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The Impact of Japanese Monetary Policy Crisis Management on the Japanese Banking Sector

Abstract

The paper analyses the impact of Japanese monetary policy crisis management on the Japanese banking sector since the 1998 Japanese financial crisis. It shows how low-cost liquidity provision as a means to stabilize banks has created a growing gap between deposits above lending and has compressed interest margins as the traditional source of bank's income. Efficiency scores are compiled to estimate the impact of monetary policy crisis management on the efficiency of banks. The estimation results provide evidence that the Japanese monetary policy crisis management has contributed to declining efficiency in the banking sector despite or because of growing concentration.

JEL-Codes: E520, E580, F420, E630.

Keywords: Japan, monetary policy, crisis management, banking sector, city banks, regional banks, shinkin banks, concentration.

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1 Introduction

During the second half of the 1980s a low interest rate policy of the Bank of Japan contributed to the emergence of a bubble in the Japanese stock and real estate markets, which found its end in the early 1990s (Bayoumi and Collyns, 2000). During most of the 1990s the destabilizing impact of the resulting balance sheet recession (Koo, 2003) was contained by the Bank of Japan's gradual interest rate cuts to (close to) zero. This enabled the Japanese banks to cover losses from declining asset prices by providing credit to Japanese enterprises operating in Southeast Asia (Hoffmann and Schnabl, 2008). The 1997/98 Asian crisis, however, finally triggered a strong adjustment pressure on the Japanese banking sector (Schnabl, 2015) which went along with a consolidation process among Japanese banks and financial institutions (Hosono et al., 2009).

The persistence of the zero interest rate policy since 1999 and the advent of unconventional monetary policy measures have been widely understood as stabilization measures for the Japanese banking sector (Posen, 2000; Koo, 2003). As the ample low-cost liquidity provision of the Bank of Japan stabilized asset prices, it also stabilized the banks´ balance sheets by reducing the amount of (potential) bad loans. On the other side, the low-cost liquidity provision of the Bank of Japan is argued to have prevented Schumpeter's (1942) creative destruction and thereby a sustained recovery of Japanese banks (Sekine et al., 2003; Peek and Rosengren, 2005; Caballero et al., 2008). To this end the impact of the Japanese monetary policy crisis management on the Japanese banking sector is theoretically indeterminate.

Previous empirical studies have found that the Japanese banking sector exhibits major technical and scale inefficiencies with considerable differences among the various bank-types (e.g. Fukuyama, 1993; McKillop *et al.*, 1996; Altunbas *et al.*, 2000; Drake and Hall, 2003; Drake *et al.*, 2009; Assaf *et al.*, 2011). Studies on productivity development of Japanese banks (e.g. Fukuyama, 1995; Fukuyama and Weber, 2002; Assaf *et al.*, 2011) have found that the Japanese banking sector has been struggling to increase productivity since the early 1990s.

However, few attempts have been made to understand the impact of the Japanese monetary policy crisis management on the efficiency of the Japanese banking sector. Therefore, we add to the existing literature by analyzing the adjustment of Japanese banks to the Bank of Japans' low interest rate policies and unconventional monetary policy measures. Based on micro data, we empirically test for the determinants of Japanese banks' efficiency while controlling for their adjustment to the Bank of Japan's monetary policy crisis management.

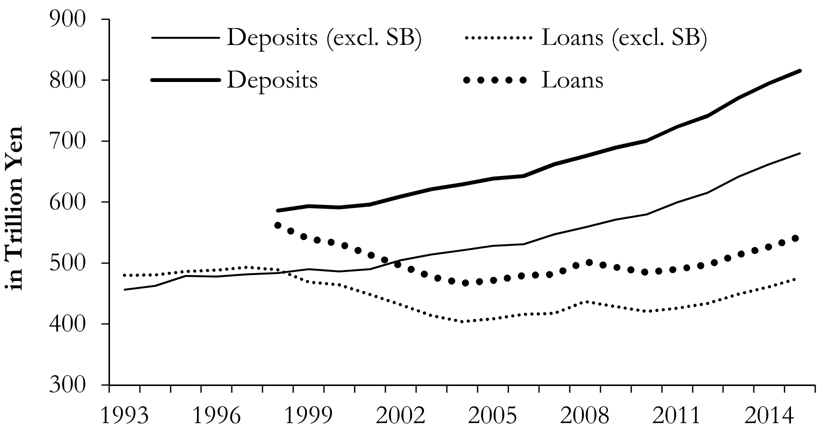
2 Monetary Policy Crisis Management on the Japanese Banking Sector

The development of the Japanese banking sector since the 1998/99 Japanese financial crisis has to be seen in the context of the lasting stagnation of the domestic economy (Schnabl, 2015). During the Japanese bubble economy (1985-1990) Japanese banks' credit to the private sector had strongly grown, with credit expansion continuing slowly until 1998. With the Asian crisis and the Japanese financial crisis a credit crunch set in (Ishikawa and Tsutsui, 2005), which can be seen as either supply or demand driven. The gradual erosion of the banks' traditional sources of income triggered a search for alternative revenues and a struggle to increase efficiency via concentration.

2.1 Declining Income

The observed credit crunch, which lasted from 1998 until the advent of the Abenomics has two origins. On the one side, declining asset prices forced Japanese banks to reduce their risk exposure by curtailing outstanding credit to risky enterprises (see e.g. Koo, 2003). On the other side, sluggish investment of the corporate sector and the need to deleverage lowered Japanese firms' demand for loans while simultaneously increasing their deposits at banks. In this context, the low and zero interest rate policy as well as unconventional monetary policy measures can also be understood as a subsidy for enterprises (in particular large enterprises)[1], which further reduced their demand for credit because of growing cash reserves (see Gerstenberger, 2017).

Figure 1: Deposits and Loans of Japanese Banks



Notes: SB - shinkin banks; *Source*: Bank of Japan.

[1] The monetary policy crisis management reduced the financing costs of enterprises by continuously depressing interest rates. In addition, the resulting depreciation of the yen subsidized the large export-oriented enterprises.

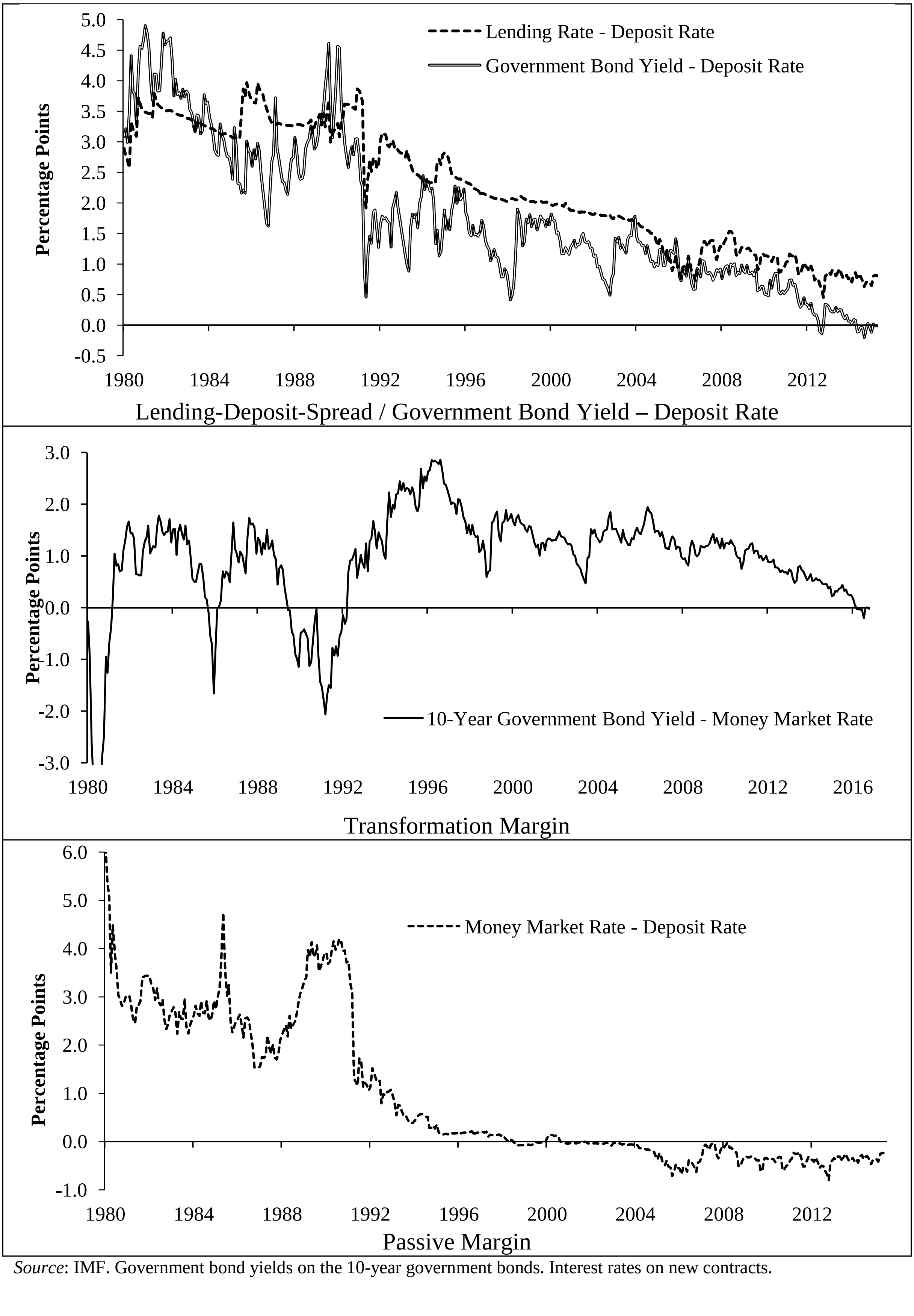
As a result, the total amount of loans in banks' balance sheets substantially fell. The increasing inflow of personal and corporate deposits combined with declining volumes of credit led to an increasing gap between loans and deposits (Figure 1). The credit business started to recover only from the year 2012, but without contributing to a shrinking gap between deposits and loans. The loan-deposit ratio fell from almost 1 at the beginning of the 1990s to less than 0.7 in 2015.

The stagnation of the traditional credit business became paired with declining margins in the loans and investment business. Monetary policy rescue measures of the Bank of Japan gradually depressed short-term money market rates to finally zero by March 1999. The Bank of Japan continued to reduce interest rates at the long end of the yield curve via fast growing bond purchases of the Bank of Japan (Yoshino and Taghizadeh-Hesary 2016).[2] As a result, the spread between average lending and deposit rates (on new contracts) declined from an average of 3.5 percentage points during the 1980s to currently less than one percentage point as shown in the upper panel of Figure 2.

The decline in lending to the private sector could be partially substituted by the purchase of government bonds (see section 2.2). Yet, also the margin between the government bond yield and the deposit rate declined from 3.5 percentage points in the 1980s to close to (and even below) zero in the course of the Abenomics since 2013 (see upper panel of Figure 2). Furthermore, the scope to generate profits by transforming short-term borrowing in the money market into long-term lending also shrank. The transformation margin, i.e. the spread between the 10-year government bond yields and the money market rate, declined from the top of close to three percentage points in 1998 to merely zero in the present (see center panel of Figure 2). Moreover, the passive margin, i.e. the difference between the money market rate and the average deposit rate was depressed from 3 to 4 percentage points in the 1980s to zero by 2005. It has been negative since then (see lower panel in Figure 2).

[2] The Bank of Japan cut short-term interest rate from 6 percent in 1991 to zero by March 1999. The size of the balance sheet of the Bank of Japan has increased from 18% of GDP in January 1999 to 95% by the end of 2016 due to extensive bond purchases, in particular government bonds.

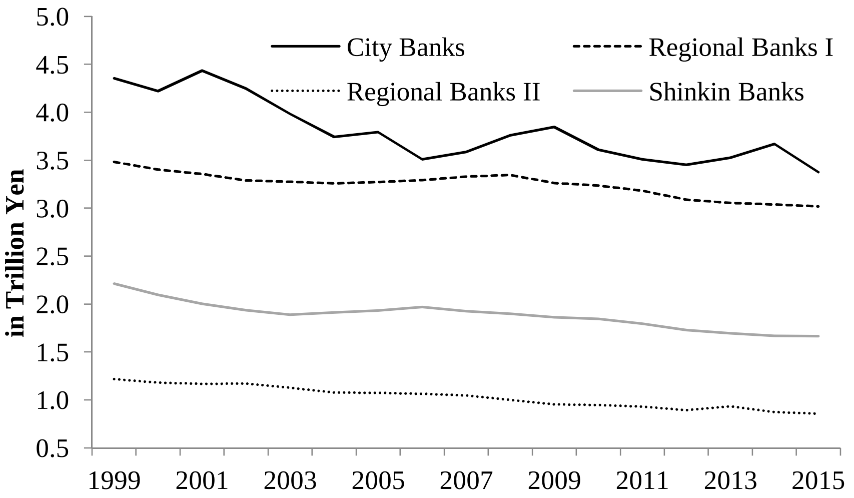
Figure 2: Interest Rate Spreads in the Japanese Banking Sector



Source: IMF. Government bond yields on the 10-year government bonds. Interest rates on new contracts.

As Japanese banks were not able to compensate the decrease in interest margins with a boost in lending volumes, net interest income substantially declined, thereby depressing profits. Between 1999 and 2014, revenues from the traditional credit business of large city banks decreased by 16 percent, of the first-tier regional banks by 13 percent, of the second-tier regional banks by 28 percent and of the shinkin banks by 25 percent (Figure 3).[3]

Figure 3: Net Interest Income per Bank Type



Source: Japanese Bankers Association. Net interest income equals interest income minus interest expenses.

In addition to declining interest margins, Japanese banks suffered high losses from provisions and write-offs of non-performing loans. With the outbreak of Japanese financial crisis, the strategy towards the bad loan problem changed. During the 1990s Japanese banks had been advised to keep the bad loans in their balance sheets and build respective provisions. In contrast, from the year 2002 the Financial Revitalization Program urged banks to resolve the provisions and to write down the bad loans.[4] The realized losses constituted an additional

[3] *City banks* are large commercial banks operating at a national and international level having branches in all major cities in Japan. *Tier-one and tier-two regional banks* are mainly active in retail banking and focus on specific regions (e.g. one prefecture). They mainly engage in lending to the corporate sector specifically small and medium enterprises (approximately 70 percent of all loans are granted to SMEs). Tier-one and tier-two regional banks have a different history and therefore statistics of the Japanese Bankers Association are aggregated in two different categories. Since the financial market liberalizations in the 1990s the business model of both groups is mainly the same. Now, the main difference between the two groups is that tier-two regional banks are significantly smaller. *Shinkin banks* are credit associations operating within a prefecture managing deposits and providing loans to and from their owners (mainly SMEs).

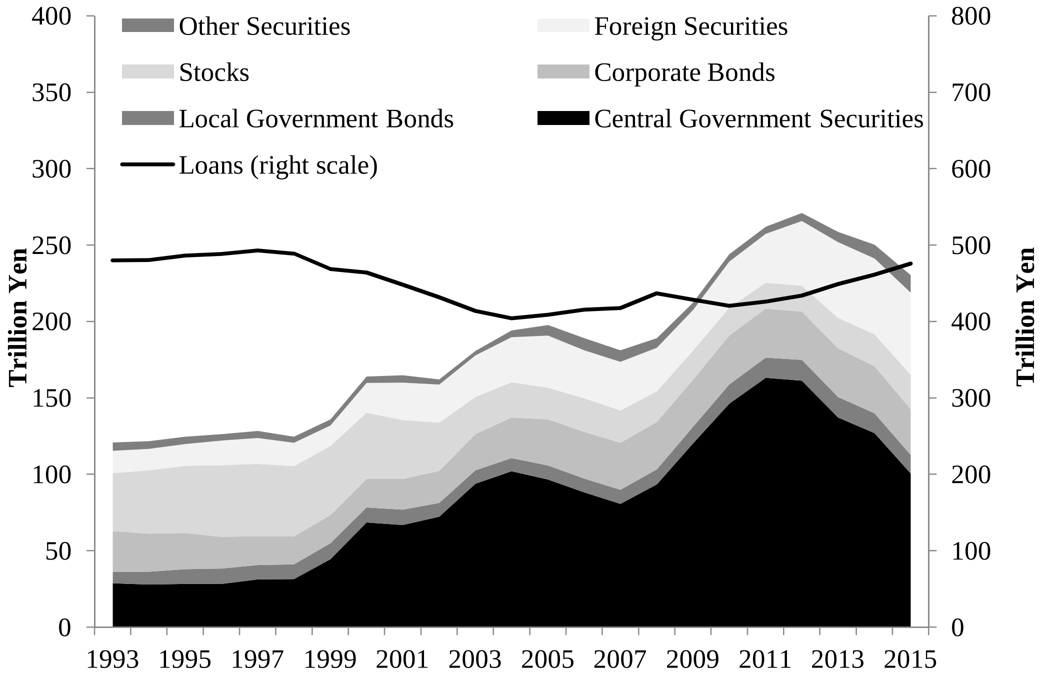
[4] Between 1999 and 2014 the overall volume of write downs of bad loans by Japanese banks was equivalent to 18 trillion yen, out of which city banks wrote down 12.5 trillion yen, tier-one regional banks 5.6 trillion yen and tier-two regional banks 0.6 trillion yen (Source: Japan Deposit Insurance Corporation). This process was supported by recapitalizations equivalent to 13 trillion yen (111 billion dollar).

burden for Japanese banks until the start of the Abenomics, which had to be compensated by additional revenues.

2.2 Alternative Sources of Income

Additional revenues were in the first place generated by the substitution of credit to the private sector by the purchase of central government bonds (JGB) and local government bonds (LGB) (Figure 4). This became possible, because general government debt as share of GDP increased from 70 percent in 1990 to 250 percent in 2016. Between 1999 up to year 2012 the share of government bonds out of total assets increased from 5 percent to 27 percent for city banks, from 8 percent to 17 percent for tier-one regional banks, from 5 percent to 15 percent for tier-two regional banks and from 12 percent to 25 percent for shinkin banks. The purchases of government bonds were lucrative until the start of the Abenomics (January 2013).

Figure 4: Composition of Investment Securities - all Banks (1993-2015)

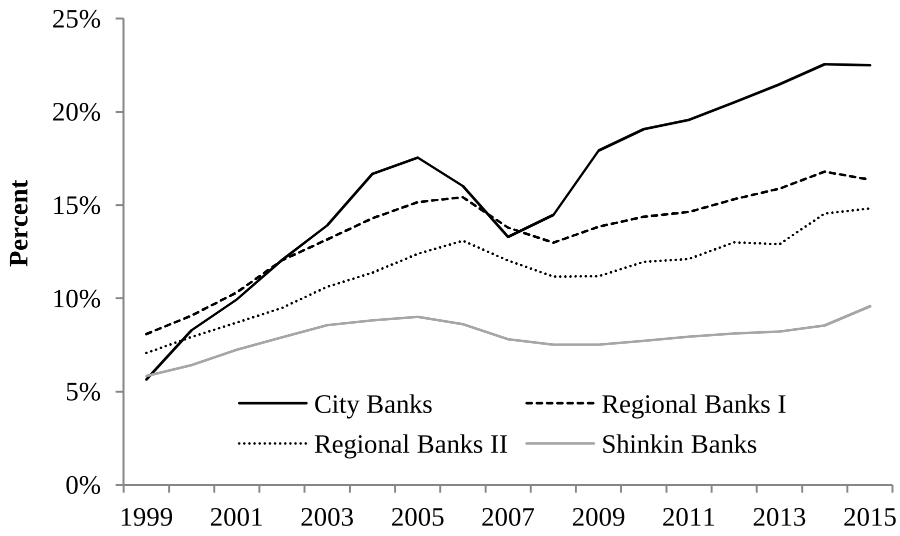


Source: Bank of Japan.

The shift of the Bank of Japan's monetary policy towards aggressive quantitative easing made government bond yields more volatile and pushed them into negative territory. Banks strongly reduced their JGB holdings. By the end of 2016, the share of government bonds out of total assets had declined to 9 percent (city banks), 13 percent (tier-one regional banks) and 10 percent (tier-two regional banks). The decline of government bonds in the balance sheets has been less pronounced in the case of regional banks as they have been holding more local government bonds that were less purchased by the Bank of Japan up to the present. For shinkin banks the decline of central government bond holdings has been widely compensated by purchases of local government bonds (Bank of Japan, 2016).

Given declining income from the traditional banking business, Japanese banks felt forced to generate more revenues from fees and commissions. The financial deregulation in the late 1990s (Big Bang) paved the way for diversifying into new business areas.[5] Japanese banks developed new financial services and formed business alliances with non-bank companies.[6] Banks expanded sales of investment trusts and private pension policies to households and increased their corporate customer fees, e.g. for the arrangement of syndicated loans and sales of derivatives to firms (Bank of Japan, 2005).

Figure 5: Fees and Commissions as Share of Ordinary Income by Bank Type



Source: Japanese Bankers Association, Shinkin Central Bank.

In particular, regional banks and shinkin banks turned from a purely lending based business model to a more service oriented business model by providing services to corporate customers to resolve challenges such as establishing new business relationships, exploring new markets

5 The Financial Services Agency's guidelines state that this includes consultations and support in connection with business matching and mergers and acquisitions (Ishikawa *et al.* 2013).

6 In the early 2000s Japanese banks increased business alliances with securities, and insurance companies and entered into consumer finance through joint ventures or partnerships with consumer finance companies. Cooperating with firms that have physical or electronic networks (e.g. railway and mobile phone companies) banks started to offer new financial services, such as means of small-value payments (Bank of Japan, 2006).

or finding business successors (Ishikawa *et al.*, 2013). As a result, revenues from fees and commissions (as a share of total ordinary income) significantly increased for all types of banks (Figure 5). The highest increase has been realized by the large city banks, which became strongly involved in the investment business and profited from having large, export-oriented enterprises as customers.

2.3. Adjustment of Costs

Depending on the ability to compensate declining revenues from the traditional banking business by new sources of income Japanese banks had to cut personal expenses as well as general and administrative expenses. The pressure to cut costs has been stronger for the small shinkin banks and tier-two regional banks than for the larger tier-one regional banks and the city banks.

Between 1999 and 2014 personal expenses declined by 2 percent for city banks and by 10 percent in the case of tier-one regional banks. In contrast, the tier-two regional banks reduced personal expenses by 24 percent and the shinkin banks by even 35 percent. A similar pattern has evolved with respect to non-personal expenses, which increased for city banks by 9 percent and for tier-one regional banks by 1 percent. In contrast, general and administrative expenses were cut by 14 percent for both tier-two regional banks and shinkin banks.[7]

The pressure to reduce costs has come along with a concentration process in the Japanese banking sector. The number of Japanese financial institutions (including city banks, trust banks, tier-one regional banks, tier-two regional banks and shinkin banks) declined from 606 in 1990 to 379 in 2016 (Hosono et al., 2009; Japanese Bankers Association, 2017). As shown in Figure 6, since 1990 the number of city banks declined from 13 to today 5. While all tier-one regional banks survived up to the present, the number of the smaller tier-two regional banks declined from 68 in 1990 to presently 41. The number of shinkin banks is down from 451 in 1990 to 265 in 2016.

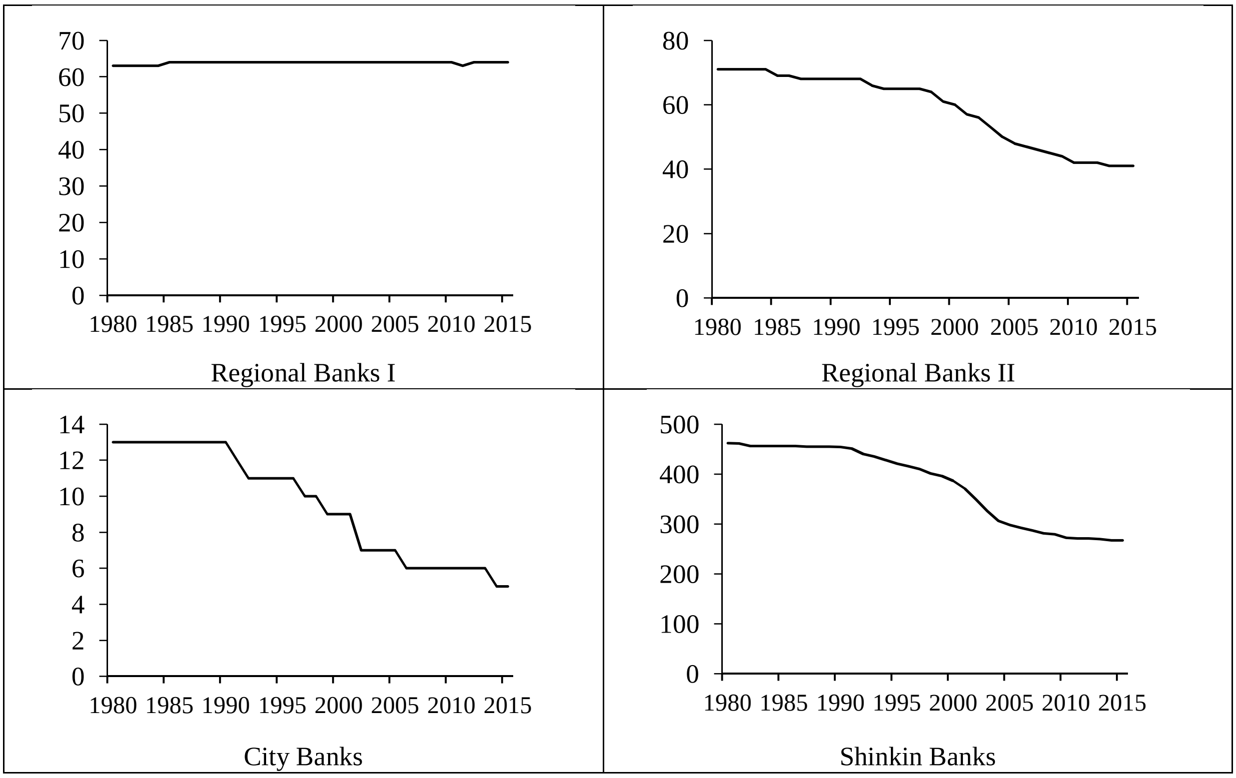
Moreover, for all four bank types the number of branches declined continuously since the mid-1990s (Figure 7).[8] The reduction in the number of branches, however, has been larger for smaller banks (tier-two regional banks and shinkin banks) than for larger banks. A similar

7 All data provided by the Japanese Bankers Association and the Shinkin Central Bank.

8 There is no distinction between branches with employees, which provide all services, i.e. branches (shiten: 支店) and main braches (honshiten: 本支店) and branches with limited services, in particular with ATM machines (shu chou jo: 出張所). The sharp increase of branches of city banks from 2015 to 2016 is due a sharp extension of ATM-corners by the Mitsui-Sumitomo Bank in the areas, where the Tokyo Olympics will take place.

pattern accrues to the number of regular employees, which have been more reduced by the tier-two regional banks and the shinkin banks (Figure 8). The substitution of regular employees by part-time employees allowed banks to adjust more easily to volatile business conditions.

Figure 6: Number of Banks

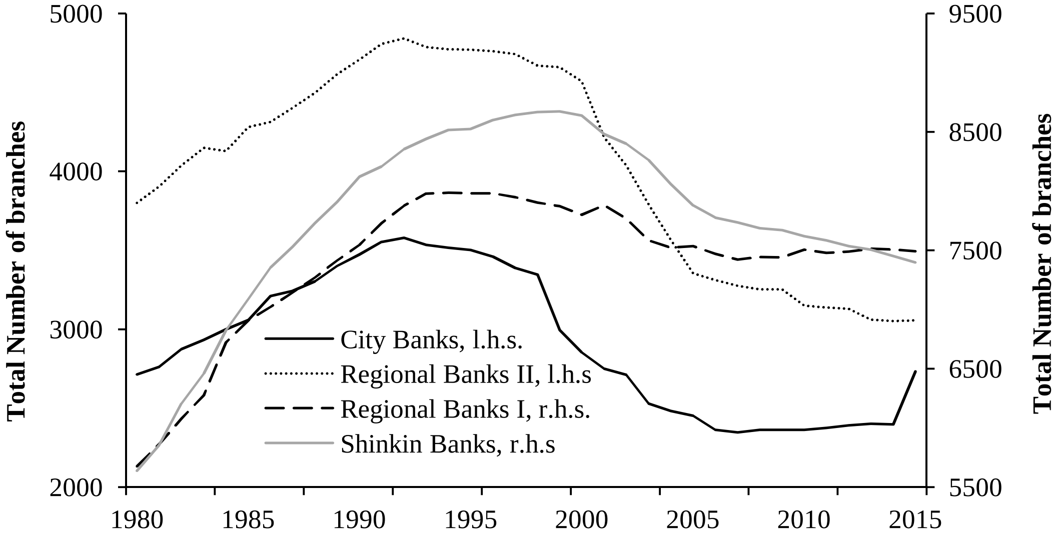


Source: Japan Financial Yearbook (日本金融名鑑).

The continuing pressure on profits as a result of the Bank of Japan's monetary policy crisis management may suggest, that efficiency has increased due to the observed concentration process and other adjustment measures. However, at the same time the declining degree of competition as a result of increasing concentration combined with the persistent low-cost liquidity provision by the Bank of Japan may have reduced the pressure on Japanese banks' to increase efficiency (see Schnabl 2015).[9] Additionally, squeezed profits may have also reduced the banks’ resources to implement efficiency-enhancing measures. Hence, the impact of Japanese monetary policy crisis management on bank’s efficiency is theoretically indeterminate and therefore an empirical issue.

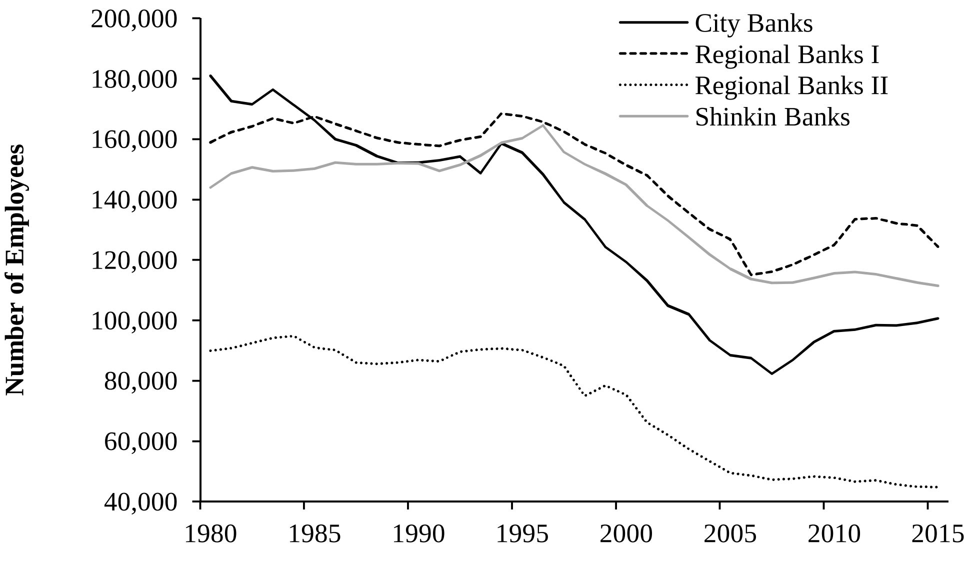
9 For instance, Hosono *et al*., 2009) provide evidence that mergers and acquisitions in the Japanese banking sector have not necessarily been efficiency improving.

Figure 7: Number of Branches



Source: Japan Financial Yearbook.

Figure 8: Number of Regular Employees



Source: Japan Financial Yearbook.

3 Development of Japanese Banks' Efficiency

As shown above during the post-bubble period the Bank of Japan's monetary policy crisis management has substantially changed the operating environment of Japanese banks as the gradual reduction of interest rates and the unconventional policy measures eroded their traditional sources of income. In order for banks to remain profitable in a low interest rate environment a more efficient utilization of resources is crucial.

3.1 Concept of Efficiency Measures

To evaluate Japanese banks' efficiency development, we estimate for each bank i and each year t an output-oriented technical efficiency score TE_{it} that reflects the bank's distance to a pre-specified benchmark (i.e. the efficiency frontier) (Farrell, 1957).[10] Technical efficiency can be defined as a bank's ability to produce a maximum set of outputs (e.g. loans, securities, operating income) given a set of inputs (e.g. deposits, employees, branches). Farrell's (1957) output-oriented technical efficiency score TE_{it} equals one when optimum efficiency is reached. Higher values than unity indicate inefficiencies.[11] Following Charnes *et al.* (1978) and Banker *et al.* (1984) we further decompose a bank's technical efficiency score TE_{it} into pure technical efficiency (PTE_{it}) and scale efficiency (SE_{it}) with:

$$TE_{it} = PTE_{it} \times SE_{it}$$

The decomposition helps to identify whether Japanese banks' overall technical inefficiencies are due to inefficient operations (measured by PTE_{it}) or due to not operating at an optimal scale (measured by SE_{it}), or both. We are, furthermore, able to determine if Japanese banks are operating under increasing, constant or decreasing returns to scale, hence whether they are too small or too big.[12] Prior studies on the Japanese banking sector indicate that pure technical inefficiencies are larger than scale inefficiencies as Japanese banks have been following a gradual consolidation process since the bursting of the bubble economy (Fukuyama, 1993; McKillop *et al.*, 1996; Drake and Hall, 2003; Azad *et al.*, 2014).

A common method employed to compute efficiency scores is the Data Envelopment analysis (DEA) which measures efficiency as "*relative to a non-parametric, maximum likelihood estimate of an unobserved true frontier, conditional on observed data […]*" (Simar and Wilson, 2007: 32). DEA is a flexible non-parametric approach that does not require a specific functional form of a bank's production function. However, the downside is that it does not allow for random errors and is hence sensitive to random variations in the data. As it has no statistical foundation, it is not possible to infer statistical significance of the estimates (see

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[10] Farrel (1957) decomposes a firm's *overall efficiency* (or *economic efficiency*) in *technical efficiency*, reflecting a firm's ability to produce a maximum set of outputs from a given set of inputs, and price efficiency (or *allocative efficiency*), reflecting a firm's ability to choose an optimal set of inputs given respective prices. We focus on *technical efficiency* of Japanese banks as input prices were not available.

[11] For details see Appendix A1.

[12] Increasing (decreasing) returns to scale indicate that the bank is too small (big).

Coelli et al., 2005). We cope with this problem by using the bootstrap approach by Simar and Wilson (1998, 1999) that allows to determine the statistical properties of the non-parametric estimators of banks efficiency. This enables us to obtain bias corrected efficiency scores.[13]

3.2 Input and Output Data

In modeling the bank's production function we follow the intermediation approach by Sealey and Lindley (1977) which considers banks as institutions transforming deposits into loans and into other earning assets using labour and physical capital as inputs.[14] This is in line with previous studies of the Japanese banking sector (e.g. Fukuyama, 1993; Drake and Hall, 2003). The banks' activities are modeled in a three-input and two-output framework.

Table 1: Sample Structure of Efficiency Analysis

	CB	RB I	RB II	SB	Total
1999	9	48	26	254	337
2000	9	48	28	255	340
2001	7	48	32	266	353
2002	7	56	36	269	368
2003	7	58	38	271	374
2004	7	62	40	272	381
2005	6	62	40	272	380
2006	6	62	40	271	379
2007	6	61	39	271	377
2008	6	59	37	269	371
2009	6	61	37	269	373
2010	6	61	37	268	372
2011	6	61	40	267	374
2012	6	62	41	269	378
2013	5	61	39	267	372
2014	5	59	38	263	365
2015	5	57	37	190	289

Source: Author's calculations. CB: city banks, RB I: tier-one regional banks, RB II: tier-two regional banks, SB: shinkin banks

The data set on Japanese banks is compiled from BankScope.[15] It is completed by data from annual reports of individual banks, the Nikkei NEEDS database as well as information from the Japanese Bankers Association. Our final dataset for the efficiency analysis comprises 6,183 observations of 401 Japanese banks for the financial years 1999 to 2015. Our sample

13 For more information on DEA see Appendix A2.
14 In contrast, the production approach (Benston and Smith, 1976) assumes that banks are primarily producing services for account holders.
15 Bureau van Dijk, www.bvdep.com

covers almost the full spectrum of bank types operating in Japan including 16 city banks, 64 tier-one regional banks, 41 tier-two regional Banks and 280 shinkin banks (see Table 1).[16]

Following Assaf *et al.* (2011) and Fukuyama and Weber (2009) the inputs are total deposits and short-term borrowed funds (X1), physical capital (land, premises and fixed assets) (X2) and labor (number of employees) (X3). The outputs are total loans and bills discounted (Y1) as well as securities issued (Y2). The inputs and outputs (excluding employees) are measured in yen and deflated using the GDP deflator provided by the World Bank. Descriptive statistics of inputs and outputs are provided by bank type in Table 2.

Table 2: Descriptive Statistics of Inputs and Outputs

	CB	RB I	RB II	SB	Total
(X1) Deposits (billion yen)	57,500	3,210	1,300	367	1,860
(X2) Physical Capital (billion yen)	568.0	45.2	21.2	5.8	22.8
(X3) Employees (number of)	15,067	2,031	1,091	397	963
(Y1) Loans (billion yen)	35,700	2,260	977	201	1,190
(Y2) Securities (billion yen)	17,100	976	313	106	548

Notes: Sample means per bank type; CB: city banks, RB I: tier-one regional banks, RB II: tier-two regional banks, SB: shinkin banks. *Source:* Bankscope, annual reports of individual banks, Nikkei NEEDS database, Japanese Bankers Association.

3.3 Results for Efficiency Scores

Table 2 summarizes the annual mean efficiency scores for the Japanese banking sector over the period 1999-2015 as compiled by DEA.[17] Columns two to four list the average bias corrected technical efficiency (*TE*), pure technical efficiency (*PTE*) and scale efficiency (*SE*) estimates. Columns five to seven summarize the share of banks operating under increasing (IRS), constant (CRS) or decreasing returns to scale (DRS).

Table 3 provides evidence that the Japanese banking sector had large inefficiencies in all sample years. On average Japanese banks could have increased output by around 26.9 percent if inputs had been used more efficiently. Over time the average technical efficiency of the Japanese banking sector increased considerably between the years 2000 and 2004 and

[16] Total numbers differ from the annual numbers in Table 1 due to different participation behaviour of banks in our sample. Banks which were involved in mergers and acquisitions are post-merger treated as separate entities.

[17] We used the FEAR software by Wilson (2008) to obtain the bias corrected efficiency scores.

deteriorated thereafter. Technical efficiency has particularly declined since 2010 and especially with the introduction of the Abenomics in 2013.

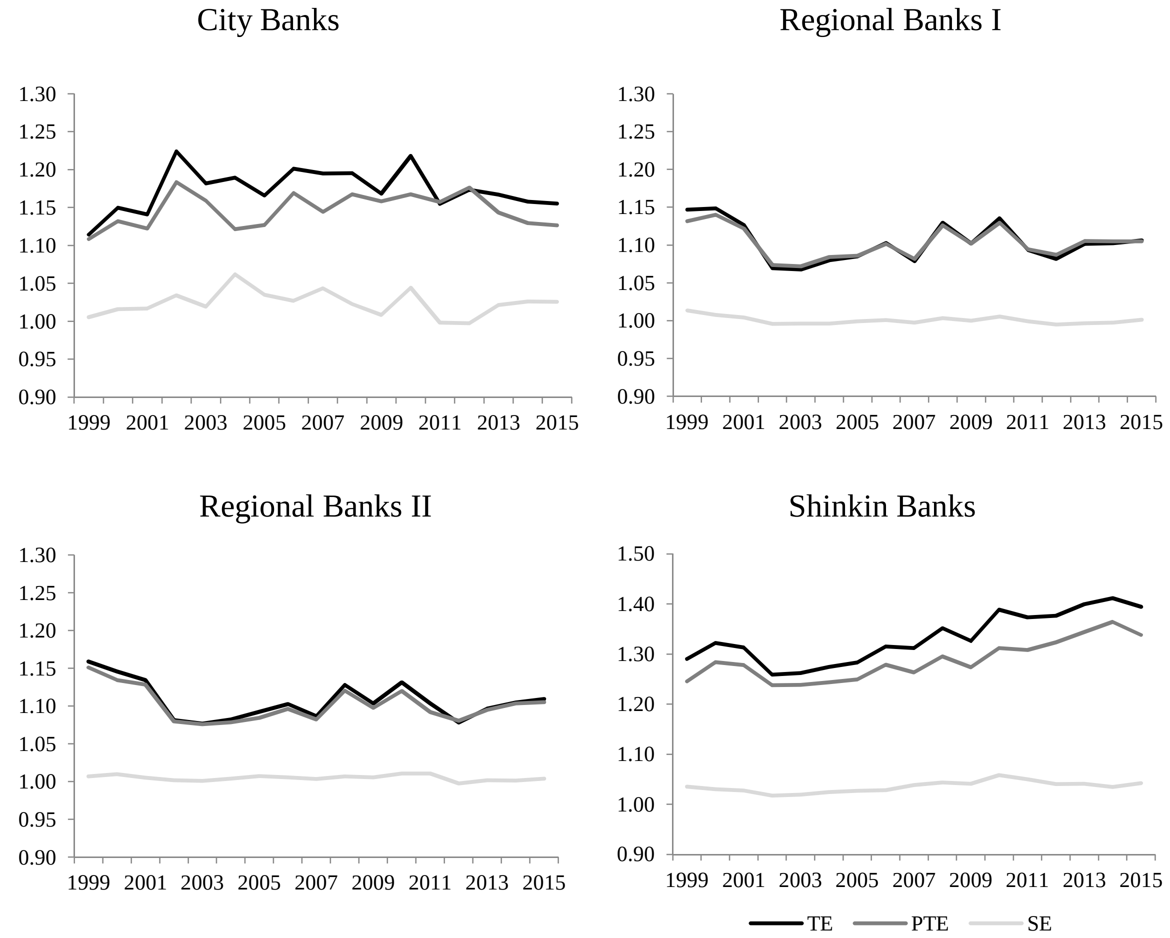
Table 2: Annual Average Efficiency Scores of All Banks (1999-2015)

Year	TE	PTE	SE	IRS	CRS	DRS
1999	1.255	1.219	1.030	91%	4%	5%
2000	1.279	1.247	1.026	86%	4%	10%
2001	1.268	1.240	1.023	89%	6%	5%
2002	1.212	1.196	1.013	88%	5%	7%
2003	1.212	1.195	1.014	87%	4%	9%
2004	1.221	1.198	1.019	90%	4%	6%
2005	1.229	1.203	1.021	91%	4%	6%
2006	1.256	1.229	1.022	92%	3%	4%
2007	1.249	1.213	1.029	92%	5%	3%
2008	1.292	1.249	1.034	91%	4%	6%
2009	1.265	1.226	1.031	89%	3%	8%
2010	1.319	1.261	1.046	91%	3%	6%
2011	1.295	1.247	1.037	95%	3%	2%
2012	1.293	1.256	1.028	88%	5%	7%
2013	1.316	1.276	1.030	92%	3%	4%
2014	1.326	1.292	1.026	86%	5%	8%
2015	1.297	1.258	1.031	81%	6%	13%
Average	1.269	1.235	1.027	89%	4%	6%

Notes: Bias corrected values based on bootstrapping procedure; TE: technical efficiency score estimated assuming constant-returns-to-scale; PTE: pure technical efficiency estimated assuming variable-returns-to-scale; SE: scale efficiency; values above unity indicate inefficiencies; IRS/CRS/DRS: share of banks operating under increasing-returns-to-scale/constant-returns-to-scale/decreasing-returns-to-scale; *Source:* Authors' calculations.

Pure technical efficiency amounting on average to around 1.24 explains the largest share of Japanese banks' technical inefficiencies. Thus, output of the Japanese banking sector could have been 24 percent higher if the banks had been operating at the pure technical efficiency frontier. Scale inefficiencies have been rather small with only 1.027 in average. Thus, banks could have increased output only by 2.7 percent if they had operated at an optimal scale. However, scale inefficiencies have been increasing since around 2007 despite the acceleration of the concentration process. According to the used efficiency measure 90 percent of the banks have operated under increasing returns to scale (i.e. below their optimal scale), which implies further concentration potential. Only around 6 percent have been operating under decreasing returns to scale. This suggests that although the consolidation process in the Japanese banking sector has advanced since the 1990s scale inefficiencies have not been resolved, leaving room for further merger activities.

Figure 9: Annual Efficiency Scores by Bank Type (1999-2015)



Notes: TE: technical efficiency score estimated assuming constant returns to scale; PTE: pure technical efficiency estimated assuming variable returns to scale; SE: scale efficiency estimated as the ratio TE/PTE; values above unity indicate inefficiencies, bias corrected values based on bootstrapping.

Figure 9 shows the development of the efficiency scores over time by bank type.[18] City banks have exhibited rather large technical inefficiencies compared to both types of regional banks. With an average technical efficiency score of 1.172 in our sample period city banks could have increased output by around 17.2 percent. Over time the efficiency development of city banks has been rather unsteady with periods of significantly declining overall efficiency (e.g. 1999-2002, 2006, 2010) followed by periods of improvements (e.g. 2003-2005, 2006-2009, 2012-2015). Overall, technical efficiency and both components decreased between 1999 and 2015. The mean *SE* score corresponds to 1.024 with on average 40 percent of city banks operating under decreasing returns to scale and thus *above* their optimal scale. This implies that the consolidation process of city banks into so-called “mega banks” has not necessarily helped to increase their efficiency.

[18] For a more detailed overview of the results see Table 6 to Table 9 in Appendix A3.

Tier-one and tier-two regional banks have been on average the most efficient banks according to our measure with both having an average *TE* score of 1.10 in our observation period. For both types of banks scale inefficiencies have been rather small such that a further consolidation among regional banks cannot be expected to improve their efficiency. Pure technical efficiency considerably increased between 1999 and 2003 and has slightly decreased since then.

Shinkin banks have exhibited by far the largest inefficiencies with an average technical efficiency score of 1.33. Technical inefficiencies have increased from 1.29 in 1999 to 1.39 in 2015 despite the significant consolidation process. Shinkin banks' inefficiencies are mainly driven by pure technical inefficiencies, however, scale inefficiencies are also larger compared to other bank types. The average scale efficiency score for shinkin banks is 1.035 and hence scale inefficiencies are above the total sector mean. According to the efficiency measure an average around 96 percent of shinkin banks have been operating below their optimal scale i.e. they have been too small, as compared to only 17 percent of city banks, 71 percent of tier-one regional banks and 84 percent of tier-two regional banks.

4 Adjustment Measures as Drivers of Japanese Banks Efficiency

Based on the efficiency measures compiled above we trace the determinants of the banks' inefficiencies since the 1998/99 Japanese financial crisis. In particular, we control for the impact of the Bank of Japan's monetary policy crisis management and the bank's strategies to cope with the low interest rate environment.

4.1 Estimation Framework and Methodology

To identify the sources of Japanese banks' inefficiencies we regress the efficiency estimates as compiled in Section 3 on a set of explanatory variables.[19] We estimate the following model:

$$\hat{\theta}_{it} = \beta_0 + \beta_1 z_{it} + \delta_t + \varepsilon_{it} \tag{1}$$

where the dependent variable $\hat{\theta}_{it}$ is bank i's estimated efficiency score at time t. In our analysis we run equation (1) for both the estimated technical efficiency $\widehat{TE}_{it}$ as well as pure

[19] For more information and an overview of efficiency studies using such a two-stage approach see Simar and Wilson (2007). Studies on the Japanese banking sector using a two-stage approach include Altunbas *et al.* (2000), Fukuyama and Weber (2009) and Assaf *et al.* (2011).

technical efficiency scores $\widehat{PTE}_{it}$ as dependent variables.[20] The vector z_{it} represents a matrix of explanatory variables including those commonly found in the literature to have a significant impact on banks' efficiency as well as variables reflecting the banks adjustment strategies to monetary policy crisis management as described in section 2. Furthermore, we control for year fixed effects δ_t. The term ε_{it} is an error term.

To estimate equation (1) we use the bootstrapped truncated regression model proposed by Simar and Wilson (2007). Given the bounded nature of the estimated efficiency scores with $\widehat{TE}_{it} \geq 1$ and $\widehat{PTE}_{it} \geq 1$ a truncated regression model leads to more consistent and accurate estimates than Tobit or OLS models that were traditionally used in two-stage efficiency studies of the banking sector (e.g. McKillop *et al.*, 2002, Fukuyama and Weber, 2009).

4.2 Variable Definitions

The data basis for our regression analysis is the dataset presented in section 3.2. Due to missing data the sample for our regression analysis is slightly smaller than the original sample comprising only 5,823 observations of 389 different banks. Descriptive statistics of all explanatory variables can be found in Table 3.

Control variables that were found to have a significant impact on Japanese banks' efficiency are the market share (*MS)*, non-performing loans (*NPL)*, the return on average assets (*ROAA)* and bank size (Fukuyama and Weber, 2009; Assaf *et al.*, 2011). Market share (*MS)* is proxied by the ratio of bank *i*'s deposits to total banking sector deposits and was in previous studies found to have a positive impact on efficiency (Fukuyama and Weber, 2009). Non-performing loans *NPL* are measured as risk-monitored loans over total loans. They are expected to have a negative impact on Japanese bank's efficiency as found in previous studies (Altunbas *et al.*, 2000). Furthermore, we expect the return on average assets to be positively correlated with bank efficiency (Assaf *et al.*, 2011).

To control for the impact of the Japanese monetary policy we include the net interest margin (*NIM)* defined as bank's net interest revenue as a share of its average total earning assets (in percent). Whereas the net interest margin is traditionally regarded as reflecting asset productivity (Assaf *et al.*, 2011), we use it as an indicator of the bank's exposure to the low interest rate environment and unconventional monetary policy.[21] A positive coefficient of

[20] We omit $\widehat{SE}_{it}$ from our regression analysis as a bank's scale efficiency is the quotient of $\widehat{TE}_{it}$ and $\widehat{PTE}_{it}$ and is solely determined by the bank's size.

[21] Busch and Memmel (2015) and Claessens *et al.* (2017) show empirically that banks' net interest margins significantly react to changes in interest rates triggered by central banks.

NIM in our estimation indicates that low net-interest margins have successfully incentivized Japanese banks to increase efficiency to mitigate losses in revenues.[22] In contrast, a negative coefficient indicates that banks with declining net interest income were less able or willing to increase efficiency and suffer from higher inefficiencies.

Table 3: Descriptive Statistics - Regression Analysis

	Mean	SD	Min	Max
TE	1.25	0.16	1.00	2.22
PTE	1.21	0.14	1.00	2.16
MS	0.17	0.66	0.01	17.22
NPL	7.45	4.10	0.00	37.35
ROAA	0.09	0.45	-7.24	2.07
NIM	1.71	0.38	0.10	3.51
SECLOAN	0.51	0.28	-0.01	2.95
GOVSEC	0.38	0.21	-0.07	8.28
NIOI	0.07	0.47	-12.37	28.66

Source: Authors' calculations

As discussed in Section 2 Japanese banks have increasingly invested in securities - particularly government bonds - and have raised the share of non-interest income (i.e. fees and commissions). As proxies for changes in the bank's portfolio mix we include the securities to loan ratio (*SECLOAN)* as well as the share of government securities among total securities (*GOVSEC).* The ratio of non-interest operating income to total operating income (*NIOI)* aims to capture the effect of bank's effort to diversify their revenue structure. The impact of a bank's diversification strategy on its efficiency is theoretically indeterminate.[23]

Bank size is captured by a set of dummy variables to allow for nonlinearities in the relationship between efficiency and bank size, with thresholds chosen following Berger and Mester (1997). The definitions of small, medium, large and huge banks as well as the distribution across the bank types are presented in Table 4. It is assumed that there is no clear

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[22] Note that higher values of $\widehat{TE}_{it}$ and $\widehat{PTE}_{it}$ indicate lower efficiency and higher inefficiency. A positive coefficient implies that an increase in the net-interest margin would lower efficiency/increase inefficiency.

[23] A higher share of securities can have a positive impact on a bank's efficiency, because securities investment is associated with lower operating costs than the provision of loans as the latter involves evaluation and monitoring activities (Sarmiento and Galán, 2015). However, simultaneously the expansion of non-interest income by providing more fee-based services and products involves more resources. Therefore, an adjustment of a bank's revenue structure might be associated with decreasing efficiency.

link between bank size and efficiency.[24] Furthermore, we control for the distinct organizational and governance characteristics of the banks by including dummies for each bank type (*CB*, *RB I*, *RB II*, *SB*).[25]

Table 4: Bank Size Dummy Variables

	Definition	CB	RB I	RB II	SB
SMLBANK	TA <114 billion Yen	0%	0%	0%	23%
MEDBANK	114 billion Yen ≤ TA < 1.14 trillion Yen	0%	13%	54%	70%
LARBANK	1.14 trillion Yen ≤ TA < 11.4 trillion Yen	20%	86%	46%	7%
HUGBANK	TA ≥ 11.4 trillion Yen	80%	1%	0%	0%

Notes: 114 billion Yen equal around 1 billion USD; CB: city banks, RB I: tier-one regional banks, RB II: tier-two regional banks, SB: shinkin banks.

4.3 Estimation Results

Table 5 reports the estimation results of equation (1) for both technical efficiency $\widehat{TE}$ as well as pure technical efficiency scores $\widehat{PTE}$ as dependent variables.[26] Column two and four show the results for a model including the explanatory variables which are usually used in the literature. Column three and five extend the estimates by including variables that may influence bank's efficiency in a low interest rate and unconventional monetary policy environment. This includes the net-interest margin, the securities to loan ratio, the share of government bonds and the ratio of non-interest operating income to total operating income. In addition, dummies for bank size and bank type are included.

Table 5 shows that all traditional control variables (*MS*, *NPL*, *ROAA*) are statistically significant with the expected sign, apart from the coefficient of *ROAA* which is statistically insignificant in the extended model. With rising market share (*MS*) (a larger share of deposits out of total deposits), the efficiency is larger. A higher non-performing loan ratio (*NPL*) is linked to a lower degree of efficiency. A higher return on average assets (*ROAA*) is linked to a higher degree of efficiency.

24 For a sample of Japanese commercial banks Altunbas *et al.* (2000) identify a positive impact of size - measured by total assets - on efficiency. However, for the case of Japanese shinkin banks Fukuyama and Weber (2009) find a negative relationship between size and bank's efficiency.

25 The bank size dummy thresholds were chosen in a way as to avoid a multi collinearity problem with the bank type dummies. All bank types include at least two different size groups.

26 Estimated using the *simarwilson* STATA command by Tauchmann (2016).

Table 5: Estimation Results

	TE (1)	TE (2)	PTE (1)	PTE (2)
MS	-0.0468*** [0.0162]	-0.0501*** [0.0174]	-0.0665** [0.0291]	-0.1603*** [0.0346]
NPL	0.0036*** [0.0006]	0.0047*** [0.0006]	0.0027*** [0.0006]	0.0050*** [0.0006]
ROAA	-0.0255*** [0.0052]	-0.0056 [0.0049]	-0.0160*** [0.0054]	0.0046 [0.0050]
NIM		-0.2173*** [0.0095]		-0.2565*** [0.0089]
SECLOAN		-0.2378*** [0.0089]		-0.1741*** [0.0092]
GOVSEC		-0.0356*** [0.0111]		-0.0168* [0.0101]
NIOI		-0.0031 [0.0042]		-0.0046 [0.0040]
MEDBANK	-0.0251*** [0.0053]	-0.0418*** [0.0051]	0.0822*** [0.0059]	0.0626*** [0.0054]
LARBANK	-0.0722*** [0.0107]	-0.1150*** [0.0108]	0.0705*** [0.0115]	0.0474*** [0.0118]
HUGBANK	-0.0883 [0.0741]	-0.1238* [0.0643]	0.0975 [0.0860]	0.1586* [0.0866]
RB I	-0.3006*** [0.0652]	-0.2286*** [0.0588]	-0.2637*** [0.0683]	-0.2446*** [0.0683]
RB II	-0.2748*** [0.0660]	-0.1691*** [0.0616]	-0.2417*** [0.0695]	-0.1931*** [0.0705]
SB	0.0923 [0.0650]	0.2036*** [0.0601]	0.0949 [0.0695]	0.1209* [0.0712]
Constant	1.1621*** [0.0668]	1.6225*** [0.0646]	1.0503*** [0.0708]	1.6510*** [0.0750]
Observations	5,823	5,215	5,618	5,030

Notes: Negative coefficients indicate positive impacts on efficiency and vice versa. Reference categories are SMLBANK and CB. Standard errors in brackets * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The net-interest margin (*NIM)* – which has been compressed by low interest rate and unconventional monetary policy – has decreased Japanese bank's efficiency (positive coefficient, significant at the one-percent level). The impact is rather large. A one percentage point decline of the net-interest margin reduces a bank's pure technical efficiency score by around 0.26 points ceteris paribus. This either indicates that the depressed competition due to the consolidation in the banking sector and/or the provision of low-cost liquidity by the Bank of Japan have reduced the pressure on banks to improve their efficiency, or the loss in their traditional source of income has constrained their ability to do so. Either way, declining short- and long-term interest rates had clearly a negative impact on Japanese banks' efficiency.

Shifting their portfolio from loans to securities has helped Japanese banks to mitigate the negative impact on efficiency. A higher ratio of securities to loans (*SECLOAN)* is associated with higher technical as well as higher pure technical efficiency (negative coefficients, significant at the one-percent level). Moreover, a higher share of government securities (*GOVSEC)* seems to have boosted efficiency (negative coefficients, significant at the one-percent level). This supports our presumption that in an environment of low private sector loan demand – and therefore increasing competition in the loan market[27] – a switch to the less resource consuming lending to the public sector has been lucrative for Japanese banks. The coefficient of the non-interest operating income to total operating income ratio *NIOI* is negative for both technical efficiency and pure technical efficiency,[28] but statistically insignificant at the common levels.

The results with respect to the impact of banks size on efficiency are indeterminate. Small banks are used as reference group. For technical efficiency, all coefficients for medium-sized, large and huge banks are negative and mostly statistically significant at the common levels. This suggests that a larger size is linked to higher technical efficiency.[29] However, the positive coefficients of *MEDBANK*, *LARBANK* and *HUGBANK* in the estimation model with $\widehat{PTE}$ indicate that pure technical efficiency of larger banks is lower compared to the reference category *SMLBANK*, i.e. small banks. The reversal of the coefficients' signs in the $\widehat{TE}$ and $\widehat{PTE}$ models implies that the positive scale efficiency effects of a larger size over-compensate the negative size impacts on pure technical efficiency. Hence our results suggest that the ongoing consolidation process in the Japanese banking sector has been reducing scale inefficiencies by increasing the size of banks, however, with the side effect of increasing pure technical inefficiencies.

Our estimation results also confirm our findings in Section 3 concerning the efficiency differences between the different types of banks. With city banks (CB) being used as a reference group, tier-one regional banks (RB I) are indicated to be the most efficient banks. This applies to both technical and pure technical efficiency (largest negative coefficients, significant at the one-percent level). Also tier-two regional banks (RB II) show a higher technical and pure technical efficiency than city banks (column 3 and 5), though the gap is smaller than for tier-two regional banks. In contrast, shinkin banks (SB) exhibit larger and

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[27] As of the beginning of the 2000s competition among banks in the loan business intensified, putting lending rates under pressure and further lowering interest margins. City banks have expanded their lending activities to rural areas, whereas regional banks have expanded to urban areas. Some regional banks have set up branches in neighbouring prefectures or major cities (Bank of Japan, 2006, 2008, 2012).

[28] This is in line with findings of DeYoung (1994) for commercial banks in the U.S.

[29] The negative coefficients of *MEDBANK*, *LARBANK* and *HUGBANK* mean that technical inefficiencies are lower as compared to the reference category *SMLBANK.*

statistically significant technical and pure technical inefficiencies than any other bank type. However, the coefficient is only statistically significant for two out of four specifications.

5 Conclusion and Policy Recommendation

Since the bursting of the Japanese bubble economy and increasingly since the Asian and Japanese financial crisis, Japanese banks have been under a persistent adjustment pressure. We have shown that the low-interest and unconventional monetary policy measures of the Bank of Japan have not only in the short term helped to prevent a financial meltdown. The very expansionary monetary policy has also undermined the traditional source of income of Japanese banks, which was strongly tilted toward credit provision to households and enterprises.

The Bank of Japans' monetary policy crisis management has also become an important driving force of a gradual consolidation process in the Japanese banking sector which has led to a declining number of banks, branches and regular employees. This suggests increasing efficiency due to increasing economies of scale. Alternatively, a lower degree of competition because of growing concentration and persistent low-cost liquidity provision by the Bank of Japan has contributed to declining efficiency.

Our analysis provides evidence in favour of significant efforts of banks to increase efficiency, in particular for regional banks. Yet, over time the erosion of the traditional sources of income is identified to have triggered losses in efficiency. In particular, for city banks, which have formed large financial conglomerates (so-called mega banks) the concentration process is likely to have gone too far, therefore contributing to declining efficiency. For the small regional and shinkin banks even a very drastic consolidation process seems not have been large enough to achieve sufficient efficiency gains.

The announced continuation of the ultra-expansionary monetary policy by the Bank of Japan is likely to accelerate the concentration process among banks, because the interest rate margin can be expected to become further depressed and the role of public bonds as an instrument to stabilize profits will be further declining. Our analysis therefore suggests, that Japanese monetary policy crisis management will from now on further contribute to a declining efficiency in the Japanese banking sector. Because concentration which is accompanied by declining pure technical efficiency is linked to welfare losses, a gradual exit from ultra-expansionary monetary policy is recommended. This would ensure more efficient allocation of capital in the Japanese economy, which is based on competition among banks rather than low-cost liquidity provision by the central bank.

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A Appendix

A1. Estimating Efficiency Scores

We assume as set of banks each producing y outputs using x inputs. The production technology is given by S and models the transformation of inputs $x \in \mathbb{R}_{+}^{N}$, into outputs $y \in \mathbb{R}_{+}^{M}$. Hence, S models the set of all feasible input/output vectors:

$$S = \{(x, y): x \text{ can produce } y\} \tag{2}$$

Farrell's (1957) output measure of technical efficiency models the maximum proportionate increase in output for a given set of input x and technology: [30]

$$\theta(x, y) \equiv sup\,\{\theta: (x, \theta y) \in S\} \tag{3}$$

with $\theta(x, y)$ being greater than or equal to one. Note, that the Farrell output-oriented technical efficiency measure is equivalent to the reciprocal of Shephard's (1970) output distance function:

$$D_O(x, y) \equiv inf\,\{\theta: (x, y/\theta) \in S\} \tag{4}$$

with $D_O(x, y) \leq 1$ ((Färe *et al.*, 1985). Figure 10 illustrates the technical efficiency concept for the one-input-one-output case using output-oriented measures. Bank A, B, C and D produce output y using input x and an unknown technology S. The line S_{CRS} represents the technology frontier assuming constant-returns-to-scale. Following Farrell's (1957) definition bank A is technically efficient as it lies at the technology frontier S_{CRS} and produces the optimal output y_A^* given input x_A. Bank B, C and D are technically inefficient as the output is below their optimal level y_B^*, y_C^* and y_D^*. Farrell's (1957) output-oriented score of technical efficiency correspond to the ratios $TE_B^{CRS} = 0y_B^*/0y_B$, $TE_C^{CRS} = 0y_C^*/0y_C$ and $TE_D^{CRS} = 0y_D^*/0y_D$. Technical efficiency score $TE = 1$ if the bank is technically efficient and $TE > 1$ if the bank is technically inefficient.

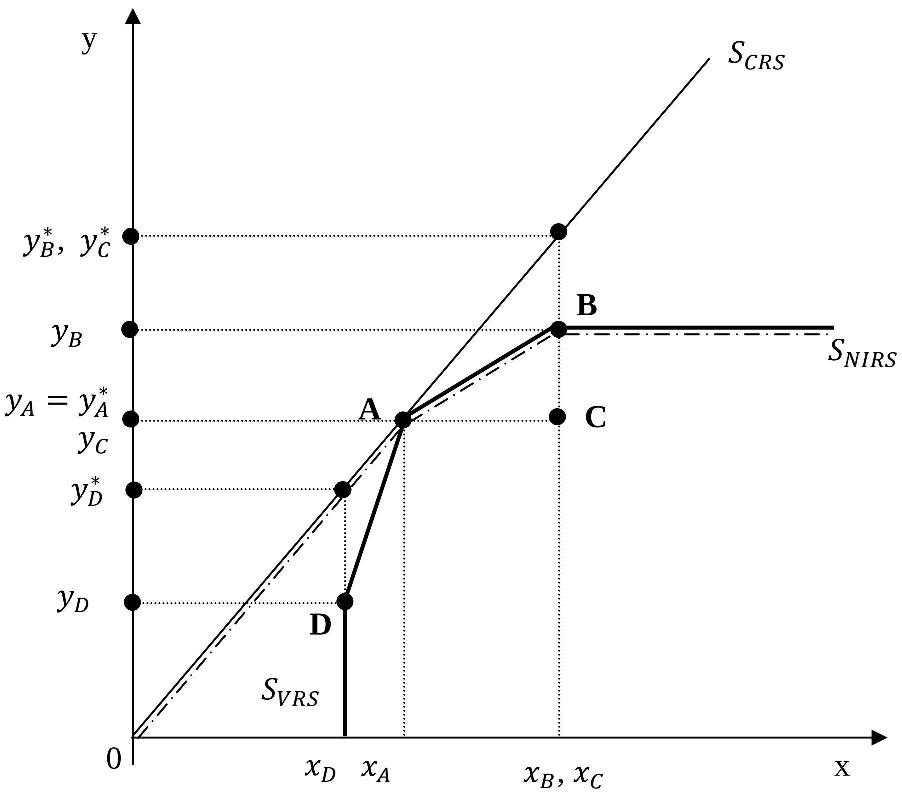
The assumption of a constant-returns-to-scale technology frontier is only appropriate if all banks are operating at an optimal scale. However, it can be shown that if banks are not operating at their optimal scale the technical efficiency estimate is confounded by scale inefficiencies. Charnes *et al.* (1978) and Banker *et al.* (1984) extend the technical efficiency

[30] Input-oriented measures focus on the optimal (i.e. minimal) set of inputs for a target output set.

concept and propose a decomposition of TE into *pure technical efficiency* (PTE) and *scale efficiency* (SE) by relaxing the constant-returns-to-scale assumption for the underlying technology:

$$TE = PTE \times SE \tag{5}$$

Figure 10: Output-Oriented Technical Efficiency Measure



Notes: Illustration of output-oriented technical efficiency measure and components. Lines S_{CRS}, S_{VRS} and S_{NIRS} correspond to the constant-returns-to-scale, variable-returns-to-scale and non-increasing-returns-to-scale production frontiers, respectively.

Assuming banks A, B, C and D are using a variable-returns-to-scale technology[31] as indicated in Figure 10 by the S_{VRS} frontier, bank A, B and D would be technically efficient as all three are operating at the production frontier ($TE_A^{VRS} = TE_B^{VRS} = TE_D^{VRS} = 1$). However, banks B and D are technically inefficient as regards to the constant-returns-to-scale frontier S_{CRS} ($TE_B^{CRS} > 1$ and $TE_D^{CRS} > 1$). The reason for the difference is that B and D are not operating

[31] Variable-returns-to-scale encompasses both decreasing as well as increasing-returns-to-scale.

at their optimal scale hence they exhibit scale inefficiencies. TE^{VRS} can hence be regarded as measuring *pure technical efficiency* PTE. The scale efficiency measure corresponds to:

$$SE = \frac{TE^{CRS}}{TE^{VRS}} \tag{6}$$

As regards to our example illustrated in Figure 10 the (overall) technical efficiency score of bank C corresponds to $TE_C = TE_C^{CRS} = 0y_C^*/0y_C$, the pure technical efficiency score to the ratio $PTE_C = TE_C^{VRS} = 0y_B/0y_C$ and the scale efficiency score to $SE_C = 0y_C^*/0y_B$.

Though the scale efficiency score SE enables to determine whether scale inefficiencies exist or not, it does not indicate whether the bank is operating under increasing or decreasing returns to scale. To determine the nature of the scale inefficiencies a third technology frontier with the assumption of non-increasing-returns-to-scale must be imposed (line S_{NIRS} in Figure 10) and efficiency scores TE^{NIRS} have to be estimated (Coelli *et al.*, 2005; Banker *et al.*, 1984). The nature of scale inefficiencies are determined by comparing TE^{NIRS} and TE^{VRS}. If $TE^{NIRS} = TE^{VRS}$ the bank exhibits decreasing-returns-to-scale, if $TE^{NIRS} \neq TE^{VRS}$ it is operating under increasing-returns-to-scale.[32] Referring to our example banks C and B depict decreasing-returns-to-scale and bank D increasing-returns-to-scale.

A2. Data Envelopment Analysis

The output distance functions $D_O^t(x_i^t, y_i^t)$ needed to construct technical efficiency scores can be estimated using either econometric or mathematical programming techniques with both differing in the way the efficiency frontier is estimated (Coelli *et al.*, 2005). The former, known as *Stochastic Frontier Analysis*, is a parametric method imposing a functional form on the production frontier and econometrically estimating the function's parameters. It is susceptible to misspecifications. The second approach is a linear programming technique constructing the efficiency frontier by enveloping input/output data of the decision making unit (DMU), with the non-parametric frontier formed by the "best practice" DMUs (Drake *et al.*, 2006). The approach is referred to as *Data Envelopment Analysis* (Charnes *et al.*, 1978).

The basic CRS output-oriented DEA model to estimate the relative efficiency at time t_1 can be described as follows. Assuming *N* inputs and *M* outputs for each bank i with $i = 1 \ldots, L$ the linear programming model is given by:

[32] Note that output- and input-oriented models may lead to different results in the findings of the nature of scale inefficiencies. See Golany and Yu (1997) for how to treat this problem.

$$[D_O^{t1}(x_i^{t1}, y_i^{t1})]^{-1} = \max_{\theta_i \lambda_i} \theta$$

$$\theta y_{im}^{t1} \leq \sum_{j=1}^{L} \lambda_j^{t1} y_{mj}^{t1}, \qquad m = 1 \dots, M,$$

$$\sum_{j=1}^{L} \lambda_j^{t1} x_{nj}^{t1} \leq x_{in}^{t1}, \qquad n = 1 \dots, N,$$

$$\lambda_i^{t1} \geq 0 \qquad i = 1 \dots, L.$$

where $x_i^{t1} = (x_{i1}^{t1}, \dots, x_{in}^{t1}, \dots x_{iN}^{t1})' \in \mathbb{R}_+^N$ is the set of inputs for each bank i at time t and $y_i^{t1} = (y_{i1}^{t1}, \dots, y_{im}^{t1}, \dots y_{iM}^{t1})' \in \mathbb{R}_+^M$ the set of outputs; $\lambda_i^{t1} = (\lambda_1^{t1}, \dots, \lambda_L^{t1})'$ is a vector of bank-specific weights conveying information on each bank's benchmark comparators.[33] To estimate scale efficiencies and to determine their nature the above described DEA model must additionally be run with (1) variable-returns-to-scale and (2) non-increasing-returns-to-scale imposed. Hence, the following additional restriction must be included:

$$\sum_{j=1}^{L} \lambda_i^{t1} = 1 \text{ (for VRS)}$$

$$\sum_{j=1}^{L} \lambda_i^{t1} \leq 1 \text{ (for NIRS)}$$

A3. Detailed Results

Table 6: Efficiency Scores City Banks (1999-2015)

Year	TE	PTE	SE	IRS	CRS	DRS
1999	1.114	1.108	1.005	0%	78%	22%
2000	1.150	1.132	1.016	11%	33%	56%
2001	1.141	1.122	1.017	14%	43%	43%
2002	1.224	1.183	1.034	14%	43%	43%
2003	1.182	1.159	1.019	29%	43%	29%
2004	1.190	1.121	1.062	14%	29%	57%
2005	1.166	1.127	1.035	0%	33%	67%
2006	1.201	1.169	1.027	33%	33%	33%
2007	1.195	1.144	1.043	33%	33%	33%
2008	1.195	1.168	1.023	0%	33%	67%
2009	1.168	1.158	1.008	33%	33%	33%
2010	1.218	1.167	1.044	33%	50%	17%
2011	1.155	1.157	0.998	0%	50%	50%
2012	1.173	1.176	0.997	33%	50%	17%
2013	1.167	1.143	1.021	0%	40%	60%
2014	1.158	1.129	1.026	0%	60%	40%
2015	1.155	1.127	1.026	40%	40%	20%
Average	1.172	1.146	1.023	17%	43%	40%

Notes: TE: technical efficiency score estimated assuming constant returns to scale; PTE: pure technical efficiency estimated assuming variable returns to scale; SE: scale efficiency; values above unity indicate inefficiencies, corrected values based on bootstrapping; IRS/CRS/DRS: share of banks operating under increasing-returns-to-scale/constant-returns-to-scale/decreasing-returns-to-scale; *Source:* Authors' calculations.

33 Note that an efficient bank i with $\theta_i = 1$ will be its own benchmark, hence λ_i includes only zeros except for a 1 in the ith position (Loukoianova, 2008)

Table 7: Efficiency Scores Regional Banks I (1999-2015)

Year	TE	PTE	SE	IRS	CRS	DRS
1999	1.147	1.132	1.013	75%	6%	19%
2000	1.149	1.140	1.008	58%	13%	29%
2001	1.126	1.122	1.004	69%	21%	10%
2002	1.069	1.074	0.996	64%	14%	21%
2003	1.068	1.072	0.996	64%	12%	24%
2004	1.080	1.084	0.996	79%	10%	11%
2005	1.085	1.086	0.999	74%	10%	16%
2006	1.103	1.102	1.001	79%	6%	15%
2007	1.079	1.081	0.997	77%	13%	10%
2008	1.130	1.126	1.003	80%	3%	17%
2009	1.102	1.102	1.000	66%	3%	31%
2010	1.135	1.129	1.005	74%	3%	23%
2011	1.094	1.094	0.999	89%	7%	5%
2012	1.082	1.087	0.995	65%	10%	26%
2013	1.101	1.105	0.996	82%	7%	11%
2014	1.102	1.105	0.997	64%	14%	22%
2015	1.106	1.105	1.001	54%	14%	32%
Average	1.102	1.102	1.000	71%	10%	19%

Notes: Bias corrected values based on bootstrapping procedure; TE: technical efficiency score estimated assuming constant-returns-to-scale; PTE: pure technical efficiency estimated assuming variable-returns-to-scale; SE: scale efficiency; values above unity indicate inefficiencies; IRS/CRS/DRS: share of banks operating under increasing-returns-to-scale/constant-returns-to-scale/decreasing-returns-to-scale; *Source:* Authors' calculations.

Table 8: Efficiency Scores Regional Banks II (1999-2015)

Year	TE	PTE	SE	IRS	CRS	DRS
1999	1.159	1.151	1.007	92%	0%	8%
2000	1.146	1.134	1.010	86%	0%	14%
2001	1.134	1.128	1.005	84%	3%	13%
2002	1.081	1.080	1.002	83%	8%	8%
2003	1.077	1.076	1.001	79%	3%	18%
2004	1.082	1.078	1.004	85%	8%	8%
2005	1.092	1.085	1.007	93%	5%	3%
2006	1.103	1.096	1.006	93%	8%	0%
2007	1.086	1.082	1.004	90%	10%	0%
2008	1.128	1.120	1.007	81%	8%	11%
2009	1.104	1.098	1.006	81%	8%	11%
2010	1.131	1.120	1.010	86%	8%	5%
2011	1.103	1.092	1.011	93%	5%	3%
2012	1.078	1.081	0.997	73%	12%	15%
2013	1.097	1.095	1.002	87%	8%	5%
2014	1.105	1.103	1.001	74%	13%	13%
2015	1.110	1.105	1.004	70%	11%	19%
Average	1.105	1.099	1.005	84%	7%	9%

Notes: Bias corrected values based on bootstrapping procedure; TE: technical efficiency score estimated assuming constant-returns-to-scale; PTE: pure technical efficiency estimated assuming variable-returns-to-scale; SE: scale efficiency; values above unity indicate inefficiencies; IRS/CRS/DRS: share of banks operating under increasing-returns-to-scale/constant-returns-to-scale/decreasing-returns-to-scale; *Source:* Authors' calculations.

Table 9: Efficiency Scores Shinkin Banks (1999-2015)

Year	TE	PTE	SE	IRS	CRS	DRS
1999	1.290	1.246	1.037	96%	2%	2%
2000	1.322	1.284	1.031	93%	2%	5%
2001	1.313	1.278	1.028	95%	3%	2%
2002	1.259	1.238	1.018	96%	2%	2%
2003	1.262	1.238	1.019	95%	1%	4%
2004	1.274	1.244	1.025	95%	2%	3%
2005	1.283	1.249	1.028	96%	1%	2%
2006	1.315	1.279	1.029	96%	1%	2%
2007	1.312	1.263	1.040	97%	1%	1%
2008	1.352	1.295	1.044	96%	3%	1%
2009	1.326	1.273	1.041	96%	2%	1%
2010	1.389	1.312	1.060	97%	1%	1%
2011	1.373	1.308	1.051	99%	1%	0%
2012	1.377	1.323	1.041	97%	1%	2%
2013	1.399	1.344	1.042	97%	1%	1%
2014	1.412	1.365	1.035	95%	2%	4%
2015	1.394	1.338	1.045	92%	2%	6%
Average	1.331	1.286	1.036	96%	2%	2%

Notes: Bias corrected values based on bootstrapping procedure; TE: technical efficiency score estimated assuming constant-returns-to-scale; PTE: pure technical efficiency estimated assuming variable-returns-to-scale; SE: scale efficiency; values above unity indicate inefficiencies; IRS/CRS/DRS: share of banks operating under increasing-returns-to-scale/constant-returns-to-scale/decreasing-returns-to-scale; *Source:* Authors' calculations.