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HOW DOES LOAN-TO-VALUE POLICY STRENGTHEN BANKS' RESILIENCE TO PROPERTY PRICE SHOCKS – EVIDENCE FROM HONG KONG

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How Does Loan-To-Value Policy Strengthen Banks' Resilience to Property Price Shocks – Evidence from Hong Kong*

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Abstract

This paper sheds light on the transmission mechanism of loan-to-value (LTV) policy to financial stability by providing three findings from Hong Kong. First, there is evidence that LTV cap tightening since 2009 has dampened both borrowers' leverage and credit growth, and that lower leverage has played a major role in strengthening banks' resilience to property price shocks. Second, the effect on loan growth is found to be state-dependent due to loan market disequilibrium, with a much stronger impact on loan supply than on demand, suggesting that calibrating this tool to curb loan growth needs an accurate estimate of both loan demand and supply. Operationally, this could pose challenges for policymakers. Finally, we find evidence of low responsiveness of housing demand to caps on LTV ratios, which is suggestive of a weak direct pass-through of LTV policy to the property market. These findings together support the view that operationally it would be optimal for LTV policy to primarily target household leverage, and that there are limitations in using this instrument to stabilise credit growth and property prices.

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1.   Introduction

Although there is a growing consensus that LTV policy plays an important role in containing systemic risks associated with credit-property price spirals, there is an on-going debate about the design of the operational framework for this macroprudential instrument to achieve this policy goal. In particular, would it be optimal for LTV policy to target household leverage, credit growth or property prices in pursuit of financial stability? Theoretically, the answer depends crucially on two factors, namely (i) the extent of the pass-through of LTV policy to each of these three variables, and (ii) their respective contribution to financial stability. So it is important to understand the transmission mechanism of LTV policy.

Empirical evidence of the transmission mechanism of LTV policy, however, remains scant, so there is insufficient guidance on the optimal target of this macroprudential tool from the literature. This paper attempts to contribute to the literature by quantifying the significance of LTV policy on borrowers' leverage and credit growth (i.e. henceforth referred to as the direct and indirect effects respectively[1]) and the respective contribution of these macro variables to financial stability, using data from Hong Kong covering the period June 1999 to December 2012. Hong Kong is a natural choice for analysing this issue for two reasons. First, Hong Kong has long adopted LTV policy as a key macroprudential tool since 1991. Second, frequent and large swings of property prices in Hong Kong facilitate a clear identification of the impact of LTV policy on banks' resilience to property price shocks.

The main body of this paper contains three parts. In the first part, we investigate the significance of the direct effect by developing a simple error-correlation model to reveal whether there is a long-run relationship between the market LTV ratio (proxied by the average LTV ratio of new mortgage approvals by banks) and LTV caps.

The second part studies the significance of the indirect effect by estimating the impact of LTV ratios on loan demand and supply. We estimate the demand and supply equations for mortgage loans with a framework that allows for, but does not impose, disequilibrium. This empirical specification reflects three considerations. First, theoretically LTV policy is likely to affect both demand for and supply of mortgage loans[2]. Estimating a demand-supply system could therefore in theory facilitate a clearer identification of the policy impact than the reduced-form approach adopted by most existing studies. Second, given that the loan demand function is essentially derived from the demand for properties, the estimated sensitivity of loan demand to LTV ratios could shed light on the extent of pass-through

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[1]   Theoretically, the direct effect improves banks' resilience because mortgagors would hold a larger equity buffer at origination than otherwise, contributing to a lower likelihood of negative equity and thus lower default risk. The indirect effect primarily avoids banks underwriting excessively fresh mortgage loans, which are generally subject to higher default risks due to a relative low portion of equity.

[2]   LTV cap tightening may reduce the demand for mortgages, as homebuyers may be forced out of the property market because of higher liquidity hurdles or lower returns on equity for property investment. LTV cap tightening may also reduce credit supply by leading banks to lend less than they otherwise would.

of LTV policy to the property market, which is a core interest of this paper. Finally, loan market disequilibrium, which has been widely documented in both the theoretical and empirical literature[3], has important policy implications for the transmission of LTV policy to on credit growth (See Figure 1 for illustration).

The third part, by leveraging on the empirical result in the previous two parts, quantifies the relative contribution of the direct and indirect effects of the five rounds of LTV cap tightening in Hong Kong during the period 2009 to 2012 to strengthening the banking sectors' resilience to property price shocks and therefore overall financial stability.

Regarding key findings, this paper provides fresh evidence that LTV cap tightening dampens mortgagors' leverage significantly, with the long-run elasticity estimated at 0.33. A back-of-the-envelope calculation based on the estimated elasticity finds that had the HKMA not tightened LTV caps in 2009, the market LTV ratio would be higher than 60%, instead of its actual value of 52% at the end of 2012.

We also reveal that the policy effect on credit growth is state-dependent attributable to loan market disequilibrium and a much stronger effect of LTV ratios on loan supply than demand. This finding suggests that calibrating the tool to target credit growth needs an accurate estimate of loan supply and demand. The potential model risks in estimating these variables could pose challenges for policymakers operationally. In addition, the low sensitivity of loan demand to LTV ratios is suggestive of weak direct pass through of LTV policy to the property market.

Finally, in quantifying the contribution of the direct and indirect effects which increase the resilience of the banking sector to property price shocks, we find that in a simple stress-testing exercise with a hypothetical stress scenario (including a 60% drop in property prices), the five rounds of LTV cap tightening from 2009 to 2012 have dampened both borrowers' leverage and loan growth. However, the first effect is estimated to have played a much larger role in reducing the sensitivity of mortgage default risk to property price shocks.

These findings consistently support the view that operationally it would be optimal for LTV policy to primarily address excess household leverage, and that there are limitations in using this macroprudential tool to stabilise credit growth and property prices. The remainder of the paper is

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[3]   The study by Stiglitz and Weiss (1981) is an early attempt to advance the theory of loan market disequilibrium by showing that credit rationing exists if banks face the adverse selection problem. A profit-maximising bank may charge an interest rate below the market clearing rate, as a higher interest rate could attract more risky borrowers and discourage safer borrowers, which could increase the credit loss of the bank's loan portfolios. Stiglitz and Weiss (1981) also outlined theoretically that excess supply of credit could exist. See also Jaffee (1971) for theoretical discussions. Early empirical studies including Fair and Jaffee (1972), Fair and Kelejian (1974), Maddala and Nelson (1974), Amemiya (1974) and Laffont and Garcia (1977), focus mainly on estimation methods. More recent studies such as Pazarbasioglu (1996), Kim (1999), Ghosh and Ghosh (2000) and Poghosyan (2010) apply the disequilibrium approach to study the relationship between credit supply and real sector performance, in particular in the testing of the credit crunch hypothesis. Both theoretical and empirical studies show that disequilibrium can exist in loan markets.

organised as follows. Section 2 briefly reviews some related work. Sections 3 to 5 present a detailed discussion of the three parts mentioned previously respectively. Section 6 concludes.

2.   Related Literature

The literature on the transmission mechanism of LTV policy is largely unexplored. Recent theoretical work by the CGFS (2012) sheds light on this issue by sketching a transmission map of LTV policy suggesting that LTV cap tightening could strengthen banks' resilience through its dampening effect on borrowers' leverage and credit growth. Crowe et al. (2011) show that many recent banking crises accompany property busts were preceded by a rapid increase in household leverage and credit growth. LTV policy could therefore reduce the banks' vulnerability at source. Crowe et al. (2011) find evidence of a significant effect of LTV policy on the property market, although a horse-race assessment using a dynamic stochastic general equilibrium (DSGE) model shows that LTV policy reacting to credit growth is superior to adjusting the policy to target property prices.

There is a growing body of research on the effect of LTV policy on credit growth. Although various theoretical studies show that LTV policy can reduce excess credit growth, empirical evidence is rather mixed. On the theoretical front, various studies incorporating LTV policy in their models have found that the macroprudential instrument is effective in preventing excessive credit growth. Mendicino (2012) develops a business cycle model with credit friction and shows that countercyclical LTV ratios in response to credit growth can smooth the credit cycle. A similar result is found by Christensen (2011) using a DSGE model. Lambertini *et al.* (2011) use a model of the housing market that incorporates expectations driven cycles to show that countercyclical LTV rules responding to credit growth can reduce the volatility of loans and the loan to GDP ratio. Funke and Paetz (2012) apply an open economy DSGE modelling framework with a nonlinear LTV policy rule that reacts when property price growth exceeds a certain threshold to examine Hong Kong's LTV policy. Their simulation results suggest that LTV policy can reduce household debt level.

However, empirical evidence on the effectiveness of LTV policy in containing excessive credit growth is mixed. Lim *et al.* (2011) conduct a panel regression for 49 countries and conclude that caps on LTV ratios lessen the procyclicality of credit growth. But results in other cross-country studies are less conclusive. For instance, Nier *et al.* (2012) find that limits on LTV ratios reduce credit growth for a subsample of 21 emerging market economies (EMEs), but not for the whole sample containing both EMEs and advanced economies. Ahuja and Nabar (2011) also find mixed results: that although LTV caps reduce property loan growth for a full sample of 49 emerging and advanced economies, the effect for a subset of economies with fixed exchange rates and currency board arrangements is insignificant. The empirical study of Kuttner and Shim (2012) on 57 advanced and emerging market economies finds that five different prudential measures, including LTV limits and maximum debt service to income ratio, collectively show a strong link to housing credit growth but the individual impact of LTV limits on housing credit growth is not significant. They acknowledge that it is difficult to

disentangle the individual effects as some of these policies tend to be implemented concurrently. Mixed results are also found in single-country studies. For example, Igan and Kang (2011) show that the LTV policy in Korea is not effective in constraining credit growth while Lee (2013) finds a modest impact on household debt.

The mixed empirical findings may be partly attributable to the state-dependent nature of mortgage loans, which is consistent with findings in both banking and housing literatures. Specifically, for the former, Fair and Jaffee (1972), Amemiya (1974) and Laffont and Gracia (1977), and a more recent study by Chen and Wang (2008) provide supporting empirical evidence. For the latter, Chang et al. (2011) find a state-dependent nature of housing market returns that reflects a non-linear response to macroeconomic shocks.   Using regime switching models, Chang et al. (2012, 2013) show that housing market returns in Singapore and Hong Kong are state dependent. [4]

3.   An Empirical Model of the Policy Impact on Borrowers' Leverage

One salient operating feature of LTV policy is that authorities achieve their macroprudential objectives through adjusting the regulatory LTV cap instead of the actual LTV ratio in the market. Theoretically, the latter is determined together with mortgage terms both by banks and homebuyers (Zumpano et al, 1986). An important empirical question, therefore, is to what extent is the LTV cap (serving as a macroprudential instrument) taken into account when banks and homebuyers determine mortgage contracts?

To answer this question, an error-correction regression model is specified to estimate the determinants of the market LTV ratio (*LTV*). The model postulates that a higher LTV cap (*LTVcap*), a higher price return relative to its volatility (*Proreturn*) and rental yield (*Proyield*) for property investment, and a lower debt-servicing ratio for new mortgages (*DSR*) tend to be associated with a higher market LTV ratio, as banks and mortgagors tend to accept a higher LTV ratio when the property market is buoyant, the debt servicing burden is low, and the LTV cap is less restrictive.

We estimate the model using aggregate data covering the period June 1998 to December 2012.[5] Data definitions and sources are detailed in Appendix 1. The estimation result is presented below:

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[4]   Our study is related to the literature on the Hong Kong housing market. Leung and Tang (2012) discuss the property and
        mortgage markets in Hong Kong. See also Leung et al. (2013).

[5]   The estimation sample is constrained by the availability of data for LTVs, which are only available from June 1998.

$$\Delta LTV_t = -0.001 - 0.221 * \Pi_{t-1}^{LTV} + 0.067 * \Delta LTVcap_{t-1} - 0.697 * \Delta DSR_{t-2}$$
$$[-0.88] \quad [-4.76] \qquad\qquad [2.93] \qquad\qquad\qquad [-2.05]$$
$$Adj. \ R^2 = 0.15$$

Figures in brackets are *t-statistics*

$$\tag{1}$$

where the error correction term:

$$\Pi_t^{LTV} = LTV_t - (0.605 + 0.326 * LTVcap_t + 0.285 * Proreturn_t + 1.436 * Proyield_t$$
$$[14.3] \quad [16.2] \qquad\qquad [2.91] \qquad\qquad [6.11]$$
$$- 0.696 * DSR_t)$$
$$[-6.83]$$
$$Adj. \ R^2 = 0.77$$

$$\tag{2}$$

The empirical results are broadly in line with our expectations. In particular, the LTV cap is found to be one binding factor affecting the market LTV ratio, with the long-run elasticity estimated at 0.33. To shed light on the responsiveness of the market LTV ratios to LTV caps, Figure 2 shows the cumulative contribution of the determinants to the change in the market LTV ratio since September 2007. As can be seen, the five rounds of LTV cap tightening from 2009 to 2012 contribute significantly to the reduction in the market LTV ratio. Had the HKMA not tightened LTV caps, the market LTV ratio may well have exceeded 60%, instead of its actual value of 52% at the end of 2012.

4.   An Empirical Model of the Policy Impact on Credit Growth

4.1   The Empirical Framework

The model adopted in this paper to estimate the indirect effect of LTV policy follows to a large extent those developed by Fair and Jaffee (1972), Amemiya (1974) and Laffont and Gracia (1977). The model in a general form can be specified by the following four equations:

$$DD_t = \alpha_0 + \boldsymbol{\alpha_1} \boldsymbol{X_{1t}^D} + \alpha_2 r_t + \mu_t^D \tag{3}$$

$$SS_t = \beta_0 + \boldsymbol{\beta_1} \boldsymbol{X_{1t}^S} + \beta_2 r_t + \mu_t^S \tag{4}$$

$$Q_t = \min(DD_t, SS_t) \tag{5}$$

$$\Delta r_{t+1} = \gamma(DD_t - SS_t) \tag{6}$$

where DD_t and SS_t are the unobservable quantity demanded and quantity supplied of mortgage loans at time t respectively. X_{1t}^D and X_{1t}^S are vectors of exogenous variables for the demand and supply equations respectively. r_t is the mortgage interest rate, which is assumed to have a negative effect on DD_t (i.e. $\alpha_2 < 0$) and a positive effect on SS_t ($\beta_2 > 0$). μ_t^D and μ_t^S are disturbance terms, which are assumed to be uncorrelated and serially independent random variables with zero means. One main departure from a standard equilibrium framework is that the actual quantity of mortgage loans observed in the market, Q_t, is not determined by equating DD_t and SS_t at the equilibrium level of r_t. Instead, Q_t is posited to be determined by the minimum of DD_t and SS_t as specified by eq. (5), which essentially allows, but does not impose, excess demand or excess supply to occur at the prevailing market interest rate. Eq. (6) further assumes that changes in the mortgage interest rate in the next period are proportional to the level of excess demand in the current period. The coefficient γ, which measures the adjustment speed of the price of mortgage loans, is assumed to be a positive number. This modelling approach is widely used in the banking literature. The model, in fact, can be re-formulated as a regime-switching model, which is widely applied in empirical studies in other areas, e.g. housing markets (Chang et al., 2012, 2013).

The system of equations cannot be estimated directly due to the fact that DD_t and SS_t are unobservable. However, the parameters can be estimated using the following method: Consider time t with $r_{t+1} > r_t$ where excess demand occurs, implying $Q_t = SS_t$. Substituting $Q_t = SS_t$ into eq. (6) yields $DD_t = \Delta r_{t+1}/\gamma + Q_t$. The demand equation, i.e. eq. (3), therefore can be represented by:

$$Q_t = \alpha_0 + \boldsymbol{\alpha_1} X_{1t}^D + \alpha_2 r_t \ - \frac{\Delta r_{t+1}}{\gamma} + \mu_t^D \tag{7}$$

Similarly, the supply equation can be represented by the following equation when considering time t with $r_{t+1} < r_t$:

$$Q_t = \beta_0 + \boldsymbol{\beta_1} X_{1t}^S + \beta_2 r_t \ + \frac{\Delta r_{t+1}}{\gamma} + \mu_t^S \tag{8}$$

All parameters can be estimated using the entire sample by slightly adjusting the term $\Delta r_{t+1}/\gamma$ in eq. (7) and (8) and re-defining the two equations respectively as:

$$Q_t = \alpha_0 + \boldsymbol{\alpha_1} X_{1t}^D + \alpha_2 r_t \ - \frac{\Delta r_{t+1}^+}{\gamma} + \mu_t^D \tag{9}$$

where $\Delta r^{+}_{t+1} = \begin{cases} \Delta r_{t+1}, & \text{if } r_{t+1} > r_t \\ 0, & \text{otherwise} \end{cases}$, and

$$Q_t = \beta_0 + \boldsymbol{\beta_1} X^{S}_{1t} + \beta_2 r_t - \frac{\Delta r^{-}_{t+1}}{\gamma} + \mu^{S}_t \qquad (10)$$

where $\Delta r^{-}_{t+1} = \begin{cases} -\Delta r_{t+1}, & \text{if } r_{t+1} < r_t \\ 0, & \text{otherwise} \end{cases}$

4.2 The Specification for the Demand for Mortgage Loans

Since the demand for mortgage loans is derived from the demand for residential properties, the factors which explain the demand for mortgage loans (i.e. X^{D}_{1t}) are similar to those affecting the demand for properties.

There are two main channels through which LTV ratios affect the demand for mortgages. First, a lower market LTV ratio implies a higher down payment requirement, which forces marginal homebuyers out of the property market (Zumpano *et al.*, 1986). The higher liquidity hurdle (i.e. a lower LTV ratio) reduces the demand for mortgages, implying a positive relationship between the market LTV ratio and the demand for mortgages.

Second, from a property investor's perspective, a lower market LTV ratio constrains investors' ability to take higher leverage to improve their return on equity (*ROE*) for property investment, contributing to lower demand for properties. So, *ROE*, which is partly determined by LTV ratios, is considered to be one determinant of the demand for mortgages. Omitting the time subscript, the *ROE* is defined as:

$$ROE = \frac{(V * GPR - L * r)}{E} = \frac{1}{1 - LTV}(GPR - LTV * r), \qquad (11)$$

where *V* and *L* are the value of the property and the amount of mortgage loans respectively. *E* is the value of equity, which is derived from *E = V – L*. *GPR* is the gross property return, which is defined as the sum of the annual growth rate of property prices and the average annual rental yield of residential properties. The first term at the right hand side is the ratio of the value of property (*V*) to equity (*E*) or a leverage ratio for property investment expressed in terms of *LTVs*, while the second term is the net annual property return. We conjecture a positive relationship between *ROE* and the demand for mortgages. A lower *ROE*, due either to a lower market LTV ratio (i.e. lower leverage)[6], a fall in

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[6]   Mathematically, eq. (11) implies that the relationship between *LTV* and *ROE* is dependent on the sign of (*GPR-LTV*r*). However, a rational property investors should require a positive return, i.e. *GPR-LTV*r>0*, implying a positive relationship between *LTV* and *ROE*.

property prices and rental yields, or an increase in mortgage interest rates is expected to reduce the demand for mortgages. Notice that r serving as the price for mortgage loans is included in the demand equation through the term ROE instead of as a separate explanatory variable. By definition, so long as ROE is estimated to have a positive impact on the demand for mortgages, r is negatively correlated with the quantity demanded for mortgages, implying a downward sloping demand curve.

Since other policy measures, such as the special stamp duty (SSD) and limits on the debt-servicing ratio ($DSRs$) implemented in the sample period may also affect the demand for mortgage loans, three variables capturing the effect of prudential measures other than LTV policy are included in eq. (9) to disentangle the effect of LTV policy on the demand for mortgage loans from other policies. These three policy variables are briefly discussed below.

The SSD introduced in November 2010 is essentially an *ad valorem* tax on property transactions. A simple and usual way to capture the policy impact is to modify ROE in eq. (11) by refining the variable GPR as an after-tax property return. Such a specification, however, may not be feasible given the complex structure of the stamp duty rate[7]. Nevertheless, an interaction term of ROE and a dummy variable for capturing the effect of the SSD[8] is included in the model. The interaction term is expected to have a negative impact on the demand for mortgages.

Two dummy variables, $DSR10$ and $DSR12$, are included to capture the two rounds of tightening on the limit of DSRs for residential mortgages in August 2010 and September 2012 respectively.[9] $DSR10$ and $DSR12$ are expected to have a negative effect on the demand for mortgages.

Macroeconomic conditions are one factor affecting the demand for residential properties. So, the unemployment rate (U_t) is included in eq. (11) to explain the demand for mortgages and is expected to have a negative impact on the demand for mortgage loans. The model also includes a dummy variable (CNY) to account for a lower demand for properties during the month of Chinese New Year.

In sum, the demand equation for mortgage loans is specified below:

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[7]   The stamp duty rate for the SSD introduced in November 2010 varies with the holding period of the property by the seller before disposal. The stamp duty rate is (a) 15% if the property has been held for six months or less; (b) 10% if the property has been held for more than six months but for 12 months or less; and (c) 5% if the property has been held for more than 12 months but for 24 months or less.

[8]   Defined as one for monthly observations after November 2010 and zero otherwise.

[9] $DSR10$ is defined as one for observations since August 2010 and zero otherwise, while $DSR12$ is defined as one for observations since September 2012 and zero otherwise.

$$Q_t = \alpha_0 + \alpha_1 \Delta LTV_t + \alpha_2 ROE_t(LTV_t, r_t) + \alpha_3 ROE_t(LTV_t, r_t) * (SSD_t) +$$

$$\alpha_4 DSR10_t + \alpha_5 DSR12_t + \alpha_6 U_t + \alpha_7 CNY_t - \frac{\Delta r_{t+1}^+}{\gamma} + \mu_t^D \tag{12}$$

4.3 The Specification for the Supply of Mortgage Loans

The supply equation postulates that banks' supply of mortgage loans is determined mainly by the annual percentage change of the market LTV ratio, a risk-adjusted return of mortgage lending on capital, annual growth rate of property prices and bank's liquidity.

An increase in the market LTV ratio is hypothesised to have a positive impact on the supply of mortgage loans. [10] This specification is consistent with various theories (Kent, 1980 and Stiglitz and Wesis, 1981), which assert that the actual price of a mortgage loan is determined not only by the mortgage rate, but also by other contractual terms, such as LTV ratios and maturity. So, in the absence of changes in the mortgage interest rate, banks can shift their supply of mortgage loans by adjusting these non-price mortgage terms. For example, banks may reduce their supply of mortgage loans by demanding higher down payments (i.e. a lower LTV ratio), implying a positive relationship between the market LTV ratio and the supply of mortgage loans. With this specification, the impact of LTV policy on the supply of mortgage loans can be revealed by quantifying (i) the impact of a LTV cap on the market LTV ratio (as discussed in Section 3), and (ii) the impact of the market LTV ratio on the loan supply (to be detailed in the following section).

A rise in a risk-adjusted return of mortgage loans on capital (*RAROC*) is expected to have a positive impact on the supply of mortgages. *RAROC* is defined as:

$$RAROC = \frac{(1-t) * (r-c)}{k} \tag{13}$$

where *t* is the profit tax rate. *c* is the total cost of mortgages defined as the sum of funding costs, administrative costs and expected credit losses. *k* is the estimated amount of regulatory capital required per Hong Kong dollar of mortgage loans. By definition, a rise in the mortgage rate (*r*) is expected to have a positive impact on the supply of mortgage loans through its impact on *RAROC*. Therefore, a positive estimated coefficient for *RAROC* implies an upward sloping supply curve.

Collateral values are postulated to have a positive impact on the supply of mortgage loans. A similar specification is adopted by Atanasova and Wilson (2004) to examine the determinants of UK banks'

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[10]   LTV ratios have long been considered as one indicator of the availability of mortgage loans in the empirical literature. For example, Del Giovane *et al*. (2010) suggest that the slowdown in mortgage loans to households in Italy in recent years is associated with a tightening of credit standards through reductions in LTV ratios and increases in margins on riskier loans from the second half of 2007 onwards.

supply of corporate loans. In our model, the changes in collateral values are determined by the annual growth rate of property prices (*PPG*). This specification is consistent with the financial accelerator theory:[11] that rises in property prices lead to higher collateral values, which in turn increase the supply of loans.

The annual growth of customer deposits (*CD*), which proxies for the change in banks' liquidity, is assumed to have a positive impact on the supply of mortgage loans. A similar specification is adopted by Clauretie (1973), Laffont and Garcia (1977) and Arsenault *et al.* (2012) in studying the US loan market.

In addition, *DSR10* and *DSR12*, which capture the effect of tightening on the limit of DSRs, are included in the supply equation. In principle, tightening DSR caps could generate a binding effect on the supply of mortgage loans. The supply equation for mortgage loans is therefore specified as below:

$$Q_t = \beta_0 + \beta_1 \Delta LTV_t + \beta_2 RAROC_t(r_t) + \beta_3 PPG_t + \beta_4 CD_t +$$
$$\beta_5 DSR10 + \beta_6 DSR12 - \frac{\Delta r_{t+1}^-}{\gamma} + \mu_t^s \tag{14}$$

4.4 The Estimation Method

The two-stage least square (TSLS) method is adopted to estimate the model instead of applying the method of ordinary least squares because estimators of the latter are statistically inconsistent. Estimators from the TSLS method, according to Fair and Jaffee (1972), Maddala and Nelson (1974) and Laffont and Garcia (1977), are consistent.[12] In the TSLS estimation, Δr_{t+1}^+, Δr_{t+1}^- and variables involving r_t are instrumented by their lagged terms. The model is estimated using a monthly dataset covers the period June 1999 to December 2012. To eliminate the price inflation effect, the dependent variables are standardised by the amount of outstanding mortgage loans (See Appendix 1 for data definitions and sources).

4.5 Estimation Results

Table 1 presents three models for the demand and supply of mortgage loans. Model 1 is essentially an unrestricted model that consists of all explanatory variables included in eq. (12) and (14). Models 2 and 3 consider different specifications by excluding insignificant explanatory variables. Specifically, in Model 2, *DSR10*, which is found to be insignificant in both the demand and supply equation in

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[11] See Bernanke (2007).

[12] Estimators from the maximum likelihood (ML) estimation method are also consistent. See Fair and Kelejian (1974), Amemiya (1974), Maddala-Nelson (1974) and Quandt (1988). However, preliminary analysis using the ML estimation method finds unstable estimates, which vary significantly with the initial value for the estimates. So, we adopt the TSLS method in this study rather than the ML method.

Model 1, is dropped. The insignificance of *DSR10* suggests that the measure to standardise the *DSR* cap taken in August 2010[13] had only a limited impact on the demand for and supply of mortgage loans. In Model 3, we further exclude ΔLTV_t and *DSR12* from the demand equation. The low explanatory power of ΔLTV_t in the demand equation suggests that a higher liquidity constraint on marginal homebuyers associated with LTV cap tightening would not significantly reduce the demand for mortgage loans. The result may be partly attributable to the mortgage insurance programme in Hong Kong, which allows homebuyers who have sound financial conditions to borrow mortgage loans with a LTV ratio higher than the cap. Overall, the estimation results are broadly consistent with our expectations. In the remaining discussion, we focus on Model 3 unless otherwise stated.[14] Detailed analysis is given below:

(a)   The estimation results reveal that demand does not necessarily equal supply at the prevailing mortgage interest rate in the Hong Kong mortgage market. This can be seen by noticing that the coefficient of $1/\gamma$, which reveals the adjustment speed of the mortgage interest rate in response to disequilibrium, is estimated to be significantly different from zero in all models. Therefore, the null hypothesis of perfect market adjustment (i.e. $\gamma = \infty$ or $1/\gamma = 0$) can be rejected. Generally speaking, if disequilibrium occurs, a period of less than one-half month is required for the mortgage rate to adjust to a new equilibrium. The existence of disequilibrium suggests that demand or supply can be the sole binding factor in determining credit volumes, suggesting that the effect of LTV policy on credit growth may be state dependent, particularly if there is asymmetric responsiveness of loan demand and supply to LTV ratios.

(b)   The estimation results show a much stronger impact of LTV policy on the supply of mortgage loans than on the demand for mortgage loans. We show this by a counterfactual simulation exercise. In the exercise, we first estimate loan demand and supply under a counterfactual "no policy" scenario by assuming that the HKMA had not tightened LTV caps for the whole period 2009 to 2012. The estimated loan supply and demand under the counterfactual scenario should be larger than under the actual scenario in which the five rounds of LTV cap tightening were implemented. By comparing the demand and supply estimates in the "no policy" scenario to the corresponding estimates in the actual scenario, the dampening effects of LTV cap tightening on the loan demand and supply over the period can be calculated. In practice, the estimates under the actual scenario are derived using the actual movement of all variables in Model 3. In deriving the estimates under the counterfactual scenario, the only difference is to supersede the actual series of the market LTV ratio by a hypothetical series that counterfactually removes the impact of LTV cap tightening. We derive this hypothetical series of the market LTV ratio using the

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[13]   The measure requires banks to standardise the limit on DSRs of mortgage applicants to 50% from the previous range of 50% to 60%. In addition, banks are required to stress-test mortgage applicants' repayment ability by assuming an increase in mortgage rates of at least two percentage points. The stressed DSR is limited to 60%.

[14]   However, the discussion would be not affected qualitatively if another model is chosen because the estimation results are broadly stable across the models.

econometric model of the determinants of the market LTV ratio presented in Section 3. Figure 3, which plots the counterfactual series of the market LTV ratio against the actual series, shows a significantly higher market LTV ratio under the counterfactual scenario. Figures 4 and 5 show the supply estimates and demand estimates respectively. An estimation based on Figure 4 reveals that had the HKMA not tightened LTV caps in the period, the supply of mortgage loans might be around 10.5% higher than under the actual scenario. By contrast, the estimated loan demand under the counterfactual scenario is only 1.5% larger than under the actual scenario. These results suggest that the dampening effect of the five rounds of LTV cap tightening is much stronger on loan supply than loan demand.

(c)   The estimation results (a) and (b) together suggest that the effect of LTV policy on loan growth in Hong Kong is likely to be state-dependent. Specifically, the policy is more effective in limiting credit growth when there is excess credit demand for loans and less effective in the case of excess supply. Therefore, to evaluate whether the significant dampening impact on the supply of mortgage loans was effectively translated into lower loan growth, we need to assess the state of the market (i.e. whether there was excess demand or excess supply of loans). Figure 6, which presents the estimated mortgage demand and supply, reveals that from the beginning of the tightening of macroprudential policy in October 2009, the number of months with estimated excess demand is more than that with estimated excess supply, suggesting that credit supply is a major factor in determining the volume of new mortgage loans. In other words, LTV policy was effectively transmitted to the mortgage loan market through its dampening impact on the supply of mortgage loans.

5.   An Analysis of the Transmission Mechanism of LTV Policy

This section attempts to shed light on the transmission mechanism of LTV policy by using the above econometric models which estimate the policy's impact on borrowers' leverage (in Section 3) and overall credit growth (in Section 4). Our aim is to quantify the extent to which LTV policy is transmitted to improve the resilience of the banking sector's mortgage loan portfolio and to property price shocks through the direct and indirect effects.

To this end, we specify an econometric model that links the default risk of mortgage loans in Hong Kong to an indicator of the proportion of mortgage loans in negative equity in banks' mortgage loan portfolios (P^{NE}), which by construction could reflect the direct and indirect effects outlined above. The model also includes the unemployment rate and the proportion of mortgage loans with a distressed level of DSR (P^{DSR}) to improve explanatory power. Similar empirical models, which hypothesise that negative equity and a high level of debt-servicing burden are two triggers for mortgage defaults, have been developed by Foote $et\ al.$ (2008) and Elul $et\ al.$ (2010). We first define P^{NE}, and then discuss how the direct and indirect effects are transmitted to default risk through their impact on P^{NE}.

For any mortgagor *i* with the mortgage loan being originated at time *k*, the LTV ratio for that loan at the current time *t* > *k* can be defined as:

$$ltv_{k,t}^i = \frac{L_{k,t}^i}{V_{k,t}^i} = \frac{L_k^i(1 - CLR_{k,t}^i(\mathbf{rr}_{k,t}, s_k^i, m_k^i))}{V_k^i(1 + CPR_{k,t}^i)} \tag{15}$$

where L_k^i and V_k^i are the amount of the mortgage loan and the value of the property at origination (i.e. the LTV ratio at origination = L_k^i / V_k^i). The outstanding loan amount at time *t* ($L_{k,t}^i$) is determined by $L_k^i(1 - CLR_{k,t}^i(rr_{k,t}, s_k^i, m_k^i))$, where $CLR_{k,t}^i(rr_{k,t}, s_k^i, m_k^i)$ is the cumulative amount of loan repayments from *k* to *t* as a percentage of L_k^i, which is dependent on the reference interest rate (e.g. the best lending rate) during the period ($\mathbf{rr}_{k,t}$), the interest rate spread (s_k^i) and the maturity (m_k^i). Similar to a conventional mortgage contract in Hong Kong, both s_k^i and m_k^i are assumed to be fixed at origination. The property value at time *t* ($V_{k,t}^i$) is determined by the initial value of the property (V_k^i) and the cumulative growth rate of property prices ($1 + CPR_{k,t}^i$) from *k* to *t*.

For a mortgage loan portfolio that consists of mortgage loans made from *k* = 1 to *t* with N_k cases of mortgage loans being made at any time *k*, the amount of mortgage loans in negative equity at time *t* can be defined as:

$$NE_t = \sum_{k=1}^{t} \sum_{i=1}^{N_k} L_{k,t}^i I(ltv_{k,t}^i > 1) \tag{16}$$

where $I(ltv_{k,t}^i > 1)$ is an indicator function. In practice, data for individual mortgage loans are not publicly available, only data for the average values of $L_k^i, V_k^i, s_k^i, m_k^i, CPR_{k,t}^i$ are available monthly (See Appendix 1). So, we redefine eq. (15) based on their average values by assuming that all mortgage contracts in the same month have the same contractual terms and their properties have identical price movement:

$$\overline{ltv}_{k,t} = \frac{\overline{L}_{k,t}}{\overline{V}_{k,t}} = \frac{\overline{L}_k(1 - CLR_{k,t}(\mathbf{rr}_{k,t}, \overline{s}_k, \overline{m}_k))}{\overline{V}_k(1 + \overline{CPR}_{k,t})} \tag{17}$$

P^{NE} thus can be defined as

$$P_t^{NE} = \frac{\sum\limits_{k=1}^{t} N_k \overline{L}_{k,t} I(\overline{ltv}_{k,t} > 1)}{\sum\limits_{k=1}^{t} N_k \overline{L}_{k,t}} \tag{18}$$

The direct and indirect effects of LTV cap tightening can be analysed using eq. (17) and (18). For illustration, assuming there is a significant risk of a property price correction occurring at an unknown future time $T > t$ and policymakers adopt a series of policy actions to tighten LTV caps from t to T. The policy actions reduce the sensitivity of mortgage default risk to the possible property price correction by reducing P_t^{NE} through its impact on $\overline{L}_k / \overline{V}_k$ (i.e. the direct effect) and that on $N_k \overline{L}_{k,t}$ (i.e. the indirect effect) for loans made from t to T. For the direct effect, a lower $\overline{L}_k / \overline{V}_k$ (i.e. a higher initial portion of equity) for loans made from t to T contributes to a lower P_T^{NE} by reducing the chance of $\overline{ltv}_{k,T} > 1$ for any given property price shock. For the indirect effect, a lower $N_k \overline{L}_{k,t}$ from t to T avoids banks underwriting excessive fresh mortgage loans that are subject to higher risk of $\overline{ltv}_{k,T} > 1$ due to a thin equity portion to buffer property price shocks because of a small cumulative amount of loan repayments.

The estimation result for the model (see Appendix 2) suggests that P^{NE} is a significant determinant of a problem loan ratio measured by the sum of the 3-month delinquency ratio and the rescheduled loan ratio for mortgage loans in Hong Kong. The model is employed to quantify the direct and indirect effects of the five rounds of LTV cap tightening in Hong Kong for the period October 2009 to December 2012. Details of the analysis are as follows.

Recall that in Section 4 we defined actual and counterfactual scenarios (the latter assumes no LTV measures in place from late 2009). All differences in these two scenarios are reflected in (i) the movement of the market LTV ratio during the period 2009 to 2012 and (ii) the estimated amount of new mortgage loans made during the period. The direct and indirect effects on mortgage default risk could be revealed respectively by analysing the impact of (i) and (ii) on P^{NE}.

We apply the econometric model to estimate the problem loan ratio from 2013 Q1 to 2014 Q4 under the actual and "no policy" scenarios, assuming there is a significant adverse economic shock in the eight quarters starting from 2013 Q1. This shock includes: a 60% drop in property prices; a 300-basis-point increase in the reference interest rate; a 20% decline in household income and the unemployment rate increasing to 8.5%.

Figure 7, which presents the estimation result, shows that the problem loan ratio in the actual scenario (denoted by d_A) would increase from 0.03% in 2012 Q4 to around 0.95% in 2014 Q4. By contrast,

the problem loan ratio in the counterfactual scenario (denoted by d_C) would be much higher at 2.32%. The results show that the five rounds of the LTV cap tightening work to improve the banking sectors' resilience to a severe property price shock.

Our core interest, however, is the relative contribution of the direct and indirect effects of the LTV cap tightening to the 1.37 percentage point reduction in the estimated problem loan ratio from the counterfactual "no policy" scenario to the actual scenario. To this end, we apply the Shapley approach to decompose the direct and indirect effect.[15] In this context, the contribution of the direct effect to the problem loan ratio can be calculated by the following procedure. First, we "switch off" the direct effect in the actual scenario by estimating the problem loan ratio (denoted by d_{ND}) using the actual movement of all variables, except the market LTV ratio (i.e. $\overline{L}_k / \overline{V}_k$) which is superseded by the respective series in the counterfactual scenario. Similarly, we "switch off" the indirect effect in the actual scenario by estimating the problem loan ratio (denoted by d_{NI}) using the actual movements of all variables, except the variable of new mortgage loans made (i.e. $N_k \overline{L}_{k,t}$) which is superseded by the respective series in the counterfactual scenario. The contribution of the direct effect can be computed by $1/2(d_{ND} - d_A)$ $+1/2(d_C - d_{NI})$, which is essentially the average of the marginal contribution of the direct effect in the two scenarios.   By the same logic, the contribution of the indirect effect is derived by $1/2(d_{NI} - d_A)$ + $1/2(d_C - d_{ND})$.   Table 2, which summarises the decomposition result, shows that of the estimated 1.37 percentage point reduction in the problem loan ratio attributed to the LTV cap tightening, the direct and indirect effects account for 1.21 and 0.16 percentage points respectively. In other words, the effect of LTV policy on reducing the sensitivity of mortgage default risk to property price shocks is mainly through direct effects. Indirect effects, though these help to reduce mortgage default risk, play a much less important role.

6.   Conclusion

This paper provides three novel findings of the transmission mechanism of LTV policy to financial stability in Hong Kong, which support the view that operationally it would be optimal for LTV policy to primarily target household leverage, and that there are limitations in using this macroprudential tool to stabilise credit growth and property prices.

First, although there is evidence that LTV cap tightening in Hong Kong since late 2009 reduced borrowers' leverage and credit growth effectively, the former effect is estimated to have played a major role in reducing the sensitivity of mortgage default risk to property price shocks. This finding is

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[15]   Generally, the decomposition can be carried out considering the marginal effect on a variable of the sequential elimination of each of the contributing factors, and then assign to each contributing factor the average of its marginal contributions in all possible elimination sequences. For details, see Shorrocks (1999), Israeli (2007) and Bargain (2009).

consistent with the empirical results of other studies (Foote et al., 2008; Elul et al., 2010; Crowe et al., 2011) that rapid rises in household leverage during the boom phase are at the root of sharp rises of mortgage defaults when the cycle turns. Assigning LTV policy to target household leverage should therefore help to address these vulnerabilities at source.

Second, the finding that there may be a state-dependent effect of LTV policy on credit growth underscores the difficulties in deploying this instrument to dampen excess credit growth. The state-dependent feature implies that calibrating this tool to target credit growth needs an accurate estimate of both loan demand and supply. These variables, however, are unobservable, meaning that calibration needs to rely heavily on model estimates. Operationally, the potential model risks could pose challenges for policymakers.

Third, although the extent to which LTV policy affects property prices is not explicitly modelled in this paper, signs of a limited direct policy effect on the property market are found. In particular, theoretically if LTV policy has a significant impact on the property market, the pass-through would be mainly on the demand for properties. If so, the demand for mortgage loans, which is essentially derived from the demand for properties, should be significantly sensitive to LTV ratios. Our estimation, however, finds low responsiveness of the demand for mortgage loans to LTV ratios, which is suggestive of a limited impact of LTV policy on the property market. This finding may imply that LTV policy may be less effective in stabilising the property market.

Our findings help to answer some important policy questions that arise when the cycle turns. When should policymakers consider relaxing LTV caps? Does a sharp drop in credit growth or property prices justify a relaxation of the instrument? Our findings would support a simple rule that relaxing the measure may be considered only when household leverage is less of a macroprudential concern. Although there is a conventional view that relaxing LTV caps could help to moderate the downward phase of the credit cycle, our findings suggest that the effectiveness crucially hinges on whether demand or supply factors drive credit growth. If a reversal of the credit cycle mainly reflects a sharp drop in the demand for properties, relaxing LTV caps is expected to produce only a limited stabilising effect on credit growth. In such circumstance, other policy tools may be needed instead.

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Table 1. Estimation Results for the Demand and Supply of Mortgage Loans

	Model 1	Model 2	Model 3
Demand Equation			
Constant	0.030 ***	0.031 ***	0.031 ***
	[9.376]	[9.930]	[10.247]
ΔLTV	0.0005	-0.0012	
	[0.035]	[-0.084]	
ROE(LTV,r)	0.013 ***	0.013 ***	0.013 ***
	[6.427]	[6.425]	[6.659]
*ROE(LTV,r)*SSD*	-0.015	-0.009	-0.011 **
	[-1.344]	[-1.503]	[-2.148]
DSR10	0.003		
	[0.732]		
DSR12	-0.004	-0.004	
	[-0.708]	[-0.746]	
U	-0.153 ***	-0.168 ***	-0.166 ***
	[-2.830]	[-3.137]	[-3.166]
CNY	-0.007 ***	-0.007 ***	-0.007 ***
	[-2.902]	[-2.958]	[-2.918]
$-\Delta r_{t+1}^{+}$ (i.e., $1/\gamma$)	3.138 **	3.069 **	3.041 **
	[2.428]	[2.449]	[2.354]
Adjusted R^2	0.323	0.345	0.348
Supply Equation			
Constant	0.017 ***	0.017 ***	0.016 ***
	[10.273]	[11.843]	[9.921]
ΔLTV	0.085 ***	0.073 ***	0.081 ***
	[3.761]	[3.453]	[3.579]
RAROC(r)	0.011	0.011 **	0.017 ***
	[1.445]	[2.081]	[2.674]
PPG	0.021 ***	0.023 ***	0.022 ***
	[3.375]	[3.696]	[3.513]
CD	0.070 ***	0.067 ***	0.068 ***
	[5.427]	[5.330]	[5.286]
DSR10	0.003		
	[0.991]		
DSR12	-0.013 **	-0.010 **	-0.013 **
	[-2.561]	[-2.139]	[-2.468]
$-\Delta r_{t+1}^{-}$ (i.e., $1/\gamma$)	3.138 **	3.069 **	3.041 **
	[2.428]	[2.449]	[2.354]
Adjusted R^2	0.134	0.142	0.133

Sample period: June 1999 - December 2012
***, ** indicate statistically significant at the 1% and 5% levels respectively.
[Figures in brackets are t-statistics]

Table 2. Estimated Non-Performing Ratio of Mortgage Loans with a Hypothetical Severe Property Price Shock

Estimated non-performing loan ratio at end-2014 (%)	
Actual scenario (A)	0.95%
Counterfactual "no policy" scenario (B)	2.32%
(A) - (B)	-1.37%

Decomposition analysis	Estimated non-performing loan ratio at end-2014 (%)
1) Actual scenario (both the direct and indirect effects)	$d_A = 0.95$
2) Only the direct effect	$d_{NI} = 0.98$
3) Only the indirect effect	$d_{ND} = 2.03$
4) Counterfactual "no policy" scenario	$d_C = 2.32$

Figure 1. A Supply-and-Demand Diagram to Illustrate the Effect of LTV Policy under Scenarios of Excess Supply and Excess Demand in Loan Markets.
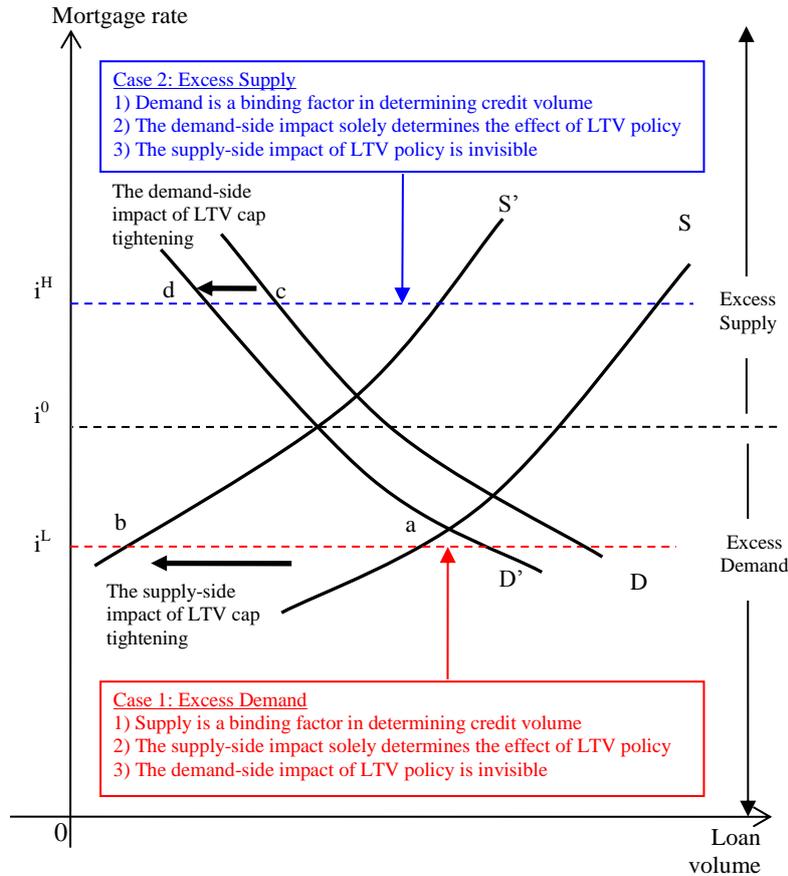
Note: The figure illustrates the implication of loan market disequilibrium for the effect of LTV policy on credit growth. Assume that LTV cap tightening shifts the demand from D to D' moderately and supply from S to S' more significantly. In Case 1 where demand exceeds supply (implying credit supply is the binding factor) at the prevailing mortgage interest rate (i^L), the effect of the tightening solely reflects the supply-side impact, while the demand-side impact is invisible. In this case, the loan volume decreases considerably from *a* to *b*. In Case 2 where supply exceeds demand at the prevailing mortgage interest rate (i^H), the effect of the tightening solely reflects the demand-side impact, while the supply-side impact is invisible. The loan volume decreases marginally from *c* to *d*. In this hypothetical case, LTV policy is expected to be more effective when there is excess credit demand but less so when excess credit supply occurs, suggesting a state-dependent feature of the policy effect.

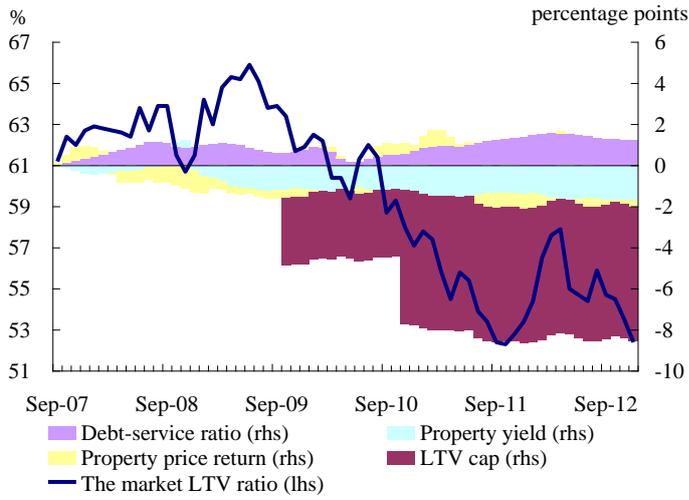**Figure 2. Contributions of Main Factors to Change in the Market LTV Ratio**

Figure 3. The Market LTV Ratio under the Actual and Counterfactual "No Policy" Scenarios
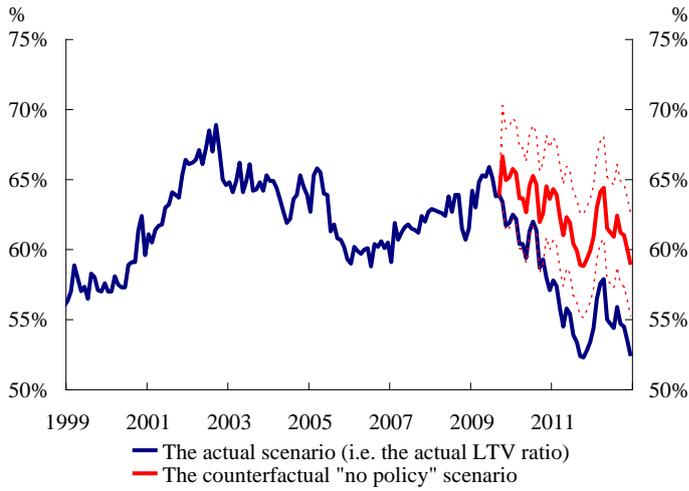
Figure 4. Estimated Supply of Mortgage Loans under the Actual and Counterfactual "No Policy" Scenarios
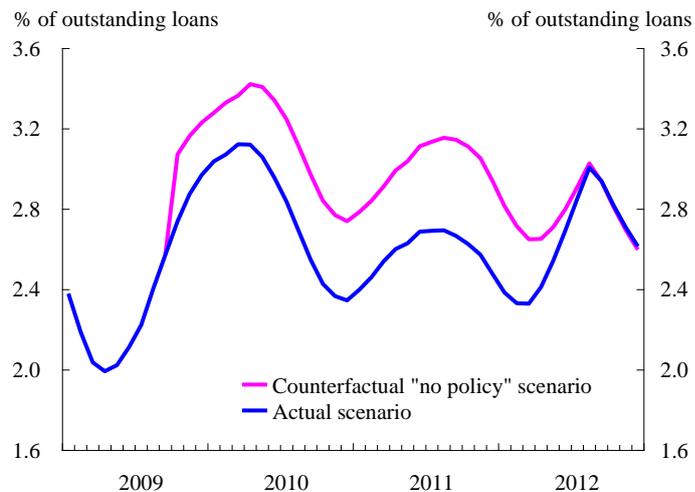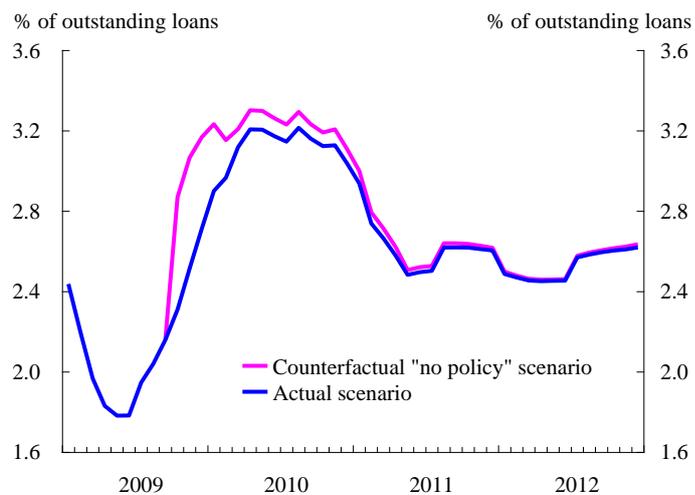
% of outstanding loans   % of outstanding loans

Figure 5. Estimated Demand for Mortgage Loans under the Actual and Counterfactual "No Policy" Scenarios

% of outstanding loans   % of outstanding loans

25

Figure 6. Estimated Demand for and Supply of Mortgage Loans

Excess demand (+) for or excess supply (-) of mortgage loans (rhs)
Demand for mortgage loans (lhs)
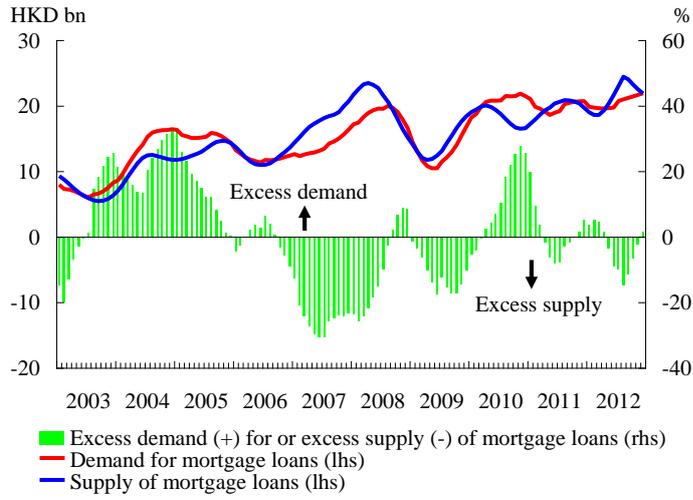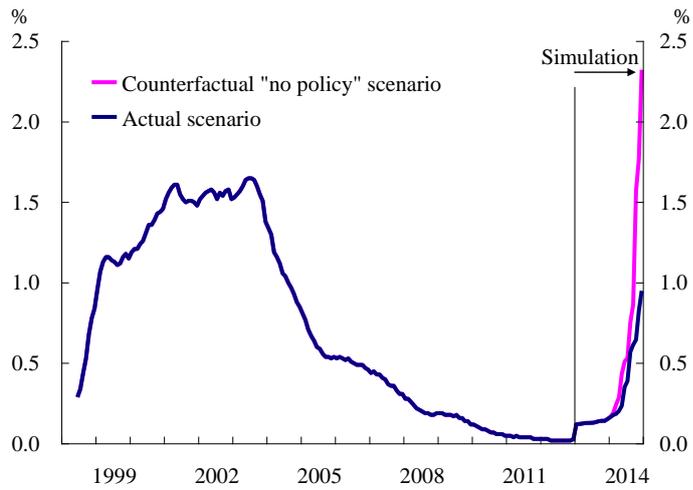Supply of mortgage loans (lhs)

Figure 7. Estimated Non-Performing Loan Ratio for Mortgage Loans under the Actual and Counterfactual "No Policy" Scenarios

Appendix 1. Data Definitions and Sources

Data used in the estimation is mainly sourced from the monthly Residential Mortgage Survey conducted by the Hong Kong Monetary Authority. Residential mortgage loans (RMLs) reported by the survey represent about 99% of the total RMLs of the Hong Kong banking sector. Since key variables are only available since June 1999, the estimation sample covers the period June 1999 – December 2012.

Q_t is measured by the amount of new mortgage loans drawn down during the month as a percentage of the amount of outstanding mortgage loans in the previous month. LTV_t refers to the average LTV ratio for new loans approved during the month. Due to the stationarity problem, the annual percentage change of LTV_t instead of the level is used in estimating the demand equation.[16] The mortgage interest rate r_t is calculated based on the interest rate margin of new loans approved reported in the survey and reference interest rates (i.e. the best-lending rate (BLR) and the 1-month HIBOR). r_t reflected the average mortgage interest rate for BLR-based mortgages before September 2009. Since September 2009, r_t reflects the average of BLR- and HIBOR-based mortgage rates because of a significant market share of the latter. Data for the number of new mortgage loans drawn down during the month, the contractual life of new loans approved during the month, the 3-month delinquency ratio and the rescheduled loan ratio, which are employed mainly for the analysis in Section 4 are also obtained from this survey.

For other variables in the demand equation, GPR_t, a component of ROE, is calculated as the sum of the annual growth rate of the residential property price index (PPG_t) and the average rental yield of residential properties. Data for these two variables are obtained from the Rating and Valuation (R&D) Department of the Hong Kong SAR Government (HKSARG). U_t is the 3-month moving average of seasonally adjusted unemployment rate from the Census and Statistics Department (C&SD) of HKSARG.

In constructing the variable RAROC in the supply equation, all data are from the HKMA, except data for the profit tax rate (t), which are from the Inland Revenue department. The funding cost is defined as the composite interest rate[17] times the share of non-capital funding (i.e. 1-k). The administrative cost is estimated by multiplying the difference between r_t and the funding cost by the cost-to-income ratio of retail banks in Hong Kong. The expected credit loss is estimated by the long-run average of the 3-month delinquency ratio of mortgage loans times the loss-given-default, which is assumed to be 50%. CD_t is the annual growth of Hong Kong dollar deposits of the Hong Kong banking system, which is obtained from the HKMA.

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[16]   Hurlin and Kierzenkowski (2006) point out that including non-stationary variables in the estimation of disequilibrium models could lead to counter-intuitive empirical results.

[17]   Since the composite interest rate is only available since December 2003, data before that are estimated based on an empirical relationship between the composite interest rate and the 1-month HIBOR.

Appendix 2. The Determinants of the Problem Loan Ratio for Mortgage Loans

The econometric model of the problem loan ratio for mortgage loans (*Ploan*) is specified as below, which is similar to those adopted by recent empirical work which finds that negative equity and a high level of debt-servicing burden are two triggers of mortgage defaults:

$$\ln(Ploan_t) = \alpha_0 + \alpha_1 P^{NE} + \alpha_2 (U + (1-U) * P^{DSR}) + \varepsilon \qquad (A2.1)$$

Apart from P^{NE} which measures the severity of the problem of negative equity in a mortgage portfolio (discussed in the main text), we include an indicator of the average debt-servicing burden of borrowers as one explanatory variable (i.e. $U + (1-U) * P^{DSR}$). Essentially, we assume that default risk should be higher for unemployed borrowers. For other borrowers, we construct P^{DSR} to measure their debt-servicing burden. To this end, we first define a debt servicing ratio for mortgagor i in a similar fashion as eq. (13) in the main text:

$$dsr_{k,t}^i = \frac{LR_{k,t}^i(r_t, s_k^i, m_k^i, L_{k,t}^i)}{Y_t^i(1 - Tax_t^i)} \qquad (A2.2)$$

where $LR_{k,t}^i(r_t, s_k^i, m_k^i, L_{k,t}^i)$ and $Y_t^i(1 - Tax_t^i)$ are the amount of the mortgage loan repayment and disposable income at time *t*. $LR_{k,t}^i(r_t, s_k^i, m_k^i, L_{k,t}^i)$ is dependent on the current reference interest rate (r_t), the outstanding loan amount at time t ($L_{k,t}^i$), the interest rate spread (s_k^i) and the maturity (m_k^i). $L_{k,t}^i$ is determined by $L_k^i(1 - CLR_{k,t}^i(rr_{k,t}, s_k^i, m_k^i))$ defined in eq. (13). The disposable income at time t ($Y_t^i(1 - Tax_t^i)$) is determined by the household income (Y_t^i) and the income tax rates (Tax_t^i) at time *t*. In a similar fashion as eq. (15), we can redefine eq. (A2.2) based on the average values of the variables[18]:

$$\overline{dsr}_{k,t} = \frac{\overline{LR}_{k,t}(r_t, \bar{s}_k, \bar{m}_k, \overline{L}_{k,t})}{\overline{Y}_t(1 - \overline{Tax}_t)} \qquad (A2.3)$$

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[18] Average household income ($\overline{Y}_t$) is proxied by median monthly household income for household resided in private housing, with seasonal adjustment, while average tax rate ($\overline{Tax}_t$) is proxied by final salary tax as a percentage of total income (after deductions other than self education expenses and concessionary deductions).

For any mortgage loan portfolio that consists of mortgage loans repayment at time t with N_k cases of mortgage loans being made at time k, the amount of mortgage loans with a distressed level of DSR (defined as a DSR higher than 60%)[19] at time t can be defined as

$$DSR_t = \sum_{k=1}^{t} N_k \overline{L}_{k,t} I(\overline{dsr}_{k,t} > 0.6) \qquad (A2.4)$$

where $I(\overline{dsr}_{k,t} > 0.6)$ is an indicator function. P^{DSR} thus can be defined as

$$P_t^{DSR} = \frac{\sum_{k=1}^{t} N_k \overline{L}_{k,t} I(\overline{dsr}_{k,t} > 0.6)}{\sum_{k=1}^{t} N_k \overline{L}_{k,t}} \qquad (A2.5)$$

The estimated result of the model is shown below:

$$\ln(Ploan_t) = -6.803 + 6.293 * P_t^{NE} + 2.317 * (U_t + (1-U_t) * P_t^{DSR})$$
$$[-55.8] \quad [16.2] \qquad [9.73]$$

$Adj.\ R^2 = 0.63 \qquad Sample : Jun\ 1998 - Dec\ 2012$

[Figures in brackets are t-statistics]

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[19]   In the 2009/10 Household Expenditure Survey (by C&SD), the expenditure for basic needs (food, energy, transport and part of the services) is around 40% of household resided in private housing. Therefore the threshold of distressed level of DSR is set at 60%.