Residential mortgage default risk and the loan-to-value ratio

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Many residential mortgage holders in Hong Kong have experienced negative equity as a result of the sharp fall in property prices since the Asian financial crisis.

This study looks at the impact of negative equity on the probability of default on mortgage loans, which is an important issue as residential mortgage lending represents a significant component of bank assets. The study suggests that residential mortgage default risk is positively correlated with the current loan-to-value (CLTV) ratio, the level of interest rates and the unemployment rate, and negatively correlated with financial market sentiment.

Given the importance of the CLTV ratio for estimating the probability of defaults, the study lends strong support to the prudential policy of encouraging the adoption of a maximum 70% LTV ratio in residential mortgage lending.

Introduction

The sharp fall in property prices following the Asian financial crisis has led many residential mortgage holders in Hong Kong to experience negative equity. At the end of September 2004, there were about 25,400 loans with a market value lower than the outstanding loan amount. The total value of these loans was HK$43 billion. The rate of mortgage delinquency reached a peak of 1.43% in April 2001. While it has improved since the second half of 2001, the delinquency rate in September 2004, at 0.47%, was still higher than the 0.29% recorded in June 1998, when data were first collected.[1] Given that residential mortgage lending represents a significant component of bank assets, how the negative equity positions of borrowers' mortgages affect borrowers' decisions to default is of interest to policymakers.[2]

This study uses micro-level mortgage loan data and macroeconomic information to examine the determinants of residential mortgage default risk in Hong Kong. It estimates the effect of changes in these determinants, in particular the current loan-to-value (CLTV) ratio, on default probabilities. The results suggest that the CLTV ratio is critical to mortgage default decisions. The study finds that default probability is positively correlated with the CLTV ratio, the level of interest rates and the unemployment rate, and negatively correlated with changes in stock prices.

Theoretical background

There are two alternative views of home mortgage default behaviour (Jackson and Kasserman, 1980). The *equity theory of default* holds that borrowers

[1] The improvement would have been smaller, if rescheduled loans were taken into account.

[2] "Decision to default" is a widely used term in literature. In practice, however, such defaults are best seen as arising from the financial hardship of borrowers.

base their default decisions on a rational comparison of financial costs and returns involved in continuing or terminating mortgage payments.[3] The alternative is the *ability-to-pay theory of default* (the cash flow approach). According to this approach, mortgagors refrain from loan default as long as income flows are sufficient to meet the periodic payment without undue financial burden. Under the equity theory, the CLTV ratio, which measures the equity position of the borrower, is considered to be the most important factor in default decisions. By contrast, under the ability-to-pay model, the current debt servicing ratio (CDSR), defined as the monthly repayment obligations as a percentage of current monthly income, which captures the repayment capability of the borrower, plays a critical role in accounting for defaults.

Recent research has attempted to incorporate trigger events, such as divorce, loss of a job, and accident or sudden death, in influencing default behaviour (Riddiough, 1991). Another factor relates to the lender's influence on default decisions. Workout plans helping borrowers who are faced with financial hardships provide an alternative to default. Taking into account the financial health of the borrower, the lender may respond in different ways to the threat of a possible default, such as loan restructuring, mortgage recourse, adoption of an extended repayment plan, or refinancing. In Hong Kong, post-foreclosure debt collections and possible initiation of a bankruptcy petition by creditors are believed to be the major deterrents to default. Lender's influence and transaction costs are clearly two reasons why a borrower does not default when the value of the property falls below the outstanding amount of the mortgage loan.

Previous empirical work has no firm conclusions about the relative importance of equity and affordability in mortgage default behaviour. While most of the literature finds the equity position to be the primary determinant in mortgage default decisions, some studies argue that non-equity effects, such as the source of income, are more significant. The importance of loan-to-value (LTV) ratio can be overstated if other variables are excluded from the empirical specification.

Empirical analysis

Research on mortgage default or prepayment behaviour using micro-level data is typically based on techniques used in survival analysis and duration modelling. An alternative approach, where survival time is less an issue, is to estimate binary choice models for a particular study period. Following many previous studies, this paper applies the logit model to explain mortgage defaults (see Box A).

The dependent variable is the default status of a loan. In this study, a mortgage loan is defined as a default case if it is overdue for more than 90 days. Based on this definition of default, the dependent variable used in the logit model is equal to 1 if the loan becomes overdue for more than 90 days and 0 otherwise.

Both the loan-related and non-loan-related factors, as well as macroeconomic variables, are used as explanatory variables. Reflecting the structure of Hong Kong's mortgage market and data availability, loan-related factors include the CLTV ratio, CDSR, mortgage rates, and the LTV ratio and the debt servicing ratio at origination. Non-loan-related factors include seasoning variables and property-related variables such as the property area, current unit property price and the age of the property.[4] In addition to the interest rate variable, which is already included as loan-related data, the unemployment rate and the change in the Hang Seng Index (HSI) are selected as proxies for macroeconomic conditions. The former is intended to reflect the stress in the labour market, and the latter is chosen to represent general financial market sentiment. A summary of these variables is given in Appendix 1.

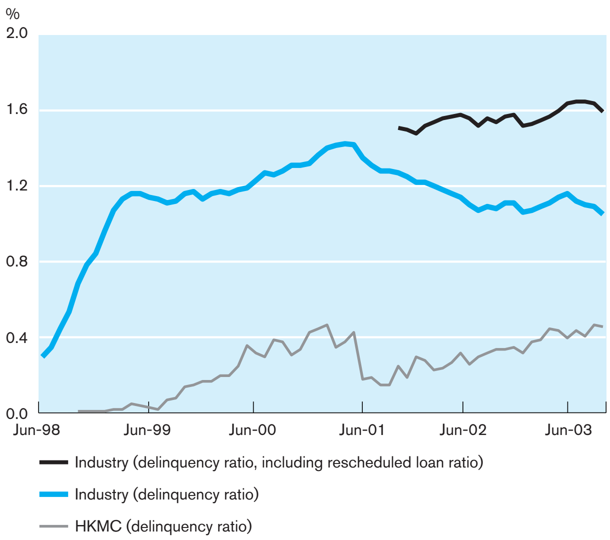
[3] Borrowers attempt to maximise the equity position in the mortgaged property at each point of time. They cease to continue payments if the market value of the mortgaged property declines sufficiently to equal the outstanding mortgage loan balance at any time.

[4] Seasoning variables measure how long the mortgage is expected to be served or has been served. The current unit property price is defined as the current price of the property per square foot.

Micro-level loan data are obtained from the Hong Kong Mortgage Corporation (HKMC). It should be noted that the HKMC's mortgage portfolio is believed to be of better quality than the industry average, as reflected by the consistently lower-than-average delinquency rate (Chart 1).[5]

CHART 1

Mortgage delinquency rate in Hong Kong



Note: Information of rescheduled loans of HKMC's portfolio is not available.
Sources: HKMA and HKMC Monthly Mortgage Portfolio Statistics.

The study covers the period from July 2000 to September 2003. "Snapshots" are taken in January and July of each year to examine loan delinquencies. All loan data of the eight selected months are pooled to form one cross-sectional data set. Data for all loans in a specific month are matched with macroeconomic conditions in that month. The data set is designed in such a way to capture the effect of varying economic conditions on default probability.[6] It should be noted that treating some of these loans, which continue to be in the HKMC's portfolio, as different observations in the various months could cause biases in the statistical analysis. To examine the issue of repeated observations, the model is estimated by using both the variance-adjusted and weight-adjusted methods. The estimation results are presented in Table 1. By comparing the estimated variances and coefficients obtained from the three different approaches, it is found that the assumption of independence among repeated observations may not be too strong. A brief discussion of this issue is given in Box B.

For simplicity, the analysis in the following sections is based on the set of estimated coefficients using the variance-adjusted method. As shown in Table 1, the results suggest the higher the CLTV ratio of a loan, the greater is the default probability; and the higher the mortgage rate, which implies a relatively heavier payment burden for the borrower, the greater is the likelihood of default.[7] This lends support to both the "equity theory" and the "ability-to-pay" approaches to explaining default decisions. Both labour and stock market conditions are found to have a significant impact on default probability. While the default probabilities are positively correlated with the unemployment rate, they are negatively correlated with changes in the HSI. Most non-loan factors (seasoning and property variables) are statistically insignificant, and they are therefore dropped from the subsequent statistical analysis.

[5] As the current study utilises only loan data from the HKMC, inference regarding the overall market drawn from findings of this study should be made with caution. In particular, the default probabilities estimated in this paper are likely to be lower than the industry average.

[6] In some studies, data on residential mortgages in different regions were matched with economic variables in the corresponding regions to assess the role of macroeconomic conditions (e.g. Campbell and Dietrich (1983), Cunningham and Capone (1990), and Lawrence and Smith (1992)). This approach is not feasible in the present case since there is no "regional" variation in the macroeconomic conditions in Hong Kong.

[7] The models were initially specified to combine the explanatory variables including the CDSR. Contrary to expectation, CDSR is found not to be significant. However, this could be due to the data quality of the derived CDSR, and should not be interpreted as CDSR not being a factor determining default risk. In view of this, mortgage rates are used as a proxy for CDSR.

TABLE 1
Estimation results

Variables	Model A	Model B	Model C
Current unit property price	-0.24 (0.00)	-0.24 (0.08)	-0.30 (0.00)
CLTV	0.02 (0.00)	0.02 (0.00)	0.02 (0.00)
Mortgage rate	0.37 (0.00)	0.37 (0.00)	0.39 (0.00)
Unemployment rate	0.49 (0.00)	0.49 (0.00)	0.66 (0.00)
Percentage change in HSI	-0.15 (0.00)	-0.15 (0.00)	-0.13 (0.00)
Constant	-12.75 (0.00)	-12.75 (0.00)	-13.70 (0.00)
Wald Test	708.45 (0.00)	330.63 (0.00)	676.58 (0.00)
Pseudo R^2	0.18	0.18	0.18
Log- Pseudo Likelihood	-1646.20	-1646.20	-1598.10
Goodness-of-fit Test	50754 (1.00)	50754 (1.00)	N.A.

Notes: 1. The estimation period for all models is from Jul 00 to Sep 03. Model A refers to the regression using data without adjustment. Models B and C refer to the regressions using the variance-adjusted and weight-adjusted methods respectively. For the weight-adjusted method, the goodness-of-fit test statistic is not available.
2. Numbers in parentheses are p-values.
3. The Wald test statistic tests the null hypothesis that all coefficients in the model are zero.
4. The Pseudo R^2 is McFadden's (1974) likelihood ratio index. It equals to 1 - (L_{UR}/L_0), where L_{UR} is the log-likelihood function for the estimated model with all coefficients present, the L_0 is the log-likelihood function with an intercept only (under the null hypothesis that all coefficients are zero in the restricted model). If all coefficients are zero, then the Pseudo R^2 equals to 0.
5. The goodness-of-fit test checks whether the selected model differs from the theoretical distribution for most of the selected months or not.

The estimated parameters are not easy to interpret, and, in particular, cannot be used in the same way as the parameters in linear regression. As shown in Equation (1) of Box A, the default probability is a non-linear function of the independent variables. Equation (2) computes the effects of changes in the CLTV ratio on the default probability, under the assumption that all other explanatory variables are at their mean levels. Such effects are derived and summarised in Chart 2.

To illustrate how labour market conditions affect default probability, Chart 3 shows the simulated default probability in relation to the CLTV ratio when the unemployment rate is set at 8.5% and 4.5%, as well as its mean level (6.5%). The estimated default

CHART 2
Default probability and CLTV ratio (all other variables at mean levels)

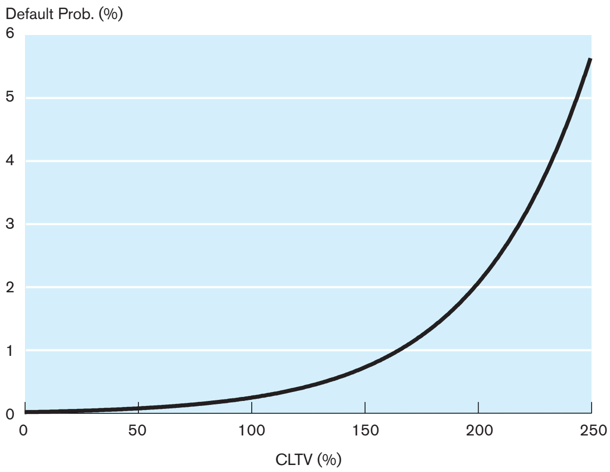


CHART 3
Default probability and CLTV ratio at different unemployment rates

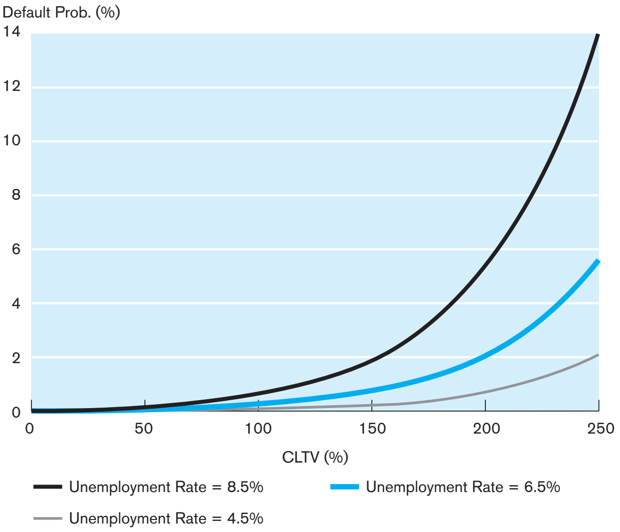
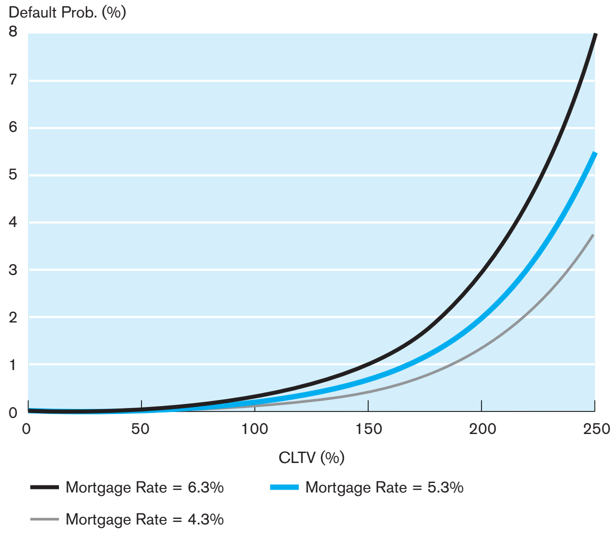


CHART 4
Default probability and CLTV ratio at different mortgage rates



probability is 2.0% if the CLTV ratio is 200%, and the unemployment rate is at its mean level (6.5%). With a higher unemployment rate, the default probability curve is high. When unemployment rates are at 8.5% and 4.5%, the estimated default probabilities are 5.3% and 0.8% respectively. Similar comparisons, holding other variables at their mean levels, between default probability and the CLTV ratio at different levels of mortgage rate or percentage change of HSI are given in Charts 4 and 5 respectively. In general, a higher mortgage rate or a lower percentage change of HSI tends to raise the default probability at a given CLTV ratio level. Illustrations showing how the estimated default probability changes at selected CLTV ratio levels with varying macroeconomic conditions are given in Table 2.

CHART 5
Default probability and CLTV ratio at different changes of Hang Seng Index

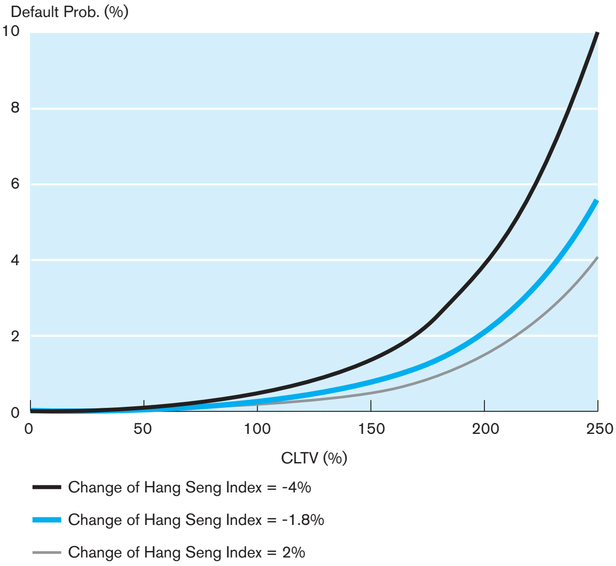


TABLE 2

Estimated default probability at different CLTV ratio levels under varying macroeconomic conditions

CLTV ratio Level (%)	All other explanatory variables at mean levels								
	Unemployment Rate			Mortgage Rate			Change of HSI		
	8.5%	6.5% *	4.5%	6.3%	5.3% *	4.3%	-4.0%	-1.8% *	2.0%
50	0.24	0.09	0.03	0.13	0.09	0.06	0.17	0.09	0.07
75	0.41	0.15	0.06	0.22	0.15	0.11	0.28	0.15	0.11
100	0.69	0.26	0.10	0.37	0.26	0.18	0.47	0.26	0.19
125	1.15	0.43	0.16	0.62	0.43	0.30	0.79	0.43	0.32
150	1.92	0.73	0.27	1.05	0.73	0.50	1.32	0.73	0.54
175	3.20	1.22	0.46	1.75	1.22	0.84	2.20	1.22	0.90
200	5.27	2.03	0.77	2.91	2.03	1.41	3.66	2.03	1.51
225	8.58	3.38	1.29	4.80	3.38	2.36	6.01	3.38	2.52
250	13.65	5.57	2.15	7.80	5.57	3.91	9.73	5.57	4.18

Note: * The mean level of the variable in question.

The 70% LTV ratio and asset quality

The quarterly survey on residential mortgage loans in negative equity provides the statistics on the average CLTV ratios since March 2002 for residential mortgages which are in negative equity. In September 2004, the average CLTV ratio was estimated at 121%. To assess how the relaxation of the maximum 70% LTV ratio guideline on property lending may affect banks' asset quality, we consider a hypothetical scenario under which the guideline was relaxed to 90% before 1997. We further assume that all banks would aggressively exploit this relaxation to expand their business by extending mortgage loans to cover 90% of the property values.[8] We then compare the estimated potential amount of defaulted loans based on the actual average CLTV ratio and the simulated CLTV ratio under the hypothetical scenario. The difference of the two ratios measures the impact of a relaxation of the guideline.

Using the negative equity loan position in September 2004 as an example, the impact is simulated and presented in Table 3. With the sharp fall in property prices since late-1997, the average CLTV ratio of the negative equity loans under the hypothetical scenario would be about 163%, significantly higher than the actual CLTV ratio reported by the mortgage survey.

At this level of CLTV ratio, the default probability of these negative equity loans, as derived from our model, would have been 0.95%, which is twice the actual level of 0.45%. Correspondingly, the potential amount of loans in default is estimated to rise from HK$0.2 billion to HK$0.4 billion, an increase of HK$0.2 billion or 50%. These are conservative estimates since the delinquency rate of HKMC's loan portfolio is only two-fifths of the industry's. If the estimated probability of default is adjusted proportionally to the ratio of actual delinquency rate of the industry to that of HKMC, the estimated increase in the potential amount of defaulted loans would be more than twice this amount.[9]

[8] This assumption is made to assess the maximum effect. However, this is an unlikely scenario, since banks will decide on the maximum loan amount based on their assessment on the credit worthiness of the borrowers and the debt servicing ratio. This is evidenced by the fact that the actual LTV ratio for new loans made around 1997 was on average below 60%, far lower than the maximum ratio of 70% permitted under the guideline.

[9] There are also other caveats. On the one hand, the impact can be underestimated as loans which were originally in the positive equity region could have fallen into negative equity region if the loans were initially originated at a LTV ratio of 90% under the hypothetical scenario. On the other hand, as pointed out in footnote 8, in reality, it is unlikely that banks would be so aggressive to fully exploit the hypothetical relaxation.

TABLE 3

Estimated loan defaults with and without a relaxation of the maximum LTV ratio guideline

	Actual Policy of Maximum LTV Ratio	Hypothetical Maximum LTV Ratio
Maximum LTV Ratio Guideline (%)	70	90
Average CLTV Ratio Level (%)	127	163
Default Probability (%)	0.45	0.95
Estimated Amount of Default Loans (HK$ billion)	0.2	0.4

Note: Mortgage loans in negative equity amounted to HK$43 billion in September 2004.

Conclusion

This analysis of mortgage default probability in Hong Kong confirms the importance of the CLTV ratio as a determinant of mortgage defaults. The mortgage rate, which serves as a proxy for the payment burden of borrowers, is also positively correlated with mortgage default risks. These results provide support for both the "equity theory" and the "ability-to-pay" approaches of explaining mortgage default. In addition, both labour and stock market conditions are found to have a significant impact on default probability. While default probability is positively correlated with the unemployment rate, it is negatively correlated with changes in the HSI.

With the CLTV ratio found to be critical to mortgage default decisions, this study lends strong support to the prudential policy of encouraging the adoption of the maximum 70% LTV ratio in residential mortgage lending.

APPENDIX 1

Data

Variables	Expected Sign[6]
Loan-related factors[1]	
Loan-to-value ratio at origination (%)	+/-
Current loan-to-value ratio (%)	+
Current loan-to-value ratio squared	-
Debt servicing ratio at origination (%)	+/-
Current debt servicing ratio (%)[2]	+
Mortgage rate (%)[3]	+
Non-loan-related factors[1]	
Seasoning	
Expected seasoning at origination (months)	+/-
Seasoning up to the study period (months)	-
Property	
Property area (sq. ft.)	+/-
Current unit property price (HK$)[4]	+/-
Age of property (months)	+/-
Age of property squared	+/-
Macroeconomic conditions[5]	
Change in HSI (%)	+
Unemployment rate (%)	-

Notes:
1. Data obtained from HKMC.
2. Current debt servicing ratio is defined as the payment in the current month divided by the estimated income in the current month. Monthly income at origination is estimated by mortgage payment for the first month divided by the debt servicing ratio at origination. Income in the current month is derived by adjusting the estimated monthly income at origination by the nominal wage index.
3. The mortgage rate is given by prime rate pluses mortgage rate spreads. This variable is also used as a macroeconomic condition variable.
4. Defined as the current price of the property per sq. ft.
5. Data obtained from CEIC.
6. Expected signs indicated are based on theoretical deliberations and previous empirical findings.

Box A: The logistic function and the derivation of the relationships between default probability and the level of CLTV ratio

In general, if the default probability ($P(Y)$) is a linear function f of a vector of explanatory variables x, where x includes loan-related and non-loan-related variables, under the logistic distribution, the default probability can be specified as:

$$P(Y = default) = \frac{e^{f(x)}}{1+e^{f(x)}} \qquad (1)$$

and $\quad f(x) = c+\beta_1 X_1+\beta_2 X_2+\ldots+\beta_n X_n$

where c is the constant term, X_i is the explanatory variable and β_i is the coefficient.

With the estimated results of Equation (1), the relationship between default probability and the level of CLTV ratio, holding other explanatory variables at their mean levels, can be derived based on Equation (2).[10]

$$\hat{P}(Y = default)\Big|_{X_2=\bar{X}_2,\, X_3=\bar{X}_3,\, \ldots,\, X_n=\bar{X}_n} = \frac{e^{\ln\left(\frac{\bar{P}}{1-\bar{P}}\right)+\hat{\beta}_1(X_1-\bar{X}_1)}}{1+e^{\ln\left(\frac{\bar{P}}{1-\bar{P}}\right)+\hat{\beta}_1(X_1-\bar{X}_1)}} \qquad (2)$$

where $\bar{P}$ is the average default probability, $\bar{X}_1$ is the mean level of the CLTV ratio and $\hat{\beta}_1$ is the estimated coefficient for the ratio.

[10] Another way to see the relationship is to derive the marginal effect of the j^{th} explanatory variable on the default probabilities by the following formula:

$$\frac{\partial P(Y=default)}{\partial X_j} = Z\ \hat{\beta}_j \text{ where } Z = \frac{e^{\hat{c}+\hat{\beta}_1\bar{X}_1+\hat{\beta}_2\bar{X}_2+\ldots+\hat{\beta}_n\bar{X}_n}}{(1+e^{\hat{c}+\hat{\beta}_1\bar{X}_1+\hat{\beta}_2\bar{X}_2+\ldots+\hat{\beta}_n\bar{X}_n})^2}$$

Box B: An assessment of the issue of repeated observations

Given that major characteristics of the loan - the CLTV ratio and mortgage rate - would have changed tangibly in the six-month intervals, pooling the data together may be in general acceptable (Loh and Tan, 2002). However, the results should be interpreted with caution. To the extent that some characteristics specific to an individual loan may have remained the same throughout the period, pooling the loan data together may result in using repeated observations in the sample and could cause biases in the statistical analysis. For instance, the true variance would be underestimated, so it may wrongly reject the null hypothesis (Type I errors) in parameter testing (Neuhaus, 1992; Williams, 2000; Cho and Kim, 2002). A conventional method to deal with repeated observations is to consider an unbiased variance estimation which adjusts the variance for the intra-cluster correlation. This method avoids Type I errors in hypothesis testing. Another method is to introduce sampling weights - weights are given to specific loans in order to make adjustments for the relative frequencies that these loans are included due to the sampling design.[11] In this study, logistic regressions are performed using both methods to assess the possible biases.

The estimation results for regressions using unadjusted, variance-adjusted, and weight-adjusted methods are given in Table 1. As expected, Models A and B have the same estimated coefficients but different standard errors because Model A uses the traditional variance estimators with full scores but Model B calculates the variance estimators by using grouped scores.[12] Empirical results show that there is no change in the significance of the coefficients between Models A and B. At the same time, the estimated coefficients of Model C are similar in magnitude to that of Models A and B. All these imply that the assumption of independence among repeated observations may not be too strong.[13]

[11] The weight attached is the inverse of the frequency that a particular loan appears in the sample. This is particularly applicable for cases that the attributes of repeated observations are constant.

[12] Scores are the first partial derivatives of the log-likelihood function with respect to the model parameters. Full scores include all individual observations (regardless of whether they are repeated observations) in the computation, while for grouped scores, repeated observations are grouped as specific independent observations in the calculation.

[13] Various studies have shown that the estimated variances of coefficients are biased because of the correlation of repeated observations, but the values of estimated coefficients remain unbiased (Cirillo et al., 1996; Cho and Kim, 2002). The estimated results of this study are in line with these studies.

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