FEATURE ARTICLE

Determinants of the performance of banks in Hong Kong

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This study identifying the major determinants of the performance of banks in Hong Kong has found that market structure is not a significant contributing factor. However, the cost efficiency of banks is a major determinant of profitability. As larger banks are found to be generally more cost efficient than their smaller counterparts in our previous study on banks' efficiency, they can offer services at lower prices to compete with smaller banks, yet still attain similar or even higher profit levels. Therefore, smaller banks may be more vulnerable to intense competition in the loan market than larger banks, particularly in price wars.

Introduction

The factors determining the performance of banks and how their profits and pricing behaviour are affected by market structure have been studied extensively. Among the various approaches, a number of studies have focused on the structure-performance relationship of banks, with the structure-conduct-performance (SCP) hypothesis and the efficient-structure (EFS) hypothesis widely tested.[1] In general, banks' profitability and pricing power are hypothesised to be determined by the market structure of the banking industry, such as the number of participating banks in the market and the market share of banks, and bank-specific factors, including cost efficiency, scale efficiency, and the risk attitude of banks. Macroeconomic factors, for example, real GDP growth and unemployment, may also be important determinants.

For the structure-performance relationship of banks, empirical results have been mixed. In some studies, market structure was found to be one of the main determinants of the performance of banks. Banks' profitability was found to be positively related to the level of market concentration. This was interpreted as profitability being enhanced by a higher degree of price co-ordination, which was helped by fewer competitors. This suggests that concentration could have an adverse effect on the competitive environment of the industry. Likewise, some studies found that banks with a larger market share and possessing strong market power could earn supernormal profits, which would hamper competition and could affect the health of smaller banks. Conversely, other studies found that the relationship between banks' performance and concentration/market power is spurious, with efficiency being the principal determinant of both profitability and market structure. Their findings showed that individual banks' relative performance and the sector's profitability was more dependent on the production efficiency of banks, in addition to other operating factors and macroeconomic conditions. Which of these hypotheses is valid points to different implications for increased concentration (and thus of mergers and acquisitions) in the banking industry. Understanding the relationships between

[1] For a detailed summary of the studies published on or before 1983, see Gilbert (1984). For studies published after 1983, see for example Smirlock et al. (1984, 1986), Smirlock (1985), Allen and Hagin (1989), Timme and Yang (1991) and Berger (1995).

market structure, production efficiency and banks' performance in Hong Kong is, therefore, useful to policy makers. This is particularly so in view of recent market consolidation resulting in fewer banks and new larger banks, and the fact that larger banks appear to have performed better than their smaller counterparts.[2]

This paper examines the issue by identifying the key determinants of the relative performance of banks. Based on the approach proposed by Berger and Hannan (1993) and with the aid of a panel data set of retail banks covering the period 1991-2005, the paper examines what factors determine the performance of banks, and tests whether market concentration and efficiency are among the main factors contributing to the profitability of banks in Hong Kong. It also evaluates possible policy implications of what effects these and other determinants may have on banks' performance.

Literature review

The structure-performance relationship of banks has been extensively studied for the US banking industry.[3] Earlier studies have usually been based on regression analyses in which indicators of bank performance, such as bank profitability and prices, were regressed on indicators of market structure such as the concentration index of the banking industry and market share of individual banks. While a positive correlation between banks' performance and market concentration (or market share) was frequently found, the interpretation of this result, and hence the policy implication, varied among the studies: Some authors interpreted it as support for the SCP hypothesis, which asserts that banks in a concentrated market are more likely to engage in some form of non-competitive behaviour such as collusion, consequently setting less favourable prices to customers and earning higher profits.[4] Others viewed it as support for the EFS hypothesis, which states that efficient firms increase in size and market share because of their ability to generate higher profits, which usually leads to increased concentration of markets and higher market share for individual banks.[5] The ambiguity in interpreting the result indicates the significant limitation of the approach.

Berger and Hannan (1993) tackled the problem by explicitly incorporating two efficiency indicators, which measure the X-efficiency and scale efficiency of banks, as explanatory variables in the regression equations, together with two market structure indicators, which are proxied by banks' market concentration and market share. In Berger and Hannan (1993), profit rates and prices are employed as the dependent variables to proxy for banks' performance. The X-efficiency variable, which is computed from an estimated efficient cost frontier from the data, aims to measure the closeness of cost of banks to the minimum that can be achieved on the efficient cost frontier, which is defined by the best-practice banks in the sample. The scale-efficiency variable, which is derived from an estimated cost-function of banks from the data, aims to measure the closeness of cost for the bank's actual output level to the cost of the bank's minimum average cost output. Other factors such as the population of the state where the banks' headquarters are located, branching restrictions of banks and the business failure rate are included in the estimation to control for the differences in market size, regulatory restrictions and business conditions respectively.

[2] Using the panel set of retail banks in Hong Kong covering the period 1991-2005, a regression of banks' return on assets on their asset size shows that the two variables are positively related.

[3] See Footnote 1.

[4] See Berger and Hannan (1989) and Hannan (1991).

[5] For example, see Demsetz (1973,1974) and Peltzman (1977).

Four important hypotheses that relate to the performance of the US banking industry were tested in Berger and Hannan (1993). In addition to the SCP, they also tested the relative market power (RMP) hypothesis, which asserts that banks with larger market share are able to exercise market power to earn higher profits. Since the SCP and RMP hypotheses assert that higher profits are associated with anti-competitive pricing behaviour in the market, prices should be positively related to market concentration and market share. The remaining two hypotheses tested by Berger and Hannan (1993) relate to the EFS hypothesis: Under the X-efficient hypothesis (ESX), banks with superior management of costs for a given output level should attain higher profits. Under the scale efficient hypothesis (ESS), banks operating at optimal economies of scale should have the lowest average costs, resulting in higher profits. Both ESX and ESS imply that efficiency is positively related to banks' profitability. It is also expected that efficient banks can offer more favourable prices to bank customers, leading to a negative relationship between efficiency and prices. Empirically, Berger and Hannan (1993) found that market concentration (i.e. the SCP hypothesis) better explains bank profits and prices than efficiency (i.e. the ESX and ESS hypotheses) and market share (i.e. the RMP hypothesis). Goldberg and Rai (1996) later applied the Berger-Hannan approach on 11 European banking industries, but found that cost efficiency was the main determinant of banks' performance in some European countries with low market concentration, while scale efficiency and market structure only played a small role.

The empirical specification

In this paper, we employ the approach of Berger and Hannan (1993) to examine how banks' performance is determined, by including direct measures of efficiency in the empirical analysis, along with variables representing market structures and other controlling factors. Two equations are specified as follows:

$$\Pi_{it} = \beta_0 + \beta_1 CONC_t + \beta_2 MS_{it} + \beta_3 DUM_t + \beta_4 CIE_{it} + \beta_5 SIE_{it} + \boldsymbol{\beta}_6 \mathbf{z}_{it} + f(e_{it}), \quad (1)$$

and

$$P_{it} = \beta_7 + \beta_8 CONC_t + \beta_9 MS_{it} + \beta_{10} DUM_t + \beta_{11} CIE_{it} + \beta_{12} SIE_{it} + \boldsymbol{\beta}_{13} \mathbf{z}_{it} + f(e_{it}), \quad (2)$$

where i indexes bank and t indexes time; Π and P are the profitability and pricing ability of banks, which are adopted as measures of banks' performance; $CONC$ is market concentration and MS is banks' market share, which represent the market structure of the banking sector; DUM is the dummy variable introduced to quantify the impact of regulatory liberalisation; CIE and SIE denote cost inefficiency (i.e. X-inefficiency) and scale inefficiency of banks respectively.[6] $\mathbf{z}$ is a vector of control variables and $f(e_{it})$ consists of autoregressive terms of a white noise process to capture autocorrelation in residuals.

Profitability of banks Π is measured by the return on assets (ROA), which is defined as the ratio of post-tax profits (or losses) to total net assets.[7]

[6] For the study of how cost efficiency and scale efficiency affect the performance of banks, the actual explanatory variables used in the regression analyses, for estimation convenience, are cost inefficiency and scale inefficiency. This approach follows the specifications of Berger and Hanan (1993) and Goldberg and Rai (1995).

[7] The total net assets are the total assets less provisions.

The pricing ability *P* is proxied by the interest rate spread (*IRS*) of banks, which is defined as the average price of interest-bearing assets minus the average cost of interest-bearing liabilities. The former is adjusted to exclude the portion of interest incomes and assets contributed by inter-bank placements to reflect more closely the price of loans to non-bank customers. A higher *IRS* may suggest greater market power, as such banks could charge loans with a higher spread over their interest costs.

CONC is proxied by the Herfindahl-Hirschman index (*HHI*), which is defined as the sum of the squared market share of assets of individual banks, ranging from zero to one. A large number of banks, each with a small share, produce an *HHI* close to zero, while a single monopolist bank with a 100 percent share produces an *HHI* of one. *MS* is measured as the ratio of individual banks' total assets for each period to the sum of assets of all banks for that period. Regarding the sign of the estimated coefficients of *CONC* and *MS*, the SCP hypothesis suggests a positive sign for *CONC* in equations (1) and (2), while the RMP hypothesis predicts a positive sign for *MS* in the two equations.[8]

DUM is defined as one after 2001 Q2, and zero otherwise. *DUM* is specified this way to examine the effect of a series of regulatory liberalisation measures in the banking sector taking place around 2001:

(a) the interest rate deregulation was fully completed by July 2001, with interest rate restrictions on current and savings accounts also removed[9];

(b) the restriction on the number of branches and offices of foreign banks was completely removed in 2001; and

(c) the market entry criteria have been relaxed since 2002.

Note, the regulatory liberalisation was implemented around the same time as a sharp rise in *CONC*, due to a number of mergers and acquisitions. Therefore, putting *CONC* and *DUM* in the same equations may subject the estimation to the problem of multicollinearity. This issue will be further discussed in the following sections.

The variable *CIE*, which is derived from a stochastic cost frontier, represents the cost inefficiency of banks. Cost inefficiency is an estimate of the percentage by which total production cost could have been reduced if the bank had operated on the stochastic cost frontier, holding the output levels and input prices constant. Cost inefficiency refers to the situation in which the bank can reduce the production cost and still obtain the same quantity of outputs, given the input prices, but has failed to do so. Theoretically, such a deviation occurs when the bank does not choose the right mix of inputs to produce the target output or employs excessive quantities of the factor inputs to produce the same amount of output. The estimate of *CIE* in this paper is equivalent to the variable *IE* (i.e. inefficiency estimate) in Wong et al. (2006a). Under the ESX hypothesis, the sign of the estimate coefficient for *CIE* is negative in equation (1) when *ROA* is the dependent variable, and is positive in equation (2) when *IRS* is the dependent variable.

[8] The SCP hypothesis suggests a positive sign for *CONC* in equations (1) and (2), as it asserts that banks in a concentrated market are more likely to engage in some form of non-competitive behaviour, which allows banks to set less favourable prices to customers and earn higher profits. The RMP hypothesis suggests a positive sign for *MS* in the two equations as it asserts that banks with larger market shares are able to exercise market power to earn higher profits.

[9] The deregulation of interest rates in Hong Kong was undertaken in two phases. Phase 1, in July 2000, removed the interest rate cap on time deposits with a maturity less than seven days and the prohibition on benefits for all deposits with the exception of Hong Kong dollar current and savings accounts. Phase 2, in July 2001, removed all interest rate rules over current and savings accounts.

Scale inefficiency *SIE* used in the regression analyses is computed from the parameters of the cost function estimated in Wong et al. (2006a), which is also adopted to calculate the *CIE*. *SIE* measures the absolute deviation of the bank's actual output level from its optimal-scale output level that has the minimum average cost. By definition, *SIE* ranges from zero to one. The lower the *SIE* value, the closer the bank operates to its optimal scale. Detailed derivations of the *CIE* can be found in Wong et al. (2006a) and the definition of *SIE* is provided in the Appendix. The coefficient estimate for *SIE* is expected to be negative in equation (1) and positive in equation (2), if the ESS hypothesis holds.

Some variables reflecting bank characteristics are incorporated to control for other heterogeneities in the samples. These include the ratio of loan loss provisions to total loans (*LLoss*), the ratio of total interest-bearing funds[10] to assets (*DEPASS*), and the capital adequacy ratio (*CAR*). *LLoss* is included in the estimation to capture differences in the quality of banks' loan portfolios. A higher *LLoss* of banks indicates a loan portfolio of poorer credit quality, which may lead to lower profits due to higher operating costs relating to credit risk and loan loss management[11]. It may also trigger banks to shift to other assets with lower risks, resulting in lower *IRS*. *DEPASS* is adopted as a proxy for the leverage of banks. A higher *DEPASS* indicates that a greater portion of the bank's assets is funded by non-equity funds, which could lead to higher funding costs, resulting in lower *ROA* and *IRS*. Such a relationship implies a negative estimated coefficient for *DEPASS* in regression equations (1) and (2). However, according to Goldberg and Rai (1995), a higher *DEPASS* may indicate that banks are more aggressive in asset-liability management, which could lead to higher *ROA* and *IRS*. If this is the case, a positive sign for the coefficient estimate of *DEPASS* in equations (1) and (2) is expected. *CAR* is considered as a proxy for banks' risk attitude. The coefficient estimate is expected to be negative, as a more aggressive portfolio (with a lower *CAR* value) should normally require a higher *ROA* or *IRS* for compensation.

In addition to bank characteristics, we incorporate Hong Kong's real GDP growth rate (*GDP*) and the unemployment rate (*UR*) into equations (1) and (2) to control for the influence of economic cycles. Generally, banks should generate higher profits and be able to charge higher prices under good economic conditions.

Data and estimation method

We employ in the estimation a panel data set that involves 38 retail banks in Hong Kong for the period 1991 Q1 to 2005 Q4.[12] Retail banks are the locally incorporated banks plus a number of the larger foreign banks whose operations are similar to those of the locally incorporated banks in that they operate a branch network and are active in retail banking. The banking data are obtained from the regulatory returns that Authorized Institutions in Hong Kong must file with the Hong Kong Monetary Authority. As our aim is to examine the profit-structure relationship in Hong Kong, the data used in the study cover only the banks' Hong Kong offices.

[10] Interest-bearing funds are defined as the sum of deposits from customers, inter-bank borrowings, and the amount payable under repos and negotiable debt instruments issued and outstanding.

[11] This includes, for example, cost relating to credit approval control, foreclosing bad loans, debt recovery expenses, and other loan-restructuring expenses.

[12] Initially, 45 banks in various periods were covered by the study. After removing samples with missing information, 38 retail banks remained in the estimation. Note, that the number of banks covered by the study varied in different periods. After the major mergers and acquisitions, the number fell from 38 during 2001 Q2 to 28 during 2005 Q4.

TABLE 1

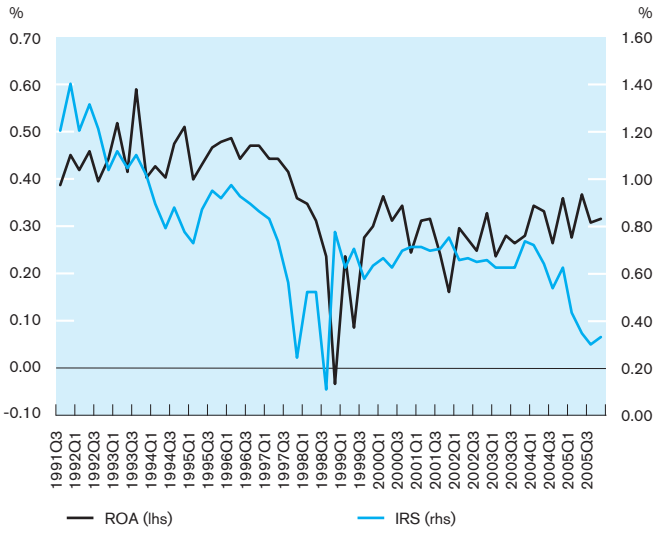
General features of the data
(Sample period: 1991Q1-2005Q4; No. of observations: 1,418)

Variable	Mean	Median	Std. Dev.	Minimum	Maximum
ROA [a]	0.0036	0.0035	0.0030	-0.0263	0.0434
IRS [a]	0.0076	0.0074	0.0034	-0.0053	0.0377
CONC	0.0973	0.0869	0.0211	0.0790	0.1392
MS	0.0275	0.0101	0.0510	0.0001	0.2860
CIE	0.16	0.14	0.09	0.03	0.79
SIE	0.07	0.05	0.07	2.13e-05	0.45
LLoss	0.02	0.02	0.02	0.00	0.21
DEPASS	0.83	0.85	0.10	0.19	0.92
CAR	0.22	0.20	0.14	0.09	1.10
GDP Growth [b]	0.0110	0.0120	0.0158	-0.0390	0.0650
Unemployment rate	0.0440	0.0445	0.0215	0.0150	0.0860

Notes:
[a] Quarterly figures, not annualised.
[b] Seasonally adjusted Hong Kong real GDP growth rates obtained from the Census and Statistics Department.

CHART 1

Time series plots of average quarterly ROA and IRS



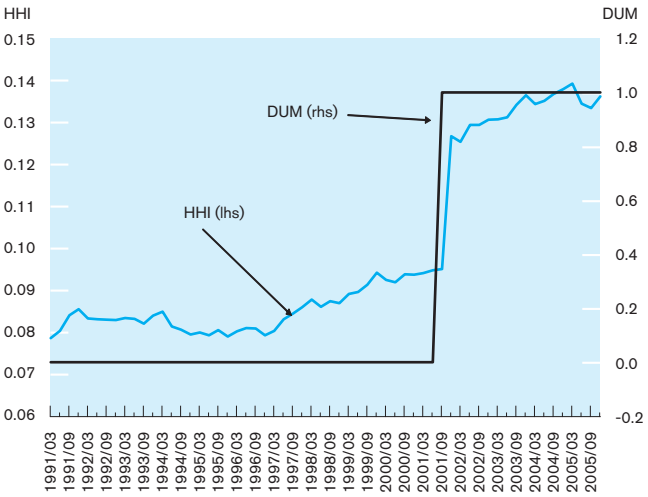
Sources: HKMA

After removing outliers and missing data, 1,418 observations are used for the study. Table 1 reports some descriptive statistics about the data set. Chart 1 depicts the average *ROAs* of retail banks for the study period. It shows that prior to 1998 Q4 (before the effects of the Asian financial crisis were fully reflected), banks' profitability was usually higher than 0.4%. A sharp fall to the negative region of the *ROA* for the fourth quarter of 1998 indicates the lag effect of the financial crisis. Although banks on average recovered from their quarterly loss after 1998 Q4, their *ROAs* were shown to have since stayed at a lower level of around 0.3%. The *IRS* exhibited a mild downward trend in the study period, suggesting that the pricing ability of banks was generally lower in recent years than previously.

The impact of industry consolidation on market concentration is apparent. Chart 2 shows market concentration measured by the *HHI* increased sharply around the second half of 2001, reflecting

CHART 2

Market concentration and regulatory liberalisation



Notes:
(1) The HHI is the sum of the squared market share of assets of all retail banks in the market, ranging from zero to one.
(2) DUM is defined as one after 2001 Q2 and zero otherwise to capture the effect of regulatory liberalisation occurring around 2001.

Source: HKMA

merger and acquisition activities. As major regulatory liberalisation occurred roughly at the same time as market consolidation, the variable *DUM* is similar to the evolution of market concentration. Such a close resemblance of the time series pattern of *CONC* and *DUM* suggests a degree of multicollinearity.

Equations (1) and (2) are estimated by the least squares method. A fixed cross-sectional effect is specified in the estimation to capture unobserved idiosyncratic effects of different banks. To correct for the presence of cross-section heteroskedasticity, the cross-section weights are used in the estimation. The coefficient variances are derived by the White cross-section method so that the estimator is robust to cross equation correlation and different error variances in each bank.

Estimation results

Estimation results are presented in Table 2 where Models A and B follow the specification in equations (1) and (2) respectively. The adjusted *R*-squared statistics of the two models, which measure the goodness of fit, are 0.46 and 0.41 in Models A and B respectively, indicating that the specifications are reasonably adequate. While not all variables included in Models A and B are statistically significant and obtain an expected sign, the *F*-statistics for both models reject the hypothesis that the set of selected variables do not give significant explanatory powers on *ROA* or *IRS*. Key findings are summarised as follows:

TABLE 2
Estimation results of ROA and IRS

Variable	ROA Model A	IRS Model B
Constant	0.0027	-0.0004
$CONC_t$	0.0046	-0.0346
MS_{it}	0.0040	-0.0088
CIE_{it}	-0.0068**	0.0027*
SIE_{it}	-0.0005	0.0051*
$LLoss_{it}$	-0.0165*	-0.0107
$DEPASS_{it}$	0.0035	0.0127**
CAR_{it}	0.0015	-0.0025
GDP_t	0.0112**	0.0287*
UR_t	-0.0359**	0.0027
Adj. R-squared	0.4573	0.4143
F-statistics	33.2766	24.8776

Note:
* and ** denote significance at the 5% and 1% levels respectively.

(1) The estimated coefficients of *CONC*, *MS*, and *DUM* are found insignificant in the models (at the 5% significance level). It was also found that the sign and significance of the coefficient estimate for *CONC* change significantly when *DUM* is included in the estimation due to the problem of multicollinearity.[13] Given this, the dummy variable is finally excluded in the specification of the equations (1) and (2). The estimated results for *CONC* and *MS*, therefore, represent the net effect of increased market concentration in conjunction with the series of regulatory liberalisation. This empirical evidence suggests that market structure, as measured by market concentration and market share of banks, is either not a significant determinant of banks' performance; or, to the extent that market consolidation in recent years has hampered competition thus enhancing banks' profitability, its adverse effect has been largely offset by regulatory liberalisation and technological progress during the same period. The emergence of a number of larger banks through mergers and acquisitions, which should be more capable of competing with existing large banks also may have contributed. This is in line with the empirical results found in Wong et al. (2006b) and Wong et al. (2007), which showed that banks in Hong Kong operated in a competitive fashion in the loan market during the period 1991-2005 without any significant sign of collusion on pricing.[14]

[13] The correlation coefficient between CONC and DUM is around 0.95.

[14] Market consolidation in recent years resulted in an increase in market concentration, which normally favours the development of collusion among banks.

(2) For cost efficiency, the estimated coefficient of *CIE* is found to be negative in the *ROA* regression and positive in the *IRS* regression. *CIE* is statistically significant at the 1% and 5% level in the *ROA* and *IRS* regressions respectively. This suggests that banks with a higher level of cost efficiency are able to improve their profits through optimising the input mix to produce a given level of outputs, and to offer more favourable prices to customers. This empirical result is consistent with the *X-efficiency* hypothesis.

(3) Since larger banks have been found to be more cost efficient than their smaller counterparts[15], the above finding suggests that for the same product in the loan market, larger banks can offer lower prices to customers than smaller ones, yet attain a similar or even higher level of profits. Therefore, to the extent that price competition squeezes interest margins and profits of banks, smaller banks are more likely to find themselves operating at a loss. This suggests that smaller banks are more vulnerable to intense price competition in the loan market.

(4) For scale efficiency, the coefficient of *SIE* is found to be negative in the *ROA* regression but positive in the *IRS* regression. However, it is statistically significant only in the *IRS* regression, suggesting that while banks can offer more favourable prices to customers by optimising their production scale, the effect of scale efficiency on profits is not significant.

(5) As expected, the credit quality of loan portfolios is found to be one of the determinants of banks' profitability. Banks with higher loan loss provisions to assets appear to earn less profit. A higher level of loan provisions suggests poorer credit quality of loan portfolios, which may call for higher operating costs relating to credit risk and loan loss management, such as credit approval control, foreclosing bad loans, debt recovery expenses, and other loan-restructuring expenses, leading to lower profits. On the other hand, the ratio of loan loss provisions to assets does not appear to be a significant determinant of loan prices.

(6) *DEPASS* and *CAR*, which measure the risk attitude of banks, do not appear to be significant determinants of banks' profitability. However, *DEPASS* is found to be positively correlated with the interest rate spread, indicating that aggressive banks may be more likely to participate in markets with higher risks, where higher prices are charged.

(7) For macroeconomic factors, the real GDP growth rate and unemployment rate are found to be positively and negatively related to banks' profitability respectively, and the real GDP growth rate is found to be positively related to the interest rate spread of banks. This indicates that in a good economic environment banks are more capable of charging higher prices in the loan markets and earn higher profits.

Conclusion

Empirical evidence finds that market structure, as measured by market concentration and market share of banks, is either not a significant determinant of banks' performance; or, to the extent that market consolidation in recent years has hampered competition thus improving banks' profitability, its adverse effect has been largely offset by regulatory liberalisation and technological progress during the same period. The emergence through mergers and acquisitions of a number of larger banks, which should be more capable of competing with existing large banks, may have also contributed. This finding is consistent with the empirical results of our previous studies[16] showing that the banking sector in Hong Kong operated with a high degree of competition without any significant sign of collusive pricing. Nonetheless, with bank consolidation

[15] See Wong et al. (2006a)

[16] See Wong et al. (2006b) and Wong et al. (2007).

expected to continue, the impact of market concentration on competition in future needs to be closely monitored.

On the other hand, cost efficiency is found to be positively correlated with banks' profitability and negatively correlated with loan prices. Banks with a higher level of cost efficiency appear to be able to improve their profitability and offer more attractive prices to customers. This suggests that banks with a lower production cost may earn higher profits through optimising the input mix to produce outputs. Since larger banks are found to be more cost efficient in general, as shown in Wong et al. (2006a), larger banks can offer their services at lower prices to compete with smaller banks but still attain a similar or even higher level of profits. To the extent that price competition squeezes interest margins and profits, smaller banks are more likely than larger ones to incur losses. Therefore, smaller banks may be more vulnerable to intense price competition in the loan market.[17]

Empirical results also indicate that banks with a loan portfolio of lower credit quality earn less profit, probably due to higher operational costs relating to credit risk and loan loss management. Loan prices are observed to be sensitive to banks' risk attitude. Aggressive banks may be more likely to participate in markets with higher risks, where higher spreads are charged. In addition, banks' profitability and loan spreads are in general positively correlated with the macroeconomic environment.

[17] For illustration, we select three larger banks and three smaller banks to calculate the impact of cost efficiency on profits and *IRS*. Based on the data set used in this study, the average XIEs of these banks in 2005 Q4 were 0.066 and 0.190 respectively. Using the estimated coefficients in Table 2, the difference in XIEs of larger banks and smaller banks has caused an annualised *ROA* gap of 0.34%, while the resulting gap on *IRS* is -0.13%. In other words, *ROA* of larger banks in general is larger than that of smaller banks by 0.34%, while their *IRS* is lower than that of smaller banks by 0.13% due to the difference in their cost efficiency. The differences are considered significant, given that the average values of annualised *ROA* and *IRS* of all banks in the data set are 1.44% and 3.04% respectively.

APPENDIX

Measures of scale inefficiency

The measure of scale efficiencies indicates how the scale of banks with a particular level of production and management technology deviates from their optimal economies of scale.[18] It is given by:

$$S_i = \sum_{j=1}^{J} \frac{\partial \ln C_i}{\partial \ln y_{ji}}$$
$$= \sum_{j=1}^{J} \tau_j + \sum_{j=1}^{J} \sum_{l=1}^{J} \gamma_{jl} \log y_{li} + \sum_{k=1}^{K} \omega_{jk} \log w_{ki}$$

The variable S_i is estimated for each of the banks at their respective output levels. Other notations can be referred to Wong et al. (2006a). Banks experience a constant return to scale when the estimate of S_i is equal to 1. If S_i is less than one, banks are operating below their optimal scale levels and they could lower costs by increasing output further. On the other hand, while S_i is greater than one, banks are required to downsize in order to achieve optimal input combinations. Both cases imply a degree of inefficiencies. A measure of scale inefficiency, SIE, is used in the actual regression:

$$\mathrm{SIE}_i \begin{cases} = S_i - 1 & \text{if } S_i > 1 \\ = 1 - S_i & \text{if } S_i < 1 \end{cases} \qquad \text{(A1)}$$

In such form, the smaller the SIE, the closer the banks' scale is to the optimal level.

[18] Detailed discussions of scale economies can be found in Murray et al. (1983).

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