A DSGE-Based Assessment of Nonlinear Loan-to-Value Policies: Evidence from Hong Kong

Michael Funke*          Michael Paetz†
Hamburg University        Hamburg University

February 3, 2012

Abstract

After the financial crises from 2008-2009, the design of macroprudential policies has arrived in the centre of the macroeconomic discussion. With respect to house price booms, recent research suggest the use of loan-to-value (LTV) policies as a stabilization tool. However, policymakers are rather reluctant and change LTV ratios only in the case of extreme events. This paper builds a Hong Kong specific New Keynesian DSGE model to analyse LTV policies. We conclude that linear Taylor-type rules can increase the volatility of the business cycle, while nonlinear rules, reacting on very high property price inflation, can help to reduce the transmission of house price cycles on the real economy.

Acknowledgements

The views expressed in the paper are those of the authors. No responsibility should be attributed to the Bank of Finland.

Keywords: DSGE models, housing, open economy, Hong Kong, LTV policies.
JEL classification: C63, E21, E32, E69, F41.

*email: funke@econ.uni-hamburg.de
†email: michael.paetz@wiso.uni-hamburg.de
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1 Introduction

The monetary policy consensus which has emerged until the global crisis 2008-2009 proceeds from the assumption that central banks have to keep inflation low and stable. It favours an explicit or implicit inflation target and associated central bank communication to anchor inflation expectations. It also puts a lot of weight on the transparency and predictability of central banks’ short-term interest rate decisions via the Taylor rule. Now, in the wake of the global financial crisis, the consensus is not absolute any more and in the newly prioritised area of macroprudential supervision the focus has shifted towards financial stability. In the case of monetary policies, the debate is closely related to the role (if any) of asset prices in monetary policy formulation.\(^1\)

In advanced economies recessions that simultaneously occur with a real estate bust tend to be deeper and last longer than those that do not, and their cumulative losses are three times the loss done during recessions without real estate busts [Reinhart and Rogoff (2009)]. Since the financial system is procyclical, booms in the real economy improve borrower creditworthiness and increase the value of bank assets. Consequently, macroprudential policies have been designed to increase the stability and resilience of the financial system as a whole, not just individual institutions or markets. The idea is that these policies should stop loan-driven bubbles or at least limit the damage of asset price busts.\(^2\) An immediate consequence is that it is not sufficient to wait and clean up during the bust phase: proactive monetary policy also needs to lean against the build-up of financial imbalances caused by exaggeratedly optimistic expectations believing that prices will go on rising. This presents an opportunity to use mandatory maximum loan to value (LTV) ratios as a stabilisation tool to break the self-reinforcing spiral reasonably early.\(^3\)

On the other hand, conducting monetary policy and tempering boom-bust-cycles in this way is not easy. It is difficult to imagine that central banks have the foresight to prick asset bubbles, i.e. price increases not justified by fundamentals. Central bankers may also tend to shy away from second-guessing the markets. According to the opposite view, bubbles are therefore identified too late and with a considerable degree of uncertainty.\(^4\) Often bubbles look unsustainable only when they have

\(^1\)A thorough assessment of the lessons for monetary policy from asset price fluctuations is provided in (IMF, 2009, chapter 3).

\(^2\)A discussion paper from the Bank of England (2009) sketches the elements of a macroprudential regime and identifies what needs to be decided before it can be put into practice. Such leaning against the wind macroprudential regulation is already common in some parts of the world. For an analysis and survey of country-specific cases and the scant empirical evidence, see Ahuja and Nabar (2011), Crowe et al. (2011), Igan and Kang (2011) and Wong et al. (2011).

\(^3\)A LTV limit tends to affect financially constrained consumers and particularly younger households. Estimates for the OECD indicate that a 10 percent increase in the maximum LTV ratio is associated with a 12 percent rise in home ownership of younger households, while the effect for older households is much smaller [see Andrews et al. (2011)].

\(^4\)The argument that bubbles are hard to spot at an early stage with sufficient certainty is convincing although Phillips et al. (2011, 2012) have recently provided recursive regression method-
already burst. Another criticism of time-varying LTV ratios is that they increase the cost of intermediation during the boom and thereby reduce desirable economic expansion. Furthermore there is a risk that setting monetary policy in response to asset price movements will lead to large output losses that exceed by a wide margin those that would arise from a possible bubble burst. In addition to the fact that the central bank must form a view of whether a particular asset price increase is dangerous or not, one has to determine a threshold level determining the asset price levels with which the central bank feels uncomfortable. This scepticism leads to the tenet of "benign neglect", i.e. the view that is is better to wait on the sidelines because the cost of intervention may greatly exceed the potential negative side effects of pre-emptive policies [Bernanke and Gertler (2001)]. In summary, the monetary policy toolkit is too blunt an instrument to be used to target asset prices and the adequate response to house price booms is more an art than a science.

It is well-known that a currency board system constitutes a very special monetary regime. A central bank under a currency board exchange rate regime doesn’t have tools for active monetary policy. Under Hong Kong’s currency board, the Hong Kong Monetary Authority (HKMA) exchanges the base currency on demand, thus creating effective bounds on the interbank market interest rate fluctuations, similar to the standing facilities of independent central banks. If Hong Kong’s interbank market interest rates differ sufficiently from the base currency interbank market interest rates, profitable arbitrage opportunities arise. Thus, Hong Kong’s interbank market interest rates fluctuate within the band of the transaction costs of engaging in the foreign interbank market. Therefore Hong Kong has to rely upon macroprudential policies as a toolkit and is a precedent to analyse the working of LTV policies. We extend the current literature in several aspects. First, we provide an open-economy DSGE modelling framework under which we can analyze the effects of LTV policies in a currency board country. Second, we calibrate the LTV policies assuming the most likely case that the central bank only reacts once house price inflation exceeds pre-defined thresholds. Such a policy rule is somewhere in between the two polar policy stances "lean against the wind" and "clean up afterwards" mentioned above. The rest of the paper is structured as follows. In Section 2 we lay out the model, which is based on the work of Funke and Paetz (2011), while section 3 illustrates the historical LTV policy in Hong Kong. Section 4 calibrates the model and clarifies the workings of macroprudential policies by analysing impulse response functions. The subsequent section 5 evaluates different policies in terms of their inflation-output trade-off, and the final section concludes.

ologies for identifying bubble behaviour and consistent dating of their origination and collapse in real time. This is blatantly due to the nature of bubbles.
2. The Theoretical Framework

In this section we sketch the baseline DSGE framework. The model is a modified version of Funke and Paetz (2011), who estimate a DSGE model with a housing market for Hong Kong in the spirit of Iacoviello (2005) or Monacelli (2009). It is based on the seminal work of Kiyotaki and Moore (1997), who introduce the distinction of patient and impatient households into modern macroeconomics. Credit market frictions are introduced by a binding collateral constraint on borrowers, and monetary policy is described by an exchange-rate peg. The intratemporal decisions of domestic households are based on the open economy framework of Galí and Monacelli (2005). Instead of assuming an LTV shock, we use a threshold rule for describing interventions of the HKMA on LTV limits. In what follows we briefly sketch the model foundations. A detailed version of the model can be found in Funke and Paetz (2011).

Households are divided into $\omega$ borrowers and $(1-\omega)$ savers, denoted as $b$ and $s$, respectively. Except for the discount factors, households are assumed to be completely symmetric. The two sectors of the economy, namely residential and non-residential goods, are denoted by the subscripts $C$ and $D$, respectively. In the following, small-case letters are used for a logarithmic representation and hats ($\hat{\cdot}$) denote percentage deviations of a variable from equilibrium.

2.1 Households

**Borrowers** The representative impatient borrower is infinitely-lived and seeks to maximize

$$E_0 \sum_{t=0}^{\infty} \beta_b^t \left[ \frac{1}{1-\sigma} \left( X^b_t \right)^{1-\sigma} - \frac{1}{1+\varphi} \left( N^b_{C,t} \right)^{1+\varphi} - \frac{1}{1+\varphi} \left( N^b_{D,t} \right)^{1+\varphi} \right],$$

where $E_0$ is the conditional expectation operator evaluated at time 0, $X^b_t$ represents the welfare-relevant consumption index and $N^b_{j,t}$ represents the labour supply in sector $j$. Moreover, $\varphi$ and $\sigma$ are the corresponding intertemporal elasticities of substitution with respect to labour and consumption, respectively, and $\beta_b$ represents the borrowers discount factor.

The welfare-relevant consumption index is a weighted average of the flow of non-durable consumption expenditures and the stock of durables,

$$X^b_t \equiv \left( \tilde{C}^b_t \right)^{1-\gamma \tilde{D}^b_t} \left( D^b_t \right)^{\gamma \tilde{D}^b_t},$$

where $\tilde{C}^b_t \equiv C^b_t - h_CC^b_{t-1}$, $C^b_t$ and $D^b_t$ represent composite indices of non-durable and durable consumption services, respectively, $h_C$ represents habit formation in consumption, $\gamma$ is the share of housing in consumption, and $\tilde{D}^b_t \equiv \exp \left( \tilde{d}^b_t \right)$ is a household-specific housing preference shock that affects the marginal rate of substi-
tution between non-residential and residential goods.

Borrowers can trade nominal riskless bonds, but are unable to tap the international markets to finance their expenditures. Consequently, they face a sequence of budget constraints, given by

\[ C^b_t + P_{D/C,t}I^b_{D,t} - B^b_{H,t} = -R_{t-1} \frac{P^b_{H,t-1}}{\Pi_{C,t}} + \sum_{j=C,D} \frac{W^b_{j,t}N^b_{j,t}}{P_{C,t}}, \]

where \( \Pi_{C,t+1} \equiv \frac{P_{C,t+1}}{P_{C,t}} \) is the CPI based inflation rate, \( B^b_{H,t} \) represents the stock of real domestic debt (denominated with the domestic non-residential price index), \( R_{t-1} \) the nominal interest rate (the lending rate on a loan contract issued in \( t-1 \)), \( W^b_{j,t} \) the sector-specific wage rate, \( I^b_{D,t} \equiv D^b_t - (1 - \delta)D^b_{t-1} \) defines housing investments, \( P_{D/C,t} \equiv \frac{P_{D,t}}{P_{C,t}} \) are relative house prices, and \( \delta \) represents the depreciation rate of the residential stock.

Borrowers do not save and are restricted by the following borrowing constraint

\[ R_t B^b_{H,t} \leq (1 - \delta) E_t \left[ P_{D/C,t+1}D^b_t \Pi_{C,t+1} \right] LTV_t, \]

where \( LTV_t \) represents the LTV ratio, which is set by the monetary authority.\(^5\)

Moreover, \( \delta \) represents the depreciation rate of houses. This equation relates the amount that will be repaid by a borrower in the following period to the expected future value of durable stocks (adjusted for depreciation and the LTV ratio). According to (4) the fraction of residential goods, which can be used as collateral decreases, when the LTV ratio is lowered. As a consequence, borrowers are forced to reduce their debt.\(^6\) In this respect, household debt in this model can be thought of as mortgage secured credits.

**First order conditions:**

\[ \frac{W^b_{j,t}}{P_{C,t}} = \left( X^b_{t} \right)^{\sigma} \left( N^b_{j,t} \right)^{\varphi} \left( \tilde{C}^b_{t} \right)^{\gamma E^{D,b}_{C}} \left( 1 - \gamma E^{D,b}_{t} \right)^{\gamma E^{D,b}_{C}} \left( D^b_t \right)^{\gamma E^{D,b}_{C}}, \]

\[ \left( \frac{\gamma E^{D,b}_{C}}{1 - \gamma E^{D,b}_{t}} \right) \frac{\tilde{C}^b_{t}}{D^b_t} + (1 - \chi) (1 - \delta) \psi_t P_{D/C,t} E_t \left[ \Pi_{D,t+1} \right] LTV \]

\[ + \beta_{C}(1 - \delta) E_t \left[ \left( \frac{1 - \gamma E^{D,b}_{C}}{1 - \gamma E^{D,b}_{t}} \right) \left( \frac{X^b_{t+1}}{\chi^b_{t+1}} \right)^{\sigma} \left( \tilde{C}^b_{t+1} \right)^{\gamma E^{D,b}_{C}} \right] \frac{P_{D/C,t+1}}{P_{C,t+1}} \]

\(^5\)HKMA is the sole prudential overseer of banks and mortgage products in Hong Kong and is thus responsible for the formulation and enforcement of LTV limits.

\(^6\)As a point of clarification, there is a fine but important distinction between whether LTV ratios move endogenously in response to shocks, or whether regulators impose their terms and conditions to curb real estate bubbles.
\[ R_t \psi_t = 1 - \beta_b E_t \left[ \left( \frac{1-\gamma \varepsilon_{t+1}^D}{1-\gamma \varepsilon_t} \right) \left( \frac{X_{t+1}^b}{X_t^b} \right)^{-\sigma} \left( \frac{D_{t+1}^b}{C_{t+1}^b} \right)^{\gamma \varepsilon_{t+1}^D} \right] \times \left( \frac{C_t^b}{D_t^b} \right)^{\gamma \varepsilon_t} \frac{R_t}{\Pi_C t+1} \right], \]

where \( \lambda_t \psi_t \) represent the Lagrangian multiplier on the borrowing constraint, and \( \psi_t \) can be interpreted as the marginal value of borrowing.

**Savers**  Patient savers are able to make intertemporal decisions in the standard way. The representative household is infinitely-lived and seeks to maximize

\[
\max E_0 \sum_{t=0}^{\infty} \beta_t \left[ \frac{1}{1-\sigma} (X_t^s)^{1-\sigma} - \frac{1}{1+\varphi} (N_{C,t}^s)^{1+\varphi} - \frac{1}{1+\varphi} (N_{D,t}^s)^{1+\varphi} \right],
\]

subject to

\[
C_t^s + P_{D/C,t} I_{D,t} - B_{H,t}^s - \xi_t B_{F,t}^s = -R_{t-1}^s \frac{B_{H,t}^s}{\Pi_{C,t}} - \frac{R_{t-1}^s}{\Pi_{C,t}} \xi_t B_{F,t-1}^s + \sum_{j=C,D} W_{j,t}^s N_{j,t}^s,
\]

where \( \xi_t \) represents the nominal exchange rate, \( B_{F,t}^s \) foreign bond holdings, \( R_t^s \) the foreign interest rate, and all other variables are defined in the same way as for the borrowers.

**First order conditions:**

\[
\frac{W_{j,t}^s}{P_{C,t}} = \frac{(X_t^s)^{\sigma} (N_{j,t}^s)^{\varphi} \left( \hat{C}_t^s \right)^{\gamma \varepsilon_t^D}}{(1-\gamma \varepsilon_t^D) (D_t^s)^{\gamma \varepsilon_t^D}}, j = C, D, \tag{8}
\]

\[
P_{D/C,t} = \left( \frac{\gamma \varepsilon_t^D}{1-\gamma \varepsilon_t^D} \right) \frac{\hat{C}_t^s}{D_t^s} + \beta_s (1-\delta) E_t \left[ \left( \frac{1-\gamma \varepsilon_{t+1}^D}{1-\gamma \varepsilon_t} \right) \left( \frac{X_{t+1}^b}{X_t^b} \right)^{-\sigma} \hat{C}_{t+1}^s \left( \frac{D_{t+1}^b}{C_{t+1}^b} \right)^{\gamma \varepsilon_{t+1}^D} \right] \times \frac{R_t}{\Pi_{C,t+1}} \right], \tag{9}
\]

\[
1 = \beta_s E_t \left[ \left( \frac{1-\gamma \varepsilon_{t+1}^D}{1-\gamma \varepsilon_t} \right) \left( \frac{X_{t+1}^b}{X_t^b} \right)^{-\sigma} \hat{C}_{t+1}^s \left( \frac{D_{t+1}^b}{C_{t+1}^b} \right)^{\gamma \varepsilon_{t+1}^D} \right] \times \frac{R_t}{\Pi_{C,t+1}} \right], \tag{10}
\]

\[
1 = \beta_s E_t \left[ \left( \frac{1-\gamma \varepsilon_{t+1}^D}{1-\gamma \varepsilon_t} \right) \left( \frac{X_{t+1}^b}{X_t^b} \right)^{-\sigma} \hat{C}_{t+1}^s \left( \frac{D_{t+1}^b}{C_{t+1}^b} \right)^{\gamma \varepsilon_{t+1}^D} \right] \times \frac{R_t}{\Pi_{C,t+1}} \right]. \tag{11}
\]
Concerning the international dimension, the model follows the literature on New Open Macroeconomics, beginning with Galí and Monacelli (2005). Since foreign investors are allowed to buy domestic houses and vice versa, both consumption indices are given by a weighted average of domestic and foreign consumption:

\[ C_t \equiv \left( (1 - \alpha_C) \frac{1}{\eta_C} C_{H,t} (j) \alpha_C^{\eta_C-1} + \alpha_C^{\eta_C} C_{F,t} (j) \right)^{\frac{1}{\eta_C}}. \]  

\[ D_t \equiv \left( (1 - \alpha_D) \frac{1}{\eta_D} D_{H,t} (j) \alpha_D^{\eta_D-1} + \alpha_D^{\eta_D} D_{F,t} (j) \right)^{\frac{1}{\eta_D}}. \]

Assuming that the law of one price holds on a brand level, Funke and Paetz (2011) show that the sectoral terms-of-trade (denoted by \( \hat{\xi}_{C,t} \) and \( \hat{\xi}_{D,t} \), respectively) are connected through the exchange rate channel, that is

\[ (1 - \alpha_C) \hat{\xi}_{C,t} - (1 - \alpha_D) \hat{\xi}_{D,t} = \hat{p}_{D/C,t} - \hat{p}_{D/C,t}. \]

**International risk-sharing** Savers are able to share country-specific risks internationally via the trading of bonds on complete security markets, implying a risk-sharing condition:

\[ \left( \frac{X_{t}}{X_{t}^*} \right)^{-\sigma} \left( \frac{\hat{C}_{t}^{\hat{\xi}^{D,*}_{t}}}{\hat{C}_{t}^{\hat{\xi}^{D,*}_{t}}} \right)^{\gamma} \left( \frac{\hat{D}_{t}^{\hat{\xi}^{D,*}_{t}}}{\hat{D}_{t}^{\hat{\xi}^{D,*}_{t}}} \right)^{\gamma} = R_t \]

where \( R_t \) is the consumer price based real effective exchange rate and \( \xi^{D,*}_{t} \) represents the foreign counterpart to domestic preference shocks.

### 2.2 Firms

Retailers produce final goods in sector \( j \) are produced by combining domestic intermediate goods using a CES production function. The wholesale sector produces intermediate goods, using a Cobb-Douglas production function, \( Y_{j,t} (k) = N_{j,t} (k) \). Price adjustment of the monopolistically competitive firms is assumed to follow a variant of Calvo pricing: A randomly selected fraction of firms in each sector \( (1 - \theta_j) \) adjusts prices, while the remaining fraction of firms \( \theta_j \) does not adjust. In addition, a fraction of \( (1 - \tau_j) \) firms behaves in a forward-looking way, while the remaining fraction \( \tau_j \) uses the recent history of the aggregate price index when they set prices. Thus, \( \tau_j \) is a measure of the degree of backward-looking price-setting. These assumptions yield the conventional mark-up rule, whereby firms set the price as a

\[ \text{In recent years strong demand from mainland Chinese was an important factor boosting property prices in Hong Kong. Therefore HKMA has curbed the LTV ratio forborrowers whose principal income is not derived from Hong Kong in June 2011. Ultimately, this measure is intended to increase the funding pressure for buyers from the mainland of China.} \]
mark-up over current and future real marginal costs \((mc_{j,t+k})\) and deviations of the time-varying mark-up from its steady state \((\hat{\mu}_j)\) such that

\[
\bar{p}_{j,H,t} = \hat{\mu}_j + (1 - \beta \theta) \sum_{k=0}^{\infty} (\beta \theta)^k E_t (mc_{j,t+k} + p_{j,H,t}).
\] (16)

2.3 Equilibrium

Aggregate goods market clearing for each good \(k\) in each sector \(j\) requires

\[
Y_{C,t}(k) = C_{H,t}(k) + \int_0^1 C_{H,t}(k) \, di
\] (17)

\[
Y_{D,t}(k) = I_{D,t}(k) + \int_0^1 I_{D,t}(k) \, di
\] (18)

where \(I_{D,t}\) represent housing investments from country \(i\), which are defined in the same manner as domestic housing investments.

Obviously, aggregated real output (denominated with the aggregated producer price index \(P_{H,t}\)) must fulfill

\[
P_{H,t} Y_t = P_{C,H,t} Y_{C,t} + P_{D,H,t} Y_{D,t}.
\]

Moreover, the price index for aggregated output is a weighted average of domestic prices for non-residential consumption and housing \(P_{H,t} = P^{1-\xi} e^{D} e^{C} P_{D,H,t}^{\xi} e^{D,*}\), where \(\xi\) represents the share of the housing sector in aggregate production, which we allow to be affected by domestic and foreign preference shocks. Log-linearising real output yields:

\[
\hat{y}_t = \frac{P^{\xi}}{Y} \hat{y}_{C,t} + \frac{\delta P^{1-\xi} D}{Y} \hat{y}_{D,t} + \Xi \ln P_{D/C} (\varepsilon^{D,*} + \varepsilon^{D}),
\] (19)

where \(Y = P^{\gamma} C + \delta P^{1-\gamma} D, \Xi \equiv (1 - \xi) \frac{\delta P^{1-\xi} D}{Y} - \xi \frac{P^{\xi}}{Y} \) and \(\hat{P}_{D/C,H,t} = \hat{P}_{D/C,t} - \alpha_D \hat{s}_{D,t} + \alpha_C \hat{s}_{C,t}\).

2.4 Monetary Policy

Finally, we adopt a standard formulation for the structure of monetary policy-making under a currency board system. To be specific, we assume a credible exchange rate peg, implying \(\hat{e}_t = 0\). Consequently, monetary policy is conducted to ensure \(\Delta \hat{s}_{C,t} = \hat{\pi}_{C,F,t} - \hat{\pi}_{C,H,t}\), which implies \(\Delta \hat{s}_{D,t} = \hat{\pi}_{D,F,t} - \hat{\pi}_{D,H,t}\) via (15), and eliminates any pressure on the exchange rate.

2.5 LTV Policy

Much recent research is devoted to the analysis of Taylor-type rules for LTV ratio, like

\[
\hat{u}_t = -\phi_{u,v} \hat{x}_t,
\] (20)
where $x_t$ can be any variable, to which the loan-to-value ratio should react, like levels or growth rates of GDP, credits, the credit-to-GDP ratio or (relative) house prices, and $\phi_{ltv}$ determines the strength of the intervention.\textsuperscript{8} We believe such mechanical rules to be a nice illustration, but a rather unrealistic assumption. Notwithstanding the general consideration above, it is still an open question how a workable implementation of a time-varying LTV policy can be designed. One could also state that expectations should be realistic when applying macroprudential policies in practice. It is very difficult to discern in real time whether asset price booms are driven by benign or malign developments. Even the most comprehensive early warning yardstick indicators of financial vulnerability are noisy, sometimes sending wrong signals and implying the risk of policy errors. Put differently, it is difficult to separate "good" from "bad" house price booms in real time. This will elicit infrequent interventions by policymakers.\textsuperscript{9} Even for a central bank favouring early intervention it is thus reasonable to assume that she will react only occasionally and once house price inflation exceeds a defined threshold. In addition, policymakers have an asymmetric target: They care about too high inflation rates in the housing sector, since they fear that bubbles evolve, which can lead to tremendous downturns in the case of a burst. However, they do not care about too low inflation in the housing market.

To reflect these concerns, we assume a non-linear loan-to-value policy, described by

$$\hat{ltv}_t = \phi_{ltv}'(\hat{x}_t - \bar{x})^+,$$

(21)

where $\bar{x}$ represents the threshold value, and $\phi_{ltv}$ determines the strength of the reaction.\textsuperscript{10} According to (21), the loan-to-value ratio is lowered, whenever deviations of $x$ from equilibrium are greater than $\bar{x}$. The following section is devoted to the illustration of such a non-linear policy rule.

The DSGE framework described above features the main characteristics of the Hong Kong economy. We deviate from all other work on DSGE models including a housing sector in at least three important assumptions, which are all necessary extensions for analysing Hong Kong: (i) residential goods can also be bought by foreigners, (ii) monetary policy is described by an exchange rate peg, and (iii) the LTV ratio is set by the HKMA. In the next sections we interpret LTV policies through the lens of this model.

\textsuperscript{8}As usual, variables with a hat represent percentage deviations from equilibrium.

\textsuperscript{9}It must be pointed out that LTV limits are assumed to be valid. Procyclical LTV ratios may be circumvented by households through recourse to foreign banks and/or nonbank intermediaries.

\textsuperscript{10}In practice, a conservative choice of the threshold helps to avoid a misclassification of "good" real estate booms caused by fundamentals as unsustainable "bad" real estate booms financed through credit.
3. Historical LTV Policies in Hong Kong

The empirical literature on the effectiveness of LTV limits in Hong Kong is relatively limited, albeit growing. Gerlach and Peng (2005) show that following the introduction of LTV limits, credit expansion in Hong Kong SAR has become less sensitive to property prices. Recently, Wong et al. (2011) have assessed the effectiveness and drawbacks of LTV limits in Hong Kong. The result of their econometric analysis is that the main channel through which LTV policies limit house price appreciation is via household leverage.

LTV policies to curb a sizzling property market have a relatively long history in Hong Kong. The regulatory measures in Hong Kong from 1990 - 2010 can be broadly divided into four phases. (i) Prior to the sharp rise in residential property prices in 1996, the 70 percent limit was introduced as a prudential measure to guard against overexposure to the property market. (ii) In light of the Asian financial crisis, the HKMA issued guidelines to adopt a maximum LTV ratio of 60 percent for so-called luxury properties. (iii) In October 2001 the HKMA restored the maximum LTV ratio of 70 percent again. (iv) In the wake of the global recession 2008-2009, the HKMA announced a new round of residential mortgages tightening measure aiming at curbing residential properties prices on 19 November 2010. The maximum LTV ratio for properties with a value of at least HKD 12 million was lowered from 60 percent to 50 percent. The maximum LTV ratio for residential properties with a value between HKD 8 million and HKD 12 million was reduced from 70 percent to 60 percent. On the contrary, the maximum LTV ratio remained at 70 percent for residential properties at the lower end of the market. Finally, regardless of their market value the maximum LTV ratio for all non-owner-occupied residential properties was reduced to 50 percent.

In our baseline calibration scenario below, we assume that LTV ratios are lowered when quarterly property price inflation exceeds a threshold value of 4 percent. To motivate this policy scenario in a transparent fashion, we first illustrate the assumed policy rule. Figure 1 provides a graphical summary of property price inflation in Hong Kong together with the (0,1) dummy variables $DUM_A^t$ and $DUM_B^t$ indicating periods of tightened LTV caps from Wong et al. (2011) from 1985 - 2010.11 In addition, the Figure illustrates a policy threshold of 4 percent (the horizontal red line). To begin with, the graph indicates that LTV policies in Hong Kong have been actively managed in a countercyclical fashion to guard against asset price swings. In addition, the assumed threshold in the baseline scenario mimics the actual LTV ratios.

11Outside the estimation period for the DSGE model, the HKMA has once again tightened residential LTV ratios. Initially, HKMA curbed LTV ratios in November 2010. In June 2011, HKMA further lowered the LTV ratio for residential mortgages for HKD 10 million or more to 50 percent. The LTV ratio for transaction between HKD 7 million and HKD 10 million were lowered to 60 percent. The LTV ratio for transaction less than HKD 7 million remained at 70 percent. Ultimately, these decisions reflect that the HKMA is getting increasingly worried about the risks banks are taking in lending as the real estate market has essentially reached the 1997 peak level, and the current real estate boom is entirely driven by easy credit, which is not sustainable.
policies very well. Conflicting signals are only apparent in the late 1980s, and in 2004 and 2008.

Figure 1: Quarterly Property Price Inflation, Indicators of Actual LTV Caps, and the Assumed Threshold in the DSGE Model

![Figure 1](image_url)

**Notes:** The property price inflation is derived by dividing the annual change of the Territory-Wide Residential Property Prices by 4 (taken from the Rating and Valuation Department). The resulting series is then detrended using an HP-filter with smoothing parameter $\lambda = 1600$. $DUM_A^t$ ($DUM_B^t$) is defined as one for observations within the six-month period right after (before) the tightening of LTV caps and zero otherwise. See Wong et al. (2011), pp. 17-18. The horizontal line gives the baseline policy threshold according to the nonlinear policy rule (21).

## 4 Simulations

This section describes the workings of the model by running a simulation for a plausible calibration and a LTV policy, which solely depends on property price inflation. This is primarily done for illustrative reasons. A comprehensive evaluation of different policies under different assumptions on the shock size and parameters, is carried out in the subsequent section.

**Calibration** We set the depreciation rate of durables to a value of 0.05, and the discount factors of borrowers and savers to standard values of 0.96 and 0.99, respectively. The degrees of openness in both sectors are set to 0.5. The share of the durables sector in aggregate production is set to 10 percent, and the share in the welfare relevant consumption index is equal to 0.5. This corresponds to a very strong housing wealth effect. However, Funke and Paetz (2011) found values in this range for all scenarios they considered. Concerning the supply side, mark-ups in both sectors are set to 10 percent, and the share of firms, which do not adjust prices in each period (the Calvo parameter), is set to 50 percent in the consumption goods and 30 percent in the housing sector. Moreover, backward-looking price setters make-up a fraction of 30 percent in both sectors, and consumption habits are set to $h_c = 0.2$. The intertemporal substitution elasticities with respect to consumption and labour supply are set to 1 and 5, respectively. Concerning the share of borrowers, we use rather high value of 35 percent. The intratemporal substitution elasticities between
domestic and foreign goods in both sectors are set to a value of 2, and finally, the equilibrium loan-to-value ratio is fixed at 70 percent.

Since we need strong deviations of house price inflation from equilibrium in order to illustrate our threshold-rule, we focus on the shock type, which has been identified as the main driver of house price booms: a housing preference shock of domestic savers. We assume that the shock follows an AR(1) process, \( e_{t,s} = \rho_{d,s} e_{t-1,s} + \epsilon_t \), with a persistence parameter \( \rho_{d,s} = 0.3 \). To create a strong increase in property prices, we assume that the innovation \( \epsilon_t \) is of size 3. This leads to an annual increase in inflation of more than 20 percent at impact. This is no unrealistic value in the history of Hong Kong: In the second half of 1991 and in the middle of 1997 quarterly house price inflation climbed above 10 percent. For some quarters the annual increase in prices was actually above 70 percent. In both periods, the HKMA lowered the LTV ratio several times as response to the drastic increase in house prices. While until the beginning 1991, the official LTV ratio was about 90 percent, a maximum of 70 percent was introduced in November. In 1994 even a temporary guideline of 40 percent was introduced, since property lending increased rapidly. In 1997 the HKMA recommended a maximum of 60 percent on luxury goods, among other measures to reduce the housing price boom.

Concerning the interventions of the HKMA by decreasing the LTV-ratio, we assume that the central bank reacts when the quarterly property price inflation passes a value of 4 percent, which refers to an annual inflation rate of roughly 17 percent:

\[
\hat{l}_{tv} = -\phi'_{ltv} (\hat{\pi}_{D,t} - 4)^+. 
\]  

For the simulation of such a nonlinear rule with DYNARE, we use the algorithm proposed by Holden (2011), which allows to simulate models with one non-negativity constraint. Details on the transformation of our setup into a problem with one non-negativity constraint are given in the appendix. To compare the nonlinear interventions with a linear Taylor-type LTV-policy, as recently suggested for example in Christensen and Meh (2011), Gelain (2011), Suh (2011) or Lambertini et al. (2011), respectively, we also simulate the model for the linear loan-to-value macroprudential policy rule:

\[
\hat{l}_{tv} = -\phi_{ltv} \hat{\pi}_{D,t},
\]

We calibrate the reaction parameters in a way that lead to equal responses of the LTV ratio at impact. Hence, \( \phi_{ltv} = 4.5 \) and \( \phi'_ {ltv} = 55.12 \). This leads to a fall in the LTV ratio from 70 to roughly 55 percent as response to an increase in annual property price inflation of around 20 percent.

**Impulse Responses** Figure 1 illustrates the impulse responses of our simulation exercise for the standard model with no interventions (red line), the time-varying

\[\text{12Note, that } \phi'_{ltv} \text{ is much higher, since the policymaker reacts only on the fraction of property price inflation, which lies above the threshold value.}\]
policy (blue line), and the threshold rule (green line), respectively.

Figure 2: Impulse Responses, Positive Saver’s Housing-Pref erence Shock

output  property price inflation  producer price inflation

consumption  employment  aggregate inflation

housing investments  stock of durables  debt

terms-of-trade, consumption  terms-of-trade, durables  loan-to-value ratio

Notes: The reactions of all variables are given in percentage devia tions from equilib rium, except the inflation rates (which represent annual deviations from equilibrium in percentage points), and the loan-to-value ratio (which represents the actual ratio).

The general response to the increase in the saver’s housing preference is straightforward. The positive preference shock increases the demand for housing and consum ption goods. This leads to a boom in the economy, accompanied by an increase in both inflation rates. The higher value of houses loosens the borrowing constraint and, consequently, debt rises slightly. The rise in domestic prices leads to a downturn in both sectoral terms-of-trade, and hence to a fall in foreign demand, which leads to a fall in output and a return to equilibrium of all variables in the medium term.\textsuperscript{13}

Analysing the loan-to-value policies brings up at least three results worth noticing: First, macroprudential policies are no silver bullet. Even though the loan-to-value

\textsuperscript{13}Since the exchange rate is fixed the domestic interest rate reacts only to a negligible extend due to the influence of the preference shock on risk-sharing via (15).
ratio is decreased sharply from 70 to slightly above 55 percent, house price inflation decreases only slightly, no matter whether we assume a time-varying or a non-linear policy. Nevertheless, the reduction in property price inflation at impact equals 1.4 percent with a time-varying policy and 5.1 percent with a non-linear policy. Moreover, the LTV policy seems to have a very strong impact at household debt. So, if reducing debt levels is the policy goal, our simulation results suggest that LTV policies are very successful. The second and more pleasant result is, that loan-to-value policies strongly dampen the deviations from equilibrium for nearly all other variables. The third insight from Figure 1 is the most policy-relevant result. The graphs illustrate, that apart from the question how a countercyclical loan-to-value rule could be designed, non-linear interventions are not only more realistic, but also perform better. Although the loan-to-value ratios are decreased by the same amount at impact, house prices increase to a lesser extend, since all agents know that in the next period, the loan-to-value ratio will not be raised above the equilibrium value of 70 percent. While the countercyclical rule implies additional disturbances and leads to an increase in volatility in the medium-term (compared to the threshold rule), the non-linear rule converges to the baseline scenario soon after the house price inflation cooled down.

In Figure 3 we show the dynamics of the price levels and losses in terms of volatility for different variables of interest. For the derivation of losses, we summed up the absolute values of the deviations from equilibrium (future values are discounted with the discount factor of the patient households: \( \sum_{t=0}^{T} \beta_t |\hat{x}_t| \)).\(^{14}\) Due to the fixed exchange rate regime, price levels have to return to their pre-shock equilibrium value.\(^{15}\) Analysing the price level dynamics, confirms our previous results: the threshold rule, combines both other scenarios and leads to the lowest increase in prices, and the smoothest return to equilibrium. Moreover, losses are the lowest for the threshold rule for all variables except output (here losses after 17 quarters are slightly lower for the time-varying LTV policy). However, the most astonishing result is that the volatility of all inflation rates is higher for a time-varying policy than in the baseline. The countercyclical variations increase the volatility by increasing the LTV ratio, when property prices fall.

Altogether our simulation exercise clearly supports the usage of threshold based LTV policies, although their direct impact on property price inflation is limited. However, they dampen the effects of the increase in property prices on real variables and consumer prices to a non-negligible extend by reducing private debt. Moreover, the concerns that these policies could do more harm than good, if they act automatically and in a countercyclical way, are eliminated, once we simulate the model using a more realistic non-linear rule, which only reacts on extreme events. The subsequent section evaluates different threshold policies according to their implied

\(^{14}\)Recall, that the equilibrium interest rate is given by \( R = \beta_s^{-1} \).

\(^{15}\)This is a standard result in small open economy models with an exchange rate peg (see for example Galí and Monacelli (2005)). To transmit this result into reality, we would have to add a trend inflation rate.
5. Evaluation of Different LTV Thresholds

Having shown how LTV policies work in general, this section analyses different threshold levels for different calibrations of the model. Table 1 and 2 provide loss measures in terms of volatility, by summing up the deviations from equilibrium for the most interesting variables. As in Figure 3, we sum up absolute values and discount future deviations with the patient household’s discount factor: $\sum_{t=0}^{\infty} \beta_t |\hat{x}_t|$.

The tables also illustrate the results for different threshold levels (3,4,5). To compare the outcomes of the threshold rules with a time-varying policy, we changed the reaction parameter of the Taylor-type rule so that the impact reductions of the LTV ratio are equal for both policy types. The first column under each variable refers to the standard scenario without LTV policy, the second column refers to the time-varying Taylor type policy, and the third column refers to the threshold rule. In addition to our baseline calibration, we also evaluate three scenarios taken from the estimations of Funke and Paetz (2011): the baseline estimation with a fairly low share of borrowers (0.09), the estimation with a fixed high share of borrowers (0.35), and the estimation with uniformly distributed prior for $\gamma$ and $\omega$ (the estimated share volatility.
Table 1: Volatility of Different Scenarios for an Increase in Annualised Inflation at Impact $\approx 24\%$.

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Notes: Summed up absolute values of the deviations from equilibrium, discounted with the patient household’s discount factor: $\sum_{t=0}^{\infty} \beta_t |\hat{x}_t|$, where $\hat{x}_t$ represents the deviations of $x_t$ from equilibrium.

(1) refers to the standard scenario without LTV policy; (2) refers to the time-varying policy scenario, and (3) refers to the threshold rule.
Table 2: Volatility of Different Scenarios for an Increase in Annualised Inflation at Impact ≈ 33%

### Baseline

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### Funke/Paetz(2011), Baseline Estimation

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### Funke/Paetz(2011), High Share of Borrowers (\( \omega = 0.35 \))

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### Funke/Paetz(2011), \( \omega \) and \( \gamma \) Uniformly Distributed

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<td>3.60 3.38 3.95</td>
<td>2.29 2.22 2.73</td>
<td>52.73 56.08 50.67</td>
<td>10.57 302.64 181.36</td>
<td>6.10 11.00</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>15.26 15.30 14.35</td>
<td>0.62 0.92 0.70</td>
<td>2.09 2.31 1.98</td>
<td>3.60 3.44 3.87</td>
<td>2.29 2.21 2.63</td>
<td>52.73 54.94 50.97</td>
<td>10.57 221.63 140.69</td>
<td>4.50 11.00</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>15.26 15.29 14.62</td>
<td>0.62 0.80 0.65</td>
<td>2.09 2.24 2.01</td>
<td>3.60 3.49 3.79</td>
<td>2.29 2.21 2.52</td>
<td>52.73 53.98 51.30</td>
<td>10.57 151.11 95.93</td>
<td>3.10 11.00</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** Summed up absolute values of the deviations from equilibrium, discounted with the patient household’s discount factor: \( \sum_{t=0}^{\infty} \beta^t |\hat{x}_t| \), where \( \hat{x}_t \) represents the deviations of \( x_t \) from equilibrium. (1) refers to the standard scenario without LTV policy, (2) refers to the time-varying policy scenario, and (3) refers to the threshold rule.
of borrowers here is 24 percent). For table 1 we assumed a shock size, implying an impact increase in annualised inflation of 24 percent. When adjusting the reaction parameter for the additional scenarios, we calibrated \( \phi_{ltv} \) and \( \phi'_{ltv} \) to match the impact reduction in the LTV ratio of the corresponding baseline scenario. Finally, in Table 2 we strengthens the shock to increase inflation at impact to 33 percent in annual terms. Then, we repeated the whole procedure from Table 1, starting with a baseline calibration for the Taylor type rule of \( \phi_{ltv} = 4.5 \) and a threshold value of 4.

Both tables confirm our results from Figure 3 for all scenarios: While the Taylor type rule increases the volatility of the property price inflation (and most other variables), the threshold rule decreases the volatility of most variables. Moreover, LTV variations are transmitted via the private debt channel, and the volatility of household’s debt increases strongly, when the LTV ratio is used as a policy tool. However, by comparing the debt volatility of both policy types, we see that under the threshold rule the debt volatility is much lower. Moreover, this increase is primarily due to a strong fall at impact, when the LTV ratio is lowered for one period and the borrowing constraint tightens. The overall conclusion of the modelling exercise is that a limited response of monetary policy to house prices can be an effective tool to tame property price booms and contain the associated risks.\(^{16}\)

6 Conclusions

The global financial crisis of 2008-2009 drew attention to the important issue of combating escalating house prices and the need for more pro-active policies to avert future crises. Can anything be done to avert such crises in the future? This topic is now an active area of macroeconomic research. In our paper we offer a quantitative evaluation and deeper understanding whether and to what extent LTV policies can help to dampen house price bubbles. A key strength of the threshold model presented above is that it facilitates a more nuanced view of “what LTV policies do”. In other words, our claim - or at least our hope - is that the threshold policy approach is a productive conceptual tool for confronting key empirical facts.

The choice of Hong Kong owes to its long experience with LTV rules, the absence of an independent monetary policy under the currency board system and to the comparatively strong link between the housing market and macroeconomic business cycles there. The examination of nonlinear LTV policies through the lens of a DSGE model indicates that preventive LTV policies have a good chance to contain the risk of boom-bust cycles. Furthermore, the narrow design and focus reduces negative side effects and costs.

\(^{16}\)A caveat is in order while discussing our calibration results. In housing markets expectations may lead to the settling in of rational and self-fulfilling price bubbles. Such bubble solutions, however, are rules out in the model. Our conclusions are subject to this restriction. In other words, we need to avoid any overconfidence that the LTV tools are the resolution of all issues. At best, they can relieve some of the pressure on traditional macroeconomic tools.
In this paper we have exclusively analysed preemptive LTV policies. An alternative toolkit has been suggested by Jeanne and Korinek (2010). They show that the existence of collateralised borrowing gives rise to an externality and a free-market equilibrium which is too much volatile. When credit is collateralised, the interaction between debt accumulation and asset prices contributes to magnify the impact of booms and busts, i.e. borrowing and asset prices feed each other during booms and busts. Therefore regulation is desirable and a counter-cyclical tax on debt can make everybody in the economy better off.\textsuperscript{17}

**Appendix**

**Impulse-Responses Under the Threshold Rule** For the simulation of the model with a non-linear rule we use the algorithm proposed by Holden (2011), which allows to handle one non-negativity constraint in DYNARE. In order to use this methodology, we have to transform equation (21) into a non-negativity constraint. We do so by introducing one auxiliary variable:

\[
ltv^a_t = \bar{x} - \hat{x}_t \geq 0.
\]  

The LTV policy is now redefined in terms of this auxiliary variable:

\[
\tilde{ltv}_t = -\phi'_{ltv}(ltv^a_t + \hat{x}_t - \bar{x}).
\]  

So if \(\bar{x} - \hat{x}_t > 0\), the target variable is below the threshold, \(ltv^a_t = \bar{x} - \hat{x}_t\), and the central bank does not intervene on the housing market (\(\tilde{ltv}_t = 0\)). However, if \(\bar{x} - \hat{x}_t \leq 0\) the auxiliary variable becomes zero, and \(\tilde{ltv}_t = -\phi'_{ltv}(\hat{x}_t - \bar{x})\). Details on the implementation of the algorithm in DYNARE can be found in the appendix of Holden (2011).

**References**


\textsuperscript{17}Political economy considerations may, however, limit the counter-cyclical use of tax tools.


