Aduba and Izawa *Financ Innov* (2021) 7:57
https://doi.org/10.1186/s40854-021-00268-8

Financial Innovation

RESEARCH

Open Access

Impact of learning through credit and value creation on the efficiency of Japanese commercial banks

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Abstract

This study investigates the learning curve of commercial banks regarding the efficiency of credit and value creation. However, current empirical methods for accessing the learning curve in organizations are not suitable for use in financial institutions. Considering bank-specific characteristics, we *introduce a dynamic learning curve using a cost function adjusted to capture learning-by-doing in banks.* Using the model, we test several hypotheses on the impact of bank intermediary experience (learning) on the efficiency of credit and value creation in Japanese commercial banks. The findings show that bank intermediary learning significantly improves the cost efficiency gain in the gross value created, total credit created, and investment. However, bank intermediary experience has no significant effect on the efficiency of the economic value created for all the banks analyzed. These findings have practical implications for evaluating cost dynamics in bank credit and value creation, risk management, lending to the real sector, and shareholder value creation.

Keywords: Bank experience, Credit creation, Investment, Japanese banks, Learning curve, Value creation

JEL Classification: G21, G32, M11

Introduction

There is a growing body of evidence suggesting that bank *experience* could contribute to improved bank performance. For example, bank experience has been found to significantly improve performance when: competition triggered learning (Barnett et al. 1994), merger-acquisition triggered knowledge integration and codification, thereby reducing bank failure rates (Zollo and Singh 2004), and survival-enhancing learning resulting from both success and failure experience potentially improved camel ratings (Kim et al. 2009). Recently, a study by Bush (2015) found that bank operating experience could create a mechanism that reduces the cost of producing financial services and improves the efficiency of the banking sector. The rationale is that bank production [intermediation] experience resulting from the sustained effort in value addition and asset transformation processes create knowledge that lowers the cost of producing financial services and ultimately improves bank performance [efficiency].

As a financial intermediary, banks create specialized commodities, such as loans and other asset portfolios, using labor and capital goods, and sell them at a price that is expected to cover the direct cost of production, including the opportunity cost (Benston and Smith 1976). The process of creating these specialized financial commodities may include risk management (Berger and Humphrey 1992), service/utility provision (Grigorian and Manole 2006), and value addition (Drake et al. 2006). These processes involve extensive documentation, information gathering, monitoring, and other inputs that incur substantial costs. Rational banks minimize these input costs and realize cost efficiency. Cost efficiency in the banking sector is sometimes associated with scale economies or bank size (Asongu and Odhiambo 2019; Berger and Mester 1997; Bossone and Lee 2004; Clark 1984). However, organizational learning literature suggests that cost efficiency could also be associated with production experience (Argote 2012).

Moreover, economies of learning (experience) differ from economies of scale in that the former explains cost efficiency in relation to accumulated knowledge in human capital or technology, whereas, the latter links cost efficiency to large scale production at a point in time (Besanko et al. 2013). In the context of loan production, for example, the efficiency gains from experience could cause a decline in the amount of monitoring labor (cost) required for the same volume of loans as the bank recognizes what information is crucial and sufficient for efficient monitoring, or as more effective screening technologies and characteristics of the applicant population are learned over time (Bush 2015). Additionally, to the extent that financial firms can capture knowledge gained from experience, changing processes, and organizational structure, policymakers would not want these experienced firms to disappear as this could lead to loss of information capital (i.e. information on existing borrowers), which has been adequately captured in these financial firms (Bush 2015).

The foregoing describes learning-by-doing, which is defined as a mechanism that reduces the costs of production by leveraging on the experience gained in the production process. This phenomenon has been quantified using the learning curve theory. The learning curve theory suggests that unit cost decreases with cumulative experience (output) at a uniform rate called the learning rate. The learning curve, which is designed to explain efficiency in the manufacturing process, has found limited application in the financial sector (banking sector). Applying the learning curve to banks poses a challenge because outputs in banks are either micro products (Clark 1984) and/or a multiproduct (Mörttinen 2005). Empirical banking literature suggests that the choice of bank outputs largely depends on the study objective. In this study, we theorized that the process of creating credit/investment (converting deposit to loans and securities), creating value (generating economic returns such as shareholder returns and gross value added), and managing risk in banks generate knowledge that may reduce the amount (cost) of inputs, labor, physical capital, and financial capital used. A policy question is whether bank experience accounts for cost efficiency in bank productions. More specifically, whether bank experience have significant impact on the efficiency of credit and value creation. The answer might improve our understanding of organizational learning in the banking sector, and more importantly, the role of bank intermediary experience in cost efficiency gain in banks.

Motivated by the above question, we investigate the efficiency gains that might result from learning-by-doing in banks using a sample of Japanese commercial banks. [1] This study has two main contributions; first, we introduce a cost function adjusted to capture learning in bank production, while considering bank-specific features. Second, and arguably the most significant contribution, we test for bank experience in *credit creation*, proxied by the total amount of loans and other interest-bearing investment, and *value* creation, proxied by economic value added (EVA) and gross value added (GVA). These proxies capture the fundamental roles of the banking sector and, in our opinion, should provide empirical outcome that is useful to both bank managers and policymakers. Our findings show that bank intermediary experience significantly accounts for cost efficiency gain in loan production, security investment, and gross value added (GVA). However, bank intermediary experience does not have significant effect on the efficiency of shareholder returns (EVA).

The remainder of this paper is organized as follows. Second section reviews relevant literature on the measurement of productivity using the learning curve theory. Third section presents the empirical approach and the data. Fourth section presents the empirical results and discussion. Final section presents the implication of the findings, recommendation, conclusion, caveat, and future research directions.

Related literature

Learning in industry

The learning curve theory proposed and applied by Wright (1936), Arrow (1962) and others, has been used to quantify cost reduction in the form of changes in unit inputs (such as labor) required in the production process. These changes in unit input requirement not attributable to *fluctuations in prices* of variable inputs or *scale economies*, could be explained by the efficiency gain over time in the working process (Aduba and Asgari 2020). This efficiency gain has been linked to the improvement in experience with routines of the production tasks, information sharing, re-engineering and redesigning, efficient production scheduling, efficient supply chain management, and strategic decision making. This phenomenon is well documented in the manufacturing industry (especially at the plant or factory level) and has been described in the literature as *learning-by-doing* (Arrow 1962; Bahk and Gort 1993; Balasubramanian and Lieberman 2010; Irwin and Klenow 1994; Levitt et al. 2013).

Factors that contribute to learning-by-doing in organizations are diverse. However, the *knowledge* generated during the production or service process seems to be the most crucial factor for organizational learning. This knowledge, scholars argue, may turn out to be a sustainable competitive advantage of the organization (Argote and Ingram 2000). Furthermore, this knowledge (*know-what, know-how, know-why, and know-who*) could result from within or outside the organizations and could either be process improvement or product innovations, that is, improvement in product/service quality, or both (Bahk and Gort 1993; Darr et al. 1995). Nevertheless, other deliberate actions or managerial levers such as direct labor hiring, service innovation or setting up specific units

[1] To our knowledge, only Bush (215) has directly measured bank performance using bank operating experience in a manner directly implying learning-by-doing.

(R&D) to create technological knowledge about a production function through simple or rigorous scientific experiments, could also accelerate the learning process in organizations (Lapré and Van Wassenhove 2001).

Measuring organizational learning begins with defining and operationalizing the learning [experience] term. The literature contains several definitions of organizational learning. However, in the context of this research, the definition proposed by Fiol and Lyles (1985) appears to have the key elements needed. According to these authors, "organizational learning is the process of improving actions through better knowledge and understanding." The productivity gains that stem from improving actions through better knowledge and understanding of the production or service process in organizations is significant (Argote 2012). To measure this productivity gain through knowledge requires operationalizing the knowledge term. The initial standard measure of knowledge or experience in the learning curve formulation is the cumulative number of units produced or services delivered, defined in terms of physical, tangible output or volume of shipment in factories. However, as literature on the learning curve advanced, other variants of outputs such as defect rate, quality, number of projects completed, total-factor productivity (TFP), service time and value-added (defined in financial term) were used to measure learning-by-doing in manufacturing and service organizations. Consequently, the learning curve has been applied across several industries: in pizza franchises using cumulative pizzas produced (Darr et al. 1995), in the hotel industry using the number of available rooms (Baum and Ingram 1998), in factories using TFP (Lapré and Van Wassenhove 2001), in manufacturing at 3-digit ISIC using value-added (Aduba and Asgari 2020; Asgari and Yen 2009; Bahk and Gort 1993; Karaoz and Albeni 2005; Pramongkit et al. 2000, 2002), in hospitals using the number of successful cardiac surgeries performed (Ramanarayanan 2011), and in many other industries.

Learning in the financial sector (banks)

Two strands of literature attempt to link bank experience with improved performance. The first strand appears to connect bank performance with economies of scale and economies of specialization resulting from bank learning. For example, Benston and Smith (1976) argued that financial intermediaries like banks achieved economies of scale as a consequence of specialized skills where designed routines and information about existing consumers can be used to process other consumers and a marginal reduction in costs are expected to occur. Similarly, Clark (1988) also argued that when information on a previous borrower is reused to make other lending decisions, as long as the cost of reuse is less than the independent cost of production, reuse can help reduce the incremental cost of extending additional credits. Studies on economies of scale and scope in banking also link cost efficiency with human capital and technology embodied in financial capital infrastructure (Bossone and Lee 2004; Clark 1988). These studies do not directly measure bank learning; however, at the heart of their argument is an indirect reference to bank experience reducing costs over time. Succinctly, Arnould and Anjan (1997) posit that the ability of market participants (including banks) to appreciate the payoff implications of new security (investment) will likely depend on their *experience* with existing securities.

The second strand of literature applies the theory of organizational learning to evaluate the role of bank experience in productivity improvement. Using various conceptual frameworks, these studies link bank experience with improved bank performance. Barnett et al. (1994) examined the performance of Illinois banks in terms of the year-to-year changes in returns on average assets (ROAA). The authors used a dynamic performance model that incorporates competition and takeover rate of banks in Illinois. They found that performance is negatively related to a bank's rate of being taken over only in profitable banks, and that competition can reduce a bank's ROAA by 0.08. They also found that bank performance was related to experience (the historical path followed) and the distinctive competencies of the banks studied. Relatedly, a study of deliberate learning in the corporate acquisition of banks in the USA was undertaken by Zollo and Singh (2004). The authors defined performance as return on assets (ROA) of an acquiring bank relative to the average ROA of banks in the same geographical area as the acquiring bank, arguing that productivity could result from two sources of experience: knowledge codification and acquisition experience. Knowledge codification was operationalized as the sum of acquisition tools developed by the acquiring bank, whereas, acquisition experience was operationalized by the number of previous acquisitions completed. They found that knowledge codification significantly and positively influences acquisition performance; however, acquisition experience does not.

Kim et al. (2009) studied survival enhancing learning derived from the bank's own extreme performance experiences (success and recovery). The authors defined success experience as "the cumulative history of exceptionally strong performance of banks," and recovery experience as "a type of failure experience that occurred when banks recovered from extremely poor performance." Both experience terms were operationalized using CAMELS (capital adequacy, asset quality, management, earnings, liquidity, and sensitivity) ratings per discount factor. They argued that bank failure rate is a function of cumulative success and recovery experiences, in addition to organizational characteristics, industry and environmental conditions, operating experience, and so on. Their findings indicated that both success and failure experiences generate survival-enhancing learning in the banks, only after a certain experience is obtained. Additionally, De Young (2002) introduced a framework that allows learning to improve bank performance through the general experience and technology-based experience effects. Testing the framework on a sample of internet-based banks in comparison to traditional branching banks in the US, the author found strong evidence of the general experience effect that is available to new banking start-ups and a weak effect of technology-based experience on profitability and performance in general. Finally, Bush (2015) tested for experience effect in bank production using operating time (years since the charter was granted) as a measure of experience. The author found that cost reduces by 10.9 per cent with 10 per cent gains in the experience of a bank approximately one year old.

However, another strand of literature focuses on the development of learning frameworks for financial risk analysis, and credit misclassification and scoring using innovation or technology-based approaches, such as computing algorithms and machine learning for improving performance in the financial sector. For example, researchers have employed varieties of machine learning technologies to detect and respond to systemic risks in early fashion that have consequences for policy consolidations (Kou et al. 2019). Besides, regarding screening the potential credit repayment behavior of applicants, reject inference and machine learning techniques have also been deployed in financial institutions. In a recent study, Shen et al. (2020) have proposed a novel three-stage reject inference learning framework using unsupervised transfer learning and a three-way decision theory that was found to demonstrate superior results for credit management applications, in comparison with other reject inference methods. Thus far, we have reviewed the various ways in which learning in the financial institutions are conceptualized. In what follows, we develop a framework based on the theory of learning curve to better understand the role of experience in bank production technologies (performance).

Research methods

The motivation behind applying the learning curve in organizations is that it can show the extent to which organizational performance improves with experience. This improvement or gain in experience is quantified using either of the three specifications: a power function (1), a production function embedded in a power function (2), and/or a production function that incorporates an experience term (3).[2]

$$\tau_t = \theta . X_t^{-\varnothing} \tag{1}$$

$$\tau_t = \omega . X_t^{\varnothing} . L_t^{\vartheta} \tag{2}$$

$$Q_t = \Delta_t . G\left(X_t^{\varnothing}\right) . L_t^{\alpha} . K_t^{\beta} \tag{3}$$

However, due to industry features, none of these empirical specifications is suitable for evaluating the learning curve in banks. Taking a different approach, we formulate an empirical model similar to those used in banking efficiency literature. Our empirical model incorporates experience term which allows learning to improve bank performance. We posit that the learning characteristics of banks can be modelled if bank experience in credit and value creation are correctly operationalized.[3] We derived a cost-efficiency function from a Cobb-Douglass production function with three inputs: physical capital, ψ, deposits, and other borrowed fund, D, and financial capital or equity, K. This can be expressed as;

$$\varnothing = \beta_0 \psi^{\beta_1} . D^{\beta_2} . K^{\beta_3} \tag{4}$$

The bank's total cost of producing output $\varnothing$ is;

$$₵ = w_p \psi + w_d D + w_k K \tag{5}$$

If$₵ = f(\emptyset)$, then the constrained output maximization is;

[2] Where X_t is a cumulative output (a proxy of experience) represented by the chosen output. τ_t is the cost required to produce an additional unit of output at time, θ is the cost required to produce the first unit,Q_t is the output level at time, ∇_t is the current level of knowledge and L_t, W_t, and K_t are physical labour, wage rate, and capital employed, respectively.

[3] Our empirical model differs from that of Bush (2015) in two ways; (1) input prices, and (2) by choice of experience terms.

Maximize

$$\varnothing = \beta_0 \psi^{\beta_1} . D^{\beta_2} . K^{\beta_3} \tag{6}$$

s.t.

$$\widehat{C} = w_p \psi + w_d D + w_k K \tag{7}$$

The composite function of the constrained equation becomes;

$$\xi = \emptyset + \eta \left(\widehat{C} - w_p \psi - w_d D - w_k K \right) \tag{8}$$

where η is the lagrangian multiplier.

It can be shown by derivative, that the bank's total cost function in (5) expressed in terms of input prices w_p, w_d, w_k and output $\varnothing$ is[4];

$$C = e^{\omega} . \left\{ w_p^{\frac{\beta_1}{(\beta_1+\beta_2+\beta_3)}} . w_d^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} . w_k^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} \right\} . \emptyset^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \tag{9}$$

where $e^{\omega} = \left\{ \left(\frac{1}{\beta_0} \right) \left[\left(\frac{\beta_1}{\beta_2} \right)^{\beta_2} \left(\frac{\beta_1}{\beta_3} \right)^{\beta_3} + \left(\frac{\beta_2}{\beta_1} \right)^{\beta_1+\beta_3} \left(\frac{\beta_3}{\beta_1} \right)^{\beta_3} + \left(\frac{\beta_1}{\beta_2} \right)^{\beta_2} \left(\frac{\beta_3}{\beta_1} \right)^{\beta_1+\beta_2} \right] \right\}^{\frac{1}{(\beta_1+\beta_2+\beta_3)}}$.

For convenience, the final total cost function (9) for bank *i* at time *t*, with bank-specific production technology adjusted for asset quality (risk) *R* can be expressed as[5];

$$C_{t,i} = e^{\omega} . \emptyset_{t,i}^{\beta_\emptyset} . \prod_s w_{s,t,i}^{\beta_s} . R_{t,i}^{\beta_r} \tag{10}$$

And taking the natural log of (10) will yield the empirical estimation form as;

$$lnC_{t,i} = \omega + \beta_\emptyset ln\emptyset_{t,i} + \sum_s (\beta_s) \, lnw_{s,t,i} + \beta_r lnR_{t,i} + \varepsilon_{t,i} \tag{11}$$

where R_i is asset quality proxied by the level of non-performing loans. The level of non-performing loan, in recent time, has become a crucial quasi-fixed input in modelling bank production used as a control variable for risky behavior in banks (J. Hughes and Mester 2014; Radić 2015). ε_i is the stochastic term.

Following empirical literature on the learning curve, we hypothesized that *unit cost will decrease with cumulative output* (Aduba and Asgari 2020; Darr et al. 1995; Karaoz and Albeni 2005; Levitt et al. 2013). Therefore, from (11), a cost function that incorporates experience (learning) can be specified as;

$$\ln\Gamma_{t,i} = \omega + \beta_\varnothing \ln\widehat{\varnothing}_{t-1,i} + \sum_s \beta_s \ln w_{s,t,i} + \beta_r \ln R_{t,i} + \varepsilon_{t,i} \tag{12}$$

where $\Gamma_{t,i} = \left(\frac{C_{t,i}}{\emptyset_{t,i}} \right)$ is the cost required to produce an additional unit of output. $\widehat{\varnothing}_{t-1,i}$ is the lagged cumulative output produce through time t, proxied for experience gained with bank production or financial intermediation services. Learning is measured by a

[4] See appendix A for the full details of the derivation.

[5] The alternative to Eq.(10) will be to treat equity capital as quasi-fixed input and minimize cost condition on the level of equity K. In this case, Eq. (10) will include equity level K, but exclude cost of equity. However, using full trans-log cost function A23 in appendix A, we can derive the shadow price of equity w_k using A24 in appendix A. Hence, we treated Eq. (10) as a full economic cost function with observable factor prices.

significant negative coefficient of the experience term ($\beta_{\varnothing}$). A significant negative $\beta_{\varnothing}$ in (12) implies unit cost decreases as experience is gained.

It is possible to approximate (12) using a cubic function to allow for the dynamic estimation of annual learning rates. [6] This can be expressed as;

$$ln\Gamma_{t,i} = \omega + \beta_{\varnothing 1} ln\left(\widehat{\varnothing}_{t-1,i}\right) + \beta_{\varnothing 2} ln\left(\widehat{\varnothing}_{t-1,i}\right)^{2} + \beta_{\varnothing 3} ln\left(\widehat{\varnothing}_{t-1,i}\right)^{3} + \sum_{s} (\beta_s) lnw_{s,t,i} + \beta_r lnR_{t,i} + \varepsilon_{t,i} \tag{13}$$

The first derivative of (13) with respect to $ln\widehat{\varnothing}_{t-1,i}$ yield learning elasticity ($\Omega_{t,i}$) expressed as;

$$\Omega_{t,i} = \frac{\partial (ln\Gamma_{t,i})}{\partial \widehat{\varnothing}_{t-1,i}} = \beta_{\varnothing 1} + 2.\beta_{\varnothing 2} ln\widehat{\varnothing}_{t-1,i} + 3.(\beta_{\varnothing 3} ln\widehat{\varnothing}_{t-1,i})^{2} \tag{14}$$

Equation (14) enables us to disentangle annual learning rates (progress ratio δ_t) of bank i at time t using a progress function expressed in (15)

$$\delta_{t,i} = 2^{\Omega_{t-1,i}} \tag{15}$$

For a progressive learning bank, δ_t lies between 0 and less than 1 ($0 < \delta_t < 1$). For all $\delta_{t,i} \geq 1$ implies no learning has occurred in the domain of the output proxied for the cumulative experience. This means that unit cost increase as output accumulates over time.

Outputs: definition and measurement of experience in bank production

In addition to developing the appropriate framework to study the learning curve in banks, the other task is defining the appropriate outputs in banks that capture banks production experience. This is because outputs in banks depend on the study approach and the bank production technologies adopted. Defining production technology in banks begins with operationalizing the role of banks. Bank operations generally cover three important elements: profit maximization (risk management), service provision (intermediation, and utility provision), and value addition (Berger et al. 1992; Grigorian et al. 2006; Drake et al., 2006). To study the learning curve of banks, however, we combined these three elements and defined bank inputs and outputs according to the value-added and intermediation approach. However, according to these two definitions, not all outputs qualify as experience terms.

Experience terms in learning curve studies are usually operationalized in terms of widgets of outputs and their cumulative values. This is problematic in the case of banks because outputs (the charge for services) are somewhat tricky. To overcome this difficulty, we identified bank outputs that improve when banks acquired knowledge by producing these specific outputs. [7] Following this argument, we classify the role of banks in two broad ways: *value creation* and *credit creation* (investment or risk management). We illustrate this concept using Fig. 1.

[6] The cubic learning function is especially important for estimating the dynamic annual learning rates (Badiru 1992; Karaoz and Albeni 2005, Aduba and Asgari 2020).

[7] The list of outputs considered is by no means exhaustive.

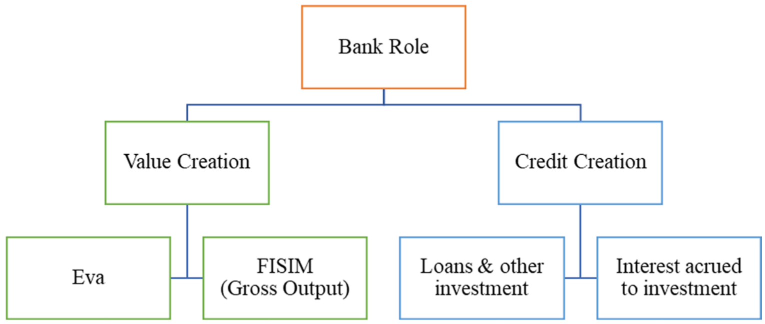

Fig. 1 Conceptual framework (source; author)

Value creation

To measure the learning curve of banks in the domain of value creation, we identified two outputs: EVA ($\varnothing_{eva}$), and GVA (FISIM, $\varnothing_{fisim}$). [8] By definition, EVA captures shareholder value (returns); EVA is arguably the most reliable value-based measurement tool used to measure shareholder value creation in banking because it adjusts for the opportunity cost of capital, reflecting the true economic profit created. Consequently, shareholder value efficiency studies in banking effectively used EVA (Amici et al. 2013; Fiordelisi 2007; Fiordelisi and Molyneux 2010; Kimball 1998; Munteanu and Brezeanu 2012; Radić, 2015; Thampy and Baheti 2012; Uyemura et al. 1996). FISIM, however, captures the gross value added to the economy from the banking sector. The FISIM approach to measuring gross output is emphasized in the value of lending service and the value of depositor service in financial institutions (Miyakawa et al. 2011). FISIM focuses on the productive activity of banks in connecting lenders to borrowers. The rationale is that a productive bank must learn to manage risks by constantly gauging the appropriate spread between interest received and interest paid out to earn a positive compensation. Analyzing these two value creation metrics using the learning curve will provide ample evidence of the cost efficiency gain in relation to bank experience in producing them.

Credit creation

Our second approach to evaluating learning in banks is through credit creation. Banks create credit by raising capital either through own-funds or through debt financing. To measure bank experience through credit creation, we proceed as follows. First, we defined $\varnothing_{TC}$ and $\varnothing_{TS}$ as the sum of the total loans created and total security investments respectively, as proxies to investigate learning by credit creation and investment. We posit that credit creation involves intensive information gathering and adequate knowledge about applicant population, risk dynamics and adequate knowledge about the interest spread that could yield positive returns. In banks, $\varnothing_{TC}$ and $\varnothing_{TS}$ cannot be cumulated because they occur naturally as cumulative minus repairment amount, reported as the consolidated amount for each fiscal year. Understandably, $\varnothing_{TC}$ fluctuates and might

[8] The framework for measuring EVA and FISIM as proxies of value creation in banks is described in Appendix A. FISIM stands for Financial Intermediation Services Indirect Measure. It is a bank output derived from the spread between loan interest receipts and deposit interest payments and adjusted by interbank rate.

be affected by management objectives and bank risk dynamics. Nevertheless, productive banks in general, will as much as possible ensure steady growth in $\varnothing_{TC}$ and $\varnothing_{TS}$. An alternative to $\varnothing_{TC}$ and $\varnothing_{TS}$ is the total returns, generally reported as interest income $\varnothing_{TI}$. As a widget of output reported for each fiscal year, $\varnothing_{TI}$ can be cumulated and could provide a good measure of efficiency in total investment.

Inputs

This study considers three main bank inputs: physical capital (labor and value of physical assets), deposits (including all other borrowed funds) and equity capital. Although what constitutes inputs in the study of banks also depends on the definition of bank production technologies adopted, however, inputs in banks have been well defined when implementing intermediation or a value-added approach. Additionally, identifying inputs becomes even easier based on the credit and value creation role of banks as described earlier.

Researchers have argued that deposits could be considered as output. However, Hughes et al. (2001) empirically showed that the technological roles of deposits are consistent with that of input. Additionally, new bank studies have increasingly recognized the role of equity capital as input due to its ability to substitute for debts in bank financing. Following this logic, we estimated the price of equity capital and include it as the input price of capital. Moreover, like many bank studies, we also included the level of non-performing loans as asset quality to penalize banks in our sample for risky behavior. Table 1 summarizes all the outputs and inputs variables.

Hypothesis development and testing

A basic assumption underlying the learning curve theory is that learning occurs when the unit cost (of inputs) decreases as more outputs are produced over time. This implies an inverse relationship between unit cost and expanding outputs over time. Following this reasoning, we developed and tested four hypotheses related to the bank outputs (experience terms) identified above. Consequently, the decision rules (expectation and implication) of these hypotheses are based on column 5 of Table 1.

Hypothesis 1a Unit cost decreases with cumulative experience in credit creation (loans).

Hypothesis 1b Unit cost decreases with cumulative experience in credit creation (interest income).

Hypothesis 2 Unit cost decreases with cumulative experience in the gross value added (lending to the real sector and service provision).

Hypothesis 3 Unit cost decreases with cumulative experience in the economic value created (shareholder returns).

Table 1 Variable and hypothesis descriptions

Output	Symbol	Description	Remark	Hypothesis	
				Expectation	Implication
Panel A: Outputs					
EVA	$Ø_{eva}$	Economic value-added, defined as a dollar surplus on capital invested	Can be cumulated and proxied for experience shareholder in value creation	Negative (−) and significant	Unit cost decreases with cumulative experience in economic value created
FISIM	$Ø_{fisim}$	Spread between interest received and interest paid adjusted by a risk factor	Can be cumulated and proxied for experience in credit/risk management	Negative (−) and significant	Unit cost decreases with cumulative experience in gross value added to the economy
TC	$Ø_{TC}$	Total credit created (sum of all loans)	Naturally reported as cumulative loans issued and can be proxied for experience in total credit creation (interest-bearing assets)	Negative (−) and significant	Unit cost decreases with cumulative experience in lending to the real sector (loans)
TS	$Ø_{TS}$	Total security investment	Naturally reported as cumulative investment in securities and other investment	Negative (−) and significant	Unit cost decreases with cumulative experience in lending to the real sector (loans)
TI	$Ø_{Ti}$	Interest on total investment	Can be cumulated and proxied for experience in credit/risk management	Negative (−) and significant	Unit cost decreases with cumulative experience in total investment
Panel B: Inputs					
Input prices	w_s	Widgets of input prices; physical capital (sum of input prices of labour and tangible fix assets) w_p, price of deposit/debt w_d, and price of capital w_k			
NPL	R_i	Assets qualities (risk) defined as the amount of non-performing loans			
Equity capital	K	Equity capital estimated as the sum of shareholder equity, loan loss reserve, Tier 1 and Tier 2 capital			

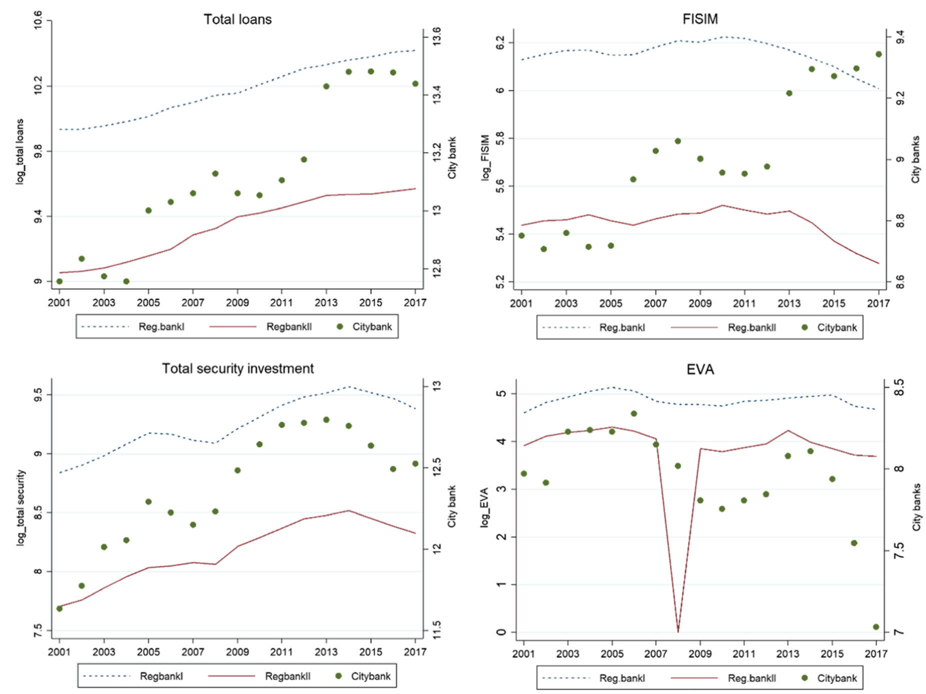

Fig. 2 The trend in some selected outputs of Japanese banks

The data

Data for this research were derived from the Japanese Bankers Association (JBA) called Zenginkyo (Japanese Bankers Association 2018). We also supplemented our data from the Financial Services Agency (FSA) official webpage. JBA publishes consolidated and unconsolidated income statement and balance sheet in English and Japanese, annually. We built panel data of all Japanese banks from the fiscal year 2001 to 2017. The initial panel data length was 1830 bank-year data (Table 1, panel B) and contained approximately 38,000 bank observations. To maintain panel data with sufficient information and degrees of freedom, we excluded banks with less than 4 years of observation, especially bankruptcy banks between 2001 and 2003. Our final sample contained a total of 250 banks with consistent data and variables of interest between 2001 and 2017 with a panel length of 1800 bank-year and approximately 30,000 bank observations.

Empirical results and discussion

Summary statistics

Appendix B shows the basic summary statistics of the variables. To see the general trend in the data, we reproduced the mean of all outputs in Fig. 2. The total credit (loans) and security investments seem to accumulate (show increasing trend) for both regional bank groups but are very unstable (fluctuates) in city banks. Credit created in city banks appears to be affected by shocks in 2002/2003 and 2008/2009, perhaps in response to the global financial crises during these periods. The trend in gross value created (FISIM) show bell shapes for both tiers of regional banks (a decreasing trend in recent years) but an increasing trend in city banks (with shocks similar to those observed in credit). Finally, the summary of the economic values created across bank groups shows that while regional bank I and II appear to have maintained constant economic value created (except in regional bank II in 2018[9]). The economic value created in city banks shows a decreasing trend.

Estimation results

This section addresses the question of whether bank experience could affect financial intermediary efficiency. Specifically, it examines how bank experience could reduce the cost of credit and value creation in Japanese commercial banks. In light of these objectives, we estimated Eq. (12) with five bank outputs proxied for experience in credit and value creation, namely: EVA, FISIM, total credit (loans), security investment, and total investment. This test describes the rate at which unit cost decreases as bank production (intermediation) experience improves in Japanese banks. Table 2 shows the estimated regression results of the individual learning proxy. [10] The dependent variable is the ratio of the total bank cost to individual output. We hypothesized, ceteris paribus, that outputs improve (cost decrease) with experience, given that agents (bank managers) are rational and that the economy is well-behaved. We disaggregated our results using a full sample and individual bank groups to better understand the dynamics of learning in specifics and across the banking industry.

Learning through value creation, credit creation and investment

Table 2 (columns 1–2) shows the regression results of learning through value creation. We emphasize on the coefficient of individual experience terms (shaded rows). The theory suggests that a negative and significant coefficient implies learning in the domain of the output proxied for experience. Estimated experience terms show that there is no significant learning in the domain of EVA in all panels (full sample and individual bank groups). However, on the gross value added to the economy (FISIM), the result shows that bank experience significantly improves cost efficiency gain.

In terms of the credit created, the results show that there is significant evidence of learning through credit creation for all bank groups, except city banks. This implies that the city bank group does not show significant cost efficiency gain in credit creation (Table 2, column 3). However, the result of learning through investment was significant for all bank groups (column 4). The alternative measure of learning through total investment (column 5) was also significant for all bank groups. The result in column 5 describes the efficiency of total investment (the sum of interest-bearing investment represented by the total interest).

To illustrate the economic implications of the estimated learning results, we reproduced the results in Table 3 and calculated other parameters based on the learning curve theory. In particular, we estimated the implied progress ratios (learning rates) from all learning elasticities. There exists significant evidence of inefficient shareholder value creation for all bank groups. Specifically, the result shows that unit cost increases

[9] The actual economic value created in Regional bank II in 2008 was negative and was reduced to zero due to log transformation.

[10] Our model diagnostics includes the specification test, heteroscedasticity, serial autocorrelation and cross-sectional dependence (see the relevant section for more details).

Table 2 Estimated regression results of the learning model (Eq. 12)

	(1) EVA	(2) FISIM (GO)	(3) Credit (tloans)	(4) Secinv	(5) TI
Panel A: Full Sample					
lnw_p	1.1432**	0.1157**	0.3080***	0.3886***	0.2398***
	(0.5014)	(0.0485)	(0.0365)	(0.1071)	(0.0585)
lnw_d	0.5630***	0.0795	0.1145***	0.1173*	0.1258***
	(0.1988)	(0.0598)	(0.0389)	(0.0684)	(0.0442)
lnw_k	−0.2209	0.0815	0.0730	0.0597	0.0705
	(0.3734)	(0.0946)	(0.0929)	(0.1110)	(0.0976)
lnNPA	−0.1623	−0.0095	0.0254	−0.0164	0.0338
	(0.1817)	(0.0124)	(0.0333)	(0.0817)	(0.0456)
$\varnothing_{it-1}$	0.1033**	−0.4050***	−0.3910***	−0.6314***	−0.3841***
	(0.0491)	(0.0609)	(0.0357)	(0.0357)	(0.0349)
_Con	2.2048	6.5630***	1.8128*	5.8399***	1.6899
	(3.5557)	(0.8573)	(0.9951)	(1.6061)	(1.1574)
Obs	1687	1687	1687	1687	1687
R_square	0.1841	0.5453	0.6336	0.6822	0.6911
F	16.1579	70.1076	58.9292	121.3465	79.2705
p	0.0000	0.0000	0.0000	0.0000	0.0000
rmse	1.0850	0.1147	0.0954	0.1562	0.0957
Panel B: City Banks					
lnw_p	1.1972*	−0.1342	0.5235**	0.6591***	0.5378***
	(0.4494)	(0.1899)	(0.1323)	(0.0975)	(0.0943)
lnw_d	0.1521	0.4139**	0.3010***	0.4229***	0.3643***
	(0.1146)	(0.1094)	(0.0167)	(0.0486)	(0.0186)
lnw_k	0.1167	−0.6238**	−0.4587**	−0.5941**	−0.5551***
	(1.1646)	(0.1661)	(0.1541)	(0.1434)	(0.1205)
lnNPA	0.3705	0.1319*	0.0487	−0.0631	0.0217
	(0.4150)	(0.0595)	(0.0299)	(0.1094)	(0.0616)
$\varnothing_{it-1}$	0.3070**	−0.4488*	−0.0098	−0.3748***	−0.0975**
	(0.0674)	(0.1648)	(0.0328)	(0.0528)	(0.0253)
_Con	−11.0532	5.7353	−5.5345**	2.7306	−3.9304*
	(10.3760)	(3.2280)	(1.7063)	(1.8650)	(1.6947)
Obs	74	74	74	74	74
R_square	0.6145	0.4830	0.8563	0.8272	0.8548
F	14.9797	23.5488	21.9727	14.9797	127.8709
p	0.0000	0.0000	0.0000	0.0000	0.0000
rmse	0.4101	0.2494	0.0723	0.1536	0.0870
Panel A: Regional Bank I					
lnw_p	0.9437	0.2676***	0.3611***	0.4180***	0.2892***
	(0.6065)	(0.0400)	(0.0432)	(0.1259)	(0.0616)
lnw_d	0.5708***	0.0466	0.1091**	0.1154	0.1243**
	(0.2008)	(0.0531)	(0.0426)	(0.0710)	(0.0472)
lnw_k	−0.0950	0.0895	0.0804	0.0681	0.0782
	(0.3064)	(0.0886)	(0.0893)	(0.1049)	(0.0938)
lnNPA	−0.0878	−0.0095	0.0147	−0.0053	0.0300
	(0.2304)	(0.0129)	(0.0366)	(0.0911)	(0.0511)
$\varnothing_{it-1}$	0.1171**	−0.4278***	−0.4435***	−0.5837***	−0.3957***
	(0.0505)	(0.1825)	(0.0408)	(0.0473)	(0.0400)
_Con	2.2965	6.8054***	2.5769**	5.0590***	1.8071
	(4.2180)	(2.3168)	(1.0362)	(1.8960)	(1.2762)

Table 2 (continued)

	(1) EVA	(2) FISIM (GO)	(3) Credit (tloans)	(4) Secinv	(5) TI
Obs	999	999	999	999	999
R_square	0.1925	0.5964	0.6557	0.6945	0.7059
F	11.0512	61.5595	48.3803	109.2990	63.5233
p	0.0000	0.0000	0.0000	0.0000	0.0000
rmse	1.1277	0.1027	0.0981	0.1481	0.0971
Panel A: Regional Bank II					
lnw_p	1.3381**	0.2253***	0.1478***	0.2893*	0.0644
	(0.6588)	(0.0395)	(0.0344)	(0.1664)	(0.0627)
lnw_d	0.7009**	0.0388	0.0998**	0.0993	0.1053**
	(0.2908)	(0.0441)	(0.0431)	(0.0706)	(0.0485)
lnw_k	− 0.7036	0.0858	0.0636	0.0550	0.0632
	(0.7483)	(0.0958)	(0.0992)	(0.1188)	(0.1026)
lnNPA	− 0.3441**	− 0.0174	0.0325	− 0.0223	0.0392
	(0.1411)	(0.0153)	(0.0274)	(0.0749)	(0.0386)
$\varnothing_{it-1}$	0.0798	− 0.2411***	− 0.4115***	− 0.7257***	− 0.4315***
	(0.0717)	(0.0426)	(0.0506)	(0.0279)	(0.0511)
_Con	− 0.0217	3.6700***	− 0.0308	4.7133***	− 1.9340**
	(2.6294)	(0.6625)	(0.9250)	(1.3106)	(0.9227)
Obs	614	614	614	614	614
R_square	0.2163	0.6437	0.6663	0.7215	0.7241
F	16.4636	49.2820	57.9316	57.8995	63.2943
p	0.0000	0.0000	0.0000	0.0000	0.0000
rmse	1.0539	0.0989	0.0827	0.1538	0.0843

Driscoll–Kraay standard errors in parenthesis.

*** p < 0.01, ** p < 0.05, * p < 0.1

EVA ∼ economic value added,

FISIM(GO)∼ Financia Intermediation Services Indirectly Measured (Gross Output)

secinv ∼ tota security investment,

tloans ∼ total loans,

TI ∼ Total Investment

$\varnothing_{it-1}$ ∼ learning elasticity

by approximately 23% in city banks, and 8% in regional bank I and 5% in regional bank II for every additional shareholder value created between 2001 and 2017.

On gross valued added, the result indicates that experience is correlated with gross value-added, that is, unit cost decreases as more experience is gained in producing additional gross value added, other things being equal. Quantitatively, unit cost decreases by approximately 27%, 26%, and 15% in city banks, regional bank I and regional bank II respectively. As a proxy for learning by value creation in lending and deposit-taking (service provision), this result suggests efficient allocation of financial resources and service provisions in the Japanese banking sector.

The cost-efficiency of credit creation and investment also significantly improve with experience. In particular, the learning curve of the credit created indicates that unit cost decreases significantly for both tiers of regional banks except in city banks. The former shows 25% cost efficiency gain due to experience in loan production; we interpret this to mean learning by credit creation in Japanese regional banks. A similar result was

Table 3 Estimated progress

	(1) EVA	(2) FISIM (GO)	(3) Credit (tloans)		(4) Secinv	(5) TI
Panel A: Full Sample						
$\varnothing_{it-1}$	0.1033**	− 0.4050***	− 0.3910***		− 0.6314***	− 0.3841***
	(0.0491)	(0.0609)	(0.0357)		(0.0357)	(0.0349)
Hypothesis	Reject	Do not reject	Do not reject		Do not reject	Do not reject
Estimated progress ratios						
δ_t	1.074	0.755	0.763		0.646	0.766
δ_t(%)	107.42	75.50	76.26		64.55	76.63
100-δ_t(%)	− 7.42	24.50	23.74		35.45	23.37
Cost implication	Inefficient	Efficient	Efficient		Efficient	Efficient
Panel B: City Banks						
$\varnothing_{it-1}$	0.3070**	− 0.4488*	− 0.0098	− 0.3748***		− 0.0975**
	(0.0674)	(0.1648)	(0.0328)	(0.0528)		(0.0253)
Hypothesis	Reject	Do not reject	Reject	Do not reject		Do not reject
Estimated progress ratios						
δ_t	1.2371	0.733	0.993	0.771		1.070
δ_t(%)	123.71	73.27	100.0	77.12		106.99
100-δ_t(%)	− 23.71	26.73	0.00	22.88		− 6.99
Cost implication	Inefficient	Efficient	Inefficient	Efficient		Efficient
Panel A: Regional Bank I						
$\varnothing_{it-1}$	0.1171**	− 0.4278***	− 0.4435***	− 0.5837***		− 0.3957***
	(0.0505)	(0.1825)	(0.0408)	(0.0473)		(0.0400)
Hypothesis	Reject	Do not reject	Do not reject	Do not reject		Do not reject
Estimated progress ratios						
δ_t	1.085	0.7434	0.735	0.667		0.760
δ_t(%)	108.46	74.34	73.53	66.73		76.01
100-δ_t(%)	− 8.46	25.66	26.47	33.27		23.99
Cost implication	Inefficient	Efficient	Efficient	Efficient		Efficient
Panel A: Regional Bank II						
$\varnothing_{it-1}$	0.0798	− 0.2411***	− 0.4115***	− 0.7257***		− 0.4315***
	(0.0717)	(0.0426)	(0.0506)	(0.0279)		(0.0511)
Hypothesis	Reject	Do not reject	Do not reject	Do not reject		Do not reject
Estimated progress ratios						
δ_t	1.057	0.846	0.752	0.605		0.7415
δ_t(%)	105.69	84.61	75.18	60.47		74.15
100-δ_t(%)	− 5.69	15.39	24.82	39.53		25.85
Cost implication	Inefficient	Efficient	Efficient	Efficient		Efficient

Driscoll–Kraay standard errors in parenthesis.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

EVA ∼ economic value added,

FISIM(GO)∼ Financial Intermediation Services Indirectly Measured (Gross Output)

FBI ∼ fee based income,

tloans ∼ total loans,

TI ∼ Total Investment

$\varnothing_{it-1}$ ∼ learning elasticity obtained for security investments. Most importantly, the result for the overall investment shows significant cost efficiency gain due to learning by investment for all bank groups. [11]

Dynamic learning through credit and value creation in Japanese banks

The empirical literature on the learning curve shows that learning is dynamic and varies over time (Aduba and Asgari 2020; Karaoz and Albeni 2005; Lapré and Nembhard 2010). Similarly, it can be argued that bank learning in the domain of credit and value creation is not static. We investigate the dynamics of credit and value creation in Japanese banks using the cubic approximation of the learning model (13). This model enables us to disentangle the dynamic annual learning rates within and across bank groups. We now focus on outputs that demonstrate learning potentials by excluding the result of EVA. We estimated the annual learning rates using (15). [12] In what follows, we graphically discuss the result using Fig. 3.

The curve of the annual learning rates for gross valued added (FISIM) shows sustained learning for both tiers of regional banks for all the years analyzed. This evidence was confirmed by the lower panel of the learning curve of gross value added expressed in terms of cost efficiency gain. The result shows that cost efficiency in the gross value created improves progressively between 10–15% per annum for both tiers of regional banks. The learning curve of the gross value added for city banks also shows learning (cost efficiency gain) only within the first half of the study period (2001–2010). However, cost efficiency was completely lost 2011 onward. This might imply an increasing cost of lending or inefficient lending in relation to the cost of lending and other variable costs.

In terms of learning through credit creation, the learning curve appears to be precisely similar to the learning curve of gross value added for all bank groups. This is expected, as the volume of credit created directly influences the spread between the returns on credit and the interest payout under a fixed interest rate regime (as is the case in Japan).

The learning curve of security investment shows progressive cost-efficiency gain for both tiers of regional banks from 2001 to 2017. Again, the learning curve of security investment for city banks shows an increasing cost from 2008 to 2017. This implies that there is cost efficiency lost in this bank group in recent years. Finally, the learning curve of total investment indicates that both tiers of regional banks show sustained learning (cost efficiency gain) from 2001 to 2017 and for city banks from 2001 to 2012 only.

In sum, the results showed that learning is dynamic and varies across bank groups. All bank groups studied showed significant and progressive learning in the domain of gross value added, credit created and investment/risk management. City banks, however, appear to have been increasingly taking on riskier behavior (as explained by increasing unit cost relative to gross value added, credit and investments).

[11] The caveat is that these results are based on a point estimation (overall average) of the impact of learning on efficiency gain. However, the year-to-year changes on efficiency gain (presented in the next section) resulting from learning show a better picture.

[12] See Appendix E for the estimated annual learning rates (progress ratios).

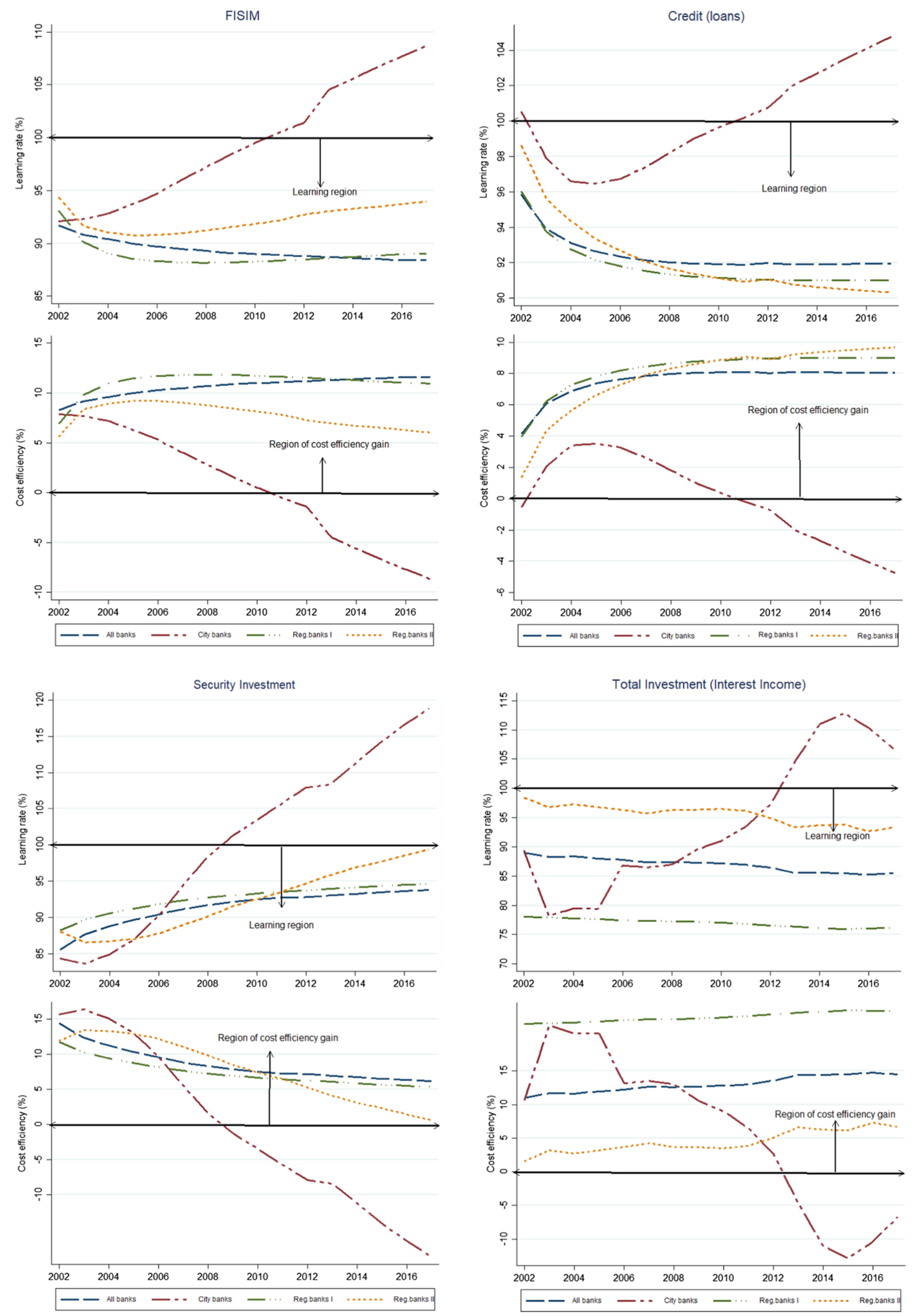

Fig. 3 Dynamic learning rates and cost efficiency in Japanese commercial banks

Further discussion and policy implications

This section discusses further insights which may be gained from the analysis of the learning curve of Japanese commercial banks. First, the findings on the efficiency of EVA (shareholder value creation) indicate that all bank groups failed to show significant cost efficiency gain. This shows that experience is not correlated with the shareholder value creation and that the unit cost of creating additional shareholder value continues to increase significantly, by between 6 and 24% over the period analyzed, depending on the bank group. These findings imply inefficient shareholder value creation in Japanese commercial banks. This result agrees with an earlier study that implied significant shareholder value inefficiency in Japanese commercial banks between 1999 and 2015 (Radić, 2015). Shareholder value creation in banks is a trade-off between different bank actions and the resultant payoff of these actions. For example, while value determinants such as aggressive efficiency program, reduction of capital investment, and aggressive risk-taking to increase net operating profit may be value-enhancing, they can adversely offset bank value creation through reduced customer satisfaction, increased business risk, and increased opportunity cost of capital respectively (Fiordelisi and Molyneux 2010). Additionally, economic value creation could also be affected by the presence of non-value enhancing units or branches in banks (Uyemura et al. 1996).

Although we do not directly measure this in our study, the lack of shareholder value efficiency in Japanese banks might point to the possible presence of non-value-enhancing units or branches. This is consistent with the long-standing position of the Japan Financial Services Agency (FSA), which in 2002 promoted the consolidation of financial institutions, especially the regional banks, to enhance profitability and to encourage smooth financing of SMEs. More than a decade later, Harimaya (2018) found that the Japanese regional banks are considered 'overbanked' and made a case for possible merger given the potential cost efficiency gain such unrealized consolidations and mergers could result in. In a more recent move, the FSA has taken more aggressive action to restructure struggling regional banks that it considers ailing and on the verge of collapsing (Kamei 2019). Therefore, from the viewpoint of organizational learning curve literature, our result implied that there is need to evaluate the value-enhancing actions of these banks to improve shareholder value efficiency, as well as overall efficiency.

Second, the findings on the learning curve of gross value added imply efficient lending and service provision for both tiers of regional banks. The findings also show that the city bank group failed to show cost efficiency gain in recent years. Related to this finding is the learning curve of credit and investment, which shows that both tiers of regional banks are cost-efficient in the domain of credit creation and total investment. However, city banks were not. This finding reflects the new micro and macroeconomic environment of these banks. For example, since the GFC of 2008, the city bank group have been expanding their overseas business operations in response to a domestic low-interest rate regime and declining demand for credit (loan) caused by demographic changes, a strategy that was meant to improve earning. However, the report of business operations of these bank groups shows that business profit declined between 2012 and 2018, exacerbated by the increasing overhead cost and exposure to higher credit risk in overseas markets (NRI 2020).

The findings of the learning curve of the total investment show that risk management has significantly improved in Japanese commercial banks and that other things being equal, this resulted from cumulative experience from previous investment despite the slow-growth economy. Using a new approach called GDP-at-risk, BoJ (2018) corroborated these findings when it established that Japanese banks have substantially and successfully managed risk on their information-intensive credit creation and other investments.

This study further provides policy direction for these findings. First, it must be noted that Japanese banks have faced recurrent financial crises, which have continued to affect the recovery of the economy (Krawczyk 2005; Ogawa and Kitasaka 2000). Second, the shrinking demand for credit and accommodative monetary policy has continued to harm earnings in these banks. In light of these challenging micro and macroeconomic environments, the following policy direction may be viable.

(1) The efficiency of EVA is fundamental in banking because banks must create economic value to remain in business sustainably. Creating economic value in these banks implies identifying the drivers of economic value (profits) and handling detailed risk-level assessment and profitability measurement. Accordingly, top-down economic value strategies with clear value-enhancing metrics such as, cost-cutting in all financial products and units (perhaps using the so-called 'Muda principle'), redeployment of capital to superior investment opportunities after proper risk assessment, and most importantly realigning business models with existing economic and demographic conditions, must be aggressively pursued (NRI 2020; Uyemura et al. 1996).[13]

(2) The internationalization of city banks has exposed them to higher credit and overseas market risk as reflected in the inefficiency of credit created and investment found in this study. However, as noted by BoJ (2019), Japanese banks (especially city banks) must as a matter of priority upgrade their risk management capabilities to withstand overseas market stress and compete favorably with foreign financial institutions. This requires requisite human resources, technical know-how (learning-by-doing) and infrastructure upgrade (NRI 2020).

Conclusion, caveat and future direction

This study addresses whether bank experience affects the cost of financial intermediation. In particular, we focused on whether bank experience improves the efficiency of credit creation, investment, and value creation. Addressing these questions requires that we study the learning curve of banks for which there was no suitable empirical method. First, we introduced a dynamic cost function that incorporated learning and applied it to Japanese commercial banks to measure learning through credit creation, investment and value creation (economic profit and the efficiency of lending to the real sector and service provision). Second, we tested our hypotheses on the effect of four learning proxies in the domain of credit and value creation on performance of Japanese banks. The findings indicate that bank intermediary experience improves the efficiency of credit creation, investment, and the gross value added in both tiers of regional banks but not in city banks (especially in recent years). Bank experience does not have significant effect on the efficiency of shareholder value (economic value created) for all bank groups. These findings have practical implications for both bank managers and policymakers. On the one hand, the results are useful to bank managers in their evaluation of cost dynamics in bank credit and value creation (risk management

[13] Muda is a Japanese term for any unproductive or wasteful activities or those that do not add value to the larger system.

Table 4 Regression diagnostic test

	Pesaran (2015)	Modified Wald test	Born and Breitung (2016)	Wooldridge (2002)
The null hypothesis (H0)	errors are weakly cross-sectional dependent	sigma(i)^2 = sigma^2 for all i	No first-order serial correlation	No first-order autocorrelation
EVA	59.349***	140,000.0***	1.08	2.142
FISIM	57.047***	11,334.37***	4.43***	20.88***
tloans	41.288***	9763.27***	2.98***	30.423***
secinv	76.832***	5989.53***	2.98***	61.735***
TI	69.368***	18,905.98***	4.54***	31.504***

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

and lending to the real sector). On the other hand, the findings provide insight and perhaps an alternative measure of bank performance (cost efficiency) for regulators. And finally, our findings necessitate further research on the role of bank experience in productivity (cost efficiency gain) of banks and other financial institutions.

This study has some limitations that could be addressed in future studies. First, banks in our sample faced a difficult and unstable micro and macroeconomic business environment in the period analyzed, and this may have impacted our results. Second, operationalizing bank experience is tricky because there exist many candidate variables as outputs in banks have many dimensions. Future research could explore other bank outputs that might capture bank experience.

Model specification and robustness check

To ensure consistent and robust estimates of our panel data modelling, we undertook the following procedure; first, we conducted a model specification test using a robust Hausman test. The test favors the fixed-effect model. Second, diagnostic tests suggest that our data suffer from autocorrelation, heteroskedasticity, and spatial cross-sectional dependence (see Table 4). Although robust or cluster standard error with feasible generalized least-squares (FGLS) based on the algorithm of Parks (1967), Wickens and Kmenta (1972), and Kmenta (1986) could correct these violations, our panel time dimension is smaller than the cross-sectional dimension. The FGLS approach becomes inappropriate in our case. Further, the introduction of time dummies does not correct or purge the spatial/cross-sectional dependence in our data. The fixed effect with Driscoll and Kraay standard errors was appropriate for our model as it corrected the cross-sectional dependence violation, as well as provided autocorrelation and heteroskedasticity consistent standard errors that are robust (Driscoll and Kraay 1998). We implemented this procedure following the algorithm by Hoechle (2007).

Appendix A

The derivative of the cost function

We assumed a bank production technology with three inputs (physical capital ψ, deposits, and other borrowed fund D, and financial capital or equity K) expressed as;

$$\varnothing = \beta_0 \psi^{\beta_1}.D^{\beta_2}.K^{\beta_3} \tag{A1}$$

The total bank cost of producing output $\varnothing$ is;

$$\mathbb{C} = w_p \psi + w_d D + w_k K \tag{A2}$$

If $\mathbb{C} = f(\emptyset)$, then the constrained output maximization is;
Maximize

$$\varnothing = \beta_0 \psi^{\beta_1}.D^{\beta_2}.K^{\beta_3} \tag{A3}$$

s.t.

$$\widehat{\mathbb{C}} = w_p \psi + w_d D + w_k K \tag{A4}$$

The composite function of the constrained equation becomes

$$\xi = \emptyset + \eta\left(\widehat{\mathbb{C}} - w_p \psi - w_d D - w_k K\right) \tag{A5}$$

where η *is the lagrangian multiplier*.

The first-order condition ensures that the first derivative of (A5) w.r.t ψ, D, K *and* η equal to zero.

$$\frac{\partial \xi}{\partial \psi} = \beta_1 \frac{\varnothing}{\psi} - \eta w_p = 0 \tag{A6}$$

$$\frac{\partial \xi}{\partial D} = \beta_2 \frac{\varnothing}{D} - \eta w_d = 0 \tag{A7}$$

$$\frac{\partial \xi}{\partial K} = \beta_3 \frac{\varnothing}{K} - \eta w_k = 0 \tag{A8}$$

$$\frac{\partial \xi}{\partial \eta} = (\widehat{\mathbb{C}} - w_p \psi - w_d D - w_k K) = 0 \tag{A9}$$

Combining (A6) and (A7), expressed in terms of D yields;

$$D = \left(\frac{w_p}{w_d}\frac{\beta_2}{\beta_1}\right)\psi \tag{A10}$$

Solving for D in (A3) yields;

$$\varnothing = \beta_0 \psi^{\beta_1}.\left(\frac{w_p}{w_d}\frac{\beta_2}{\beta_1}\psi\right)^{\beta_2}.K^{\beta_3} \rightarrow \varnothing = \beta_0\left(\frac{w_p}{w_d}\frac{\beta_2}{\beta_1}\right)^{\beta_2}\psi^{\beta_1+\beta_2}.K^{\beta_3} \tag{A11}$$

Similarly, combining (A6) and (A8) and deriving K yields;

$$K = \frac{w_p}{w_k}\frac{\beta_3}{\beta_1}\psi \tag{A12}$$

Substituting (A12) in (A11) yields;

$$\varnothing = \beta_0 \psi^{\beta_1} \left(\frac{w_p}{w_d} \frac{\beta_2}{\beta_1} \psi \right)^{\beta_2} . \left(\frac{w_p}{w_k} \frac{\beta_3}{\beta_1} \psi \right)^{\beta_3} \rightarrow \varnothing = \beta_0 \left(\frac{w_p}{w_d} \frac{\beta_2}{\beta_1} \right)^{\beta_2} . \left(\frac{w_p}{w_k} \frac{\beta_3}{\beta_1} \right)^{\beta_3} \psi^{\beta_1+\beta_2+\beta_3} \tag{A13}$$

Expressing (A13) in terms of ψ yields

$$\psi = \left[\frac{1}{\left(\frac{w_p}{w_d} \frac{\beta_2}{\beta_1} \right)^{\beta_2} \left(\frac{w_p}{w_k} \frac{\beta_3}{\beta_1} \right)^{\beta_3}} . \left(\frac{\varnothing}{\beta_0} \right) \right]^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \tag{A14}$$

$$\psi = \left(\frac{w_d}{w_p} \frac{\beta_1}{\beta_2} \right)^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} . \left(\frac{w_k}{w_p} \frac{\beta_1}{\beta_3} \right)^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} . \left(\frac{\varnothing}{\beta_0} \right)^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \tag{A15}$$

Recall that $D = \left(\frac{w_p}{w_d} \frac{\beta_2}{\beta_1} \right) . \psi$

$$D = \left(\frac{w_p}{w_d} \frac{\beta_2}{\beta_1} \right) \left\{ \left(\frac{w_d}{w_p} \frac{\beta_1}{\beta_2} \right)^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} . \left(\frac{w_k}{w_p} \frac{\beta_1}{\beta_3} \right)^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} . \left(\frac{\varnothing}{\beta_0} \right)^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \right\} \tag{A16}$$

$$D = \left(\frac{w_p}{w_d} \frac{\beta_2}{\beta_1} \right)^{\frac{(\beta_1+\beta_3)}{(\beta_1+\beta_2+\beta_3)}} . \left(\frac{w_p}{w_k} \frac{\beta_3}{\beta_1} \right)^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} . \left(\frac{\varnothing}{\beta_0} \right)^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \tag{A17}$$

Recall also that $K = \left(\frac{w_p}{w_k} \frac{\beta_3}{\beta_1} \right) . \psi$

$$K = \left(\frac{w_p}{w_k} \frac{\beta_3}{\beta_1} \right) \left\{ \left(\frac{w_d}{w_p} \frac{\beta_1}{\beta_2} \right)^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} . \left(\frac{w_k}{w_p} \frac{\beta_1}{\beta_3} \right)^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} . \left(\frac{\varnothing}{\beta_0} \right)^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \right\} \tag{A18}$$

$$K = \left(\frac{w_d}{w_p} \frac{\beta_1}{\beta_2} \right)^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} . \left(\frac{w_p}{w_k} \frac{\beta_3}{\beta_1} \right)^{\frac{(\beta_1+\beta_2)}{(\beta_1+\beta_2+\beta_3)}} . \left(\frac{\varnothing}{\beta_0} \right)^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \tag{A19}$$

Therefore, the total bank cost function in (A2) expressed in terms of input prices w_p, w_d, w_k and the output $\varnothing$ is;

$$\begin{aligned} \text{₵} = \left(\frac{1}{\beta_0} \right)^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \Bigg\{ & w_p \left[\left(\frac{w_d}{w_p} \frac{\beta_1}{\beta_2} \right)^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} . \left(\frac{w_k}{w_p} \frac{\beta_1}{\beta_3} \right)^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} \right] + \\ & w_d \left[\left(\frac{w_p}{w_d} \frac{\beta_2}{\beta_1} . \right)^{\frac{(\beta_1+\beta_3)}{(\beta_1+\beta_2+\beta_3)}} . \left(\frac{w_p}{w_k} \frac{\beta_3}{\beta_1} \right)^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} \right] + w_k \left[\left(\frac{w_d}{w_p} \frac{\beta_1}{\beta_2} \right)^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} . \left(\frac{w_p}{w_k} \frac{\beta_3}{\beta_1} \right)^{\frac{(\beta_1+\beta_2)}{(\beta_1+\beta_2+\beta_3)}} \right] \Bigg\} . \varnothing^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \end{aligned} \tag{A20}$$

From above, the final bank total cost function expressed in terms of input prices w_p, w_d, w_k and output $\varnothing$ is;

$$\text{₵} = e^{\omega} . \left\{ w_p^{\frac{\beta_1}{(\beta_1+\beta_2+\beta_3)}} . w_d^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} . w_k^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} \right\} . \varnothing^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \tag{A21}$$

$$\text{where} e^{\omega} = \left\{ \left(\frac{1}{\beta_0} \right) \left[\left(\frac{\beta_1}{\beta_2} \right)^{\beta_2} \left(\frac{\beta_1}{\beta_3} \right)^{\beta_3} + \left(\frac{\beta_2}{\beta_1} \right)^{\beta_1+\beta_3} \left(\frac{\beta_3}{\beta_1} \right)^{\beta_3} + \left(\frac{\beta_1}{\beta_2} \right)^{\beta_2} \left(\frac{\beta_3}{\beta_1} \right)^{\beta_1+\beta_2} \right] \right\}^{\frac{1}{(\beta_1+\beta_2+\beta_3)}}$$

Economic value-added (EVA™): definition and estimation

To estimate EVA, we follow empirical bank studies and define economic value added ($\varphi_{t,i}$) as the economic measure of bank net operating profit adjusted for tax ($\Pi_{t,i}$) less capital charge. The capital charge is defined as the product of capital employed (ϵ_t) and the estimated price of capital (w_k) (Fiordelisi 2007; Fiordelisi and Molyneux 2010; Radić, 2015).

$$\varphi_{t,i} = \Pi_{t,i} - w_k.\epsilon_t \tag{A22}$$

Next, we calculated ($\Pi_{t,i}$) *and* (ϵ_t) by accounting for bank-specific features. [14] To calculate the price of capital w_k, we adopted the method proposed by Hughes et al. (2001), Fiordelisi and Molyneux (2010); and Radić (2015), by including the level of equity as a quasi-fixed input in a standard trans-log cost function expressed in (A23). These authors showed that the shadow price of equity provides a good measure of the opportunity cost of capital.

$$\begin{aligned}
ln\left(\frac{C_i}{\gamma_3}\right) &= \theta_0 + \sum_i \theta_i ln\varnothing_i + \beta_{\gamma_1} ln\left(\frac{\gamma_1}{\gamma_3}\right) + \beta_{\gamma_2} ln\left(\frac{\gamma_2}{\gamma_3}\right) + \tau lnE_k + t_1 T \\
&\quad + \frac{1}{2}\left[\sum_i \sum_j \theta_{ij} ln\varnothing_i ln\varnothing_j + \beta_{\gamma_{11}} ln\left(\frac{\gamma_1}{\gamma_3}\right) ln\left(\frac{\gamma_1}{\gamma_3}\right)\right. \\
&\quad \left. + \beta_{\gamma_{22}} ln\left(\frac{\gamma_2}{\gamma_3}\right) ln\left(\frac{\gamma_2}{\gamma_3}\right) + \sigma lnE_k lnE_k + t_{11} T^2\right] \\
&\quad + \beta_{\gamma_{12}} ln\left(\frac{\gamma_1}{\gamma_3}\right) ln\left(\frac{\gamma_2}{\gamma_3}\right) + \sum_i \theta_{i\gamma_1} ln\varnothing_i ln\left(\frac{\gamma_1}{\gamma_3}\right) + \sum_i \theta_{i\gamma_2} ln\varnothing_i ln\left(\frac{\gamma_2}{\gamma_3}\right) \\
&\quad + \sum_i \theta_{ik} ln\varnothing_i lnE_k + \sum_i \theta_{it} T ln\varnothing_i lnE_k + \beta_{\gamma_{1k}} ln\left(\frac{\gamma_1}{\gamma_3}\right) lnE_k \\
&\quad + \beta_{\gamma_{2k}} ln\left(\frac{\gamma_2}{\gamma_3}\right) lnE_k + \beta_{\gamma_{1t}} Tln\left(\frac{\gamma_1}{\gamma_3}\right) + \beta_{\gamma_{2t}} Tln\left(\frac{\gamma_2}{\gamma_3}\right) + \varepsilon_t
\end{aligned} \tag{A23}$$

where $\sum_j \beta_{\gamma_j} = 1, \sum_j \beta_{\gamma_{jr}} = 0\, \forall r$ and $\sum_j \theta_{i\gamma_j} = 0$

The price of capital (w_k) is thus calculated by taking the negative derivative of the standard trans-log bank cost function in (A23) with respect to equity capital(E_k)[15];

$$w_k = -\left(\frac{\partial lnC_{it}}{\partial ln\epsilon_k}\right) \tag{A24}$$

where C_i is the total cost of bank i, $\varnothing_i$ is output for bank i, $\gamma_i (i = 1, 2, 3)$ is a vector of bank input prices, E_k is the level of equity capital, and T is the time trend. The output is the sum of four variables; loans and advances,$\varnothing_1$, security investment ($\varnothing_2$), liquid cash ($\varnothing_3$) and other interest-bearing assets ($\varnothing_4$). input prices are computed as interest expense over debt (γ_1), cost of labour over the total number of employees (γ_2) and non-interest expense over fixed assets (γ_3). We defined equity capital E_k as the sum of shareholder equity, provision for loans loss reserve and other reserves.

[14] We follow standard practice found in literature and adjusted for loan loss provision, tax provision, other provisions, non-recurrent events, and security accounting to correct for accounting distortion that affect current earnings.

[15] We impose homogeneity constraints in factor inputs by normalizing total cost and the other input prices by the third input price (γ_3) and exclude it from the model.

Financial Intermediation Services Indirectly Measured (FISIM)

FISIM is a framework for calculating financial institutions output (especially in banks) according to SNA 2008, an update to IBSC. [16] FISIM recognizes only productive activities of the banking sector, focusing on the efficiency of lending and risk assessment in deposits and loans/security investment. This approach was found to enhance the computation of the gross value added in financial institutions, compared to the IBSC. FISIM can be estimated as;

$$FISIM = FISIM_L + FISIM_D \tag{A25}$$

$$FISIM = (r_l - r_r) * G_L + (r_r - r_d) * G_D \tag{A26}$$

where r_l is the loan interest rate, r_d deposit interest rate, r_r is a reference rate, G_L total loans and G_D total deposits. The reference rate r_r is taken as the interbank interest rate. The loan interest rate refers to the ratio of loan interest to total loan, and the deposit interest rate is the ratio of interest paid on loanable fund divided by total deposit.

Appendix B

See Table 5.

[16] SNA and IBSC stand for System of National Accounts and Imputed Bank Service Charge.

Table 5 Summary of bank main activities (amount in 100millions of USD)

	Year	Total loans				Security investment			
		mean	**sd**	**min**	**max**	**mean**	**sd**	**min**	**max**
City Banks	2001	347,000	214,000	90,547	607,000	113,000	77,668	25,400	195,000
	2002	375,000	147,000	206,000	588,000	130,000	70,675	48,969	229,000
	2003	353,000	140,000	184,000	543,000	165,000	77,532	52,794	262,000
	2004	347,000	143,000	181,000	555,000	172,000	77,002	50,410	237,000
	2005	443,000	241,000	190,000	789,000	218,000	135,000	56,500	422,000
	2006	456,000	241,000	192,000	784,000	204,000	132,000	53,204	414,000
	2007	470,000	259,000	189,000	821,000	189,000	110,000	40,445	340,000
	2008	503,000	269,000	185,000	846,000	205,000	138,000	47,597	396,000
	2009	470,000	253,000	186,000	782,000	264,000	181,000	50,248	546,000
	2010	467,000	240,000	185,000	748,000	310,000	217,000	57,013	621,000
	2011	492,000	262,000	186,000	813,000	349,000	235,000	67,548	689,000
	2012	528,000	284,000	192,000	889,000	354,000	234,000	63,537	692,000
	2013	680,000	343,000	196,000	1,010,000	360,000	244,000	55,805	631,000
	2014	715,000	365,000	200,000	1,060,000	347,000	230,000	42,841	585,000
	2015	716,000	371,000	198,000	1,080,000	307,000	212,000	33,446	532,000
	2016	713,000	357,000	200,000	1,000,000	266,000	175,000	34,732	454,000
	2017	686,000	339,000	203,000	990,000	275,000	180,000	34,657	464,000
Regional Bank I	2001	20,608	13,549	2360	72,158	6901	4536	548	19,222
	2002	20,640	13,678	2484	75,181	7351	4937	653	19,821
	2003	21,062	13,862	2487	77,685	7979	5326	828	21,972
	2004	21,630	14,322	2517	77,785	8792	5798	948	24,005
	2005	22,320	14,886	2672	81,452	9665	6571	992	26,352
	2006	23,547	15,687	2677	84,137	9574	6586	947	26,348
	2007	24,304	16,480	2645	89,336	9081	6285	993	27,922
	2008	25,424	17,636	2783	93,397	8864	5691	924	23,758
	2009	25,760	17,364	2831	89,134	10,025	6294	1024	28,229
	2010	27,130	18,427	2931	92,881	11,074	6772	1096	29,382
	2011	28,523	19,330	3040	98,248	12,247	7591	1075	31,072
	2012	29,974	20,599	3099	105,000	13,135	8569	1535	37,300
	2013	30,673	21,383	3084	107,000	13,575	8857	1689	40,975
	2014	31,563	21,928	2956	108,000	14,343	8990	1797	39,948
	2015	32,193	22,446	2971	108,000	13,610	8551	1535	36,977
	2016	33,126	23,210	2967	110,000	12,963	8025	1555	34,003
	2017	33,463	24,045	3121	115,000	11,879	7859	1366	32,415

Table 5 (continued)

	Year	Total loans				Security investment			
		mean	sd	min	max	mean	sd	min	max
Regional Bank II	2001	8543	6128	1763	34,877	2220	2400	419	14,524
	2002	8627	6132	1750	35,775	2346	2381	433	13,507
	2003	8798	6292	1797	36,084	2597	2761	489	16,452
	2004	9110	6516	1850	36,451	2855	2994	500	17,286
	2005	9477	6979	1818	38,755	3086	3392	470	19,475
	2006	9877	7439	1761	40,699	3129	3113	576	16,764
	2007	10,785	8088	2455	43,714	3222	3246	675	18,326
	2008	11,223	9168	2449	51,756	3180	2810	584	14,242
	2009	12,054	10,611	2494	56,874	3700	3164	721	15,765
	2010	12,341	10,741	2579	56,852	3986	3230	721	15,909
	2011	12,728	11,357	2723	60,911	4311	3390	388	16,562
	2012	13,196	11,655	2781	62,362	4676	3574	407	17,052
	2013	13,725	11,756	2859	61,454	4804	3604	470	17,156
	2014	13,829	11,546	2791	59,490	5010	3899	403	19,307
	2015	13,846	11,985	2806	61,190	4681	3677	481	18,129
	2016	14,084	12,385	2746	63,496	4385	3662	428	18,141
	2017	14,329	12,678	2770	64,940	4130	3271	519	15,469

		FISIM				EVA				Total Interest			
	Year	mean	sd	min	max	mean	sd	min	max	mean	sd	min	max
City Banks	2001	6317	3687	1779	10,347	2897	2182	608	5746	11,954	8435	2172	20,517
	2002	6046	3788	1787	10,798	2741	2550	576	7121	10,055	5656	2225	17,401
	2003	6376	3349	2490	10,993	3747	2695	556	7570	9162	4110	4392	15,203
	2004	6095	3502	1950	10,913	3781	2198	1475	6635	9106	4110	4183	14,719
	2005	6115	4129	1012	10,595	3749	1798	2198	6650	11,476	5908	4218	18,007
	2006	7594	6760	584	17,684	4176	1739	2185	6689	16,228	10,508	4648	31,200
	2007	8324	6894	1463	18,348	3460	2143	1094	5987	17,842	11,310	4824	33,802
	2008	8604	6757	2372	17,750	3036	1689	1004	5179	15,209	9624	4527	28,864
	2009	8123	5839	2972	15,644	2462	1545	962	4291	11,807	7503	3835	22,357
	2010	7757	5514	2742	14,500	2336	1452	873	3970	11,011	6825	3669	20,332
	2011	7734	5593	2566	14,294	2458	1370	1236	4041	11,031	6874	3559	20,085
	2012	7915	5704	3021	15,074	2552	1111	1269	3988	11,170	7164	3403	20,825
	2013	10,065	5564	2870	15,675	3226	1695	1474	5480	13,914	7849	3331	21,551
	2014	10,885	6268	2714	17,571	3319	1211	1644	4540	15,581	9348	3296	25,766
	2015	10,628	6132	2576	16,974	2801	1082	1359	3883	14,830	8959	3104	24,610
	2016	10,904	6692	2417	18,362	1893	739	1021	2625	15,057	9416	2828	25,543
	2017	11,421	7306	2291	19,721	1134	576	426	1713	16,378	10,140	2764	26,946

Table 5 (continued)

	Year	FISIM mean	FISIM sd	FISIM min	FISIM max	EVA mean	EVA sd	EVA min	EVA max	Total Interest mean	Total Interest sd	Total Interest min	Total Interest max
Regional Bank I	2001	459	283	57	1558	100	108	-292	603	588	367	66	1827
	2002	470	290	59	1589	124	107	-10	610	546	336	61	1701
	2003	477	290	60	1638	139	125	-65	688	544	327	64	1714
	2004	478	296	60	1635	157	165	9	964	550	335	64	1722
	2005	468	294	57	1580	170	176	13	1162	576	362	67	1733
	2006	469	300	56	1641	158	137	17	649	616	397	72	1862
	2007	484	319	54	1751	127	134	-256	654	676	452	70	2291
	2008	497	336	53	1871	119	271	-65	2038	666	446	67	2317
	2009	494	337	54	1844	119	114	0	593	612	398	72	2050
	2010	505	330	56	1770	115	121	-232	580	612	386	70	1937
	2011	502	327	56	1746	127	116	9	615	603	383	68	1925
	2012	491	319	57	1686	130	118	9	618	587	374	68	1891
	2013	478	312	55	1622	136	122	10	675	580	374	70	1845
	2014	462	303	52	1523	141	125	9	707	572	359	67	1774
	2015	446	299	47	1444	145	118	9	630	566	357	65	1708
	2016	424	292	43	1377	115	102	6	466	543	348	59	1608
	2017	407	288	40	1417	107	98	0	459	528	363	55	1795
Regional Bank II	2001	230	148	56	808	50	64	-8	409	257	163	61	903
	2002	234	148	61	806	61	58	-2	333	246	154	61	845
	2003	235	149	61	800	66	56	10	318	246	156	61	846
	2004	240	156	59	804	69	55	6	263	254	167	59	889
	2005	234	149	57	774	74	59	14	293	259	170	57	896
	2006	230	152	54	785	68	66	8	364	273	191	57	1039
	2007	236	155	58	799	58	63	-6	287	304	216	72	1168
	2008	241	172	58	915	-2	201	-1218	183	304	218	74	1109
	2009	242	181	56	959	47	49	4	226	296	225	70	1166
	2010	250	194	58	984	44	55	-37	214	294	225	69	1073
	2011	245	190	56	966	48	49	-8	202	283	220	66	1072
	2012	241	183	56	931	52	52	0	242	279	214	67	1051
	2013	244	177	56	889	69	122	7	733	297	266	69	1502
	2014	232	168	53	850	54	43	7	159	274	185	67	875
	2015	215	159	49	795	47	38	4	161	259	180	61	855
	2016	204	150	44	756	41	31	5	120	245	169	55	821
	2017	196	144	41	732	40	33	5	132	235	163	52	791

± Amount in millions of USD .

Appendix C

See Table 6 and Fig. 4.

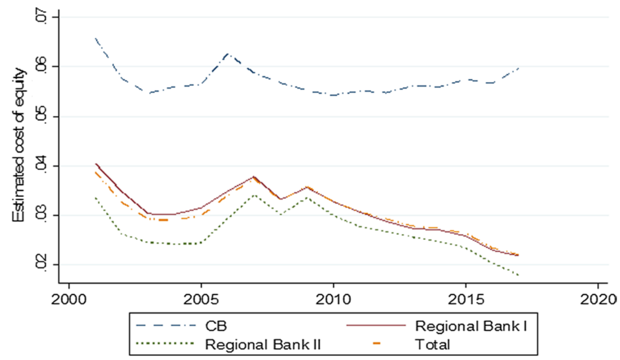

Fig. 4 Estimated cost equity

Table 6 Regression result of the estimated Trans-log cost function (Eq. A23)

lnTC	Coef	St.Err	t-value	p-value	[95% Conf	Interval]	Sig
$ln\varnothing$	2.1343	0.1325	16.11	0.000	1.875	2.394	***
$0.5^*\left(ln\varnothing^2\right)$	−0.0052	0.0123	−0.42	0.674	−0.029	0.019	
$\ln w_1$	−0.0740	0.0453	−1.63	0.102	−0.163	0.015	
$\ln w_2$	0.0631	0.0344	1.83	0.067	−0.004	0.131	*
$\ln E_k$	0.0162	0.0818	0.20	0.843	−0.144	0.176	
t	−0.0090	0.0056	−1.61	0.107	−0.020	0.002	
$0.5\times(\ln w_1)^2$	0.0102	0.0052	1.96	0.050	0.000	0.020	*
$0.5\times\ln w_2{}^2$	0.0169	0.0032	5.26	0.000	0.011	0.023	***
$0.5\times(E_k)^2$	−0.0078	0.0012	−6.61	0.000	−0.010	−0.005	***
$0.5\times T^2$	0.0006	0.0001	6.30	0.000	0.000	0.001	***
$ln\varnothing\times\ln w_1$	0.0051	0.0053	0.96	0.338	−0.005	0.016	
$ln\varnothing\times\ln w_2$	−0.0235	0.0068	−3.47	0.001	−0.037	−0.010	***
$ln\varnothing\times\ln E_k$	0.0021	0.0050	0.41	0.682	−0.008	0.012	
$ln\varnothing\times t$	0.0010	0.0003	3.20	0.001	0.000	0.002	***
$\ln w_1\times\ln w_2$	0.0059	0.0031	1.87	0.061	−0.000	0.012	*
$\ln w_1\times\ln E_k$	−0.0094	0.0052	−1.81	0.071	−0.020	0.001	*
$\ln w_2\times\ln E_k$	0.0159	0.0067	2.38	0.017	0.003	0.029	**
$\ln w_1\times t$	−0.0003	0.0005	−0.54	0.591	−0.001	0.001	
$\ln w_2\times t$	−0.0026	0.0003	−7.68	0.000	−0.003	−0.002	***
Cons.	−0.9030	0.6352	−1.42	0.155	−2.148	0.342	
/mu	−2.7213	17.0605	−0.16	0.873	−36.159	30.717	
/lnsigma2	−1.6087	5.9322	−0.27	0.786	−13.236	10.018	
/ilgtgamma	5.3698	5.9595	0.90	0.368	−6.311	17.050	
sigma2	0.200144	1.1873			1.79E−06	22,432.45	
gamma	0.995367	0.027485			0.001814	1	
sigma_u2	0.199216	1.1873			−2.12785	2.526281	
sigma_v2	0.000927	3.24 E−05			0.000864	0.000991	
Mean dependent var	29.4652			*SD dependent var*	2.2258		
Number of obs	1800			*Chi − square*	609,337.6989		
Prob > chi2	0.0000			*Akaike crit. (AIC)*	−6994.4018		

*** p < 0.01, ** p < 0.05, * p < 0.1

Appendix D

See Table 7.

Table 7 Estimation result of Cubic approximation (egn.13)

	(1) *EVA*	(2) *FISIM* (GO)	(3) Credit (tloans)	(4) *Secinv*	(5) *TI*
Full sample					
lnw_p	0.8394	− 0.0374	0.2909***	0.3839***	0.2377***
	(0.5789)	(0.1108)	(0.0601)	(0.1258)	(0.0656)
lnw_d	0.5891***	0.0555**	0.1129***	0.1231***	0.1259***
	(0.1088)	(0.0279)	(0.0223)	(0.0260)	(0.0230)
lnw_k	− 0.2071	0.0590	0.0716	0.0609	0.0695
	(0.1957)	(0.0670)	(0.0602)	(0.0699)	(0.0625)
lnNPA	− 0.0395	− 0.1130***	0.0212	− 0.0224	0.0271
	(0.1282)	(0.0269)	(0.0159)	(0.0330)	(0.0181)
$\varnothing_{it-1}$	− 0.2299	− 0.9417**	5.7486*	− 2.0566	0.8872
	(0.1664)	(0.4648)	(3.0760)	(1.4622)	(2.5243)
$(\varnothing_{it-1})^2$	0.0163	0.0842**	− 0.4362**	0.0716	− 0.1148
	(0.0278)	(0.0370)	(0.1949)	(0.1055)	(0.1582)
$(\varnothing_{it-1})^3$	0.0003	− 0.0023**	0.0102**	− 0.0009	0.0032
	(0.0012)	(0.0010)	(0.0041)	(0.0025)	(0.0033)
_Con	3.2391	5.3041***	− 26.6792*	14.2604**	− 2.2931
	(2.4567)	(1.8542)	(15.8901)	(6.4147)	(13.0633)
Obs	1687	1687	1687	1687	1687
R_square	0.0855	0.3372	0.5822	0.5847	0.5872
F	10.3957	51.7086	89.3735	142.7922	89.8418
p	0.0000	0.0000	0.0000	0.0000	0.0000
rmse	1.1443	0.1380	0.1015	0.1779	0.1102
City banks					
lnw_p	0.7469	− 0.1678	0.4931***	0.7031***	0.5531***
	(0.6236)	(0.3111)	(0.1012)	(0.1429)	(0.1152)

Table 7 (continued)

	(1) *EVA*	(2) *FISIM* **(GO)**	(3) **Credit (tloans)**	(4) *Secinv*	(5) *TI*
lnw_d	0.5775***	0.3725*	0.2916***	0.4892***	0.3768***
	(0.1097)	(0.1689)	(0.0584)	(0.1004)	(0.0680)
lnw_k	− 2.0536**	− 0.4365	− 0.3899*	− 0.6302	− 0.5387*
	(0.6376)	(0.5029)	(0.1733)	(0.5044)	(0.2499)
lnNPA	0.1352	− 0.0295	0.0573	− 0.1329**	0.0135
	(0.1432)	(0.1022)	(0.0309)	(0.0451)	(0.0334)
$\varnothing_{it-1}$	2.1559	4.8406	18.1738	54.4984	151.0664
	(17.6303)	(23.3113)	(96.7778)	(33.3907)	(82.9505)
$(\varnothing_{it-1})^2$	− 0.4496	− 0.3837	− 0.9965	− 3.5532	− 8.6660
	(1.2969)	(1.5760)	(5.6554)	(2.0481)	(4.7594)
$(\varnothing_{it-1})^3$	0.0184	0.0100	0.0182	0.0760	0.1652
	(0.0316)	(0.0354)	(0.1099)	(0.0417)	(0.0908)
_Con	1.3247	− 17.3389	− 115.8322	− 275.8021	− 880.6086
	(75.3655)	(113.2906)	(551.2763)	(180.7805)	(480.7934)
Obs	74	74	74	74	74
R_square	0.5825	0.3535	0.7835	0.7084	0.8172
F	11.3257	40.726	70.344	112.322	50.542
p	0.0000	0.0000	0.0000	0.0000	0.0000
rmse	0.3824	0.2499	0.0795	0.1788	0.0874
Regional Bank I					
lnw_p	0.6056	− 0.0449	0.3379***	0.4236**	0.2743***
	(0.9126)	(0.1531)	(0.0819)	(0.1902)	(0.0876)
lnw_d	0.6200***	0.0469	0.1076***	0.1194***	0.1240***
	(0.1478)	(0.0310)	(0.0262)	(0.0318)	(0.0266)
lnw_k	− 0.0686	0.0748	0.0790	0.0703	0.0767

Table 7 (continued)

	(1) *EVA*	(2) *FISIM* **(GO)**	(3) **Credit (tloans)**	(4) *Secinv*	(5) *TI*
	(0.1653)	(0.0732)	(0.0690)	(0.0794)	(0.0718)
lnNPA	0.1107	− 0.1440***	0.0143	− 0.0005	0.0291
	(0.2052)	(0.0338)	(0.0222)	(0.0514)	(0.0263)
$\varnothing_{it-1}$	− 0.2618	3.5565**	17.0785	− 1.7361	11.1628
	(0.3066)	(1.3716)	(16.9818)	(8.2992)	(13.0859)
$(\varnothing_{it-1})^2$	0.0137	− 0.3000**	− 1.1727	0.0640	− 0.7698
	(0.0543)	(0.1200)	(1.1732)	(0.6400)	(0.8997)
$(\varnothing_{it-1})^3$	0.0007	0.0086**	0.0261	− 0.0010	0.0171
	(0.0024)	(0.0035)	(0.0270)	(0.0163)	(0.0206)
_Con	3.0454	− 11.6691**	− 84.4241	11.4127	− 55.8601
	(3.6630)	(5.2636)	(81.7623)	(35.2986)	(63.1201)
Obs	999	999	999	999	999
R_square	0.0793	0.3690	0.6033	0.5607	0.6019
F	6.7744	48.9343	65.9328	92.4020	57.4983
p	0.0000	0.0000	0.0000	0.0000	0.0000
rmse	1.1963	0.1276	0.1046	0.1765	0.1123
Regional bank II					
lnw_p	0.8775	0.1474	0.1531*	0.2656	0.0527
	(0.7830)	(0.1303)	(0.0842)	(0.1603)	(0.0837)
lnw_d	0.7428***	0.0733	0.1010**	0.1011*	0.1094**
	(0.2529)	(0.0606)	(0.0451)	(0.0515)	(0.0473)
lnw_k	− 0.6926	0.0356	0.0617	0.0549	0.0592
	(0.6259)	(0.1538)	(0.1256)	(0.1479)	(0.1326)
lnNPA	− 0.2432	− 0.1134**	0.0315	− 0.0237	0.0326
	(0.1785)	(0.0427)	(0.0260)	(0.0451)	(0.0275)

Table 7 (continued)

	(1) *EVA*	(2) *FISIM* **(GO)**	(3) **Credit (tloans)**	(4) *Secinv*	(5) *TI*
$\varnothing_{it-1}$	0.3474	1.2743	− 3.2691	14.8398	14.2644
	(0.3148)	(1.7088)	(10.6298)	(13.5675)	(10.0397)
$(\varnothing_{it-1})^2$	− 0.0945	− 0.1295	0.1838	− 1.2967	− 1.0977
	(0.0602)	(0.1542)	(0.7531)	(1.1002)	(0.6998)
$(\varnothing_{it-1})^3$	0.0058*	0.0045	− 0.0039	0.0359	0.0272
	(0.0029)	(0.0046)	(0.0177)	(0.0296)	(0.0162)
_Con	4.5179	− 2.8296	16.7733	− 55.0559	− 62.6781
	(3.6815)	(6.4268)	(49.7791)	(55.3558)	(47.7211)
Obs	614	614	614	614	614
R_square	0.1287	0.4698	0.5800	0.6492	0.6085
F	13.6980	33.4816	71.5356	93.8622	101.9037
p	0.0000	0.0000	0.0000	0.0000	0.0000
rmse	1.0992	0.1193	0.0918	0.1708	0.0994

Driscoll–Kraay standard errors in parenthesis.

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

EVA ~ economic value added,

FISIM(GO)~ Financial Intermediation Services Indirectly Measured (Gross Output)

secinv ~ total security investment,

tloans ~ total loans,

TI ~ Total Investment

$\varnothing_{it-1}$ ~ learning elasticity

Appendix E

See Table 8.

Table 8 Estimated progress ratios

Bank category	Year	EVA	FISIM	TC	SI	TI
All banks	2002	1.0799	0.9170	0.9585	0.8558	0.8895
	2003	1.1171	0.9080	0.9390	0.8770	0.8831
	2004	1.1359	0.9040	0.9313	0.8878	0.8834
	2005	1.1500	0.9000	0.9264	0.8967	0.8801
	2006	1.1613	0.8970	0.9236	0.9045	0.8779
	2007	1.1710	0.8950	0.9214	0.9119	0.8736
	2008	1.1769	0.8930	0.9202	0.9171	0.8739
	2009	1.1809	0.8910	0.9195	0.9218	0.8733
	2010	1.1849	0.8900	0.9191	0.9248	0.8719
	2011	1.1886	0.8890	0.9189	0.9275	0.8696
	2012	1.1914	0.8880	0.9197	0.9281	0.8643
	2013	1.1946	0.8870	0.9190	0.9305	0.8556
	2014	1.1988	0.8860	0.9190	0.9328	0.8557
	2015	1.2026	0.8850	0.9193	0.9347	0.8549
	2016	1.2056	0.8840	0.9194	0.9365	0.8525
	2017	1.2075	0.8840	0.9196	0.9379	0.8552
City banks	2002	0.7213	0.9210	1.0054	0.8436	0.8934
	2003	0.8699	0.9230	0.9791	0.8362	0.7822
	2004	1.0954	0.9280	0.9661	0.8494	0.7943
	2005	1.2989	0.9370	0.9647	0.8698	0.7940
	2006	1.4746	0.9470	0.9674	0.9030	0.8683
	2007	1.6560	0.9600	0.9738	0.9445	0.8649
	2008	1.7928	0.9720	0.9820	0.9840	0.8694
	2009	1.9068	0.9840	0.9900	1.0125	0.8947
	2010	1.9946	0.9950	0.9963	1.0344	0.9099
	2011	2.0757	1.0050	1.0019	1.0571	0.9349
	2012	2.1598	1.0140	1.0074	1.0794	0.9727
	2013	2.2881	1.0450	1.0202	1.0838	1.0462
	2014	2.3936	1.0560	1.0269	1.1119	1.1099
	2015	2.5021	1.0670	1.0341	1.1408	1.1283
	2016	2.5925	1.0770	1.0409	1.1657	1.1039
	2017	2.6514	1.0870	1.0475	1.1884	1.0674
Regional bank I	2002	1.0978	0.9307	0.9603	0.8823	0.7802
	2003	1.1464	0.9015	0.9376	0.8972	0.7792
	2004	1.1740	0.8904	0.9274	0.9059	0.7780
	2005	1.1941	0.8853	0.9216	0.9125	0.7763
	2006	1.2106	0.8829	0.9180	0.9184	0.7745
	2007	1.2231	0.8819	0.9154	0.9235	0.7732
	2008	1.2317	0.8816	0.9135	0.9275	0.7729
	2009	1.2371	0.8819	0.9122	0.9305	0.7720
	2010	1.2436	0.8827	0.9114	0.9333	0.7705
	2011	1.2494	0.8836	0.9108	0.9355	0.7685
	2012	1.2556	0.8847	0.9104	0.9376	0.7658
	2013	1.2612	0.8859	0.9102	0.9394	0.7637
	2014	1.2680	0.8872	0.9100	0.9416	0.7618
	2015	1.2744	0.8886	0.9100	0.9435	0.7594
	2016	1.2795	0.8898	0.9100	0.9450	0.7607
	2017	1.2822	0.8905	0.9100	0.9463	0.7612

Table 8 (continued)

Bank category	Year	EVA	FISIM	TC	SI	TI
Regional bank II	2002	0.9907	0.9437	0.9863	0.8810	0.9844
	2003	1.0468	0.9164	0.9563	0.8657	0.9678
	2004	1.0927	0.9106	0.9435	0.8671	0.9728
	2005	1.1320	0.9077	0.9336	0.8707	0.9681
	2006	1.1668	0.9079	0.9270	0.8779	0.9631
	2007	1.2006	0.9096	0.9208	0.8895	0.9574
	2008	1.2204	0.9122	0.9167	0.9015	0.9631
	2009	1.2291	0.9154	0.9138	0.9153	0.9634
	2010	1.2430	0.9184	0.9113	0.9253	0.9649
	2011	1.2552	0.9216	0.9093	0.9352	0.9616
	2012	1.2620	0.9273	0.9106	0.9473	0.9494
	2013	1.2824	0.9303	0.9078	0.9587	0.9337
	2014	1.2968	0.9329	0.9062	0.9691	0.9370
	2015	1.3073	0.9347	0.9052	0.9767	0.9383
	2016	1.3179	0.9372	0.9041	0.9854	0.9268
	2017	1.3270	0.9396	0.9033	0.9940	0.9329

EVA Economic Value Added, *FISIM* Financial Intermediation Services Indirectly Measured, *TC* total credit, *SI* security investment, *TI* total investment (total interest income)

Acknowledgements
Not applicable.

Authors' contributions
AJJ designed, analyzed, and drafted this research work. While IH provided the source data, translated the data from Japanese to English, supervise and redraft the paper. Both authors read and approved the final manuscript.

Funding
This research was supported by JSPS KAKENHI Grant Number 19J10715. Only financial cost related to this research was covered by the grant. All other aspects of the research; from the design to the final draft, were the authors' work.

Availability of data and materials
The datasets generated and analyzed for this research work are available in the Japan Bankers Association repository (https://www.zenginkyo.or.jp/en/).

Competing interests
The authors declare that they have no competing interests.

Received: 4 May 2020 Accepted: 23 June 2021
Published online: 08 July 2021

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