# Time in delinquency: implications for mortgage lending and MBS

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## Abstract
Delinquency risk is often ignored in recent mortgage-related literature. However, it is postulated to be of sufficient influence to the yields of mortgages and the corresponding mortgage-backed securities (MBS) to warrant concern from mortgage lenders and issuers/underwriters of MBS. This paper provides the a rigorous analysis of the delinquency risk of residential adjustable mortgages (ARMs) by utilizing the 'time in delinquency' from delinquency in addition to the conventional delinquency incidence measure. Utilizing the Poisson and negative binomial models on 684 mortgage observations from 1980 to 1999, it is found that uncontrollable environmental factors are essentially responsible for delinquency incidence. However, controllable factors such as occupation of borrower, mortgage term and whether the loan consists of an initial preferential rate period are influential in determining the time in delinquency, if this situation arises. The implication is that although mortgage lenders and MBS underwriters may find that delinquency risk is largely dependent on macroeconomic trends, it may be possible to control and minimize the time in delinquency or the time before reinstatement when delinquency occurred. This is useful in reducing potential losses from default/foreclosure, as, although delinquent borrowers may not have default in mind when they initially miss an instalment, they may find default inevitable if the missed payments were to be allowed to accumulate.

## Keywords:
delinquency risk, ARMs, MBS, Poisson model, negative binomial model, default losses

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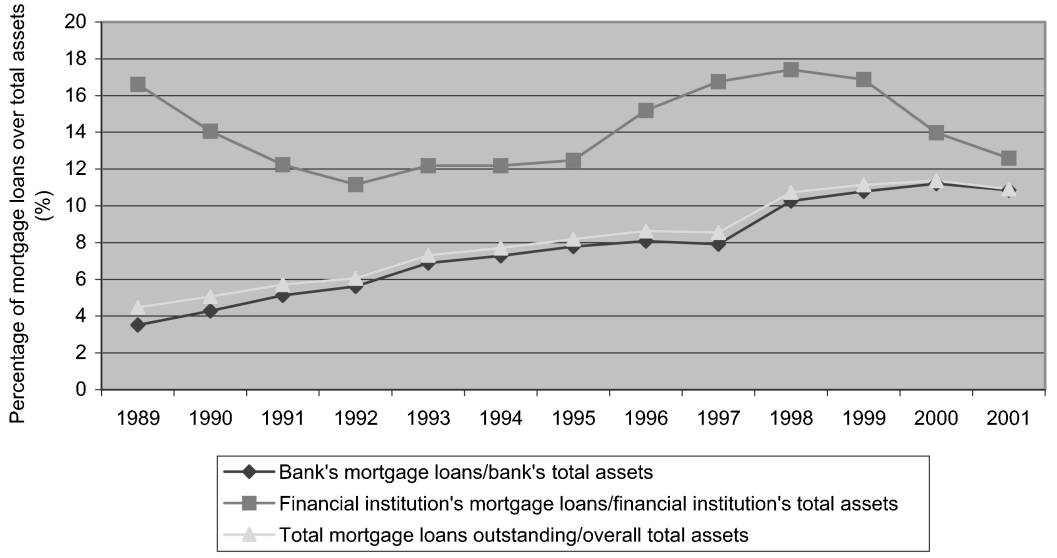
## INTRODUCTION
Mortgage lending is an imperative component of the businesses of financial institutions worldwide. This is accelerated by the growth of




* Financial Institutions account for a low proportion (about 4% in 2001) of the market share.

**Figure 1:** Proportion of mortgage loans outstanding to total assets of banks and financial institutions (1989–2001)*
*Source:* Monetary Authority of Singapore's Monthly Statistical Bulletin Database

the private residential property markets in the respective countries. With increasing mortgage loans originated, it is expected that the issuance of mortgage-backed securities (MBS) will continue to accelerate.

Similar trends can be found in Singapore (see Figure 1). In 1998, the Monetary Authority of Singapore, the *de facto* central bank, recommended the securitization of real estate (Sing and Ong 2003). Together with the provision of favourable tax treatment (Ong *et al*. 2000), there is enormous potential for the securitization of real estate and real estate-related debt in Singapore.

For this reason, understanding the underlying mortgage risks is essential. According to Campbell and Dietrich (1983), at any point of time, possible borrower action can be categorized into one of four groups:

1) Delinquent (delay payment or precursor to default);
2) Default;
3) Prepay the mortgage (through the sale of property or refinancing); and
4) Continue to service the mortgage.

Quercia and Stegman (1992) described the assumption in borrower payment models that the utility derived from each of the action is assessed and compared separately by the borrowers. Subsequently, the borrowers will select the action that yields the highest utility. Thus, a comprehension of the factors influencing each possible borrower action is essential towards understanding overall mortgage risk. However, there is generally a lack of studies on mortgage delinquency.

Quercia and Stegman (1992) argued that the apparent lack of interest in delinquency risk by both practitioners and academics is due to the fact that defaults are considered to be more serious and costly than delinquency, and that the delinquency decision is difficult to model because of its perceived unpredictability.

Delinquency thus represents the missing piece of the puzzle of the nature of mortgage risks. Without a comprehension of the motivation of each possible borrower action during the lifespan of a mortgage, we would not be able to attain a complete picture of mortgage risk.

More practically, lenders and investors in mortgage-related instruments have the misconception that delinquency risk is not costly to them. The prevalent view is that since most delinquent borrowers have every intention of keeping the property (von Furstenberg and Green 1974), they will try their best to repay the missed payments. Consequently, lenders do not view them to be as severe. However, Sandor and Sosin (1975) argued that loans that are habitually delinquent can be as troublesome and costly as loans that are foreclosed. This is a sufficient reason to warrant a better understanding of delinquency risk (Quercia and Stegman 1992). Lenders and underwriters of MBS are dependent upon the regular mortgage instalments to fund operational expenditure and coupon payments for investors of MBS, respectively. If the total delinquent payment exceeds the threshold of the MBS underwriters, the MBS investors may not be able to receive the stipulated coupon payments. In the case of mortgage lenders, liquidity problems may result.

Additionally, the nature of mortgage pass-through instruments is such that investors will experience delays in payments once delinquency occurs. Other MBS that do not have guarantees or insurances will incur the waiting period for the collection of the payments in arrears. Even if insurance or guarantees were to be available, servicers would need to make claims to the relevant insurers which would incur waiting time as well. Due to this unpredictable cash flow, investment yields might be reduced. Other sources of loss can include the threat of bankruptcy, loss of credit standing and downgrading risk status of the MBS.

Finally, delinquency is traditionally regarded as unpredictable (e.g. Canner *et al*. 1991; Quercia and Stegman 1992). By utilizing the additional measure of 'time in delinquency' (i.e. the number of months for which a delinquent loan will remain in delinquency until the missed payments are repaid), this paper aims to derive the controllable determinants of delinquency beyond the unpredictability of the conventional measure of delinquency incidence.

The research contributions of this paper include the insights provided on the nature of delinquency risk to fill the knowledge gap on overall mortgage risks, and the utilization of 'time in delinquency' or 'time before reinstatement' as an additional measure in a sample selection model[1] to assess the controllable determinants of delinquency.

The key results are that factors including loan-to-value ratio, premium of price paid over valuation, mortgage term, presence of an

initial preferential fixed rate, tenure of property, floor level of property, age of the youngest borrower (AGE) and borrower occupation earning stable income, are all significant in determining delinquency risk measured by the time in delinquency, if this situation arises. Furthermore, a more restrictive model yields a smaller number of significant variables (i.e. mortgage term, presence of an initial preferential fixed rate, tenure of property, floor level of property and borrower occupation earning stable income).

## LITERATURE REVIEW

It should be noted that most literature on mortgage risks has originated from the USA, where fixed-rate mortgages (FRMs) are prevalent (Ong 2000). Conversely, all mortgages originating in Singapore are adjustable-rate mortgages (ARMs) (Khor and Ong 1998). The exogenous and endogenous factors affecting both forms of mortgage may thus diverge. However, the level of divergence is expected to be slight. For example, Zorn and Lea (1989) suggested that ARMs in Canada have a higher probability of default than FRMs in the USA. Nonetheless, the methods and factors used in the literature to rationalize mortgage risks in FRMs serve as a platform for our analysis.

Ambrose and Capone (1996, 1998) and Waller (1988) described the aim of delinquency to be either to put the funds, originally intended to pay the instalments, to other uses as a result of financial difficulties, or to exercise the implicit put option to abandon the property. A third cause of delinquency noted by Waller (1988) is the economic incentive that borrowers can gain from living in the house rent-free before foreclosure takes place.

Von Furstenberg and Green (1974) found that the equity-value ratio possesses a significant negative relationship with delinquency, while the age of mortgages has a positive relationship. They also discovered that mortgages of existing houses are more prone to delinquency than those taken on new houses. Besides von Furstenberg and Green (1974), Herzog and Earley (1970) and Morton (1975) also found income, occupation and the number of children to be influential determinants.

Zorn and Lea (1989) argued that delinquency can be regarded as a form of borrowing from the lender at the mortgage contract rate. Therefore, when the interest rate increases, the delinquency rate will rise correspondingly as people 'borrow' at the relatively cheaper source of fund to finance other uses. Canner *et al*. (1991) found that the receipt of government assistance, the household being headed by a minority, and marital status have positive influences.

On a more sombre note, Canner *et al*. (1991) pointed out that delinquency prediction consists of a large unexplained random component, as credit problems can arise from events that are difficult to foresee. Thus, the use of ex-ante data has the ability to capture components that systematically affect delinquency and are observable to the lender at loan origination, but ignores the more unpredictable ex-post components.

## DATA AND DESCRIPTIVE STATISTICS OF VARIABLES

It is hypothesized that the main cause of delinquency is the occurrence of trigger financial commitments/difficulties (Vandell and Thibodeau 1985), causing the borrower to divert funds from paying the principal and interest, to the financial commitments. However, as concluded by Canner *et al*. (1991), forecasting such trigger events would be difficult. This paper does not attempt to do so. Instead, since the trigger events by nature occur randomly, the focus is to identify the variables that would reduce the time in delinquency and thus help lenders to minimize the losses from delinquency.

It is further hypothesized that the extent of the impact of the trigger events depends on:

1) Borrowers' *affordability*[2] to pay the instalments;
2) The level of *non-housing wealth*[3] that the borrower has accumulated; and
3) How *highly*[4] the borrower rates the property.

Along the same line of argument, the time in delinquency is hypothesized to be directly influenced by the extent of the impact of the trigger events.

### Determinants of delinquency

Table 1 presents the determinants, codes used and the expected signs of influence.

The determinants we utilize to control the effect of delinquency incidence and time in delinquency is categorized into four groups.

**Table I:** List of determinants, codes and expected signs of influence

| Variable | Code | Expected signs |
|---|---|---|
| **Mortgage loan specific characteristics** | | |
| Loan-to-value ratio | LVR | + |
| Price premium | PREMIUM | ± |
| Central Provident Fund-to-price ratio | CPFPRICE | − |
| Mortgage term | MT | + |
| Premium of mortgage rate over prime rate | RISKPRE | + |
| Preferential rate characteristics | FRM | ± |
| **Property-specific characteristics** | | |
| Tenure where freehold = 0 | TENURE | + |
| Type of property where low-rise = 0 | TYPE | + |
| Land area | LAREA | − |
| Floor level | FLOOR | − |
| Built-up area | BUAREA | − |
| **Borrower-specific characteristics** | | |
| Payment-to-income ratio | PINCRATIO | + |
| Number of borrowers | BORROWER | + |
| Age of youngest borrower | AGE | ± |
| Purpose of purchase where owner-occupation = 0 | PURPOSE | + |
| Number of years in current employment | YRSEMP | − |
| Occupation where stable income = 0 | OCCUP | + |
| **Environmental characteristics** | | |
| Change in mortgage rate | CMR | + |
| Change in gross domestic product | CGDP | − |
| Change in rents | CRENTS | − |
| Change in residential property price index | OCRPPI | − |
| Change in Straits Times Index | CSTI | ± |
| Change in unemployment rate | CUNEMP | + |

Firstly, borrower-specific characteristics refer to determinants that vary according to the individual mortgage borrowers, and include payment-to-income ratio (PINCRATIO), number of borrowers (BORROWERS), age of youngest borrower, purpose of purchase (owner occupation or investment), number of years in current employment (YRSEMP) and type of occupation (with stable or unstable earnings). The second group of determinants comprises the mortgage loan-specific characteristics, including loan-to-value ratio, price premium (PREMIUM), Central Provident Fund (CPF)[5]-to-price ratio (CPFPRICE), mortgage term, premium of mortgage rate over prime rate (RISKPRE) and the presence of an initial preferential rate period.

Property-specific characteristics are included in the third category of determinants, including tenure (freehold or leasehold), type of property (low-rise or high-rise), land area, floor level and built-up area. The final category consists of the macroeconomic factors, such as change in mortgage rate (CMR), gross domestic product (GDP), rental index, residential property price index, Straits Times Index (STI)[6] and unemployment rate.

## Descriptive statistics

The summary descriptive statistics is shown in Table 2. The period of analysis for collection of delinquency data is from January 1999 to August 2002. Out of the 684 observations under study, a total of 133 cases have become delinquent at certain times within the period of analysis.

The origination dates of the sample range from March 1980 to December 1999. Since only 14 cases originated before 1991, a better measure of central tendency would be the median, corresponding to the value in 1998. The average loan amount is $363,697, with a standard deviation of $161,537. The average amount delinquent is low, at $1414, due to the large proportion of observations that have not been in delinquency before. The standard deviation is $4725, while the maximum delinquent amount stands at $38,241. Similarly, for the proportion delinquent, the mean is a low 0.46%, with a range from 0% to 14.03%.

The average valuation is $670,357, with a higher range of $147,000 to $3,400,000. The consequent average loan-to-valuation ratio (LVR) is 0.5624. PREMIUM is shown to range from −50.00% to +52.27%, while the average value is close to 0%. The size of the CPF lump sum used by the borrowers ranges from $0 (not used) to $631,000. The resultant CPFPRICE ranges from 0% to 92.21%. The average CPFPRICE is 17.45%. The average mortgage term (MT) is 24.0137 years, which ranges from three to 33 years. The breach of the stipulated maximum loan term of 30 years, and the odd number of years, are due to negotiations between the delinquent borrower and the lender after loan origination to extend the period over which the loan shall be paid. As for the CMR, the average value is around −0.7661, with a range of around −4.0600 to +0.3500. The mean value for RISKPRE is 2.5897.

**Table 2:** Descriptive statistics of full sample

| Variable | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|
| Origination date | 19919595.60 | 1010654.37 | 1980320.00 | 19991202.00 |
| **Delinquency data** | | | | |
| Loan amount | 363696.783 | 161537.470 | 30000.000 | 1640000.000 |
| Amount delinquent | 1414.0619 | 4724.6951 | 0.0000 | 38241.0000 |
| Proportion delinquent | 0.004605 | 0.015570 | 0.000000 | 0.140300 |
| **Mortgage loan-specific characteristics** | | | | |
| Valuation | 670357.2890 | 295256.3300 | 147000.0000 | 3400000.0000 |
| Central Provident Fund lump sum | 115545.4250 | 114597.7730 | 0.0000 | 631000.0000 |
| LVR | 0.5624 | 0.1722 | 0.03158 | 0.8976 |
| PREMIUM | 0.0005840 | 0.0555700 | −0.5000000 | 0.5227000 |
| CPFPRICE | 0.1745 | 0.1504 | 0.0000 | 0.9221 |
| MT | 24.0137 | 6.2983 | 3.0000 | 33.0000 |
| RISKPRE | −1.4303 | 0.4759 | −2.1000 | −1.1000 |
| FRM | 0.6545 | 0.4759 | 0.0000 | 1.000 |
| **Property-specific characteristics** | | | | |
| TENURE | 0.7352 | 0.4416 | 0.0000 | 1.0000 |
| TYPE | 0.8676 | 0.3392 | 0.0000 | 1.0000 |
| LAREA | 2436.3158 | 983.5124 | 1317.0000 | 8256.0000 |
| FLOOR | 6.8163 | 5.4965 | 1.0000 | 35.0000 |
| BUAREA | 1509.4683 | 569.0150 | 1500.0000 | 4639.0000 |
| PPRICE | 668054.96 | 288315.61 | 160000.00 | 3400000.00 |
| **Borrower-specific characteristics** | | | | |
| Monthly instalment | 2097.9450 | 1293.6485 | 143.0000 | 18000.0000 |
| PINCRATIO | 0.267900 | 0.115800 | 0.009499 | 0.841200 |
| BORROWER | 2.0679 | 0.5426 | 1.0000 | 5.0000 |
| AGE | 36.4790 | 7.1345 | 20.1202 | 62.0427 |
| PURPOSE | 0.04414 | 0.20560 | 0.00000 | 1.00000 |
| INCOME | 103711.1310 | 61858.8788 | 16900.0000 | 747309.0000 |
| YRSEMP | 9.2914 | 7.7818 | 0.0833 | 37.0000 |
| OCCUP | 0.2085 | 0.4066 | 0.0000 | 1.0000 |
| **Environmental characteristics** | | | | |
| CMR | −0.7661 | 0.5801 | −4.0600 | 0.3500 |
| CGDP | 0.1856 | 0.2172 | 0.0366 | 2.0504 |
| CRENTS | −0.001698 | 0.078300 | −0.366400 | −0.502100 |
| OCRPPI | −0.003939 | 0.200700 | −0.439300 | 1.678100 |
| CSTI | −0.002431 | 0.251200 | −0.369000 | 1.303100 |
| CUNEMP | 0.5988 | 0.5928 | −0.3231 | 1.7500 |

Of the sample cases, 73.52% are leasehold properties and the remainder are of freehold tenure. Property type (TYPE) is dominated by high-rise properties. A total of 570 (86.76%) of the mortgages were backed by either condominium housing or apartments. Terraces, semi-detached housing or detached housing backed the remaining 87 (13.24%) mortgages. The average land area (LAREA) of the low-rise properties is 2436 square feet, and it ranges from 1317 square feet to 8256 square feet, depending on whether they are terraces, semi-detached or detached housing, in ascending order of the level of land area. The floor levels (FLOOR), where the high-rise properties are located, range from the 1st to the 33rd storey, with an average level of 6.8163. The mean built-up area (BUAREA) is 1516 square feet.

The sample of 657 residential mortgages is backed by properties with purchase prices (PPRICE) of between $160,000 and $3,400,000. The average PPRICE is $668,055. As for the change in rents (CRENTS), the mean value is around −0.1698%, with a range of between −36.64% and −50.21%.

Monthly mortgage instalments payable have an average of $2097.94. The corresponding PINCRATIO ranges from 0.0095 to 0.8412, with an average of 0.2679. BORROWER varies from 1.0000

to 5.0000, with a mean of 2.0679. Out of the 684 mortgage observations, 628 observations, or 95.59% of the sample size, purchased the property for owner-occupation purposes as opposed to, for investment purposes. The mean of the borrower's income (INCOME) is at $103,711, with a range of $16,900 to $747,309. The average YRSEMP is 9.2914 years.

In the periods under study, the change in unemployment rate (CUNEMP) ranges from −0.3231 to +1.750, with an average of 0.5988. Generally, unemployment rates in Singapore have been increasing because of the economic crises in many parts of Asia. However, due to the relatively large standard deviations, the median can be a more precise measure of central tendency.

The average change in STI (CSTI) is relatively low, at −0.002431. The relatively large standard deviations, relative to the corresponding mean values, suggest that there have been reasonably large fluctuations in the STI over the period from the origination dates of the loans to the delinquency dates or the censor dates. Similarly, in terms of the changes in GDP (CGDP), the mean is 0.1856 while the standard deviation is 0.2172.

The averages of the changes in the residential property price index (CRPPI) are consistently negative, suggesting a fall in RPPI over the study periods.

## RESEARCH METHODOLOGY

We propose to use the number of months in delinquency before reinstatement to be the dependent variable for the time in delinquency. This count data-dependent variable is the motivation behind the use of the Poisson and negative binomial models in our analysis. We have chosen not use the more conventional duration models because our sample consists of a preponderance of zeros—that is, most of the loans in the sample have not been in delinquency during our sample period, and consequently the dependent variable, as defined by the time to delinquency to occur, would have non-zero values only for a small proportion of the sample. The inclusion of these non-delinquent loans is essential, as the time in delinquency is viewed as a reinstatement decision which is a second step after the delinquency decision. Failure to account for the two-step decision process in delinquency will cause the model to be mis-specified and inefficient.

The primary equation of the Poisson regression model is:

$$\text{Prob}\ (Y_i = y_i \,|\, \boldsymbol{x}_i) = (e^{-\lambda}\lambda_i^{yi})/y_i!, y_i = 0, 1, 2 \ldots$$

where

$$\ln\lambda_i = \boldsymbol{x}'\beta$$

In the Poisson model, $\lambda_i$ is both the mean and variance of $y_{i.}$.

The negative binomial model is an extension of the Poisson regression model which allows the variance to differ from the mean, and the $\lambda_i$ is respecified so that

$$\ln\lambda_i = \boldsymbol{x}'\beta + \epsilon_i$$

where
$\exp(\epsilon i)$ has a gamma distribution with mean 1.0 and variance $\alpha$.

The corresponding equation of the negative binomial regression model is:

$$\text{Prob } (Y_i = y_i \,|\, \boldsymbol{x}_i, \epsilon_i) = (e^{-\lambda_i \epsilon i}) \; (\lambda_i \epsilon_i)^{yi} / y_i!, y_i = 0, 1, 2 \ldots$$

The estimation frameworks are well explained in Greene (2003), and it is suggested that the reader refers to it for further details.

Furthermore, due to the sample selection nature of the reinstatement decision and truncation of the data, we adopt the sample selection concept within our Poisson model. The dependent variable of the Poisson model yields a value only if the loan is delinquent. Thus, there are in effect two decisions in our model:

1) Incidence of delinquency; and
2) Time in delinquency (time before reinstatement).

The issue of truncation is obvious when we recognize that the dependent variable in the second decision only has a value if the loan is in delinquency—that is, the first decision is satisfied. Thus, the time in delinquency or time in reinstatement in the second decision is incidentally truncated. The problem of not taking into account the non-random sampling is that it introduces inconsistency into the parameters estimated, thus making any inferences dubious.

The first decision is represented by the selection equation in the sample selection methodology. Modelled using the probit model, a dummy variable is used, whereby delinquent loans are allocated the value of 1 while non-delinquent loans are allocated value of 0. Delinquency incidence is expected to be influenced by borrower, loan, property and environmental variables, as shown in Table 1.

In the second step, the main equation of interest (i.e. time in delinquency) is then assumed to be influenced by the variables categorized as borrower-, mortgage loan-, and property-specific characteristics. Environmental variables are left out from our equation of interest. Environmental variables essentially measure changes in the variables from the origination date to the date of delinquency, or—if there is no delinquency—to the date of censor. Since the period of time in delinquency before reinstatement is short, it can be reasonably assumed that these variables do not change within the delinquency period.

There are thus three types of observations in our sample:

$$\begin{aligned}
&y_2 = 0 && : \text{Prob } (y_2 = 0 \,|\, \boldsymbol{x}_1, \boldsymbol{x}_2) = 1 - \Phi\left(\boldsymbol{x}_2' \beta_2\right); \\
&y_1 = 0,\ y_2 = 1 && : \text{Prob } (y_1 = 0, y_2 = 1 \,|\, \boldsymbol{x}_1, \boldsymbol{x}_2) = \Phi_2\left[-\boldsymbol{x}_1' \beta_1,\ \boldsymbol{x}_2' \beta_2,\ -\rho\right]; \text{ and} \\
&y_1 = 1,\ y_2 = 1 && : \text{Prob } (y_1 = 1, y_2 = 1 \,|\, \boldsymbol{x}_1, \boldsymbol{x}_2) = \Phi_2\left[\boldsymbol{x}_1' \beta_1, \boldsymbol{x}_2' \beta_2, \rho\right],
\end{aligned}$$

where the dependent variables in the model are:

$y_1 =$ time in delinquency
$y_2 =$ incidence of delinquency,

and the independent variables in the model are:

$x_1$ = LVR, PREMIUM, CPFPRICE, MT, RISKPRE, FRM, TENURE,[7] TYPE, LAREA, FLOOR, BUAREA, PINCRATIO, BORROWER, AGE, PURPOSE, YRSEMP, OCCUP[8]

$x_2$ = LVR, PREMIUM, CPFPRICE, MT, RISKPRE, FRM, TENURE, TYPE, LAREA, FLOOR, BUAREA, PINCRATIO, BORROWER, AGE, PURPOSE, YRSEMP, OCCUP, CMR, CGDP, CRENTS, CRPPI, CSTI, CUNEMP.

In addition, a series of traditional model diagnostics have been carried out to improve the fit of the model. These diagnostics include outlier detection, residual analysis,[9] influence diagnostics[10] and multicollinearity.[11]

## EMPIRICAL RESULTS

The summary results are presented in Table 3 and the full results are presented in Table 4 and Table 5.

### Results and implications

Variables that are significant in explaining the incidence of delinquency (Table 6) include CPFPRICE, FRM, TYPE, FLOOR, YRSEMP, CMR, CGDP, CRENTS, OCRPPI, CSTI and CUNEMP. An

**Table 3:** Summary results

| Variables | Expected sign | Poisson model (Time in delinquency) | Negative binomial model (Time in delinquency) | Delinquency model (Incidence of delinquency) |
|---|---|---|---|---|
| **Mortgage loan-specific variables** | | | | |
| LVR | + | +* | + | − |
| PREMIUM | ± | −*** | − | − |
| CPFPRICE | − | + | − | −** |
| MT | + | +*** | +* | + |
| RISKPRE | + | + | + | + |
| FRM | ± | −*** | −*** | −*** |
| **Property Specific Variables** | | | | |
| TENURE | + | +*** | +* | − |
| TYPE | + | + | − | +*** |
| LAREA | − | − | − | + |
| FLOOR | − | −** | − | −* |
| BUAREA | − | − | − | + |
| **Borrower Specific Variables** | | | | |
| PINCRATIO | + | + | + | + |
| BORROWER | + | + | + | + |
| AGE | ± | +*** | + | − |
| PURPOSE | + | − | − | + |
| YRSEMP | − | + | + | +** |
| OCCUP | + | +*** | +*** | + |
| **Environmental Variables** | | | | |
| CMR | + | | | +*** |
| CGDP | − | | | −*** |
| CRENTS | − | | | −*** |
| OCRPPI | − | | | +*** |
| CSTI | ± | | | +** |
| CUNEMP | + | | | −*** |
| Log-likelihood | | −421.0898 | −401.0122 | −183.9097 |

*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

**Table 4:** Full results of Poisson model for time in delinquency

| Determinant | Coefficient | Standard error | t-Statistic | *p*-Value |
|---|---|---|---|---|
| Constant | −0.53832 | 0.67687 | −0.795 | 0.4264 |
| LVR | 0.62020 | 0.38196 | 1.624 | 0.1044 |
| PREMIUM | −2.15428 | 0.73511 | −2.931 | 0.0034 |
| CPFPRICE | 0.87826E-01 | 0.35239 | 0.249 | 0.8032 |
| MT | 0.28339E-01 | 0.89905E-02 | 3.152 | 0.0016 |
| RISKPRE | 0.84797E-01 | 0.15782 | 0.537 | 0.5910 |
| FRM | −0.45340 | 0.86782E-01 | −5.225 | 0.0000 |
| TENURE | 0.34989 | 0.10826 | 3.232 | 0.0012 |
| TYPE | 0.24132 | 0.36131 | 0.668 | 0.5042 |
| LAREA | −0.10082E-04 | 0.89051E-04 | −0.113 | 0.9099 |
| FLOOR | −0.20893E-01 | 0.98309E-02 | −2.125 | 0.0336 |
| BUAREA | −0.18415E-03 | 0.15110E-03 | −1.219 | 0.2229 |
| PINCRATIO | 0.28563 | 0.31794 | 0.898 | 0.3690 |
| BORROWER | 0.24204E-01 | 0.70298E-01 | 0.344 | 0.7306 |
| AGE | 0.16709E-01 | 0.60366E-02 | 2.768 | 0.0056 |
| PURPOSE | −0.12858 | 0.20224 | −0.636 | 0.5249 |
| YRSEMP | 0.13853E-03 | 0.51195E-02 | 0.027 | 0.9784 |
| OCCUP | 0.40350 | 0.81087E-01 | 4.976 | 0.0000 |
| Log likelihood | −421.0898 | | | |
| Restricted log likelihood | −506.3423 | | | |

**Table 5:** Full results of negative binomial model for time in delinquency

| Determinant | Coefficient | Standard Error | t-Statistic | *p*-Value |
|---|---|---|---|---|
| Constant | −0.74928E-01 | 1.15463 | −0.065 | 0.9483 |
| LVR | 0.14532 | 0.54128 | 0.268 | 0.7883 |
| PREMIUM | −1.60166 | 1.24114 | −1.290 | 0.1969 |
| CPFPRICE | −0.16270 | 0.44549 | −0.365 | 0.7150 |
| MT | 0.27147E-01 | 0.16441E-01 | 1.651 | 0.0987 |
| RISKPRE | 0.48654E-01 | 0.26600 | 0.183 | 0.8549 |
| FRM | −0.61549 | 0.13752 | −4.476 | 0.0000 |
| TENURE | 0.31657 | 0.19302 | 1.640 | 0.1010 |
| TYPE | −0.23508E-01 | 0.69860 | −0.034 | 0.9732 |
| LAREA | −0.10318E-03 | 0.24193E-03 | −0.426 | 0.6698 |
| FLOOR | −0.21714E-03 | 0.18140E-01 | −1.197 | 0.2313 |
| BUAREA | −0.24208E-03 | 0.25820E-03 | −0.938 | 0.3485 |
| PINCRATIO | 0.11916 | 0.51745 | 0.230 | 0.8179 |
| BORROWER | 0.50214E-01 | 0.14679 | 0.342 | 0.7323 |
| AGE | 0.17371E-01 | 0.12265E-01 | 1.416 | 0.1567 |
| PURPOSE | −0.16188 | 0.31486 | −0.514 | 0.6072 |
| YRSEMP | 0.71517E-03 | 0.80531E-02 | 0.089 | 0.9292 |
| OCCUP | 0.467088 | 0.139948 | 3.338 | 0.008 |
| Log likelihood | −401.0122 | | | |
| Restricted log likelihood | −424.3685 | | | |

interesting observation is that all environmental variables are significant at the 1% level in affecting the risk of delinquency incidence. The significance of the macroeconomic variables was expected, since declines in the economic environment would cause borrowers suddenly to face an unexpected array of financial commitments. The high significance of the uncontrollable environmental variables points to an important aspect of controlling delinquency risks: delinquency incidence could be largely random. This verifies the argument that delinquency prediction consists of a large unexplained random component, as credit problems can arise from events that are difficult to foresee (Canner *et al*. 1991). Lenders and MBS underwriters may thus find themselves at the mercy of

**Table 6:** Full results of probit model for delinquency incidence

| Determinant | Coefficient | Standard Error | t-Statistic | *p*-Value |
|---|---|---|---|---|
| Constant | 0.60072 | 1.36667 | 0.440 | 0.6603 |
| LVR | −0.18933E-02 | 0.65171 | −0.003 | 0.9977 |
| PREMIUM | −0.43960 | 1.62921 | −0.270 | 0.7873 |
| CPFPRICE | −1.64251 | 0.72584 | −2.263 | 0.0236 |
| MT | 0.11139E-01 | 0.16118E-01 | 0.691 | 0.4895 |
| RISKPRE | 0.44598 | 0.28997 | 1.538 | 0.1240 |
| FRM | −1.93008 | 0.37300 | −5.175 | 0.0000 |
| TENURE | −0.22641E-01 | 0.19185 | −0.118 | 0.9061 |
| TYPE | 1.46862 | 0.54482 | 2.696 | 0.0070 |
| LAREA | 0.15908E-03 | 0.15401E-03 | 1.033 | 0.3016 |
| FLOOR | −0.33256E-01 | 0.17585E-01 | −1.891 | 0.0586 |
| BUAREA | 0.21551E-03 | 0.17718E-03 | 1.216 | 0.2239 |
| PINCRATIO | 0.62713 | 0.68077 | 0.921 | 0.3569 |
| BORROWER | 0.18236 | 0.13752 | 1.326 | 0.1848 |
| AGE | −0.61875E-02 | 0.13518E-01 | −0.458 | 0.6471 |
| PURPOSE | 0.50632 | 0.35625 | 1.421 | 0.1552 |
| YRSEMP | 0.23941E-01 | 0.10036E-01 | 2.386 | 0.0171 |
| OCCUP | 0.26516 | 0.16683 | 1.589 | 0.1120 |
| CMR | 0.66004 | 0.24301 | 2.716 | 0.0066 |
| CGDP | −6.41884 | 0.92805 | −6.916 | 0.0000 |
| CRENTS | −0.80434 | 0.86167 | −9.335 | 0.0000 |
| OCRPPI | 4.8590 | 0.73989 | 6.567 | 0.0000 |
| CSTI | 1.2044 | 0.46999 | 2.563 | 0.0104 |
| CUNEMP | −0.68920 | 0.24118 | −2.858 | 0.0043 |
| Log likelihood | −183.9097 | | | |
| Restricted log likelihood | −325.4273 | | | |

external factors, whereby they are unable to do anything to prevent delinquency from deteriorating the quality of their investment, especially during times of economic uncertainty.

Unlike the case previously, when practitioners and academics tended to treat delinquency as unimportant, this study postulates that it is critical to minimize delinquency. This is attributable to the fact that, even when delinquency may be random, the time in delinquency or time before reinstatement can be a controllable strategy of minimizing delinquency risk.

For the time in delinquency, if this situation arises using the Poisson model, LVR, PREMIUM, MT, FRM, TENURE, FLOOR, AGE and OCCUP are found to be influential towards predicting whether the loan would transit into default. Utilizing the negative binomial model, MT, FRM, TENURE and OCCUP are found to be significant.

Lenders and underwriters can utilize this information in two ways. Firstly, when deciding on whether to approve a loan application or whether to include a loan into the portfolio for the issuance of securities, the set of main criteria should take the influential factors into account. This is to pre-empt the fact that when delinquency occurs, the time before reinstatement will be minimized. Consequently, any disruptions in the regular mortgage instalments would not cause too great a problem concerning the ability to fund operational expenditure and make coupon payments to MBS investors.

Secondly, lenders and underwriters can utilize these factors to foresee the maximum number of months that a particular portfolio of mortgage loans would take to repay the missed payments if delinquency were to

occur. This would aid the deliberation on whether the amount of reserve for the mortgage portfolio is sufficient. Additionally, insurers can also utilize this information to price their guarantees and premiums.

### Robustness tests

The Poisson model has been criticized due to its implicit assumption that the variance of $y_i$ equals its mean. Thus, there is a need to test for overdispersion in our model. If the null hypothesis of overdispersion is rejected, it may be more appropriate to adopt the negative binomial model that allows the variance of the process to differ from the mean and is formulated from cross-section heterogeneity.

The likelihood ratio, chi-squared, of the model is calculated to be 323.5775. This rejects the null hypothesis that there is no overdispersion. In addition, the Limdep software utilized calculates an overdispersion parameter, $\alpha$, automatically. $\alpha$ is found to be 0.15492 and the corresponding $p$-value of 0.0008 again rejects the null hypothesis. Thus, the negative binomial model may be more appropriate.

## CONCLUSION

This study has contributed to the field of real-estate finance by expanding the existing knowledge on mortgage risks, verifying the largely unpredictable nature of delinquency and examining the influential delinquency risk factors in a sample selection model. This provides a base for further improvements on existing mortgage decision models.

More practically, it has also simultaneously revealed critical implications for lenders and investors in the mortgage and MBS markets, respectively. Although the incidence of delinquency may be largely random, the ability to predict and control the number of months in delinquency via a set of influential factors suggests that all is not lost. Lenders and MBS underwriters may find greater success in minimizing the time in delinquency as compared to minimizing the occurrence of delinquency. As delinquency is the essential preceding step of default, it may be more efficient to engage in risk mitigation tactics for delinquent loans.

Investors should be aware that a high delinquency rate may not really signify potential delays in their coupon payments unless this is accompanied by a long period in delinquency. In addition, delinquent borrowers may not have default in mind when they initially miss an instalment, but the borrowers may find default inevitable if the missed payments were to be allowed to accumulate. High default rates would cause downgrades in the ratings and yields of the relevant securities.

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## Notes

1. Most studies consider default and prepayment as mutually exclusive options. In Singapore, the prepayment rate has been shown to be very low (Ong *et al*. 2002) Correspondingly, we have not used a competing risks model to include the prepayment option in the specification of our model. The benefit of studying defaults in the Singapore context is thus the greater efficiency in testing default and delinquency risks without the influences of the prepayment option.
2. Affordability effectively measures how comfortably the borrower can afford to pay the mortgage instalments. The greater the cushion, the less likely it will be that the borrower will fall victim to sudden financial difficulties.
3. Non-housing wealth provides a foundation upon which borrowers fall back on in times of financial crisis.
4. If the borrower likes his or her property, (s)he would try to transfer funds from sources other than mortgage payments when trigger financial events occur, thereby reducing delinquency.
5. It is highly probable that CPF funds will first be utilized to pay for the property before borrowing the rest of the purchase price, subject to certain stipulated limits. The CPF is the mandatory savings scheme in Singapore, and both the employer and employee contribute to the fund.
6. Market sentiments are proxied by a change in the STI, which is a price-weighted index consisting of 30 major stocks in Singapore.
7. TENURE: Tenure where freehold = 0
8. OCCUP: Occupation where stable income = 0
9. The residuals are found to be randomly distributed about zero. For the normality plot, there are signs of slightly heavy tail, but the departure from normality is not too distinct.
10. We utilized Cook's Distance to determine the influence of the observations. Two observations are found to have an exceptionally high Cook's Distance. However, the results of the model do not

change with the removal of these observations and re-running the model. Thus, they are retained in the final model.

11. The variance inflation factor of all regressors is below the value of 10, suggesting that multi-collinearity may not be a problem. Alternatively, the pair-wise correlations of the regressors can be analysed. High correlations (higher than 0.8) are found between CRENTS and CUNEMP and between CRPPI and CUNEMP. Consequently, we have orthogonalized CRENTS and CRPPI into OCRENTS and OCRPPI, respectively, to remove the correlation effect. These two variables are utilized in the final model.