing for several reasons. First, under the zero lower bound interest rate policy, short-term interest rates are inoperative (Girardin and Moussa, 2011). Second, the Bank of Japan loan rate, uncollateralised overnight call rates, and the Bank of Japan's total reserves, the amount of asset purchases, and government bond yields do not reflect individual bank characteristics in relation to changes in quantitative easing. Third, we could avoid aggregation bias and enhance the compatibility of quantitative easing proxy with the dependent variable and the Boone indicator. For each set of models with different threshold variables, we also control for the impact of either competition or quantitative easing. For instance, when proxies for competition are treated as threshold variables, quantitative easing will appear among the determinants, and vice versa. As quantitative easing influences deposit interest rates, it may in turn affect bank competition in the loan market. In addition, one may argue that lending rate is not a direct measure of quantitative easing, and may be affected by competition. To tackle the potential endogeneity between the three main variables of interest, we treat them as endogenous in the dynamic panel threshold model.[50] For robustness, we also use the 10-year Japanese government bond yield and the Bank of Japan total assets (Lyonnet and Werner, 2012) as other proxies for quantitative easing.

Regarding a subset of explanatory variables, we specify a number of control variables varying from bank characteristics to macroeconomic impact. To account for capitalisation and the potential moral hazard problem, we use the capital to assets ratio (Tabak et al., 2012)[51]. Bank size is taken as the natural logarithm of total assets (Delis and Kouretas,

[50] We use the first lag of the endogenous variable as its instrument to preserve information. Following Kremer et al. (2013), all available lags of the endogenous regressor are also examined. In fact, the corresponding results reveal little variation in the parameters estimated.

[51] As capital ratio is part of the formula of Z-score, we exclude it from models in which *ln*Z-score is used.

2011). We also take into consideration the impact of revenue diversification which is the ratio of non-interest income to total operating income (Anginer et al., 2014; Beck et al., 2013), assets diversification represented by the ratio of securities to assets (Zhang et al., 2013), and liquidity which is defined as liquid assets[52] to total assets (Jeon et al., 2011). GDP growth is included to reflect the influence of macroeconomic environment (Jiménez et al., 2013). Market capitalisation is accounting for financial market development and also functioning as an alternative source of fund for incumbent firms (Beck et al., 2013). Descriptive statistics of data used are displayed in Table 1.

Table 1. Descriptive Statistics

Variable	Mean	S.D.	Min	Max
BRL ratio	0.0263	0.0219	0.0000	0.6765
RSL ratio	0.0092	0.0093	0.0000	0.1958
*Ln*Zscore	3.9335	0.5223	0.0000	5.6410
Boone indicator	-0.0542	0.0579	-1.6390	-0.0391
Lerner index	0.2531	0.2664	-4.0314	0.7583
Lending rate	0.0106	0.0024	0.0012	0.0366
Size	14.5717	1.1591	12.0571	19.0109
Capital ratio	0.0432	0.0240	-0.7882	0.1279
Asset diversification	0.2394	0.0770	0.0000	0.4807
Liquidity ratio	0.0722	0.0380	0.0089	0.3679
Revenue diversification	0.2220	0.0817	0.0577	0.5445
GDP growth	0.0032	0.0234	-0.0787	0.0543
Bond yield	0.0122	0.0039	0.0041	0.0185
Bank of Japan assets	18.7201	0.2530	18.3119	19.5192
Market capitalisation	19.2235	0.2546	18.8248	19.6968

Notes: This Table reports the descriptive statistics for key variables employed in the dynamic panel threshold analysis. Number of observations: 3491. BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = \left(ROA_{it} + Capital\ ratio_{it}\right) / \sigma ROA_{it}$, lending rate=interest income on loans/loans and bills discounted, size=*ln*(total assets), capital ratio=equity/assets, asset diversification=securities/assets, liquidity=liquid assets/total assets, revenue diversification=non-interest incomes/operating income, Bond yield: 10-year Japanese government bond yield, Bank of Japan assets and market capitalisation are in natural logarithm. S.D.: Standard deviation.

[52] Liquid assets = Cash and due from banks + call loans + receivables under resale agreements + receivables under securities borrowing transactions + bills bought + monetary claims bought + trading assets + trading account securities + money held in trust (Radić, 2015).

5.5. Results

5.5.1. The Boone indicator

As introduced in section 5.3.2, the Boone indicator is estimated for each bank in the sample. This provides much more information on competition in the Japanese banking industry than other measures. More in details, the average indicator for the entire sample from 2000 to 2014 is -0.0542.[53] Reported in Mirzaei and Moore (2014), the average Boone indicator for Japanese banking between 1999 and 2011 is -0.02.[54] Figure 1 illustrates the mean value of the Boone indicator over time for all banks in our sample. Its highest score in absolute value is recorded in March 2002 at -0.0813, indicating the toughest degree of competition for the entire period. During the restructuring period (September 2000 to March 2003), the government imposed policy changes on the banking system in order to revitalise its resilience to the aftermaths of the crisis. In addition, undercapitalisation and the threat of nonperforming loans induced fragile banks to agree to merger proposals from financially healthier banks. The consolidation tendency was augmented by a number of mergers between large City Banks, indicating an adverse phase for *too-big-to-fail* banks in maintaining their market power. Afterwards, the average score slightly increased to -0.0483 in March 2004 and became relatively flat until September 2008. This may serve as evidence in supporting the positive outcomes of government intervention. Within that time frame, the turbulence caused by the huge amount of nonperforming loans had been alleviated gradually.

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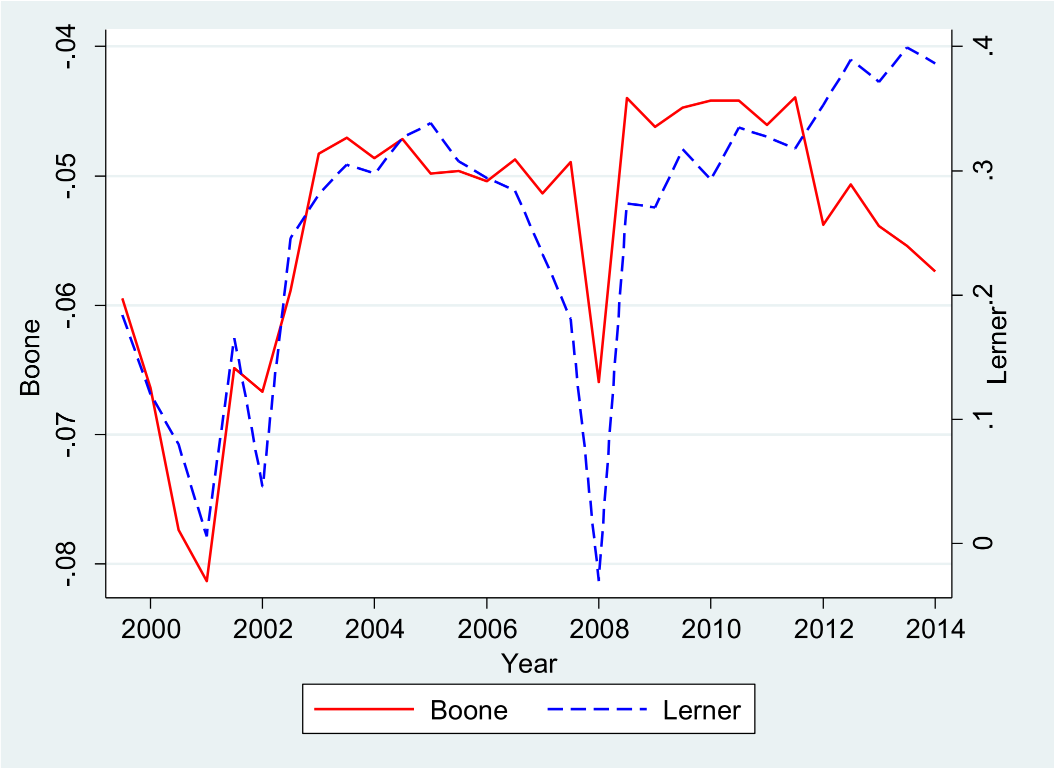
[53] Delis (2012) includes Japan in the sample of 84 countries and reports that the average Boone indicator for Japanese banks during 1988-2005 is -0.584.

[54] Note that the data are obtained from World Bank for the whole banking system.

Figure 1. The Boone Indicator and the Lerner Index



Notes: This Figure illustrates the average values of the Boone indicator and the Lerner index over time. Year denotes financial year.

There was a shift in the Boone indicator which signified higher competition during the US subprime crisis. At the end of March 2009, the corresponding Boone indicator dropped from -0.0489 (in September 2008) to -0.0659. The contagion of the global financial crisis possibly deviated Japanese banks from their profit goals. The deterioration of profit, in turn, could reduce bank market power. Between September 2009 and September 2012, the Boone indicator had a stable trend similar to its pattern after the restructuring period, before slightly decreasing towards the end of the sample period.

The corresponding stiff competition is identified by higher absolute values of the Boone indicator. There is no specific benchmark for the value of β in general, yet what we have found implies a moderate degree of competition in the banking sector, as the figures are not too distant from zero. Estimating an international sample, Clerides et al.

(2015) also find that the Japanese banking system is in the least competitive group based on profit elasticities. Table 2 provides further insight of competition among each bank type. In general, competition within City Banks (-0.0654) and Regional Banks II (-0.0559) are more intense than between Regional Banks I (-0.0518). The largest magnitude (absolute value) of the Boone indicator is recorded for City Banks in March 2002 at -0.1906. The trend of competition in City Banks during the restructuring period was more volatile than those in the other two types, indicating the effect of the aforementioned consolidation tendency. It seems that the onset of the US credit crunch 2007-2008 imposed a pronounced effect on competition between Regional Banks II, notably at -0.0809 in March 2009. A potential explanation could rest on the size factor which may denote a bank's resistance to external shocks. Regional Banks II are the smallest compared to the other two and operate under more limited geographic restrictions. Hence, it might be challenging for Regional Banks II to withstand exogenous shocks which could erode their profits and weaken their market power. Nevertheless, competition in Regional Banks II appeared to be relatively stable compared to City Banks and Regional Banks I after the global financial crisis.

With regard to the Lerner index, its trend over time illustrated in Figure 1 shows support for previous findings of the Boone indicator.[55] Our result reveals that the average Lerner index is 0.2531, with some variation across bank types (the average Lerner index reported for Japanese banks from 2003 to 2010 in Fu et al. (2014) is 0.2521). The level of competition is relatively tougher for City Banks (0.1467) and Regional Banks II (0.2421) than for Regional Banks I (0.2777), in line with the rank of Boone indicators formerly reported for three types. The trend of the Lerner index over time is very similar

[55] There are some cases when market power characterised by the Lerner index is negative, but occasionally found. Agoraki et al. (2011) and Fu et al. (2014) explain the implication of negative Lerner index by the non-optimising behaviour of banks which are unable to price above marginal cost.

to the pattern of the Boone indicator (see Fig. 1). The two points expressing the strongest competitive environment are also observed in March 2002 and March 2009. Our results, however, are different from findings of Liu and Wilson (2013), possibly because they obtain the Lerner index by estimating the whole banking system, including Trust Banks, *Shinkin* Banks and Credit cooperatives during 2000-2009. Concerning the three types in our sample, Liu and Wilson (2013) find that City Banks have the greatest market power, followed by Regional Banks I and Regional Banks II. Similar interpretation is drawn from Montgomery et al. (2014) as large banks enjoy greater market power post-mergers.

Table 2. Boone Indicator and Lerner Index per Bank Type.

Variable	Boone			Lerner		
Time	City	Regional I	Regional II	City	Regional I	Regional II
Sep-00	-0.0840	-0.0575	-0.0581	0.1337	0.2001	0.1732
Mar-01	-0.1129	-0.0597	-0.0683	-0.1054	0.1321	0.1356
Sep-01	-0.1332	-0.0605	-0.0886	-0.2174	0.1146	0.0830
Mar-02	-0.1906	-0.0625	-0.0894	-0.7096	0.0647	0.0289
Sep-02	-0.0517	-0.0535	-0.0795	0.0709	0.1813	0.1597
Mar-03	-0.1206	-0.0515	-0.0810	-0.8319	0.1173	0.0257
Sep-03	-0.0429	-0.0699	-0.0469	0.2166	0.2190	0.2822
Mar-04	-0.0616	-0.0452	-0.0503	0.1374	0.3101	0.2645
Sep-04	-0.0601	-0.0469	-0.0455	0.1992	0.3177	0.3030
Mar-05	-0.0562	-0.0461	-0.0510	0.0917	0.3196	0.2993
Sep-05	-0.0432	-0.0486	-0.0458	0.3346	0.3169	0.3385
Mar-06	-0.0432	-0.0457	-0.0563	0.3082	0.3628	0.3086
Sep-06	-0.0413	-0.0464	-0.0550	0.3191	0.3303	0.2757
Mar-07	-0.0467	-0.0453	-0.0579	0.2326	0.3249	0.2593
Sep-07	-0.0546	-0.0496	-0.0468	0.2172	0.2880	0.2889
Mar-08	-0.0574	-0.0489	-0.0539	0.2117	0.2482	0.2143
Sep-08	-0.0513	-0.0453	-0.0537	0.0899	0.1893	0.1809
Mar-09	-0.0598	-0.0562	-0.0809	-0.0583	-0.0060	-0.0608
Sep-09	-0.0428	-0.0433	-0.0452	0.1706	0.2947	0.2577
Mar-10	-0.0445	-0.0443	-0.0493	0.2579	0.2994	0.2286
Sep-10	-0.0483	-0.0440	-0.0453	0.3296	0.3270	0.3011
Mar-11	-0.0435	-0.0442	-0.0442	0.2450	0.2942	0.2965
Sep-11	-0.0458	-0.0438	-0.0446	0.3260	0.3461	0.3194
Mar-12	-0.0579	-0.0464	-0.0438	0.3335	0.3280	0.3254
Sep-12	-0.0513	-0.0436	-0.0435	0.2787	0.3167	0.3245
Mar-13	-0.0586	-0.0605	-0.0426	0.3910	0.3630	0.3309
Sep-13	-0.0916	-0.0519	-0.0437	0.4174	0.3879	0.3878
Mar-14	-0.0419	-0.0612	-0.0439	0.3781	0.3673	0.3775
Sep-14	-0.0450	-0.0642	-0.0430	0.4285	0.4013	0.3927
Mar-15	-0.0438	-0.0663	-0.0451	0.3356	0.3895	0.3878
Total	-0.0654	-0.0518	-0.0559	0.1467	0.2713	0.2421

Notes: This Table reports the average Boone indicator and the Lerner index per bank type over time. Sep: September; Mar: March; 00-15: 2000-2015.

5.5.2. Risk and competition: The Boone indicator as the threshold variable

Table 3 reports results from the dynamic panel threshold analysis for the relationship between competition and risk, with the Boone indicator as the threshold variable. Columns 1 to 3 report findings with three proxies for risks (bankrupt loan ratio, restructured loan ratio, and *ln*Z-score, respectively). In the first two columns, the threshold values found are quite close to each other (-0.0457 and -0.0481). The impact of the Boone indicator in the low regime is negative and insignificant. In the high regimes, the regime-dependent coefficients of the Boone indicator are positive and statistically significant (0.5654 and 0.4257). It suggests that when above the threshold value, the Boone indicator is positively associated with bankrupt loan/restructured loan ratios. In other words, the higher the bank competition, the lower the risk. Comparing the magnitude of the coefficients, we observe a stronger effect when risk is captured by bankrupt loan ratio (0.5654 against 0.4257). Compared to restructured loans, bankrupt loans are more detrimental as they have a smaller likelihood of recovery. This could suggest a more favourable effect of competition on reducing riskier loan portfolios. Our results, therefore, support the *competition-stability* hypothesis, in line with findings of Schaeck and Cihák (2014) for EU banks. Also examining Japanese banks but using Z-score to proxy for risk, Liu and Wilson (2013) report the existence of the *competition-fragility* hypothesis for all banks during 2000-2009.

There is a positive relationship between the Boone indicator and *ln*Z-score in both regimes. The parameters reported in column 3 are 0.3231 and 1.156 for the low and high regimes, respectively. Thus, in terms of overall bank soundness, competition appears to reduce bank stability, supporting the *competition-fragility* hypothesis. This implication is in line with the finding of Liu and Wilson (2013) who also use *ln*Z-score as an indicator for bank stability. The threshold value is identified at -0.1026, putting approximately 94% of the observations of the sample in the high regime (3283). To this end, there is evidence that both competition-risk hypotheses exist in Japanese banking. Competition is found to be a risk-reducing factor in terms of credit risks, but not in the case of overall bank stability.

We are more confident in the credibility of the former interpretation which supports the *competition-stability* hypothesis, since Z-score contains some limitations. As argued in Demirgüç-Kunt and Detragiache (2011), Z-score is an accounting-based measure, which may not fully reflect the solvency of individual banks, especially if banks are able to smooth out data before reporting. Cihák and Hesse (2007) also cast doubts on whether Z-score produces a fair measure of default risk across financial institutions. An example given in their study is cooperative banks that are less focused on profitability. Another problem of Z-score is the volatility measure in the denominator of its formula. Lepetit and Strobel (2013) compare different alternatives for the construction of Z-score. They provide evidence that the mean and standard deviation of return on assets calculated for the whole sample and the current capital ratio best fit their data.[56] To this end, our proxies of credit risks are straightforward from balance-sheet data. We do not have the issue of comparability discussed in Demirgüç-Kunt and Detragiache (2011) for the use of nonperforming loans, as banks operate under the same reporting rules. Furthermore, the data set of bankrupt and restructured loans represents a more realistic picture of the problem that Japanese banks encountered.

[56] Tsionas (2014) provides more discussion regarding the limitations of Z-score.

Table 3. Dynamic Panel Threshold Analysis for the Risk-Competition Nexus (Boone Indicator).

	1		2		3	
Dependent variable	BRL ratio		RSL ratio		lnZ-score	
Threshold estimates	-0.0457		-0.0481		-0.1026	
95% confidence interval	[-0.0459 -0.0457]		[-0.0493 -0.0457]		[-0.1151 -0.0988]	
Impact of threshold variables	Est.	S.e.	Est.	S.e.	Est.	S.e.
Low regime	-0.0571	0.0382	-0.0116	0.0097	0.3231*	0.1775
High regime	0.5654***	0.0849	0.4257***	0.0554	1.1560***	0.1676
Intercept	-0.0249***	0.0044	-0.0152***	0.0025	-0.1453***	0.0240
Impact of covariates						
Lending rate	0.0421***	0.0032	0.0372***	0.0020	0.1820***	0.0300
Size	-0.0002	0.0038	0.0096***	0.0027	0.0758***	0.0307
Capital ratio	-0.6081***	0.1054	-0.1051***	0.0421		
Asset diversification	-0.0454***	0.0091	-0.0128***	0.0050	0.1204	0.1598
Liquidity	-0.0429***	0.0096	-0.0084	0.0068	0.0982	0.2349
Revenue diversification	0.0144*	0.0087	0.0125	0.0080	0.1927***	0.0655
GDP growth	0.0573***	0.0074	0.0462***	0.0046	0.2623***	0.0596
Market capitalisation	-0.0029***	0.0008	-0.0008	0.0005	0.0373***	0.0090
Obs in low regime	611		562		208	
Obs in high regime	2880		2929		3283	

Notes: This Table reports results from the dynamic panel threshold analysis using the first lag of the endogenous variable (lending rate) as its instrument. The threshold variable is the Boone indicator. BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = \left(ROA_{it} + Capital\, ratio_{it}\right) / \sigma ROA_{it}$, lending rate=interest income on loans/loans and bills discounted, size=ln(total assets), capital ratio=equity/assets, asset diversification=securities/assets, liquidity=liquid assets/total assets, revenue diversification=non-interest incomes/operating income, market capitalisation is in natural logarithm. Est.: estimate, S.e.: standard error, Obs: number of observations. ***,**,*: significance at 1%, 5%, 10% levels respectively.

The number of banks over time in each regime classified by the Boone indicator threshold is reported in Table 4. In the low regime, there are 611 (column 1), 562 (column 2), and 208 (column 3) observations. The high regime consists of many more observations: 2880 (column 1), 2929 (column 2), and 3283 (column 3). The patterns of the number of banks are rather clear in columns 1 and 2, in which we observe some breaks in September 2003, September 2007, and March 2009. From September 2003 to September 2007, competition appeared less intensified as there were significantly fewer observations in the low regimes. From September 2009 to September 2012, a similar trend prevailed. Between March 2008 and March 2009, the number of observations in the low regimes increased quite significantly. This highlights tougher competition, probably in connection with the onset of the global financial crisis. In column 3, the identification of strong competition may not be obvious as the majority of banks are classified in the high regime. However, the threshold value itself (-0.1026) signifies a rather high level of competition in comparison to those reported in columns 1 and 2 (-0.0457 and -0.0481).

Table 4. Number of Observations in Each Regime for the Risk-Competition Nexus.

	1		2		3	
	BRL ratio		RSL ratio		lnZ-score	
	-0.0457		-0.0481		-0.1026	
	Low	High	Low	High	Low	High
Sep-00	41	87	37	91	11	117
Mar-01	43	82	43	82	19	106
Sep-01	42	86	42	86	20	108
Mar-02	51	74	51	74	30	95
Sep-02	17	110	17	110	10	117
Mar-03	42	79	39	82	21	100
Sep-03	13	108	13	108	5	116
Mar-04	13	107	12	108	4	116
Sep-04	13	107	9	111	3	117
Mar-05	14	105	11	108	3	116
Sep-05	10	109	8	111	4	115
Mar-06	13	104	9	108	4	113
Sep-06	11	106	8	109	2	115
Mar-07	11	105	11	105	6	110
Sep-07	12	103	11	104	2	113
Mar-08	23	91	23	91	5	109
Sep-08	29	86	28	87	4	111
Mar-09	49	65	46	68	12	102
Sep-09	5	109	5	109	0	114
Mar-10	9	103	7	105	3	109
Sep-10	5	106	3	108	1	110
Mar-11	4	107	2	109	0	111
Sep-11	6	105	3	108	0	111
Mar-12	9	102	8	103	1	110
Sep-12	7	103	3	107	0	110
Mar-13	15	95	15	95	10	100
Sep-13	17	93	15	95	5	105
Mar-14	23	87	22	88	6	104
Sep-14	29	81	27	83	9	101
Mar-15	35	75	34	76	8	102
Obs	611	2880	562	2929	208	3283

Notes: This Table reports the number of observations in each regime over time for the risk-competition nexus, with the Boone indicator being the threshold value, and lending rate being the proxy for quantitative easing. Threshold values for the Boone indicator are obtained from the dynamic panel threshold analysis, reported in Table 3. BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = \left(ROA_{it} + Capital\ ratio_{it}\right) / \sigma ROA_{it}$. The second row shows dependent variables, the third row shows the threshold values, the fourth row indicates low and high regimes, Mar: March, Sep: September, 00-15: 2000-2015, Obs: number of observations.

The impact of other control variables is a non-trivial concern. Quantitative easing is the variable that we consider of particular importance in affecting the risk-competition connection. We find a significant and positive impact of bank lending rate on all dependent variables. Thereby, while a rise in lending rate would increase bank stability (column 3, Table 3), it would also raise bank risk-taking in terms of higher bankrupt/restructured loan ratios (columns 1 and 2, Table 3). This finding could give support to the argument of Buch et al. (2014). Quantitative easing could explain for this reduction in credit risk because lower lending rates mitigate the interest burden for borrowers. However, banks may involve in riskier activities to seek for high yield so as to compensate for the low interest margin.

We find a negative association between bank characteristics (capitalisation, assets diversification and liquidity) and risk-monitored loan ratios. Well-capitalised banks are expected to have lower credit risk as the risk of capital loss outweighs the temptation from higher returns associated with riskier investments, in line with the finding reported in Tabak et al. (2015) for Brazilian banks. Concerning the favourable impact of asset diversification on risk, the result proposes that when diversifying earning assets, banks would benefit from lower risk-monitored loan ratios. The reason could be that managers of banks which have a well-diversified asset portfolio are expected to also effectively control their loan-generating practices. Regarding liquidity, banks having high liquidity ratio are found to be less sensitive to risk. Liquidity not only enhances banks' resilience to shocks, but also liberates banks in managing outstanding loans, rolling over debts and considering prospective loan applications. Highly liquid banks, hence, could be more flexible in extending loan maturity or amending loan contracts, which in turn would give temporarily troubled borrowers valuable opportunities to defend their financial health and commit to loan repayment.

In terms of bank size and revenue diversification, we find that large banks would have higher restructured loan ratio (column 2, Table 3), but also higher overall bank stability (column 3, Table 3) compared to their smaller peers. This could be explained through the segmentation of Japanese banking. Loan financing of systemically important banks, e.g. City Banks, is not refined within specific locations and particular types of borrowers. This may increase the likelihood of greater restructured loan ratio in comparison to small banks. However, it is more likely for *too-big-to-fail* banks to prevent restructured loans from transferring to bankrupt loans as they could benefit from various funding sources and better access to information. These advantages could also enhance bank stability. Moreover, as a feature of the *keiretsu* network, Japanese City Banks have strong ties with their clients (Lincoln et al., 1996). Management assistance from City Banks could aid temporarily distressed borrowers to reverse the situations. Affiliated firms could benefit from strategic advice of their *Main* banks to encounter challenging periods. Our results support Liu and Wilson (2013) to the extent that Japanese large banks are less risky than their smaller peers. In terms of the impact of revenue diversification, an increase in this ratio is reported to enhance bank soundness (column 3, Table 3). The more diversified the bank is in business activities, the less risk it may incur. Nguyen et al. (2012) also report that South Asian banks are more stable in response to diversifying their income.

Turning to the influence of macroeconomic variables, an increase in GDP growth would positively affect risk-monitored loan ratios. Dell'Ariccia and Marquez (2006) argue that the pro-cyclical bank lending pattern is supposed to influence bank risk since banks are more likely to relax lending standards and expand credit during economic upturn. Nevertheless, the result indicates a favourable impact of GDP growth on bank stability (column 3, Table 3), in line with Agoraki et al. (2011). With regard to the effect of market capitalisation on risk, our result denotes that the development of the stock market would have a positive effect on the banking market through lower ratio of bankrupt loans (column 1, Table 3) and higher bank soundness (column 3, Table 3). There is a weak implication that firms can seek funding from alternative markets to repay their debts. However, in developed financial markets, credit information sharing would easily assist creditors to detect firms with bad reputation and moral hazard behaviour (Beck et al., 2013).

Table 5 reports results for the competition and risk relationship with other proxies of quantitative easing. We find consistent threshold values for the Boone indicator, as well as its relationship with risk across models. The magnitudes of the impact of the threshold variable on the dependent variable are also very similar to those reported in Table 3. In particular, competition is found to reduce credit risk (high regimes, columns 1 to 4), but undermine bank soundness (columns 5 and 6). As lower bond yield and higher Bank of Japan assets indicate more aggressive quantitative easing (Krishnamurthy and Vissing-Jorgensen, 2011; Lyonnet and Werner, 2012), results in columns 1 to 4 show that quantitative easing reduces risk-monitored loan ratios, in line with results in columns 1 and 2 of Table 3. This relationship is drawn from a positive association between bond yield and bankrupt/restructured loan ratios (columns 1 and 3), and a negative association between these ratios and Bank of Japan assets (columns 2 and 4). For the impact of control variables, there is little variation in terms of signs and magnitudes, with an exception of revenue diversification. This variable reveals a statistically significant effect in reducing risk-monitored loan ratios (columns 1 to 4).

Table 5. Dynamic Panel Threshold Analysis for the Risk-Competition Nexus (Boone Indicator and other proxies for Quantitative Easing).

	1		2		3		4		5		6	
Dependent variable	BRL ratio		BRL ratio		RSL ratio		RSL ratio		lnZ-score		lnZ-score	
Threshold estimates	-0.0457		-0.0457		-0.0481		-0.0481		-0.1026		-0.1026	
95% confidence interval	[-0.0459 -0.0457]		[-0.0459 -0.0457]		[-0.0494 -0.0457]		[-0.0494 -0.0457]		[-0.1151 -0.0988]		[-0.1151 -0.0988]	
Impact of threshold variables	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.
Low regime	-0.0571	0.0374	-0.0571	0.0365	-0.0116	0.0092	-0.0116	0.0084	0.3226*	0.1815	0.3221*	0.1815
High regime	0.5436***	0.0881	0.5416***	0.0982	0.4070***	0.0603	0.4066***	0.0723	1.1667***	0.1737	1.1679***	0.1756
Intercept	-0.0241***	0.0047	-0.0240***	0.0050	-0.0145***	0.0027	-0.0145***	0.0032	-0.1465***	0.0245	-0.1467***	0.0246
Impact of covariates												
Yield	0.0153***	0.0011			0.0136***	0.0007			0.0675***	0.0119		
BoJ assets			-0.0275***	0.0021			-0.0244***	0.0013			-0.1208***	0.0214
Size	-0.0033	0.0037	-0.0039	0.0037	0.0069***	0.0026	0.0064***	0.0028	0.065**	0.0313	0.0627**	0.0310
Capital ratio	-0.5848***	0.1028	-0.5772***	0.1037	-0.0845**	0.0409	-0.0778*	0.0404				
Asset diversification	-0.0592***	0.0091	-0.0560***	0.0096	-0.0249***	0.0051	-0.0221***	0.0057	0.0690	0.1596	0.0836	0.1630
Liquidity	-0.0127	0.0102	0.0082	0.0109	0.0183***	0.0067	0.0368***	0.0075	0.2391	0.2618	0.3328	0.2764
Revenue diversification	-0.0097***	0.0034	-0.0071*	0.0037	-0.0089***	0.0026	-0.0065**	0.0030	0.0910	0.0625	0.1030	0.0641
GDP growth	0.0621***	0.0082	0.0368***	0.0082	0.0505***	0.0058	0.0281***	0.0055	0.2859***	0.0596	0.1739***	0.0673
Market capitalisation	-0.0074***	0.0009	0.0014	0.0010	-0.0047***	0.0006	0.0031***	0.0006	0.0176	0.0120	0.0562***	0.0079
Obs in low regime	611		611		562		562		208		208	
Obs in high regime	2880		2880		2929		2929		3283		3283	

Notes: This Table reports results from the dynamic panel threshold analysis using the first lag of the endogenous variable (10-year Japanese government bond yield and the natural logarithm of the Bank of Japan Total assets) as its instrument. The threshold variable is the Boone indicator. BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = \left(ROA_{it} + Capital\ ratio_{it}\right) / \sigma ROA_{it}$, size=ln(total assets), capital ratio=equity/assets, asset diversification=securities/assets, liquidity=liquid assets/total assets, revenue diversification=non-interest incomes/operating income, market capitalisation is in in natural logarithm. Est.: estimate, S.e.: standard error, Obs: number of observations. ***,**,*: significance at 1%, 5%, 10% levels respectively.

5.5.3. Risk and quantitative easing: Quantitative easing as the threshold variable

Findings for the risk-quantitative easing nexus are reported in Table 6. There exists a positive relationship between lending rate and risk in all different model specifications (columns 1 to 3). A rise in lending rate is found to increase bankrupt/restructured loan ratios and *ln*Z-score, statistically significant in both regimes. When risk is measured by bankrupt loan ratio and restructured loan ratio, the threshold value is identified at 1.2052% (column 1) and 1.0562% (column 2). When *ln*Z-score is in play, the threshold value is 0.9401% (column 3). To this end, quantitative easing is beneficial in terms of reducing credit risk. The effect is more prominent in the high regimes, where the coefficients are 0.037 (column 1) and 0.0385 (column 2). Although the coefficients indicating the impact of lending rate on risk-monitored loan ratios in the low regimes are statistically significant, the magnitude is quite negligible (0.0088 and 0.0063 in columns 1 and 2, respectively). Nevertheless, this favourable effect of lower risky loan ratios associated with quantitative easing may be at the expense of bank stability. The reason is that, reported in column 3, *ln*Z-score is also reduced, given an aggressive quantitative easing policy. Notably, the magnitude of the coefficients for the impact of lending rate provides insightful implications. Compared to the detrimental effect that quantitative easing could impose on bank stability (0.3416 and 0.2833 in the low and high regimes, respectively), the beneficial impact that it exerts on credit risk is quite small. In a nutshell, comparing the results to the hypotheses set out in section 5.2, we can conclude that quantitative easing could lower credit risk but may harm overall bank stability.

Table 6. Dynamic Panel Threshold Analysis for the Risk-Quantitative Easing Nexus (lending rate).

	1		2		3	
Dependent variable	BRL ratio		RSL ratio		lnZ-score	
Threshold estimates	1.2052%		1.0562%		0.9401%	
95% confidence interval	[0.9861% 1.2102%]		[0.9613% 1.1205%]		[0.9216% 1.0122%]	
Impact of threshold variables	Est.	S.e.	Est.	S.e.	Est.	S.e.
Low regime	0.0088***	0.0026	0.0063***	0.0020	0.3416***	0.0442
High regime	0.0370***	0.0090	0.0385***	0.0036	0.2833***	0.0751
Intercept	-0.1288***	0.0417	-0.1469***	0.0194	0.3061	0.2818
Impact of covariates						
Boone	-0.1359***	0.0557	-0.0790***	0.0234	0.9370***	0.3350
Size	-0.0140***	0.0031	-0.0014	0.0022	0.1029***	0.0356
Capital ratio	-0.5453***	0.1079	-0.0560	0.0372		
Asset diversification	-0.0791***	0.0088	-0.0387***	0.0055	0.1920	0.1889
Liquidity	-0.0619***	0.0110	-0.0243***	0.0076	0.1413	0.2368
Revenue diversification	-0.0068	0.0059	-0.0061	0.0042	0.2777***	0.0771
GDP growth	0.0387***	0.0083	0.0297***	0.0050	0.2827***	0.0602
Market capitalisation	-0.0020**	0.0009	-0.0003	0.0005	0.0374***	0.0107
Obs in low regime	2532		1789		1090	
Obs in high regime	959		1702		2401	

Notes: This Table reports results from the dynamic threshold analysis using the first lag of the endogenous variable (Boone) as its instrument. The threshold variable is lending rate. BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = \left(ROA_{it} + Capital\ ratio_{it}\right) / \sigma ROA_{it}$, lending rate=interest income on loans/loans and bills discounted, size=ln(total assets), capital ratio=equity/assets, asset diversification=securities/assets, liquidity=liquid assets/total assets, revenue diversification=non-interest incomes/operating income, market capitalisation is in natural logarithm. Est.: estimate, S.e.: standard error, Obs: number of observations. ***,**,*: significance at 1%, 5%, 10% levels respectively.

The implication of variability in our results could be interpreted by the countervailing effects of low interest rates on bank risk-taking as discussed in Buch et al. (2014). On the one hand, quantitative easing may reduce risk, as it aims to facilitate lending so that increased investment could boost economic growth. Both banks and borrowers can benefit from ample liquidity injected by quantitative easing to strengthen their resistance to exogenous shocks. Low interest rates would encourage more potential borrowers to apply for funding because of a greater probability of fulfilling their repayment duties. Evidenced in Jiménez et al. (2014), low interest rate reduces the cost burden of existing loans for borrowers. Therefore, lower bankrupt/restructured loan ratios would be expected. On the other hand, quantitative easing could amplify risk. When banks foresee an extended period of low interest rate, they may alter their risk-taking appetites towards riskier projects to pursue greater gains (Altunbas et al., 2014; Gambacorta, 2009). In more details, low yield and abundant liquidity accelerate asset prices and promote leverage, in turn induce excessive risk-taking (Dell'Ariccia et al., 2010). Larger loanable proportion of collaterals and the search for yield (Rajan, 2005) may drive banks to grant more risky loan portfolios (Jiménez et al., 2014), or to invest in higher yield-higher risk instruments. Another risk-taking channel could be through a typical type of moral hazard, where banks realise the continuity of quantitative easing policy in difficult economic times. As Altunbas et al. (2014) argue, banks may perceive the presence of a so-called *insurance effect*, in which the enforcement of monetary easing is expected during financial downturn to decelerate the fall of asset values. The prediction of lower probability of large downside risk, therefore, would magnify bank risk-taking. This perception may well be the case of prolonged low interest rate and extensive quantitative easing in Japan. Taken together, these arguments could explain for lower bank stability corresponding to quantitative easing.

Interestingly, in terms of control variables, the results reveal a negative association between the Boone indicator and risk-monitored loan ratios. Hence, greater competition would be harmful for banks because of higher bankrupt/restructured loan ratios. This finding is reinforced by the positive association between the Boone indicator and *ln*Z-score in column 3, indicating higher bank stability in lower competition. In this case, when competition is a control variable, the results do not uncover its desirable impact in reducing risky loan ratios shown in columns 1 and 2 of Table 3. The impact of other determinants in Table 6 is similar to findings reported in Tables 3 and 5, with minor variation. In particular, in terms of diminishing risk and enhancing bank soundness, there are four variables: capital ratio, asset diversification, liquidity and market capitalisation. In contrast, higher GDP growth is found to increase risk-monitored loan ratios, probably due to softened lending standards during good economic times (Dell'Ariccia and Marquez, 2006). Turning to Z-score, there is a favourable impact on bank stability during economic upturn and when banks divert their focus to noninterest income. Bank stability increases corresponding to larger bank size, while bankrupt loan ratio decreases.

The number of banks in each regime is shown in Table 7. Analysing the trend of the number of observations in column 1, we observe a significant increase of banks in the low regime after the global financial crisis. Especially, from March 2011 to March 2015, almost all banks in the sample charged less than 1.2052% lending rate. Note that this time frame covers the on-going quantitative easing policy (since October 2010). Illustrated in column 3, the distribution of the number of banks in the low regime provides further evidence for the initial quantitative easing period. Recall that the threshold value for column 3 is 0.9401%, which is lower than the values for columns 1 (1.2052%) and 2 (1.0562%). From September 2003 to March 2006, the number of banks charging lending rate lower than 0.9401% increased monotonically. This tendency indicates the effect of the first quantitative easing period (March 2001-March 2006). In the high regimes of all model specifications, it is confirmed that the number of observations gradually decreased during this period.

Table 7. Number of Observations in Each Regime for the Risk-Quantitative Easing Nexus.

	1		2		3	
	BRL ratio		RSL ratio		lnZ-score	
	1.2052%		1.0562%		0.9401%	
	Low	High	Low	High	Low	High
Sep-00	46	82	5	123	0	128
Mar-01	45	80	2	123	0	125
Sep-01	58	70	18	110	1	127
Mar-02	60	65	35	90	2	123
Sep-02	63	64	35	92	5	122
Mar-03	65	56	36	85	9	112
Sep-03	68	53	41	80	14	107
Mar-04	74	46	44	76	15	105
Sep-04	71	49	47	73	16	104
Mar-05	78	41	54	65	25	94
Sep-05	84	35	55	64	31	88
Mar-06	90	27	61	56	41	76
Sep-06	92	25	61	56	33	84
Mar-07	80	36	53	63	19	97
Sep-07	76	39	38	77	5	110
Mar-08	75	39	37	77	2	112
Sep-08	79	36	38	77	5	110
Mar-09	87	27	52	62	10	104
Sep-09	94	20	66	48	25	89
Mar-10	96	16	71	41	43	69
Sep-10	97	14	78	33	50	61
Mar-11	102	9	82	29	62	49
Sep-11	103	8	86	25	68	43
Mar-12	106	5	91	20	75	36
Sep-12	104	6	94	16	78	32
Mar-13	106	4	98	12	85	25
Sep-13	107	3	99	11	88	22
Mar-14	108	2	101	9	90	20
Sep-14	109	1	105	5	96	14
Mar-15	109	1	106	4	97	13
Obs	2532	959	1789	1702	1090	2401

Notes: This Table reports the number of observations in each regime over time for the risk-quantitative easing nexus, with lending rate being the threshold variable, and the Boone indicator being the proxy for competition. Threshold values of lending rate are obtained from the dynamic panel threshold analysis, reported in Table 6. BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = \left(ROA_{it} + Capital\ ratio_{it}\right)/\ \sigma ROA_{it}$. The second row shows dependent variables, the third row shows the threshold values, the fourth row indicates low and high regimes, Mar: March, Sep: September, 00-15: 2000-2015, Obs: number of observations.

In Table 8, we use the 10-year Japanese government bond yield (columns 1 to 3) and Bank of Japan assets (columns 4 to 6) to replace lending rate as the threshold variable. The results show a positive influence of bond yield on *ln*Z-score in both regimes of column 3. This is in line with previous findings of quantitative easing reducing bank stability, reported in column 3 of Table 6. The magnitude of the impact in the high regime (0.6513, column 3) is also notable. Interestingly, bond yield affects risk-monitored loan ratios differently in two regimes. There is a statistically significant positive relationship between bond yield and bankrupt/restructured loan ratio in the high regimes. The coefficients of bond yield's impact are 0.0131 (column 1) and 0.0107 (column 2). This relationship turns out negative in the low regimes (-0.017 in column 1 and -0.0149 in column 2). It is also worth noting that the absolute magnitudes of the impact of bond yield on risk-monitored loans in the two regimes are approximately the same (around 0.01). Additionally, the threshold value is consistently realised at 1.032%. Thus, when bond yield is below 1.032%, quantitative easing increases credit risk. In this regard, more aggressive quantitative easing would encourage banks to enrol more risk. First, banks may tend to soften lending standards due to low yield and interest rate, thereby issuing loans to less creditworthy borrowers (Jiménez et al., 2014). Second, as Ioannidou et al. (2015) argue, due to low monetary policy rate, banks may be less concerned about the compensation which should be required for the higher risk taken. In fact, Ioannidou et al. (2015) find that during monetary expansion, banks charge riskier borrowers relatively less than what they would. When bond yield is greater than 1.032%, quantitative easing reduces credit risk, similar to our previous conclusion drawn from the use of lending rate (Table 6).

Table 8. Dynamic Panel Threshold Analysis for the Risk-Quantitative Easing Nexus (10-year Japanese government bond yield and Bank of Japan assets)

	1		2		3		4		5		6	
Dependent variable	BRL ratio		RSL ratio		lnZ-score		BRL ratio		RSL ratio		lnZ-score	
Threshold variable	Yield		Yield		Yield		BoJ assets		BoJ assets		BoJ assets	
Threshold estimates	1.032%		1.032%		1.484%		118,437,502 mil JPY		118,437,502 mil JPY		118,437,502 mil JPY	
95% confidence interval	[1.032% 1.032%]		[1.032% 1.032%]		[1.484% 1.484%]		[118,437,502 118,437,502]		[118,437,502 118,437,502]		[118,437,502 118,437,502]	
Impact of threshold variables	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.
Low regime	-0.0170***	0.0014	-0.0149***	0.0010	0.0856***	0.0113	-0.0347***	0.0098	-0.0286***	0.0050	-0.1219	0.0929
High regime	0.0131***	0.0049	0.0107***	0.0028	0.6513***	0.1882	0.0007	0.0015	-0.0010	0.0010	-0.1709***	0.0194
Intercept	-0.1427***	0.0253	-0.1222***	0.0151	-2.2627***	0.8002	0.6492***	0.1814	0.504***	0.0910	-0.9858	1.9967
Impact of covariates												
Boone	-0.1837***	0.0528	-0.122***	0.0296	0.7841***	0.2696	-0.1767***	0.0530	-0.1151***	0.0273	0.8562***	0.2814
Size	-0.0232***	0.0035	-0.0095***	0.0026	0.0580**	0.0295	-0.0245***	0.0031	-0.0108***	0.0023	0.0543*	0.0283
Capital ratio	-0.4923***	0.1082	-0.0085	0.0390			-0.4981***	0.1034	-0.0142	0.0362		
Asset diversification	-0.1008***	0.0087	-0.0602***	0.0053	0.1431	0.1502	-0.1093***	0.0087	-0.0691***	0.0051	0.0609	0.1414
Liquidity	-0.0737***	0.0111	-0.0326***	0.0078	0.2455	0.2653	-0.0897***	0.0116	-0.0474***	0.0078	0.1494	0.2634
Revenue diversification	-0.0178***	0.0046	-0.016***	0.0035	0.1182*	0.0606	-0.0197***	0.0043	-0.0181***	0.0033	0.1033*	0.0562
GDP growth	0.0847***	0.0119	0.0712***	0.0078	0.3185***	0.0741	0.0081	0.0083	-0.0018	0.0053	-0.0463	0.0750
Market capitalisation	-0.0113***	0.0018	-0.0083***	0.0012	0.0479***	0.0082	0.0002	0.0011	0.0028***	0.0006	0.1032***	0.0067
Obs in low regime	1114		1114		2898		1156		1156		1156	
Obs in high regime	2377		2377		593		2335		2335		2335	

Notes: This Table reports results from the dynamic panel threshold analysis using the first lag of the endogenous variable (Boone) as its instrument. The threshold variable is the 10-year Japanese government bond yield and Bank of Japan (BoJ) assets. BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = (ROA_{it} + Capital\ ratio_{it}) / \sigma ROA_{it}$, size=ln(total assets), capital ratio=equity/assets, asset diversification=securities/assets, liquidity=liquid assets/total assets, revenue diversification=non-interest incomes/operating income, market capitalisation is in natural logarithm. Est.: estimate, S.e.: standard error, Obs: number of observations. ***,**,*: significance at 1%, 5%, 10% levels respectively.

The periods where bond yield is lower than the threshold value (1.032%) happened in March 2003, September 2010, and from September 2011 to March 2015. The last time frame includes the current quantitative easing period. If we combine this finding with the aforementioned impact of the threshold, the on-going quantitative easing may pose a threat to the banking system by augmenting credit risk. Regarding control variables, similar to the results reported in Table 6, we also find that competition increases credit risk and bank fragility. Larger size, higher capital ratio, more liquidity, greater asset diversification, revenue diversification and market capitalisation would help lower credit risk. Higher GDP growth, on the other hand, would increase credit risk exposure. In terms of bank stability, it would be enhanced following larger bank size, more diversified income, higher GDP growth, and greater market capitalisation.

A first glance at columns 4 to 6, where the Bank of Japan total assets are used as a proxy for quantitative easing, reveals a consistent estimate of the threshold value at 118,437,502 mil JPY. There is a negative association between the Bank of Japan assets and risk variables. For credit risk, this relationship is statistically significant in the low regime (-0.0347 in column 4 and -0.0286 in column 5), implying a favourable impact of quantitative easing. The influence of Bank of Japan assets on risk-monitored loan ratios in the high regime is insignificant. Differently, for bank stability, when the Bank of Japan assets are greater than the threshold, more aggressive quantitative easing policy would reduce bank soundness (-0.1709 in column 6). The relationship between quantitative easing and bank stability is insignificant in the low regime. These results strengthen those reported in columns 1 to 3, where bond yield is the proxy for quantitative easing. Up to a certain level of asset purchases (118,437,502 mil JPY), quantitative easing lessens credit risk. When the amount of asset purchases passes the threshold, quantitative easing reduces bank stability.

The time frame in each regime complements these findings. First, the periods of high regimes coincide with the two quantitative easing periods. In particular, the amount of asset purchases which were higher than the threshold is recorded from March 2001 to March 2006, and from March 2011 to March 2015. Hence, the more asset purchases of the Bank were not really effective due to its detrimental impact on bank stability. Second, the period of low regimes falls in to the gap between the two quantitative easing periods, and also embraces the global financial crisis. During this interval (September 2006-September 2010), more asset purchases would mitigate credit risk. However, overall, the estimated impact suggests that the reduction in credit risk may not be considerable compared to the reduction in bank soundness (e.g. -0.0347 in column 4 versus -0.1709 in column 6). The influence of other control variables appears consistent as previously reported in columns 1 to 3 and in Table 6.

5.5.4. Competition and quantitative easing: Quantitative easing as the threshold variable

As quantitative easing affects risk and thereby indirectly competition, it is worth exploring whether the former has a direct effect on bank competition. To test this hypothesis, we apply threshold modelling where competition is the dependent variable and quantitative easing is the threshold variable. We respectively include a number of control variables such as risk, as measured by bankrupt loan ratio, restructured loan ratio, and *ln*Z-score. In addition, we also include some environmental variables such as bank size, capital ratio, asset diversification, revenue diversification, liquidity, GDP growth, and market capitalisation. The results are reported in Table 9.

Table 9. Dynamic Panel Threshold Analysis for the Competition-Quantitative Easing Nexus.

	1		2		3	
Dependent variable	Boone		Boone		Boone	
Threshold variable	Lending rate		Lending rate		Lending rate	
Threshold estimates	0.8496%		0.6935%		0.7397%	
95% confidence interval	[0.7274% 0.9307%]		[0.6925% 0.921%]		[0.7028% 0.8084%]	
Impact of threshold variables	Est.	S.e.	Est.	S.e.	Est.	S.e.
Low regime	0.0905***	0.0233	0.0667	0.0417	0.1095**	0.0510
High regime	-0.0657***	0.0226	-0.0276***	0.0102	-0.0805***	0.0260
Intercept	0.7444***	0.1201	0.4389**	0.2130	0.9231***	0.1936
Impact of covariates						
BRL ratio	-0.0151	0.3644				
RSL ratio			-0.5595	0.4007		
lnZ-score					0.3487***	0.1058
Size	-0.0083	0.0173	-0.0052	0.0152	-0.0091	0.0186
Capital ratio	0.5151	0.3782	0.4606***	0.1868		
Asset diversification	-0.0406	0.0407	-0.0431	0.0386	-0.0415	0.0682
Liquidity	-0.1226***	0.0505	-0.1315***	0.0489	-0.1015	0.0796
Revenue diversification	0.0345	0.0268	0.0296	0.0252	0.0065	0.0437
GDP growth	0.0716*	0.0419	0.0886***	0.0398	-0.0507	0.0596
Market capitalisation	0.0051	0.0032	0.0049*	0.0027	-0.0088*	0.0046
Obs in low regime	624		181		287	
Obs in high regime	2867		3310		3204	

Notes: This Table reports results from the dynamic panel threshold analysis using the first lag of the endogenous variable (BRL ratio, RSL ratio, or lnZ-score) as its instrument. The threshold variable is lending rate. BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = (ROA_{it} + Capital\ ratio_{it}) / \sigma ROA_{it}$, lending rate=interest income on loans/loans and bills discounted, size=ln(total assets), capital ratio=equity/assets, asset diversification=securities/assets, liquidity=liquid assets/total assets, revenue diversification=non-interest incomes/operating income, market capitalisation is in natural logarithm. Est.: estimate, S.e.: standard error, Obs: number of observations. ***,**,*: significance at 1%, 5%, 10% levels respectively.

In Table 9, the proxy for quantitative easing – the bank lending rate – is the threshold variable, whereas the Boone indicator is the dependent variable. The threshold values for lending rate are 0.8496% (column 1), 0.6935% (column 2), and 0.7397% (column 3), corresponding to different risk variables included in the models. The important finding is the different impacts that lending rate places on the Boone indicator. It is positive in the low regimes, and negative in the high ones. The former implies that more aggressive quantitative easing would cause higher competition. In contrast, the latter indicates lower competition in response to a more extensive quantitative easing program. The magnitude of the effect of quantitative easing on competition is larger in the low regimes (0.0905; 0.0667; 0.1095 compared to -0.0657; -0.0276; -0.0805), although the numbers of observations in the low regimes are significantly fewer.

The number of observations in each regime enlightens the implication of our findings (Table 10). Overall, the high regimes outnumber the low ones. The number of banks classified in the low regime started increasing significantly, particularly, since September 2010 in column 1, March 2013 in column 2, and September 2012 in column 3. Based on the threshold values, more banks in the sample experienced a decrease in competition as a result of greater quantitative easing, considerably before the second quantitative easing period. After September 2012 to March 2015, there was an upward trend of the number of banks charging lending rate lower than the threshold, corresponding to the extensive quantitative easing program.

Table 10. Number of Observations in Each Regime for the Competition - Quantitative Easing Nexus (Boone indicator and lending rate).

	1		2		3	
	0.8496%		0.6935%		0.7397%	
	BRL ratio		RSL ratio		lnZ-score	
	Low	High	Low	High	Low	High
Sep-00	0	128	0	128	0	128
Mar-01	0	125	0	125	0	125
Sep-01	0	128	0	128	0	128
Mar-02	1	124	0	125	0	125
Sep-02	0	127	0	127	0	127
Mar-03	1	120	1	120	1	120
Sep-03	2	119	0	121	0	121
Mar-04	3	117	0	120	0	120
Sep-04	3	117	0	120	1	119
Mar-05	4	115	1	118	1	118
Sep-05	3	116	0	119	0	119
Mar-06	7	110	0	117	2	115
Sep-06	5	112	0	117	0	117
Mar-07	2	114	1	115	1	115
Sep-07	0	115	0	115	0	115
Mar-08	0	114	0	114	0	114
Sep-08	0	115	0	115	0	115
Mar-09	1	113	0	114	0	114
Sep-09	2	112	0	114	0	114
Mar-10	9	103	0	112	1	111
Sep-10	17	94	1	110	2	109
Mar-11	27	84	1	110	2	109
Sep-11	36	75	1	110	3	108
Mar-12	51	60	3	108	8	103
Sep-12	56	54	6	104	22	88
Mar-13	71	39	14	96	27	83
Sep-13	75	35	23	87	42	68
Mar-14	80	30	33	77	50	60
Sep-14	82	28	45	65	57	53
Mar-15	86	24	51	59	67	43
Obs	624	2867	181	3310	287	3204

Notes: This Table reports the number of observations in each regime over time for the competition-quantitative easing nexus, with lending rate being the threshold variable, the Boone indicator being the dependent variable. Threshold values are obtained from the dynamic panel threshold analysis, reported in Table 9. BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = \left(ROA_{it} + Capital\ ratio_{it}\right) / \sigma ROA_{it}$. The second row shows the threshold values, the third row shows the risk variable used in each model specification, the fourth row indicates low and high regimes, Mar: March, Sep: September, 00-15: 2000-2015, Obs: number of observations.

Based on our results, during the first two third of the sample period, the majority of banks in the sample are found to enjoy a less competitive environment brought by quantitative easing. The reason could be due to the implicit subsidisation from the government. First, quantitative easing policy aims to facilitate investment and spending through lowering lending rates paid by households and businesses (Wright, 2012). As a result, financial institutions are injected with ample liquidity to increase loan financing at low rates. Second, quantitative easing may generate a standard case of moral hazard which is the *insurance effect* discussed in Altunbas et al. (2014). Banks are less concerned about the fall of asset values as they could predict an extension of the program, or at least the prolonged low short-term interest rate, which could serve as a cushioning effect to prevent further downturn. Thereby, the threat of closure if they took on more risk would not be too high. Besides, according to Boone (2008a), more intense competition is a result of an increase in the number of firms in the industry, more aggressive interaction between firms, or a fall in costs of other incumbents. In the case of Japan, the number of commercial banks from the first quantitative easing period to before the second one did not change significantly, indeed, decreased slightly. We conjecture it is the relaxed economic condition and the implicit government protection that quantitative easing created less competition in the banking industry.

From September 2010 onwards, more banks are categorised in the low regime in which they face intense competition due to quantitative easing. It could be the case that Japanese commercial banks have become close substitutes as quantitative easing facilitates the whole banking system more extensively in the second program. Furthermore, as set out in the monetary policy statement on 30/10/2012, the Bank of Japan has committed to provide banks with unlimited long-term funding to match the net increase in loan financing to non-financial sectors. Being closer substitutes indicates more aggressive interaction between banks. As shown in Boone (2008a), it is a condition for more intense competition.

In terms of control variables, the impact of bank stability on the Boone indicator is positive, in line with the positive association between the Boone indicator (as the threshold variable) and *ln*Z-score, which we find for both regimes in column 3 of Table 3. Higher capital ratio and GDP growth reduce competition, similar to findings of Delis (2012). Capital-abundant banks tend to exercise their market power more greatly than their peers. These banks could be able to define their own high margin and take advantages of variable funding sources which result in lower costs. Higher liquidity ratio, in contrast, would lead to greater competition.

We further replace lending rate with bond yield and Bank of Japan assets. The relationship with the Boone indicator is reported in Table 11. Unlike lending rate, the analysis identifies a consistent positive relation between bond yield and the Boone indicator in both regimes (columns 1 to 3), while it is negative for the Bank of Japan assets (columns 4 to 6). The impact is statistically significant in almost all regimes, except the high one in column 6. The threshold estimates for bond yield are 1.33% (columns 1 and 3) and 1.685% (column 2). The corresponding time periods when the threshold values were recorded are March 2005 and September 2007. The impact of bond yield on the Boone indicator is more pronounced in the high regimes (0.0655, 0.5397, and 0.042 compared to 0.0149, 0.0113, and 0.009). With the Bank of Japan assets, we also find two threshold values. Reported in columns 4 and 6, it is 121,771,462 mil JPY recorded in March 2001, which marked the start of the first quantitative easing program. In column 5, the threshold estimate is 124,746,234 mil JPY recorded in September 2011. To this end, these results suggest that greater quantitative easing would lead to more intense competition. Besides, the different impacts of quantitative easing on competition between regimes are revealed only when lending rate is used.

Table 11. Dynamic Panel Threshold Analysis for the Competition-Quantitative Easing Nexus (Boone Indicator and other proxies for Quantitative Easing)

	1		2		3		4		5		6	
Threshold variable	Yield		Yield		Yield		BoJ assets		BoJ assets		BoJ assets	
Threshold estimates	1.330%		1.685%		1.330%		121,771,462 mil JPY		124,746,234 mil JPY		121,771,462 mil JPY	
95% confidence interval	[1.33% 1.415%]		[1.33% 1.685%]		[1.33% 1.415%]		[119,777,762 126,958,482]		[118,437,502 126,208,495]		[106,002,035 216,697,081]	
Impact of threshold variables	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.
Low regime	0.0149***	0.0035	0.0113***	0.0030	0.0090***	0.0036	-0.0678***	0.0262	-0.0606***	0.0240	-0.0482*	0.0279
High regime	0.0655***	0.0194	0.5397***	0.1971	0.0420**	0.0201	-0.0233***	0.0047	-0.0213***	0.0068	-0.0070	0.0061
Intercept	-0.2102***	0.0873	-2.1249***	0.7925	-0.1344	0.0908	0.8180*	0.4895	0.7236	0.4703	0.7625	0.5488
Impact of covariates												
BRL ratio	-0.6179	0.5332					-0.5277**	0.2597				
RSL ratio			-0.9872**	0.4582					-0.9149*	0.5102		
lnZ-score					0.0509	0.0749					0.0888	0.0766
Size	0.0000	0.0202	0.0001	0.0163	0.0103	0.0156	-0.0020	0.0166	-0.0005	0.0159	0.0081	0.0147
Capital ratio	0.1163	0.5167	0.4185	0.2912			0.1832	0.3176	0.4294	0.2941		
Asset diversification	-0.0042	0.0707	-0.0017	0.0514	0.0627*	0.0380	-0.0066	0.0425	-0.0157	0.0595	0.0582	0.0408
Liquidity	-0.1293**	0.0574	-0.1257***	0.0518	-0.0876	0.0579	-0.1362***	0.0555	-0.1341**	0.0588	-0.0961	0.0614
Revenue diversification	0.0213	0.0206	0.0177	0.0209	0.0349*	0.0199	0.0193	0.0207	0.0122	0.0215	0.0296*	0.0178
GDP growth	0.1291***	0.0452	0.1521***	0.0428	0.0799*	0.0476	0.0972***	0.0324	0.1322***	0.0423	0.0726*	0.0427
Market capitalisation	-0.0136***	0.0051	-0.0053*	0.0032	-0.0081	0.0062	0.0022	0.0032	0.0014	0.0039	-0.0046	0.0068
Obs in low regime	1824		3246		1824		1409		1520		1409	
Obs in high regime	1667		245		1667		2082		1971		2082	

Notes: This Table reports results from the dynamic panel threshold analysis using the first lag of the endogenous variable (BRL ratio, RSL ratio, or lnZ-score) as its instrument. The threshold variable is the 10-year Japanese government bond yield (Yield) and the Bank of Japan total assets (BoJ assets). BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = (ROA_{it} + Capital\ ratio_{it}) / \sigma ROA_{it}$, size=ln(total assets), capital ratio=equity/assets, asset diversification=securities/assets, liquidity=liquid assets/total assets, revenue diversification=non-interest incomes/operating income, market capitalisation is in natural logarithm. Est.: estimate, S.e.: standard error, Obs: number of observations. ***,**,*: significance at 1%, 5%, 10% levels respectively.

5.5.5. Robustness check with the Lerner index as a competition proxy

We further conduct the dynamic panel threshold analysis, replacing the Boone indicator by the Lerner index to examine the robustness of our findings. The results are reported in Tables A1 to A7 in the Appendices.

For the risk and competition relationship (Table A1), the threshold values are 0.2661 (column 1), 0.2835 (column 2), and 0.4117 (column 3). Unlike the Boone indicator, the Lerner index exhibits a negative relationship with risk-monitored loan ratios (columns 1 and 2). The results show that higher competition would lead to an increase in bankrupt loan ratio in both regimes and restructured loan ratio in the low regime. However, although statistically significant, the economic impact is not very strong. The reason is that in column 1, the parameters are significant at the 10% level in both regimes (-0.0116 and -0.0018), and the magnitude of the impact of the Lerner index in column 2 is quite small (-0.005 for the low regime). The positive relation between the Lerner index and *ln*Z-score in the low regime of column 3 (0.1878) also suggests that competition reduces bank stability. Overall, by using the Lerner index, we find a presence of the *competition-fragility* hypothesis. This is in line with the results reported in column 3 of Table 3. The distributions of the number of observations in each regime are reported in Table A2.

Consistent with findings for the impact of covariates in columns 1 to 3 of Table 3, we find a desirable effect of capitalisation, asset diversification, liquidity, and market capitalisation in reducing risk. Higher GDP growth and lending rate, in contrast, would engage banks in higher credit risk exposure. Therefore, quantitative easing would introduce a stabilising effect on credit risk, but not on bank soundness as we find a positive impact of higher lending rate on *ln*Z-score (column 3, Table A1). The impact of bank size is important for restructured loan ratio and bank stability, while revenue diversification is a significant determinant in all model specifications. However, the influence of revenue diversification on risk variables varies. The more diversified a bank, the higher the risk-monitored loan ratios, but also the higher the bank stability.

In Table A3, we report the results with bond yield and Bank of Japan assets as proxies for quantitative easing. The impact of the Lerner index in each regime and the threshold values across columns 1 to 6 remain similar to those reported in Table A1. Regarding the impact of other control variables, the results also do not vary significantly.

Table A4 shows the results for the relationship between risk and quantitative easing, where the Lerner index is a control variable, and lending rate is the threshold variable. The threshold values of lending rate in columns 1 and 2 are similar to those reported in columns 1 and 2 of Table 6. The impact of lending rate on risk-monitored loan ratios remains positive and significant in both regimes. Some variation is found for bank stability. The threshold of lending rate in column 3 is 0.6929%, positively related to bank stability, and statistically significant in the low regime only (the coefficient is 0.6754). To this end, our previous conclusion of less credit risk and higher bank fragility associated with greater quantitative easing remains unchanged, regardless of competition proxies. When we use bond yield and Bank of Japan assets as the threshold variable (Table A5), this conclusion is upheld, but minor variability exists. For example, compared to column 1 of Table 8, column 1 of Table A5 shows a positive impact of bond yield on bankrupt loan ratio in both regimes. Therefore, if using only the Lerner index, we may miss the different impacts that bond yield could impose on bankrupt loan ratio in different regimes.

Regarding the relationship between competition and quantitative easing, compared to the aforementioned results with the Boone indicator, we find that in the case of the Lerner index capturing competition, the nexus between competition and quantitative easing is clearly negative (columns 1 to 3 of Table A6). It is statistically significant in both regimes with the threshold value identified at 0.692%. It appears that by focusing only on the Lerner index we would have missed the change in the sign of the relationship between competition and quantitative easing between two regimes. Replacing lending rate by bond yield and Bank of Japan assets, the results shown in Table A7 are similar to those reported in Table 11. In more details, the Lerner index is positively related to bond yield and negatively related to Bank of Japan assets. The threshold values are consistent at 1.33% for bond yield and 124,746,234 mil JPY for the Bank of Japan assets. Hence, more aggressive quantitative easing would lead to more intensified competition.

5.5.6. The panel VAR specification

Given some variability in our results, which could be driven by endogeneity issues, we attempt to address the underlying dynamics between risk, competition, and quantitative easing. We adopt the methodology of panel vector autoregression (VAR) to account for the causality relationship as well as the existence of unobservable heterogeneity, specified by an individual specific term. An advantage of the model is assumption-free for the relationship between variables. We treat all three variables in the equation system as endogenous.[57] Risk, taken as bankrupt loan ratio, restructured loan ratio, and *ln*Z-score, is incorporated respectively in the analysis. The Boone indicator and lending rate are proxies for competition and quantitative easing, respectively. We also include bank size as an exogenous control variable because of its importance in the Japanese banking structure. As discussed in the Data section, City Banks are the biggest in size and operate in a wide range of geographic regions, whereas Regional Banks II are

[57] Following Love and Ariss (2014), we run the model on lag order 1 to preserve information.

the smallest. The nature of banking business also varies across three types. Besides, *too-big-to-fail* City banks are at the centre of the *keiretsu* network as well as being the important nodes channelling the impact of quantitative easing.

Following the estimation of panel VAR, we derive the Impulse Response Functions (IRFs) (Fig. 2 to 4), which enable us to interpret the reaction of one variable to a shock in another variable in the system. We also report the Variance Decomposition (VDCs) for forecast horizons of 5 and 10 periods to illustrate the variance of the response variable corresponding to a shock in another variable (Table 12). All model specifications satisfy stability condition.[58]

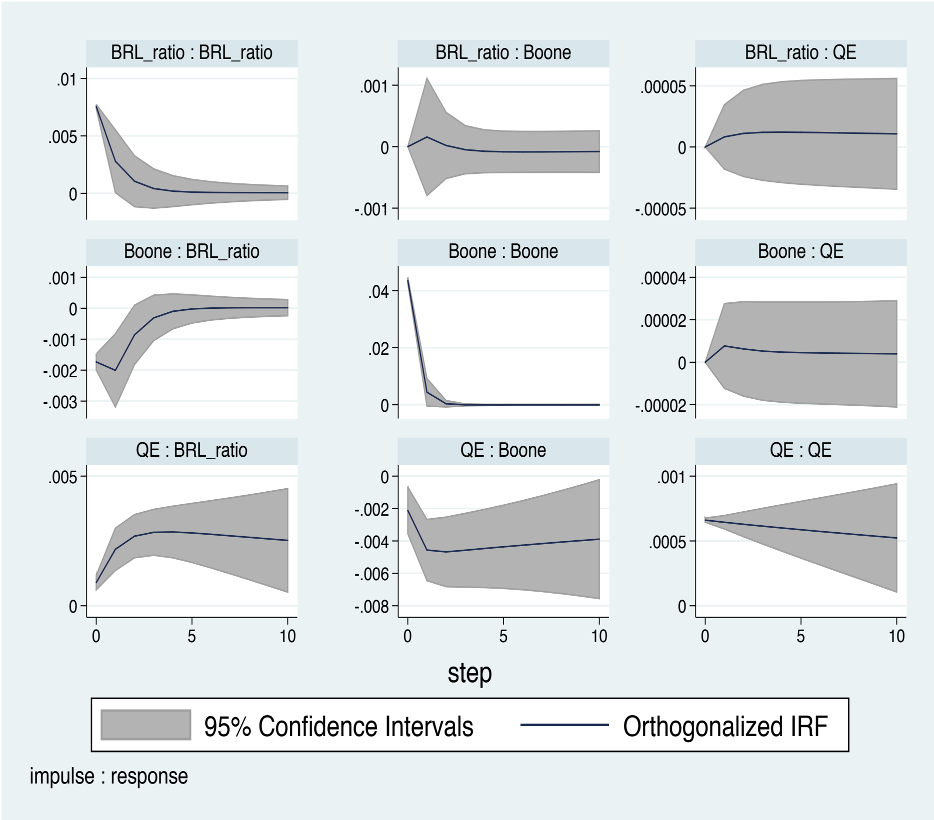
---

[58] The variables enter the equation system as endogenous, with the most exogenous ones appearing first (Love and Zicchino, 2006). Following Love and Zicchino (2006), fixed effects are removed by using the *Helmert procedure* (Arellano and Bover, 1995).

The first order VAR model takes the form: $w_{it} = \mu_i + \Phi w_{it-1} + e_{i,t}\ i = 1,..., N; \quad t = 1,..., T$ where w_{it} is a vector of three random variables: quantitative easing *QE*, Competition *Comp* and risk *R* (bankrupt loan ratio, restructured loan ratio and *ln*Z-score), Φ is a 3x3 matrix of coefficients, μ_i is a vector of *m* individual effects, and $e_{i,t}$ is a multivariate white-noise vector of *m* residuals. The equation system to be estimated with lag order one is:

$$
\begin{aligned}
QE_{it} &= \mu_{10} + a_{11}QE_{it-1} + a_{12}Comp_{it-1} + a_{13}R_{it-1} + e_{1i,t} \\
Comp_{it} &= \mu_{20} + a_{21}QE_{it-1} + a_{22}Comp_{it-1} + a_{23}R_{it-1} + e_{2i,t} \\
R_{it} &= \mu_{30} + a_{31}QE_{it-1} + a_{32}Comp_{it-1} + a_{33}R_{it-1} + e_{3i,t}
\end{aligned}
$$

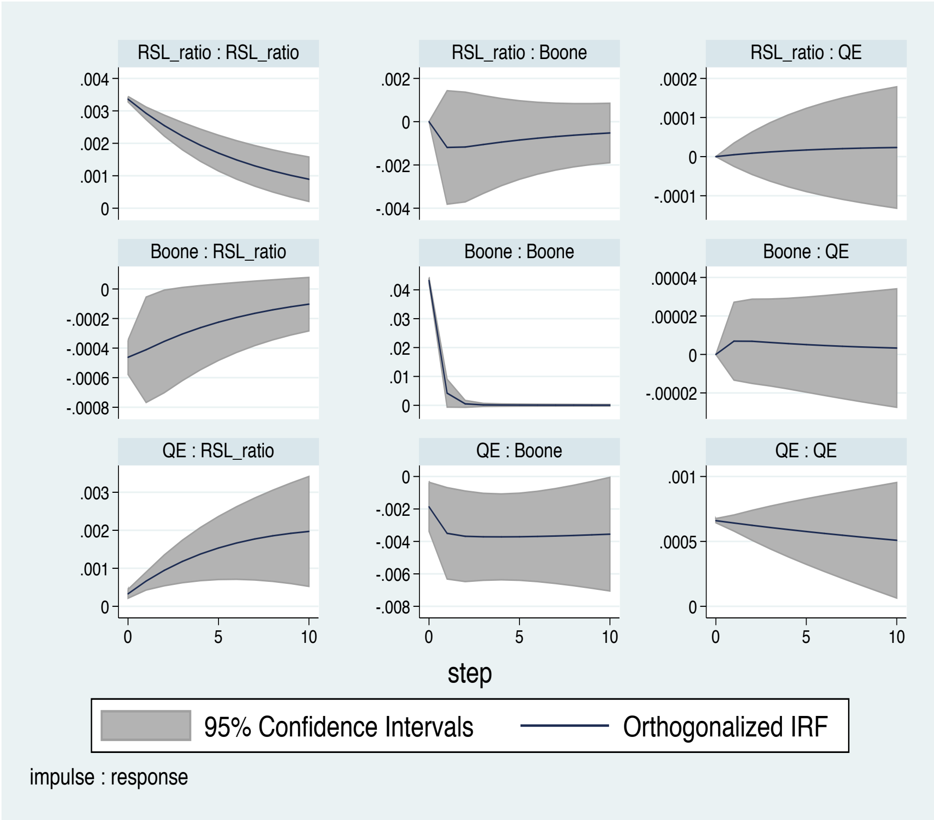
Figure 2. Impulse Response Functions-Bankrupt loan ratio



Notes: This figure illustrates the impulse-response functions (IRFs) of each endogenous variable with respect to shocks in other variables. QE: Quantitative easing represented by bank lending rate; Boone is the Boone indicator of competition; BRL_ratio is bankrupt loan ratio; step: number of periods. Errors are 5% on each side generated by Monte-Carlo simulation.

Regarding the risk-competition nexus, a shock to the Boone indicator has a negative and significant impact on bankrupt loan ratio (Fig.2, second row, first column). This negative relationship is in line with the results reported in Tables 6 and 8. Figure 4 (second row, first column) reveals a positive and significant response of *ln*Z-score to shocks in the Boone indicator. This positive association is similar to findings shown in Tables 3, 5, 6, and 8. Restructured loan ratio, on the other hand, does not show a significant response to shocks in the Boone indicator. In terms of reverse causality, shocks in risk variables generate insignificant responses of the Boone indicator. Two scenarios can be at play to interpret the results. First, a positive shock in the Boone indicator which denotes lower competition will lead to decreased credit risk and increased bank stability. This case gives support to the *competition-fragility* hypothesis. Second, a negative shock in the Boone indicator, referred as higher competition, will cause bankrupt loan ratio to decline and enhance bank stability. This situation is in line with the *competition-stability* hypothesis.

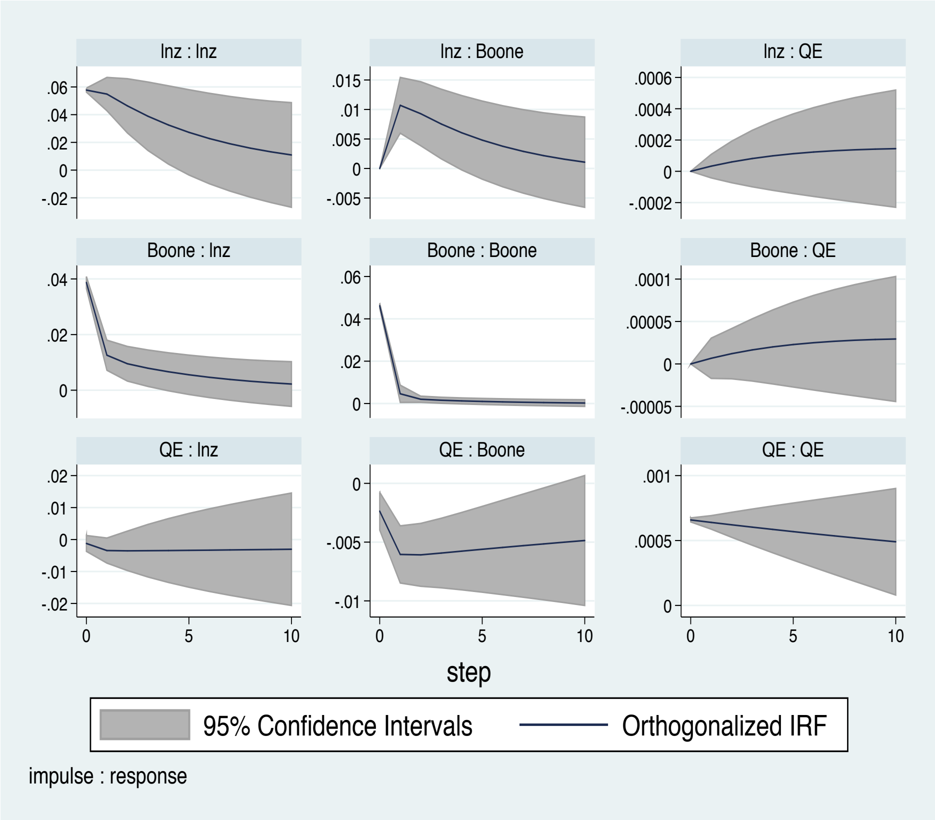
Figure 3. Impulse Response Functions-Restructured loan ratio



Notes: This figure illustrates the impulse-response functions (IRFs) of each endogenous variable with respect to shocks in other variables. QE: Quantitative easing represented by bank lending rates; Boone is the Boone indicator of competition; RSL_ratio is restructured loan ratio; step: number of periods. Errors are 5% on each side generated by Monte-Carlo simulation.

In terms of the risk-quantitative easing nexus, in the short-term, there is a positive and significant response of risk-monitored loan ratios to a one standard deviation shock in lending rate (Fig. 2-3, last row, first column). This positive reaction is similar to the findings shown in Tables 3 and 6. There is no evidence for a significant response of bank stability to a shock in lending rate. The diagrams also reveal insignificant responses of lending rate to shocks in risk variables. Thus, if there exists a positive shock in lending rate, which translates into decreased quantitative easing, credit risk could rise accordingly. Hence, the simulation base of panel VAR could reinforce the claim of lower credit risk as a result of quantitative easing.

Figure 4. Impulse Response Functions-Bank stability



Notes: This figure illustrates the impulse-response functions (IRFs) of each endogenous variable with respect to shocks in other variables. QE: Quantitative easing represented by bank lending rate; Boone is the Boone indicator of competition; lnz is the natural logarithm of Z-score $Z_{it} = (ROA_{it} + Capital\ ratio_{it}) / \sigma ROA_{it}$; step: number of periods. Errors are 5% on each side generated by Monte-Carlo simulation.

Turning to the competition-quantitative easing linkage, diagrams from the IRFs yield consensus findings for the relationship between these two aspects across different proxies for risk. A shock in lending rate would generate a negative response in the Boone indicator, marginally significant in the short-run (Fig. 2-4, last row, second column). Investigating the reverse causality, we observe an insignificant response of lending rate to a shock in the Boone indicator (Fig. 2-4, second row, last column). These findings are in line with the negative association between lending rate and the Boone indicator reported in the high regimes of Table 9. If the shock in lending rate is positive, which represents reduced quantitative easing, competition would increase. Yet, if there is a negative shock in lending rate, quantitative easing would cause higher competition.

Complementing findings of the IRFs, the VDCs show that changes in competition are important in explaining the variation in bankrupt loan ratio (5.66%), restructured loan ratio (1.26%) and *ln*Z-score (12.79%) (Table 12, 10 periods). In contrast, about 0.36% and 12.4% of variations in the Boone indicator are due to innovations from restructured loan ratio and *ln*Z-score, respectively. The variation of bankrupt loan ratio does not explain the variation in competition at all. Findings from the IRFs and VDCs reveal that competition triggers its relationship with risk.

Table 12. Variance Decompositions.

	1				2				3			
Periods	Variables	QE	Boone	BRL ratio	Variables	QE	Boone	RSL ratio	Variables	QE	Boone	lnZ-score
5	QE	0.9997	0.0001	0.0002	QE	0.9997	0.0001	0.0002	QE	0.9888	0.0004	0.0108
5	Boone	0.0438	0.9561	0.0000	Boone	0.0292	0.9683	0.0025	Boone	0.0567	0.8303	0.1130
5	BRL ratio	0.2801	0.0765	0.6434	RSL ratio	0.1168	0.0166	0.8667	lnZ-score	0.0039	0.1429	0.8532
10	QE	0.9996	0.0001	0.0003	QE	0.9992	0.0001	0.0007	QE	0.9686	0.0012	0.0301
10	Boone	0.0835	0.9164	0.0000	Boone	0.0614	0.9350	0.0036	Boone	0.1030	0.7729	0.1240
10	BRL ratio	0.4679	0.0566	0.4756	RSL ratio	0.3089	0.0126	0.6785	lnZ-score	0.0068	0.1279	0.8653

Notes: This Table reports the variance decompositions of the panel vector autoregression model for 5 and 10 periods ahead. There are 3 models, each model has 3 variables: quantitative easing *QE* represented by the lending rate, competition represented by the Boone indicator, and risk. Column 1: risk is bankrupt loan (BRL) ratio, column 2: risk is restructured loan (RSL) ratio, column 3: risk is ln*Z*-score, $Z_{it} = \left(ROA_{it} + Capital\ ratio_{it}\right) / \sigma ROA_{it}$.

Regarding the risk-quantitative easing relationship, about 46.79% of the variation in bankrupt loan ratio is explained by variations in quantitative easing, while only 0.03% of the variation in quantitative easing is explained by shocks in bankrupt loan ratio. Similarly, 30.89% of the variation in restructured loan ratio is due to shocks in quantitative easing, while 0.07% of the variation in quantitative easing is explained by changes in restructured loan ratio. Differently, changes in quantitative easing is not so important in explaining the variation of bank stability. The reason is that while 3.01% of the variation in lending rate is due to innovations in *ln*Z-score, only 0.68% of the variation in *ln*Z-score is attributed to variations in lending rate. To this end, along with results from the IRFs, quantitative easing is found to originate its relationship with risk.

The variation in the Boone indicator indicated by the variation in lending rate is distinguishably larger than the variation in lending rate explained by changes in the Boone indicator (8.35%, 6.14%, 10.3% in comparison to 0.01%, 0.01%, 0.12% in columns 1-3, respectively). Thus, a conclusion of the causality starting from quantitative easing to competition can be drawn.

5.6. Conclusion

Revisiting the risk-competition debate using the dynamic panel threshold analysis, we find evidence to support the *competition-stability* hypothesis in Japanese banking to the extent of credit risk. In more details, competition represented by the bank-level Boone indicator is found to reduce bank risk-taking by diminishing bankrupt and restructured loan ratios. However, this desirable effect may be offset by a decrease in overall bank stability. Similarly, regarding the risk-quantitative easing nexus, a more extensive quantitative easing program would assist banks in lowering their risk-monitored loan ratios. Yet, it could threaten bank solvency. Further exploring the causality relationship between competition, quantitative easing and risk, we find that competition and quantitative easing cause risk in most models.

Our findings indicate that in an environment where quantitative easing is taking place, banks might find it more challenging to compete with their counterparts. To improve their competitiveness, banks could strengthen their competence from other aspects, e.g. capitalisation, liquidity, and asset diversification. Bank executives could enhance banking services by, e.g., diversifying their investments or increasing unconventional business activities to offer more benefits to their customers in time and cost savings. In addition, focusing on relationship banking, improving their flexibility in debt rollover, and operating more efficiently may also be among the tactics bringing banks ahead their rivals. The proposed threshold values for lending rates and the Boone indicator in this study may also be useful for bank managers to construct their risk management policy.

For policymakers, e.g. the Japan Financial Services Agency, relaxing entry and exit for the banking industry, promoting small and medium sized banks, or disentangling business operation restrictions could create a competitive environment which in turn would diminish bank risk-taking. Policymakers could also encourage the mutual assistance prevailing under the *keiretsu* network. Note that a disadvantage of *keiretsu* affiliations is that *main* banks could exert their monopoly power in loan financing. Our analyses show that attempts to discourage competition increase credit risk. Therefore, our results argue that *keiretsu* should be applied with extreme caution.

Last but not least, to take into account the stability of the banking system while enforcing quantitative easing, regulators may revise rules associated with the initial credit screening and barriers in lending principles. In more details, avoiding incorrect evaluations at the beginning of the loan generating process and complying with lending standards help banks lessen the possibilities of future uncertainty. These policies should not contradict with but promote the efficacy of quantitative easing and the *Abenomics* - the current monetary and economic growth policy. Given that the Bank of Japan has adopted negative rates in January 2016 for the first time in its history, Japan would warrant a very interesting platform for future research. If the negative interest rate could drive economic recovery, it would open up a new era for monetary policy.

Appendices – Chapter 5

Table A1. Dynamic Panel Threshold Analysis for the Risk-Competition Nexus (Lerner Index).

	1		2		3	
Dependent variable	BRL ratio		RSL ratio		lnZ-score	
Threshold estimates	0.2661		0.2835		0.4117	
95% confidence interval	[-0.1724 0.3027]		[0.2728 0.3433]		[0.3997 0.4164]	
Impact of threshold variables	Est.	S.e.	Est.	S.e.	Est.	S.e.
Low regime	-0.0116*	0.0061	-0.0050***	0.0016	0.1878***	0.0354
High regime	-0.0018*	0.0010	-0.0005	0.0006	-0.0091	0.0059
Intercept	0.0047***	0.0009	0.0023***	0.0004	-0.1046***	0.0180
Impact of covariates						
Lending rate	0.0390***	0.0031	0.0347***	0.0017	0.2387***	0.0340
Size	-0.0007	0.0038	0.0094***	0.0026	0.0762***	0.0302
Capital ratio	-0.6053***	0.1046	-0.0997***	0.0393		
Asset diversification	-0.0443***	0.0104	-0.0161***	0.0047	0.0214	0.1316
Liquidity	-0.0345***	0.0104	-0.0045	0.0063	-0.0279	0.1979
Revenue diversification	0.0216***	0.0053	0.0142***	0.0029	0.1527***	0.0576
GDP growth	0.0640***	0.0072	0.0438***	0.0047	0.0674	0.0910
Market capitalisation	-0.0013*	0.0008	0.0003	0.0005	0.0131	0.0117
Obs in low regime	1160		1392		3134	
Obs in high regime	2331		2099		357	

Notes: This Table reports the results from the dynamic panel threshold analysis using the first lag of the endogenous variable (lending rate) as its instrument. The threshold variable is the Lerner index. BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = \left(ROA_{it} + Capital\ ratio_{it}\right) / \sigma ROA_{it}$, lending rate=interest income on loans/loans and bills discounted, size=ln(total assets), capital ratio=equity/assets, asset diversification=securities/assets, liquidity=liquid assets/total assets, revenue diversification=non-interest incomes/operating income, market capitalisation is in natural logarithm. Est.: estimate, S.e.: standard error, Obs: number of observations. ***,**,*: significance at 1%, 5%, 10% levels respectively.

Table A2. Number of Observations in Each Regime for the Risk-Competition Nexus (Lerner index).

	1		2		3	
	BRL ratio		RSL ratio		Z-score	
	0.2661		0.2835		0.4117	
Time	Low	High	Low	High	Low	High
Sep-00	68	60	89	39	128	0
Mar-01	85	40	97	28	123	2
Sep-01	95	33	105	23	127	1
Mar-02	99	26	107	18	124	1
Sep-02	69	58	81	46	125	2
Mar-03	88	33	102	19	119	2
Sep-03	42	79	53	68	116	5
Mar-04	37	83	50	70	115	5
Sep-04	25	95	32	88	107	13
Mar-05	27	92	34	85	101	18
Sep-05	14	105	18	101	104	15
Mar-06	14	103	23	94	90	27
Sep-06	15	102	17	100	101	16
Mar-07	25	91	28	88	98	18
Sep-07	22	93	29	86	107	8
Mar-08	48	66	60	54	110	4
Sep-08	84	31	90	25	115	0
Mar-09	100	14	105	9	114	0
Sep-09	47	67	56	58	111	3
Mar-10	39	73	50	62	110	2
Sep-10	16	95	20	91	104	7
Mar-11	30	81	43	68	109	2
Sep-11	13	98	17	94	94	17
Mar-12	18	93	25	86	98	13
Sep-12	19	91	26	84	98	12
Mar-13	11	99	22	88	86	24
Sep-13	3	107	6	104	72	38
Mar-14	2	108	2	108	86	24
Sep-14	0	110	0	110	69	41
Mar-15	5	105	5	105	73	37
Obs	1160	2331	1392	2099	3134	357

Notes: This Table reports the number of observations in each regime over time for the risk-competition nexus. The Lerner index is the proxy for competition, while lending rate is the proxy for quantitative easing. Threshold values are obtained from the dynamic panel threshold analysis, reported in Table A1. BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = \left(ROA_{it} + Capital\ ratio_{it}\right) / \sigma ROA_{it}$. The second row shows the threshold values, the third row shows the dependent variables used in each model specification, the fourth row indicates low and high regimes, Mar: March, Sep: September, 00-15: 2000-2015, Obs: number of observations.

Table A3. Dynamic Panel Threshold Analysis for the Risk-Competition Nexus (Lerner index and other proxies for Quantitative Easing).

	1		2		3		4		5		6	
Dependent variable	BRL ratio		BRL ratio		RSL ratio		RSL ratio		lnZ-score		lnZ-score	
Threshold estimates	0.2661		0.2661		0.2835		0.2835		0.4117		0.4117	
95% confidence interval	[-0.1724 0.3003]		[-0.1724 0.3039]		[0.2728 0.3433]		[0.2707 0.3436]		[0.3997 0.4164]		[0.3997 0.4163]	
Impact of threshold variables	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.
Low regime	-0.0115*	0.0060	-0.0115*	0.0060	-0.005***	0.0016	-0.005***	0.0015	0.1878***	0.0358	0.1879***	0.0362
High regime	-0.0016*	0.0009	-0.0017*	0.0009	-0.0004	0.0005	-0.0005	0.0006	-0.0074	0.0078	-0.0082	0.0077
Intercept	0.0048***	0.0009	0.0046***	0.0009	0.0024***	0.0004	0.0023***	0.0005	-0.1032***	0.0203	-0.1042***	0.0211
Impact of covariates												
Yield	0.0143***	0.0012			0.0128***	0.0007			0.0867***	0.0138		
BoJ assets			-0.0258***	0.0021			-0.0230***	0.0013			-0.1552***	0.0252
Size	-0.0034	0.0038	-0.0039	0.0038	0.0070***	0.0027	0.0066***	0.0028	0.0598*	0.0307	0.0566*	0.0307
Capital ratio	-0.5839***	0.1027	-0.5769***	0.1034	-0.0806**	0.0380	-0.0744**	0.0375				
Asset diversification	-0.0562***	0.0104	-0.0535***	0.0108	-0.0267***	0.0052	-0.0243***	0.0058	-0.0487	0.1275	-0.0313	0.1313
Liquidity	-0.0061	0.0116	0.0134	0.0123	0.0208***	0.0068	0.0383***	0.0074	0.1540	0.2300	0.2732	0.2487
Revenue diversification	-0.0011	0.0051	0.0016	0.0054	-0.0059*	0.0031	-0.0035	0.0036	0.0156	0.0509	0.0318	0.0530
GDP growth	0.0694***	0.0080	0.0454***	0.0079	0.0486***	0.0058	0.0271***	0.0057	0.0963	0.0913	-0.0484	0.1066
Market capitalisation	-0.0055***	0.0008	0.0027***	0.0010	-0.0034***	0.0006	0.0038***	0.0006	-0.0120	0.0156	0.0375***	0.0101
Obs in low regime	1160		1160		1392		1392		3134		3134	
Obs in high regime	2331		2331		2099		2099		357		357	

Notes: This Table reports the results from the dynamic panel threshold analysis using the first lag of the endogenous variable (10-year Japanese government bond yield and the natural logarithm of the Bank of Japan Total assets) as its instrument. The threshold variable is the Lerner index. BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = \left(ROA_{it} + Capital\ ratio_{it}\right) / \sigma ROA_{it}$, size=ln(total assets), capital ratio=equity/assets, asset diversification=securities/assets, liquidity=liquid assets/total assets, revenue diversification=non-interest incomes/operating income, market capitalisation is in natural logarithm. Est.: estimate, S.e.: standard error, Obs: number of observations. ***,**,*: significance at 1%, 5%, 10% levels respectively.

Table A4. Dynamic Panel Threshold Analysis for the Risk-Quantitative Easing Nexus (lending rate and Lerner index).

	1		2		3	
Dependent variable	BRL ratio		RSL ratio		lnZ-score	
Threshold estimates	1.2052%		1.0554%		0.6929%	
95% confidence interval	[1.1976% 1.2102%]		[0.9847% 1.1212%]		[0.6922% 0.7089%]	
Impact of threshold variables	Est.	S.e.	Est.	S.e.	Est.	S.e.
Low regime	0.0249***	0.0024	0.0145***	0.0015	0.6754***	0.2843
High regime	0.0540***	0.0085	0.0490***	0.0033	0.0083	0.0498
Intercept	-0.1340***	0.0378	-0.1575***	0.0153	3.3572***	1.3170
Impact of covariates						
Lerner	-0.0054	0.0045	-0.001	0.0015	0.2069***	0.0306
Size	-0.0045	0.0028	0.0036*	0.0021	-0.0160	0.0357
Capital ratio	-0.6234***	0.0999	-0.1048***	0.0425		
Asset diversification	-0.0566***	0.0102	-0.0285***	0.0058	-0.1910	0.1678
Liquidity	-0.0430***	0.0109	-0.0125*	0.0067	0.0612	0.2138
Revenue diversification	0.0178*	0.0091	0.0020	0.0035	-0.2582***	0.0726
GDP growth	0.0427***	0.0078	0.0282***	0.0043	-0.0771	0.0723
Market capitalisation	-0.0023***	0.0009	-0.0005	0.0005	0.0288***	0.0117
Obs in low regime	2352		1784		179	
Obs in high regime	959		1707		3312	

Notes: This Table reports the results from the dynamic panel threshold analysis using the first lag of the endogenous variable (Lerner index) as its instrument. The threshold variable is lending rate. BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = \left(ROA_{it} + Capital\ ratio_{it}\right) / \sigma ROA_{it}$, lending rate=interest income on loans/loans and bills discounted, size=ln(total assets), capital ratio=equity/assets, asset diversification=securities/assets, liquidity=liquid assets/total assets, revenue diversification=non-interest incomes/operating income, market capitalisation is in natural logarithm. Est.: estimate, S.e.: standard error, Obs: number of observations. ***,**,*: significance at 1%, 5%, 10% levels respectively.

Table A5. Dynamic Panel Threshold Analysis for the Risk-Quantitative Easing Nexus (10-year Japanese government bond yield, Bank of Japan assets, and Lerner index)

	1		2		3		4		5		6	
Dependent variable	BRL ratio		RSL ratio		lnZ-score		BRL ratio		RSL ratio		lnZ-score	
Threshold variable	Yield		Yield		Yield		BOJ assets		BOJ assets		BOJ assets	
Threshold estimates	0.709%		1.032%		1.484%		118,437,502 mil JPY		118,437,502 mil JPY		118,437,502 mil JPY	
95% confidence interval	[0.709% 1.032%]		[0.709% 1.032%]		[1.484% 1.484%]		[118,437,502 118,437,502]		[118,437,502 118,437,502]		[113,693,826 118,437,502]	
Impact of threshold variables	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.
Low regime	0.0081***	0.0015	-0.0117***	0.0009	-0.0072	0.0117	-0.0450***	0.0083	-0.0339***	0.0043	-0.0204	0.0943
High regime	0.0238***	0.0020	0.0169***	0.0023	0.4954***	0.1927	-0.0169***	0.0014	-0.0097***	0.0008	0.0245	0.0197
Intercept	-0.0651***	0.0121	-0.1359***	0.0131	-2.0014***	0.8190	0.5089***	0.1540	0.4399***	0.0795	0.8089	2.0389
Impact of covariates												
Lerner	-0.0053	0.0047	0.0020	0.0014	0.191***	0.0512	-0.0054	0.0047	0.0008	0.0015	0.1869***	0.0503
Size	-0.0107***	0.0033	-0.0039*	0.0022	-0.0573**	0.0282	-0.0139***	0.0029	-0.0053***	0.0020	-0.0523*	0.0269
Capital ratio	-0.5889***	0.0995	-0.0814*	0.0448			-0.5913***	0.0949	-0.0817*	0.0437		
Asset diversification	-0.0795***	0.0105	-0.0530***	0.0054	-0.1529	0.1694	-0.0917***	0.0105	-0.0623***	0.0052	-0.1914	0.1622
Liquidity	-0.0291***	0.0118	-0.0041	0.0071	0.0405	0.2623	-0.0507***	0.0123	-0.0221***	0.0072	-0.0286	0.2642
Revenue diversification	-0.0019	0.0110	-0.0205***	0.0041	-0.4013***	0.0939	-0.0032	0.0110	-0.0189***	0.0039	-0.4069***	0.0902
GDP growth	0.0694***	0.0075	0.0653***	0.0058	-0.0925	0.1230	-0.0156**	0.0072	-0.0218***	0.0040	-0.1059	0.1288
Market capitalisation	-0.0127***	0.0014	-0.0108***	0.0010	0.0766***	0.0119	0.0054***	0.0011	0.0051***	0.0006	0.0369***	0.0084
Obs in low regime	671		1114		2898		1156		1156		1156	
Obs in high regime	2820		2377		593		2335		2335		2335	

Notes: This Table reports the results from the dynamic panel threshold analysis using the first lag of the endogenous variable (Lerner index) as its instrument. The threshold variable is the 10-year Japanese government bond yield and Bank of Japan (BOJ) assets. BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = \left(ROA_{it} + Capital\ ratio_{it}\right) / \sigma ROA_{it}$, size=ln(total assets), capital ratio=equity/assets, asset diversification=securities/assets, liquidity=liquid assets/total assets, revenue diversification=non-interest incomes/operating income, market capitalisation is in natural logarithm. Est.: estimate, S.e.: standard error, Obs: number of observations. ***,**,*: significance at 1%, 5%, 10% levels respectively.

Table A6. Dynamic Panel Threshold Analysis for the Competition-Quantitative Easing Nexus (Lerner index and lending rate).

	1		2		3	
Dependent variable	Lerner		Lerner		Lerner	
Threshold variable	Lending rate		Lending rate		Lending rate	
Threshold estimates	0.6925%		0.6925%		0.6922%	
95% confidence interval	[0.6925% 0.6931%]		[0.6925% 0.6931%]		[0.6922% 0.7028%]	
Impact of threshold variables	Est.	S.e.	Est.	S.e.	Est.	S.e.
Low regime	-0.3378***	0.1323	-0.3415***	0.1325	-0.3098**	0.1396
High regime	-0.0467*	0.0243	-0.0268	0.0182	-0.0725***	0.0223
Intercept	-1.4765**	0.6572	-1.5923***	0.6568	-1.2034*	0.6585
Impact of covariates						
BRL ratio	-0.2179	0.6517				
RSL ratio			-0.9287*	0.5479		
lnZ-score					0.2983***	0.1172
Size	-0.0209	0.0179	-0.0159	0.0149	-0.0136	0.0178
Capital ratio	0.5714	0.5851	0.6140*	0.3399		
Asset diversification	0.0786	0.0629	0.0659	0.0447	0.1044*	0.0517
Liquidity	-0.0787	0.0642	-0.0767	0.0546	-0.0290	0.0614
Revenue diversification	0.1871***	0.0339	0.1831***	0.0336	0.1747***	0.0470
GDP growth	0.3219***	0.0667	0.3421***	0.0619	0.2116***	0.0663
Market capitalisation	0.0195***	0.0046	0.0196***	0.0038	0.0078	0.0056
Obs in low regime	177		177		176	
Obs in high regime	3314		3314		3315	

Notes: This Table reports the results from the dynamic panel threshold analysis using the first lag of the endogenous variable (BRL ratio, RSL ratio, or lnZ-score) as its instrument. The threshold variable is the bank specific lending rate. BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = (ROA_{it} + Capital\ ratio_{it}) / \sigma ROA_{it}$, lending rate=interest income on loans/loans and bills discounted, size=ln(total assets), capital ratio=equity/assets, asset diversification=securities/assets, liquidity=liquid assets/total assets, revenue diversification=non-interest incomes/operating income, market capitalisation is in natural logarithm. Est.: estimate, S.e.: standard error, Obs: number of observations. ***,**,*: significance at 1%, 5%, 10% levels respectively.

Table A7. Dynamic Panel Threshold Analysis for the Competition-Quantitative Easing Nexus (Lerner index and other proxies for Quantitative Easing)

	1		2		3		4		5		6	
Threshold variable	Yield		Yield		Yield		BoJ assets		BoJ assets		BoJ assets	
Threshold estimates	1.330%		1.330%		1.330%		124,746,234 mil JPY		124,746,234 mil JPY		124,746,234 mil JPY	
95% confidence interval	[1.33% 1.685%]		[1.26% 1.33%]		[1.26% 1.33%]		[118,437,502 124,746,234]		[119,777,762 124,746,234]		[109,020,450 144,384,522]	
Impact of threshold variables	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.	Est.	S.e.
Low regime	0.0131**	0.0059	0.0132***	0.0053	0.0104*	0.0053	-0.0741***	0.0244	-0.0713***	0.0246	-0.0560*	0.0288
High regime	0.0553***	0.0205	0.0525***	0.0205	0.0333	0.0234	-0.0207***	0.0082	-0.0112	0.0082	-0.0079	0.0075
Intercept	-0.1695*	0.0980	-0.1558	0.0974	-0.0866	0.1092	0.9781**	0.4859	1.1064**	0.5179	0.8833	0.5902
Impact of covariates												
BRL ratio	-0.6423	0.4896					-0.6768	0.4967				
RSL ratio			-0.0093*	0.0049					-0.0056	0.0052		
lnZ-score					0.0169	0.0889					0.0326	0.0928
Size	0.0030	0.0197	-0.0045	0.0192	0.0177	0.0163	0.0033	0.0194	0.0009	0.0187	0.0183	0.0156
Capital ratio	0.2466	0.4829	0.6435*	0.3352			0.2345	0.4831	0.6488*	0.3331		
Asset diversification	0.0816	0.0697	0.0747	0.0478	0.162***	0.0600	0.0672	0.0765	0.0898*	0.0525	0.1529***	0.0600
Liquidity	-0.0935	0.0659	-0.0722	0.0667	-0.0333	0.0828	-0.1229*	0.0730	-0.1027	0.0683	-0.0608	0.0850
Revenue diversification	0.2953***	0.0993	0.2857***	0.1036	0.3168***	0.0884	0.2904***	0.0999	0.2896***	0.1053	0.3112***	0.0891
GDP growth	0.3204***	0.0570	0.3059***	0.0564	0.2823***	0.0631	0.3590***	0.0591	0.3521***	0.0574	0.3281***	0.0703
Market capitalisation	0.0101*	0.0056	0.0178***	0.0057	0.0166***	0.0071	0.0171***	0.0047	0.0185**	0.0083	0.0149*	0.0090
Obs in low regime	1824		1824		1824		1520		1520		1520	
Obs in high regime	1667		1667		1667		1971		1971		1971	

Notes: This Table reports the results from the dynamic threshold analysis using the first lag of the endogenous variable (BRL and RSL ratio, or lnZ-score) as its instrument. The threshold variable is the 10-year Japanese government bond yield (Yield) and the Bank of Japan total assets (BoJ assets). BRL ratio: bankrupt loans to assets, RSL ratio: restructured loans to assets, Z-score $Z_{it} = (ROA_{it} + Capital\ ratio_{it}) / \sigma ROA_{it}$, size=ln(total assets), capital ratio=equity/assets, asset diversification=securities/assets, liquidity=liquid assets/total assets, revenue diversification=non-interest incomes/operating income, market capitalisation is in natural logarithm. Est.: estimate, S.e.: standard error, Obs: number of observations. ***,**,*: significance at 1%, 5%, 10% levels respectively.

Chapter 6. Conclusion

Focusing on the Japanese banking sector, this thesis examines bank competition, efficiency, and productivity in a relation with problem loans and quantitative easing policy. Japan is a unique case due to the notorious nonperforming loan problem, which put the banking system at risk in the 1990s-2000s. Besides, hesitant government responses magnified the adverse effect of nonperforming loans, threatening overall financial stability. During the course of reform, various facilitating measures have been recorded. However, Japan is a contradictory story as variability in the impact of these government assistance programmes has been recorded.

Based on a data set of problem loans which, to the best of our knowledge, has not been used in Japanese banking research, we are able to incorporate a straightforward measure of bank risk in our study. These loans are disaggregated into bankrupt and restructured loans, providing informative proxies for different problem loans' characteristics. The methodologies employed are recent, parametric, and modified to account for the impact of problem loans. Where appropriate, we also control for quantitative easing policy. During our sample period September 2000 – March 2015, this monetary easing tool was activated twice, and has been ongoing. It is of interest to observe its impact at the microeconomic level, in particular, on bank performance, competition, and risk.

Chapter three investigates the impact of bankrupt and restructured loans on bank efficiency. This chapter contributes to the existing literature in bank efficiency through the use of a translog enhanced hyperbolic distance function, which takes into account the impact of undesirable outputs, introduced by Cuesta et al. (2009). The data set regarding problem loans and problem other earning assets, our two undesirable outputs, has not been used in previous studies. We find an average technical efficiency of 61.2% for Japanese commercial banks during financial years 2000-2012. Regional Banks II are reported to be more efficient than City Banks and Regional Banks I. As expected, problem loans impose a statistically significant negative impact on efficiency. Based on the mean value of efficiency, there is room for improvement. Banks could expand their desirable outputs by 63.4%, whilst simultaneously contracting undesirable outputs and inputs by 38.8%. We further investigate the effect of bankrupt and restructured loans on bank efficiency in the second stage analysis, using fixed effect and two-stage least squares models. Among other covariates are bank competition and quantitative easing policy. The results denote a positive relationship between risk-monitored loans and efficiency. Competition, indicated by the Herfindahl-Hirschman index and the Boone indicator, affects efficiency under the *competition-efficiency* hypothesis. In details, heightened competition would stimulate banks to minimise costs and maximise outputs (Andrieş and Căpraru, 2014; Schaeck and Cihák, 2008). More aggressive quantitative easing policy appears to undermine efficiency. The analysis proceeds with the panel VAR estimation for an equation system of four variables, namely technical efficiency, net interest margin, quantitative easing, and risk-monitored loans. The aim is to explore the causality relationship between the variables of interest, taking into account the potential endogeneity issue. We find a positive response of technical efficiency to a shock in bankrupt loans, in line with the "moral hazard" and "skimping" hypotheses, with the causality originating from bankrupt loans to efficiency. Differently, the relationship between restructured loans and efficiency gives support to the "bad luck" hypothesis. Shocks in quantitative easing policy result in a reduction in technical efficiency in the short-run, but with a small magnitude. The shocks in net interest margin does not significantly explain the variation in efficiency.

This chapter provides a reference point for the potential expansion of good outputs and shrinkage of bad outputs and inputs. Alongside reducing problem loans, to improve efficiency, Japanese banks could also diversify their loan and investment portfolios to achieve the optimal desirable output mix. Investing in technology innovation would also be among strategic policies as banks could expand their market share, consequently raising good outputs. It is worth noting that caution is needed as there is a potential of high risk-taking associated with best performing banks. High efficiency may be realised in the short-run due to bank managers skipping some management practices, thus resulting in less input usage. Our analysis brings to the attention of regulators and supervisors the signals of financial instability. Best and worst performing banks could be a latent threat to the system. While highly efficient banks may be attempting more risk, weak performers may be dealing with a rise in external uncertainties. Regulations regarding the level of risk-taking in commercial banks as well as their loan issuance process would help lessen bank default risk. Effective and timely government response to negative externalities could also maintain financial stability and improve bank performance.

Chapter four measures the effect of bankrupt and restructured loans on bank productivity and investigates the banking integration process in terms of productivity growth. We use the parametric cost function to compute and decompose total factor productivity growth into the effects of undesirable outputs, quasi-fixed input, the scale effect, and technological change. Undesirable outputs are characterised by bankrupt and restructured loans, while equity is a quasi-fixed input proxy. For financial years 2000-

2014, average productivity growth is reported at 1.52% semi-annually. The trend of productivity growth over time appears to follow the timeline of government intervention and unexpected events such as the global financial crisis and the Tohoku earthquake. Indeed, during the restructuring period (2001-2003) and the US subprime crisis 2007-2008, Japanese banks experienced a fall in their productivity growth due to a drop in the scale effect and the negative impact of risk-monitored loans. We find a detrimental impact of bankrupt loans on total factor productivity growth on average. Restructured loans, in contrast, appear beneficial in the sense of reducing costs as a result of legislation changes. Equity also contributed to productivity growth, although with a small magnitude. Overall, a significant component of productivity growth was attributed to technical progress, apart from the scale effect.

It is of interest to observe whether there exists a banking integration process in Japan as after all, the banking sector has recovered from the asset bubble burst. To the best of our knowledge, this chapter is the first application of the Phillips and Sul (2007) convergence test on bank-level productivity growth. We also test for the convergence in productivity growth between and within geographic regions in Japan. The results show a lack of convergence in TFP growth of Japanese banking, as well as in the components of TFP growth at the whole panel level. This might not come as a surprise as the Japanese banking industry underwent several acute phases of financial crises, coupled at times with natural disasters. On the other hand, over the examined period of 15 years, there were several policy interventions attempting to support the banking industry. For instance, in 2008, the Bank of Japan proposed that Regional Banks would be responsible for channelling credits to SMEs. Furthermore, virtually zero interest rate policy remains an important monetary policy tool, which has been enforced for a long period (March 2001-March 2006 and since October 2012). During the course of reform, some policies were not planned efficiently as banks rescued by public capital carried on funding unprofitable firms. However, there exists evidence showing that some legislation changes have been effective, indicated by the cost-reducing impact of restructured loans.

The presented results have important policy implications. Productivity growth of the banking system would be a significant contributor to economic growth which has not been going as planned. In light of the quantitative and qualitative easing policy, bank lending is expected to rise following credit expansion to households and businesses. If bank total factor productivity growth were positive and increasing, it could be a sign for the effectiveness of this unconventional monetary policy. As there is evidence for a divergence in bank productivity growth in some regions, policymakers could take into account the differences between regions to apply appropriate policies. Additionally, enhanced supervision would be encouraged so that the escalating quantitative easing would not lead to excessive risk-taking.

The research topics in the fifth chapter relate to bank competition, risk and quantitative easing in Japan. Like in the other two main chapters, bankrupt and restructured loans are also at the centre of this study. They are the proxies for risk in the analysis for the relationship between the variables of interest. Given the extensive quantitative easing in Japan to stimulate growth, we revisit the linkage between competition and risk within this context. The hypotheses tested are *competition-stability*, *competition-fragility*, and quantitative easing-risk. To measure competition, we apply a local regression technique to obtain bank-level Boone indicator. The Boone indicator takes into account different forces which can cause an increase in competition, for example, an increase in the number of banks in the market, the lift in entry barriers, and more aggressive interaction between banks. For the main analysis, we apply the dynamic panel threshold model and panel Vector Autoregression approach to take into account the potential endogeneity. An objective is to obtain a threshold of bank competition which could identify the relationship between competition and risk in different regimes. Similarly, the model yields threshold values of quantitative easing which may signify different effects of quantitative easing on risk in different regimes. The main findings reveal that quantitative easing and competition reduce bankrupt and restructured loan ratios, but also bank stability. Regarding the causality, the results suggest that quantitative easing initiates its causal relationship with risk and competition. Between competition and risk, the former triggers its relationship with the latter.

The proposed threshold values for lending rates and the Boone indicator may be useful for bank managers to construct their risk management policy. Policymakers could also encourage the mutual assistance prevailing under the *keiretsu* network. However, the possibility of banks exerting their monopoly power by imposing higher lending rates could not be ruled out. As our findings are in favour of competition, relationship banking under *keiretsu* should be closely monitored. Policy recommendations include those which encourage competition, such as deregulation and technological advances. Notwithstanding, in an environment of low interest rates and quantitative easing, proper credit screening and lending standard compliance should remain one of the important supervisory issues.

In terms of the generalisability of our findings, it is worth mentioning their applicability in the Eurozone institutional setting. Although the structures of the banking systems in the Eurozone and Japan are different, there are some insightful implications to be drawn from our results, especially as the European Central Bank also implements quantitative easing policy, and European banks also suffered from the global financial crisis and the sovereign debt crisis. We have learned from the Japanese case that nonperforming loans are detrimental to bank performance, and that encouraging competition could reduce the nonperforming loan ratio. Besides, quantitative easing is useful to the extent of lessening credit risk. For countries with nonperforming loans (e.g. Cyprus, Greece, Slovenia, Portugal, Italy, Ireland), the national central banks should be the initiators to propose restructuring. They are the experts who have specific, detailed and privileged knowledge about the current financial situation of the banking systems, hence would be able to develop appropriate regulations or structural changes to regain or safeguard financial stability. As indicated in the European Banking Authority report on nonperforming loans (2016), policy options to ease the nonperforming loan issue are under consideration. Among them are: i) the call to enhance the quality, accuracy, and completeness of data (e.g. asset quality, the state of nonperforming loans, or collateral valuation); ii) improvements in the judicial system (e.g. timeliness of the procedure, accounting and tax regimes); and iii) a functioning secondary market facilitating the disposal of nonperforming loans.[59] Based on our research of Japan, the first area would be the key factor in addressing the problem, as policy makers would then be able to anticipate and identify the areas of risk to respond timely. This in turn strengthens the coordination between national regulators and the European Central Bank in the Single Supervisory Mechanism. The ongoing quantitative easing (extended until the end of 2017) and emergency liquidity assistance from the European Central Bank could also be effective. However, caution is needed to prevent unwanted moral hazard problem and anticompetitive behaviour.

[59] EBA report on the dynamics and drivers of non-performing exposures in the EU banking sector (22/7/2016), available from: https://www.eba.europa.eu/-/eba-provides-updates-on-npls-in-eu-banking-sector.

Limitations and directions for future research

This thesis applies the parametric approach to measure efficiency and productivity growth. In more detail, in chapter 3, we use a stochastic frontier approach to compute efficiency scores. This approach has been widely employed for European banking industries where the banking structure is different from the Japanese case (except Germany). When frontier analyses are applied to the Japanese framework, the existence of the *keiretsu* and relationship banking may result in heterogeneous production technologies. However, this issue is of less significance in our study as only commercial banks are included in our sample. Note although that Japanese banks studied herein vary in terms of size, business structure, and geographical constraints, they also share some common characteristics. For example, City Banks also offer relationship banking to their clients as in the case of Regional Banks. Nevertheless, this issue should be taken into consideration, especially when the whole banking system is examined. One potential solution is to investigate and compare bank efficiency within subsamples. Another method could be running different frontiers for subsamples simultaneously so as to achieve comparable results for the entire sample.

Moreover, another limitation of the parametric approach is that assumptions needed for the specification of the underlying function and the distribution of inefficiency. The methodology used in chapter four to compute total factor productivity growth is also parametric, thus inheriting this limitation. In this regard, the nonparametric approach has some appealing features, i.e. no such assumptions needed. Hence, it would be of interest for other studies on Japanese banking to apply a nonparametric methodology to compute efficiency and productivity with an incorporation of problem loans. Besides, to estimate productivity growth, we run the parametric cost function using the fixed effect regression rather than the frontier analysis. This enables us to overcome the aforementioned issue of frontier approaches. However, it may be criticised for not taking into account the impact of efficiency change in productivity growth. The use of stochastic frontier approaches can generate the efficiency change component. In that case, the decomposition of total factor productivity growth will have to be modified, as it will not explicitly show the impact of bankrupt and restructured loans. Nonperforming loans are among the key factors to be accounted for when one studies the performance of Japanese banks. We argue that, as they are the focus of our research in Japan, we construct the model to account directly for their effect and estimate a system of equations to yield quantitative results for their impact. Future research could estimate productivity growth using approaches that contain the efficiency change component and compare the overall total factor productivity growth obtained from different methods.

With regard to the panel VAR analysis used in chapters three and five, I opt to include additional variables in the system. For example, on the basis of quantitative easing in Japan, inflation and output could also be of interest as they are among the target variables of the implementation of quantitative easing. However, adding too many variables creates complications, especially if extra lag orders are also considered. Therefore, the choice of the number of variables of interest in a panel VAR framework should be carefully considered to allow for high degrees of freedom.

Beside the techniques used, the sample period is different in chapter three and the rest due to updated data made available at the later stage of this PhD study. We also sought to quote policy announcements, banking regulations, and the Bank of Japan's support measures. However, some of the policy documents are available in Japanese only.

Therefore, a few citations are taken from speeches and conference papers because of language barriers.

In light of the ongoing *Abenomics* and negative interest rate policy enacted in January 2016 for the first time in Japan's history, Japan would warrant a very interesting platform for future research. Arguably, prolonged negative interest rates may do more harm than good. Now that depositors are charged for keeping their money at the bank, they may hoard cash or buy gold instead. The problem with the economic slump in Japan is not that banks are not willing to lend, but perhaps the lack of borrowers as the public probably do not perceive that investment opportunities exist. If the negative interest rate could drive economic recovery, it would open up a new era for monetary policy. At the microeconomic level, future research could observe bank productivity gain to investigate the efficacy of this central banking policy. The ongoing quantitative and qualitative easing program, together with negative interest rates, would provide a great research laboratory. Other central banks could obtain some practical lessons from the Japanese experience. It could also be of great potential for studies which aim to compare the impact of unconventional monetary policy in Japan and the US, UK, and Europe. How these policies apply in different institutional settings would be intriguing.

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