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

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Abstract

In the wake of the 2008-2009 global financial crisis, the macroeconomic discussion has returned to the topic of proactive macroprudential policies. One proactive approach, the use of loan-to-value (LTV) policies to curb booming property markets, has long been used by Hong Kong's monetary authorities to actively manage and mitigate the potential fallout from housing price bubbles. Here, we analyse the merits of this countercyclical macroprudential policy in a New Keynesian DSGE model. We conclude that nonlinear LTV policy rules implemented in reaction to episodes of high property price inflation can limit transmission of housing price cycle effects to the real economy.

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1 Introduction

Prior to the 2008–2009 global financial crisis, many central banks saw their top policy priority as keeping inflation low and stable. To anchor inflation expectations, they would set an explicit or implicit inflation target and talk up efforts to hit that target. This approach, however, put considerable weight on central banks to demonstrate transparency and predictability in short-term interest rate decisions, and typically involved following a conventional or augmented Taylor rule. Post-crisis, central banks have shifted their emphasis to promoting financial stability and making macroprudential supervision effective. Formulation of monetary policy now starts with consideration of asset prices.[1]

The recent failure of central banks in advanced economies to take adequate action to deal with soaring asset prices is hard to comprehend in retrospect. Some of this may be attributed to the doctrine of *benign neglect*, whereby the central bank "waits on the sidelines" on the assumption that intervention costs could potentially exceed the negative side effects of pre-emptive policies [Bernanke and Gertler (2001)]. This doctrine is not just a reflection of the fact that central bankers tend to shy away from second-guessing markets, but has evolved out of a recognition that conducting aggressive monetary policy to temper boom-bust cycles will very likely collide with political and social agendas. The monetary authority even risks damaging its own credibility by moving pre-emptively to prick an asset bubble when it is the sole agency claiming asset price increases are unjustified by the fundamentals. Moreover, aggressive action to deal with asset prices goes beyond taking a view of whether a particular asset price increase is dangerous; the central bank must determine the threshold level at which it officially becomes uncomfortable about asset price levels (a non-trivial task given that emerging unsustainable bubbles are hard to spot).[2]

Nevertheless, economists have long understood that recessions accompanied with a real estate bust tend to be deeper and last longer than recessions not involving a real estate bust. Cumulative losses in a recession with a real estate bust can be up to three times greater than in a recession without a real estate collapse [Reinhart and Rogoff (2009)]. Moreover, economists generally treat the financial system as procyclical, implying a wide awareness that a boom in the real economy boosts borrower creditworthiness and increases the value of bank assets.

In any case, the current consensus is that macroprudential (capital requirements) policies should be designed to increase the stability and resilience of the financial system as a whole, not just individual institutions or markets. This includes effecting policies to stave off loan-driven bubbles, or at least limit damage from asset price

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

[2] While the argument that bubbles are hard to spot at an early stage with sufficient certainty is convincing, Phillips et al. (2011, 2012) have recently provided recursive regression methodologies for identifying bubble behaviour and consistent dating of bubble origination and collapse in real time.

busts.[3] There is even discussion of the pro-active view that the monetary authority needs to "lean against the wind" when there is a build-up of financial imbalances caused by over-optimistic expectations of rising prices.

Mandatory maximum loan-to-value (LTV) ratios are a familiar stabilisation tool that has been used to break such self-reinforcing spirals in their early phase.[4] Like other pro-active approaches, the use of time-varying LTV ratios has been challenged on the basis that they can increase costs of intermediation during a boom by reducing desirable economic expansion and carry the risk of output losses much larger than those that might arise from a possible bubble collapse when monetary policy set in response to asset price movements fails.

To explore whether the use of time-varying LTV ratios are actually too blunt a monetary tool for use in targeting asset prices, we look at the natural experiment of Hong Kong. The Hong Kong Monetary Authority (HKMA) uses a currency board system, an arrangement that acknowledges the central bank's limited set of tools for pursuing monetary policy. This is ideal for our purposes as the impacts of adjustments in LTV ratios can be clearly identified. Under its currency board, HKMA exchanges the base currency on demand, thereby creating effective bounds on interbank market interest rate fluctuations similar to 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. As a result, Hong Kong's interbank market interest rates fluctuate within the band of the transaction costs of engaging in the foreign interbank market.

Through examination of Hong Kong's LTV policies, we extend the current literature in several ways. First, the application of an open-economy DSGE modelling framework allows us to analyse the effects of LTV policies under a currency board regime. Second, we discuss calibration of LTV policies with an assumption that the central bank reacts only after housing price inflation exceeds a set threshold. This policy rule allows the central bank to pursue a middle-of-the-road approach that is less aggressive than the above-mentioned "lean against the wind" approach, but more active than the "wait and clean up afterwards" result engendered by benign neglect.

The rest of the paper is structured as follows. In Section 2, we lay out our model based on the work of Funke and Paetz (2011). Section 3 illustrates historical

[3] 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). Almeida et al. (2006) have shown that cross-country differences in LTV (loan-to-value) limits may explain the cross-country sensitivity of housing prices to income shocks.

[4] An LTV limit will tend to affect financially constrained consumers, particularly younger households. Estimates for the OECD indicate that a 10% increase in the maximum LTV ratio is associated with a 12% rise in home ownership of younger households. The effect for older households is much smaller [see Andrews et al. (2011)].

LTV policy in Hong Kong. Section 4 calibrates the model and clarifies the workings of macroprudential policies by analysing impulse-response functions. Section 5 evaluates different policies in terms of their inflation-output trade-off. Section 6 concludes.

2 The Conceptual DSGE Framework

In this section, we sketch out our baseline DSGE framework. This 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) and Monacelli (2009).[5] The seminal work in this area, of course, is that of Kiyotaki and Moore (1997), who were the first to distinguish between "patient" and "impatient" households. Credit market friction is introduced by a binding collateral constraint on borrowers, and monetary policy is described by an exchange-rate peg. The assumed borrowing constraint is a key feature as it leads to an amplification of housing market developments and spillovers into the rest of the economy. 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.

Households are divided into ω borrowers and $(1-\omega)$ savers, denoted as b and s, respectively. Impatient households differ from patient households in that they discount the future at a faster rate. In equilibrium, therefore, patient households are net lenders and impatient households are net borrowers. To prevent borrowing without limit, we assume that borrowers face credit constraints tied to the value of the collateral. The two sectors of the economy, residential and non-residential goods, are denoted by the subscripts C and D, respectively. We also assume competitive intermediate good producing firms, monopolistically competitive final good producers, a currency board exchange rate regime and a monetary authority conducting regulatory control over the LTV ratio. In the following, small-case letters are used for a logarithmic representation and hats ($\widehat{\ }$) denote percentage deviations of a variable from equilibrium.

2.1 Households

Infinitely-lived households share several common features. Both get utility from consumption and leisure, and both offer labour in a competitive labour market.

[5] Readers familiar with open-economy DSGE models with a housing sector in the spirit of Iacoviello (2005) and Monacelli (2009) can go directly to the discussion of parameter assignment and calibration.

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

$$E_0 \sum_{t=0}^{\infty} \beta_b^t \left[\frac{1}{1-\sigma} \left(X_t^b \right)^{1-\sigma} - \frac{1}{1+\varphi} (N_{C,t}^b)^{1+\varphi} - \frac{1}{1+\varphi} (N_{D,t}^b)^{1+\varphi} \right], \tag{1}$$

where E_0 is the conditional expectation operator evaluated at time 0, X_t^b represents the welfare-relevant consumption index and $N_{j,t}^b$ represents the labour supply in sector j. Moreover, φ and σ are the corresponding intertemporal elasticities of substitution with respect to labour and consumption, respectively. β_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,

$$X_t^b \equiv \left(\tilde{C}_t^b \right)^{\left(1-\gamma \mathcal{E}_t^{D,b}\right)} \left(D_t^b \right)^{\gamma \mathcal{E}_t^{D,b}}, \tag{2}$$

where $\tilde{C}_t^b \equiv C_t^b - h_c C_{t-1}^b$, C_t^b and D_t^b represent composite indices of non-durable and durable consumption services, respectively, h_C represents habit formation in consumption, γ is the share of housing in consumption and $\mathcal{E}_t^{D,b} \equiv \exp\left(\epsilon_t^{d,b}\right)$ is a household-specific housing preference shock that affects the marginal rate of substitution 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 expressed as

$$C_t^b + P_{D/C,t} I_{D,t}^b - B_{H,t}^b = -R_{t-1} \frac{B_{H,t-1}^b}{\Pi_{C,t}} + \sum_{j=C,D} \frac{W_{j,t}^b N_{j,t}^b}{P_{C,t}}, \tag{3}$$

where $\Pi_{C,t+1} \equiv \frac{P_{C,t+1}}{P_{C,t}}$ is the CPI based inflation rate, $B_{H,t}^b$ 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 $t-1$), $W_{j,t}^b$ the sector-specific wage rate, $I_{D,t}^b \equiv D_t^b - (1-\delta) D_{t-1}^b$ defines housing investments, $P_{D/C,t} \equiv \frac{P_{D,t}}{P_{C,t}}$ are relative house prices, and δ represents the depreciation rate of the residential stock.

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

$$R_t B_{H,t}^b \leq (1-\delta) E_t \left[P_{D/C,t+1} D_t^b \Pi_{C,t+1} \right] LTV_t, \tag{4}$$

where LTV_t represents the LTV ratio set by the monetary authority.[6] Moreover, δ 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

[6] HKMA is the sole prudential overseer of banks and mortgage products in Hong Kong. It is solely responsible for the formulation and enforcement of LTV limits.

of durable stocks (adjusted for depreciation and the LTV ratio). According to (4), the fraction of residential goods that can be used as collateral decreases when the LTV ratio is lowered. This forces borrowers to reduce their debt.[7] In this respect, household debt in this model can be thought of as mortgage-secured credit.

The resulting first-order conditions for the borrowers are:

$$\frac{W_{j,t}^b}{P_{C,t}} = \frac{\left(X_t^b\right)^{\sigma}\left(N_{j,t}^b\right)^{\varphi}\left(\tilde{C}_t^b\right)^{\gamma\mathcal{E}_t^{D,b}}}{\left(1-\gamma\mathcal{E}_t^{D,b}\right)\left(D_t^b\right)^{\gamma\mathcal{E}_t^{D,b}}}, j=C,D, \tag{5}$$

$$\begin{aligned} P_{D/C,t} &= \left(\frac{\gamma\mathcal{E}_t^{D,b}}{1-\gamma\mathcal{E}_t^{D,b}}\right)\frac{\tilde{C}_t^b}{D_t^b} + (1-\delta)\,\psi_t P_{D/C,t} E_t\left[\Pi_{D,t+1}\right] LTV_t \\ &\quad +\beta_b(1-\delta)E_t\left[\begin{array}{c}\left(\frac{1-\gamma\mathcal{E}_{t+1}^{D}}{1-\gamma\mathcal{E}_t^{D,b}}\right)\left(\frac{X_{t+1}^b}{X_t^b}\right)^{-\sigma} \\ \times\left(\frac{D_{t+1}^b}{\tilde{C}_{t+1}^b}\right)^{\gamma\mathcal{E}_{t+1}^{D,b}}\left(\frac{\tilde{C}_t^b}{D_t^b}\right)^{\gamma\mathcal{E}_t^{D,b}} P_{D/C,t+1}\end{array}\right] \end{aligned} \tag{6}$$

$$R_t\psi_t = 1-\beta_b E_t\left[\begin{array}{c}\left(\frac{1-\gamma\mathcal{E}_{t+1}^{D}}{1-\gamma\mathcal{E}_t^{D,b}}\right)\left(\frac{X_{t+1}^b}{X_t^b}\right)^{-\sigma}\left(\frac{D_{t+1}^b}{\tilde{C}_{t+1}^b}\right)^{\gamma\mathcal{E}_{t+1}^{D,b}} \\ \times\left(\frac{\tilde{C}_t^b}{D_t^b}\right)^{\gamma\mathcal{E}_t^{D,b}}\frac{R_t}{\Pi_{C,t+1}}\end{array}\right], \tag{7}$$

where $\lambda_t\psi_t$ represent the Lagrangian multiplier on the borrowing constraint, and ψ_t can be interpreted as the marginal value of borrowing. Equation (5) is the condition for the supply of labour. The first-order condition (6) equates the marginal utility of non-durable consumption to the shadow price of housing goods. Finally, (7) represents an Euler equation adjusted to capture the borrowing constraint.

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

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

subject to

$$C_t^s + P_{D/C,t}I_{D,t}^s - B_{H,t}^s - \mathfrak{E}_t B_{F,t}^s = -R_{t-1}\frac{B_{H,t-1}^s}{\Pi_{C,t}} - \frac{R_{t-1}^*\mathfrak{E}_t B_{F,t-1}^s}{\Pi_{C,t}} + \sum_{j=C,D}\frac{W_{j,t}^s N_{j,t}^s}{P_{C,t}},$$

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

[7] There is a fine, but important, distinction as to whether LTV ratios move endogenously in response to shocks or whether regulators impose their terms and conditions to curb real estate bubbles.

The resulting first-order conditions for the savers are:

$$\frac{W_{j,t}^{s}}{P_{C,t}} = \frac{(X_t^s)^{\sigma}\left(N_{j,t}^{s}\right)^{\varphi}\left(\tilde{C}_t^s\right)^{\gamma\mathcal{E}_t^D}}{\left(1-\gamma\mathcal{E}_t^{D,s}\right)(D_t^s)^{\gamma\mathcal{E}_t^{D,s}}}, j = C, D, \tag{8}$$

$$P_{D/C,t} = \left(\frac{\gamma\mathcal{E}_t^{D,s}}{1-\gamma\mathcal{E}_t^{D,s}}\right)\frac{\tilde{C}_t^s}{D_t^s} + \beta_s(1-\delta)E_t\left[\begin{array}{c}\left(\frac{1-\gamma\mathcal{E}_{t+1}^{D,s}}{1-\gamma\mathcal{E}_t^{D,s}}\right)\left(\frac{X_{t+1}^s}{X_t^s}\right)^{-\sigma}\\ \times\left(\frac{D_{t+1}^s}{\tilde{C}_{t+1}^s}\right)^{\gamma\mathcal{E}_{t+1}^{D,s}}\left(\frac{\tilde{C}_t^s}{D_t^s}\right)^{\gamma\mathcal{E}_t^{D,s}} P_{D/C,t+1}\end{array}\right], \tag{9}$$

$$1 = \beta_s E_t\left[\begin{array}{c}\left(\frac{1-\gamma\mathcal{E}_{t+1}^{D,s}}{1-\gamma\mathcal{E}_t^{D,s}}\right)\left(\frac{X_{t+1}^s}{X_t^s}\right)^{-\sigma}\\ \times\left(\frac{D_{t+1}^s}{\tilde{C}_{t+1}^s}\right)^{\gamma\mathcal{E}_{t+1}^{D,s}}\left(\frac{\tilde{C}_t^s}{D_t^s}\right)^{\gamma\mathcal{E}_t^{D,s}}\frac{R_t}{\Pi_{C,t+1}}\end{array}\right], \tag{10}$$

$$1 = \beta_s E_t\left[\begin{array}{c}\left(\frac{1-\gamma\mathcal{E}_{t+1}^{D,s}}{1-\gamma\mathcal{E}_t^{D,s}}\right)\left(\frac{X_{t+1}^s}{X_t^s}\right)^{-\sigma}\left(\frac{D_{t+1}^s}{\tilde{C}_{t+1}^s}\right)^{\gamma\mathcal{E}_{t+1}^{D,s}}\\ \times\left(\frac{\tilde{C}_t^s}{D_t^s}\right)^{\gamma\mathcal{E}_t^{D,s}}\frac{\mathfrak{E}_{t+1}}{\mathfrak{E}_t}\frac{R_t^*}{\Pi_{C,t+1}}\end{array}\right]. \tag{11}$$

The first-order conditions for saving households are similar to those of borrowing households except there is one for intertemporal saving decision rather than borrowing.

Intratemporal optimisation Concerning the international dimension, the model follows the literature on New Open Macroeconomics, beginning with Galí and Monacelli (2005). When foreign investors are allowed to buy domestic houses and domestic investors can purchase housing abroad, both consumption indices are given by a weighted average of domestic and foreign consumption:[8]

$$C_t \equiv \left[(1-\alpha_C)^{\frac{1}{\eta_C}} C_{H,t}(j)^{\frac{\eta_C-1}{\eta_C}} + \alpha_C^{\frac{1}{\eta_C}} C_{F,t}(j)^{\frac{\eta_C-1}{\eta_C}}\right]^{\frac{\eta_C}{\eta_C-1}}, \tag{12}$$

$$D_t \equiv \left[(1-\alpha_D)^{\frac{1}{\eta_D}} D_{H,t}(j)^{\frac{\eta_D-1}{\eta_D}} + \alpha_D^{\frac{1}{\eta_D}} D_{F,t}(j)^{\frac{\eta_D-1}{\eta_D}}\right]^{\frac{\eta_D}{\eta_D-1}}. \tag{13}$$

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 $\widehat{s}_{C,t}$ and $\widehat{s}_{D,t}$, respectively)

[8] In recent years, strong demand from mainland Chinese was an important factor boosting property prices in Hong Kong. In response, the HKMA in June 2011 curbed the LTV ratio for borrowers whose principal income is earned in Hong Kong Kong. The move was designed to put funding pressure on buyers from mainland China.

are connected through the exchange-rate channel, i.e.

$$(1-\alpha_C)\widehat{s}_{C,t} - (1-\alpha_D)\widehat{s}_{D,t} = \widehat{p}_{D/C,t} - \widehat{p}^{*}_{D/C,t}. \tag{14}$$

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:

$$\left(\frac{X_t^s}{X_t^{s,*}}\right)^{-\sigma}\left(\frac{\tilde{C}_t^{s\mathcal{E}_t^{D,s}}}{\tilde{C}_t^{s,*\mathcal{E}_t^{D,*}}}\right)^{\gamma}\left(\frac{D_t^{s\mathcal{E}_t^{D,s}}}{D_t^{s,*\mathcal{E}_t^{D,*}}}\right)^{\gamma} = \mathcal{R}_t \tag{15}$$

where $\mathcal{R}_t$ is the consumer price based real effective exchange rate and $\mathcal{E}_t^{D,*}$ represents the foreign counterpart to domestic preference shocks.

2.2 Firms

A DSGE model requires a few assumptions to be tractable. Here, we assume retailers produce final goods in sector j are produced by combining domestic intermediate goods using a CES production function. Further, the wholesale sector produces intermediate goods using a Cobb-Douglas production function, $Y_{j,t}(k) = N_{j,t}(k)$. Third, price adjustment of the monopolistically competitive firms is assumed to follow a variant of Calvo pricing. Specifically, a randomly selected fraction of firms in each sector $(1-\theta_j)$ adjusts prices, while the remaining fraction of firms θ_j does not adjust. In addition, a fraction of $(1-\tau_j)$ firms behaves in a forward-looking way, while the remaining fraction τ_j uses the recent history of the aggregate price index to set prices. Thus, τ_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 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 $\left(\widehat{\mu}_t^j\right)$ such that

$$\bar{p}^{n}_{j,H,t} = \widehat{\mu}_t^j + (1-\beta\theta)\sum_{k=0}^{\infty}(\beta_s\theta_j)^k E_t\left(mc_{j,t+k} + p_{j,H,t}\right). \tag{16}$$

2.3 Equilibrium

Aggregate goods-market-clearing for each good k in each sector j requires

$$Y_{C,t}(k) = C_{H,t}(k) + \int_0^1 C_{H,t}^i(k)\,di \tag{17}$$

$$Y_{D,t}(k) = I_t^D(k) + \int_0^1 I_{D,t}^i(k)\,di, \tag{18}$$

where $I_{D,t}^i$ 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 fulfil $P_{H,t}Y_t = P_{C,H,t}Y_{C,t} + P_{D,H,t}Y_{D,t}$. Moreover, the price index for aggregated output is a weighted average of domestic prices for non-residential consumption and housing $P_{H,t} \equiv P_{C,H,t}^{1-\xi\varepsilon_t^D\varepsilon_t^{D,*}} P_{D,H,t}^{\xi\varepsilon_t^D\varepsilon_t^{D,*}}$, where ξ represents the share of the housing sector in aggregate production, which we allow to be affected by domestic and foreign preference shocks. When the solution is log-linearised around its steady-state, the equation for real output is obtained:

$$\widehat{y}_t \quad = \quad \frac{P_{D/C}^{-\xi}C}{Y}\widehat{y}_{C,t} + \frac{\delta P_{D/C}^{1-\xi}D}{Y}\widehat{y}_{D,t} + \Xi\widehat{p}_{D/C,H,t} - \xi \ln P_{D/C}\left(\varepsilon_t^D + \varepsilon_t^{D,*}\right), \tag{19}$$

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

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 $\widehat{e}_t = 0$. Consequently, monetary policy is conducted to ensure $\Delta\widehat{s}_{C,t} = \widehat{\pi}_{C,F,t} - \widehat{\pi}_{C,H,t}$, which implies $\Delta\widehat{s}_{D,t} = \widehat{\pi}_{D,F,t} - \widehat{\pi}_{D,H,t}$ via (15). Essentially, the HKMA promises to raise or lower the interest rate by any amount necessary to prevent the exchange rate from deviating from the peg.

2.5 LTV Policy

We assume that the macroprudential policy conducted by the HKMA takes the form of LTV limits in mortgage contracts, i.e. the HKMA adjusts the LTV ratio in response to indicators of financial stability. Much recent research is devoted to the analysis of linear Taylor-type rules for LTV ratio limits, e.g.

$$\widehat{ltv}_t = -\phi_{ltv}\widehat{x}_t, \tag{20}$$

where x_t can be any variable to which the LTV ratio should react such as levels or growth rates of GDP, credits, the credit-to-GDP ratio or (relative) house prices, and ϕ_{ltv} determines the strength of the intervention. Concerning the notation, all real variables with a hat represent percentage deviations from equilibrium, while the net interest rate, the inflation rate and the LTV-ratio are measured in absolute deviations.[9]

While mechanical rules like (20) are nice for illustration purposes, they are unrealistic. Notwithstanding the above general consideration, the issue remains open

[9] We decided to use this convention because a Taylor-type LTV rule can be interpreted like a conventional Taylor-type interest rate rule.

as to how a workable implementation of a time-varying LTV policy should be designed. Expectations should be realistic when macroprudential policies are invoked, even though it is sometimes very difficult to discern in real time whether an asset price boom is driven by benign or malign influences. Even the most comprehensive early warning indicators of financial vulnerability may be noisy, send wrong signals or carry an inherent risk of policy error. Put differently, the challenge of distinguishing whether a housing price boom is "good" or "bad" in its midst encourages the policymaker to refrain from intervening.[10] Even if a central bank favours early intervention, it is reasonable to assume it will move, if at all, only after house price inflation exceeds a defined threshold. Notably, high inflation rates in the housing sector will provoke central bank action over fears of a massive downturn after the bubble bursts, yet the central bank is likely to remain complacent if it feels inflation in the housing market is too low.

To reflect these concerns, we assume a non-linear LTV policy, described by

$$\widehat{ltv}_t = -\phi'_{ltv} \sum_{i=0}^{T} \left(\widehat{x}_{t-i} - \bar{x}\right)^+ , \tag{21}$$

where $\bar{x}$ represents the threshold value, and ϕ'_{ltv} determines the strength of the reaction, and T represents the number of periods, the LTV ratio is decreased.[11] According to (21), the LTV ratio is lowered for T periods, 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 a nonlinear fashion. In the next sections we interpret LTV policies through the lens of this model.

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 has become less sensitive to property prices. Recently, Wong et al. (2011) have assessed the effectiveness and drawbacks of LTV limits in Hong Kong. Their econometric analysis show that

[10] It must be pointed out that LTV limits are assumed to be valid. Procyclical LTV ratios may be circumvented by households that borrow from foreign banks or nonbank intermediaries.

[11] In practice, a conservative choice of the threshold helps avoid a misclassification of "good" real estate booms caused by fundamentals as an unsustainable "bad" real estate booms financed through credit.

household leverage is the main channel through which LTV policies limit house price appreciation.

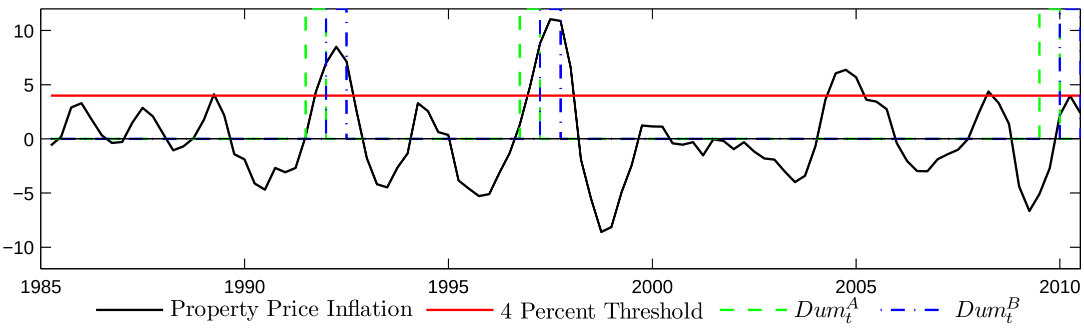
LTV policies to curb hot periods in the property market have a relatively long history in Hong Kong. The regulatory measures in Hong Kong from 1990–2010 can be broadly divided into four phases. (i) Prior to the sharp rise in residential property prices in 1996, a 70% limit was introduced as a prudential measure to guard against overexposure to the property market. (ii) In light of the Asian financial crisis, the HKMA issued guidelines to adopt a 60% maximum LTV ratio for "luxury" properties. (iii) In October 2001, the HKMA restored the 70% maximum LTV ratio. (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% to 50%. The maximum LTV ratio for residential properties with a value between HKD 8 million and HKD 12 million was reduced from 70% to 60%. At the same time, the maximum LTV ratio remained at 70% for residential properties at the lower end of the market. Finally, regardless of market value, the maximum LTV ratio for all non-owner-occupied residential properties was reduced to 50%.

In our baseline calibration scenario below, we assume LTV ratios are lowered when quarterly property price inflation exceeds 4%. 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_t^A and DUM_t^B indicating periods of tightened LTV caps from Wong et al. (2011) during 1985–2010.[12] In addition, Figure 1 illustrates a policy threshold of 4% (horizontal red line). The graph suggest 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 policies very well. Conflicting signals are only apparent in the late 1980s, 2004 and 2008.[13]

[12]Since the end of our estimation period for the DSGE model, the HKMA has again tightened residential LTV ratios. The HKMA lowered curbed LTV ratios generally in November 2010. It further lowered in June 2011 the LTV ratio for residential mortgages of HKD 10 million or more to 50%, while the LTV ratio for transactions between HKD 7 million and HKD 10 million were lowered to 60%. The LTV ratio for transactions of less than HKD 7 million were left at 70%. These decisions suggest that the HKMA is increasingly worried about the risks banks are taking in lending as the real estate market has essentially returned to its 1997 peak level and the current real estate boom is entirely driven by easy credit, i.e. unsustainable.

[13]In principle, it would be desirable to estimate the threshold parameter using the threshold estimation technique in Hansen (2000) and the time series in Wong et al. (2011). Unfortunately, the estimator is not valid in the limited dependent variable framework. Another crucial assumption in the approach is that the threshold variable is exogenous. These assumptions severely limits the usefulness of threshold regression models for our purposes here.

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



Note: 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_t^A (DUM_t^B) 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 Model Calibration and Evaluation of Different Threshold Policies

This section describes the workings of the model by running a simulation for a plausible calibration and an LTV policy that 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.

Parameters are specified based on a quarterly model. Consequently, we set the depreciation rate of durables to a value of 0.01 as in Funke and Paetz (2011) and Pariés and Notarpietro (2008), and the discount factors of borrowers and savers to standard values of 0.96 and 0.99, respectively. The mark-ups in both sectors are set to 10%, and the share of the durables sector in aggregate production is set to 10%, which is in line with the share of the real estate sector in Hong Kong's GDP in 1996. The intratemporal substitution elasticities between domestic and foreign goods in both sectors are set to standard values of 2, and finally, the equilibrium LTV ratio is fixed at 70%.

For the calibration of all other parameters, we rely on the estimations of Funke and Paetz (2011), who estimates the model for four scenarios, varying assumptions on the prior distribution of ω and γ. For our simulation purposes, we take the last scenario and assume uniformly distributed priors between zero and one for these crucial parameters. (An evaluation of other scenarios appears in the next section). The degrees of openness are set to $\alpha_C = 0.56$ and $\alpha_D = 0.5$. The share in the welfare relevant consumption index is equal to 0.44, which corresponds to a strong housing wealth effect. Funke and Paetz (2011) found values in this range for all scenarios they considered. The share of borrowers is set to a medium value of 24%.[14] On the supply side, the share of firms that do not adjust prices in each period (Calvo parameter) is set to 66% for consumption goods and 62% in the housing sector. In addition, backward-looking price setters make up 30% of the consumption goods sector and 33% of the durables sector. Consumption habits, h_c, another crucial determinant in the persistence in the model dynamics, is set to 0.2. The intertemporal substitution elasticities with respect to consumption and labour supply are set to 1.35 and 4.67, respectively.

Since we need strong deviations of house price inflation from equilibrium to illustrate our threshold rule, we focus on the type of shock identified as the main driver of house price booms, i.e. a housing preference shock of domestic savers. We assume that the shock follows an AR(1) process, $\varepsilon_t^{d,s} = \rho_{d,s}\varepsilon_{t-1}^{d,s} + \epsilon_t^{d,s}$, with a persistence parameter $\rho_{d,s} = 0.69$ [as in Funke and Paetz (2011)]. To create a strong increase in property prices, we assume that the innovation $\epsilon_t^{d,s} \overset{i.i.d.}{\sim} \mathcal{N}\left(0, \sigma_{d,s}^2\right)$, with $\sigma_{d,s} = 3.2$. This leads to an annual increase in inflation of around 25% at impact. Such strong episodes of soaring property prices have been seen twice in recent Hong Kong history. In the second half of 1991 and mid-1997, quarterly housing price inflation climbed above 10%. In several quarters, the annual increase in prices exceeded 70 %. In both episodes, the HKMA lowered the LTV ratio several times in response to the drastic rise in housing prices. In the years before 1991, the official LTV ratio was about 90%. In November 1991, a maximum of 70% was imposed. In 1994, a temporary guideline of 40% was introduced to deal with a boom in property lending. In 1997, the HKMA introduced a package of measures to reduce the housing price boom that included a 60% maximum on luxury properties.

Concerning the HKMA decreases in the LTV ratio, we assume that the central bank reacts when quarterly property price inflation surpasses a value of $\bar{x} = 4\%$, which corresponds to an annual inflation rate of roughly 17%. The LTV ratio is then decreased for one year:

$$\widehat{ltv}_t = -\phi'_{ltv} \sum_{i=0}^{4} \left(\widehat{x}_{t-i} - 4\right)^+ . \tag{22}$$

To compare the nonlinear interventions with a linear Taylor-type LTV policy as recently suggested by e.g. Angelini et al. (2011), Christensen and Meh (2011), Gelain (2011), Suh (2011) and Lambertini et al. (2011), we simulate the model for a linear loan-to-value macroprudential policy rule:

$$\widehat{ltv}_t = -\phi_{ltv}\widehat{\pi}_{D,t}. \tag{23}$$

We calibrate the reaction parameters in a way that leads to equal responses of the

[14]Estimates based on microdata for the UK and the US put the share of constrained consumers between 20% and 40%. See Benito and Mumtaz (2009) and Jappelli (1990).

LTV ratio at impact. This is the case for $\phi_{ltv} = 2.8$ and $\phi'_{ltv} = 20$.[15] This leads to a fall in the LTV ratio from 70% to 54% as response to an increase in annual property price inflation of around 25%.

For the simulation of the model with a non-linear rule, we use the algorithm proposed by Holden (2011), which allows to handle non-negativity constraints in DYNARE. To employ this methodology, we must first transform equation (21) into a non-negativity constraint. We do so by introducing one auxiliary variable:

$$ltv_t^{aux} = \bar{x} - \widehat{x}_t \geq 0. \tag{24}$$

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

$$\widehat{ltv}_t = -\phi'_{ltv} \sum_{i=0}^{T} \left(ltv_{t-i}^{aux} + \widehat{x}_{t-i} - \bar{x} \right). \tag{25}$$

When $\bar{x} - \widehat{x}_t > 0$, the target variable is below the threshold, $ltv_t^{aux} = \bar{x} - \widehat{x}_t$, and the central bank does not intervene on the housing market ($\widehat{ltv}_t = 0$). However, if $\bar{x} - \widehat{x}_t \leq 0$, the auxiliary variable becomes zero and $\widehat{ltv}_t = -\phi'_{ltv} \sum_{i=0}^{T} \left(\widehat{x}_{t-i} - \bar{x}\right)$.

To ensure the auxiliary variables are bounded, we add a sum of "shadow price" shocks to (25): $\sum_{s=0}^{T-1} \epsilon_{s,t-s}^{SP}$, where T represents the number of periods after which we believe the constraint will no longer bind. The shock terms are $\epsilon_{s,t}^{SP} \overset{i.i.d.}{\sim} \mathcal{N}(0,1)$, if $t = 0$ and zero otherwise. Consequently, when simulating the model $\epsilon_{s,t-s}^{SP} = 1$, if (and only if) $s = t$.[16] Next, we simulate the model for each shock $\epsilon_{s,\cdot}^{SP}$ and save these responses consecutively as column vectors in a matrix M. To derive the impulse responses under bounded interest rates, we then solve the following optimisation problem:

$$\alpha^* = \arg\min \left[\alpha' \left(m + v + M^* \alpha\right)\right] = \arg\min \left[\alpha' \left(m + v\right) + \frac{1}{2} \alpha' \left(M^* + M^{*\prime}\right) \alpha\right],$$

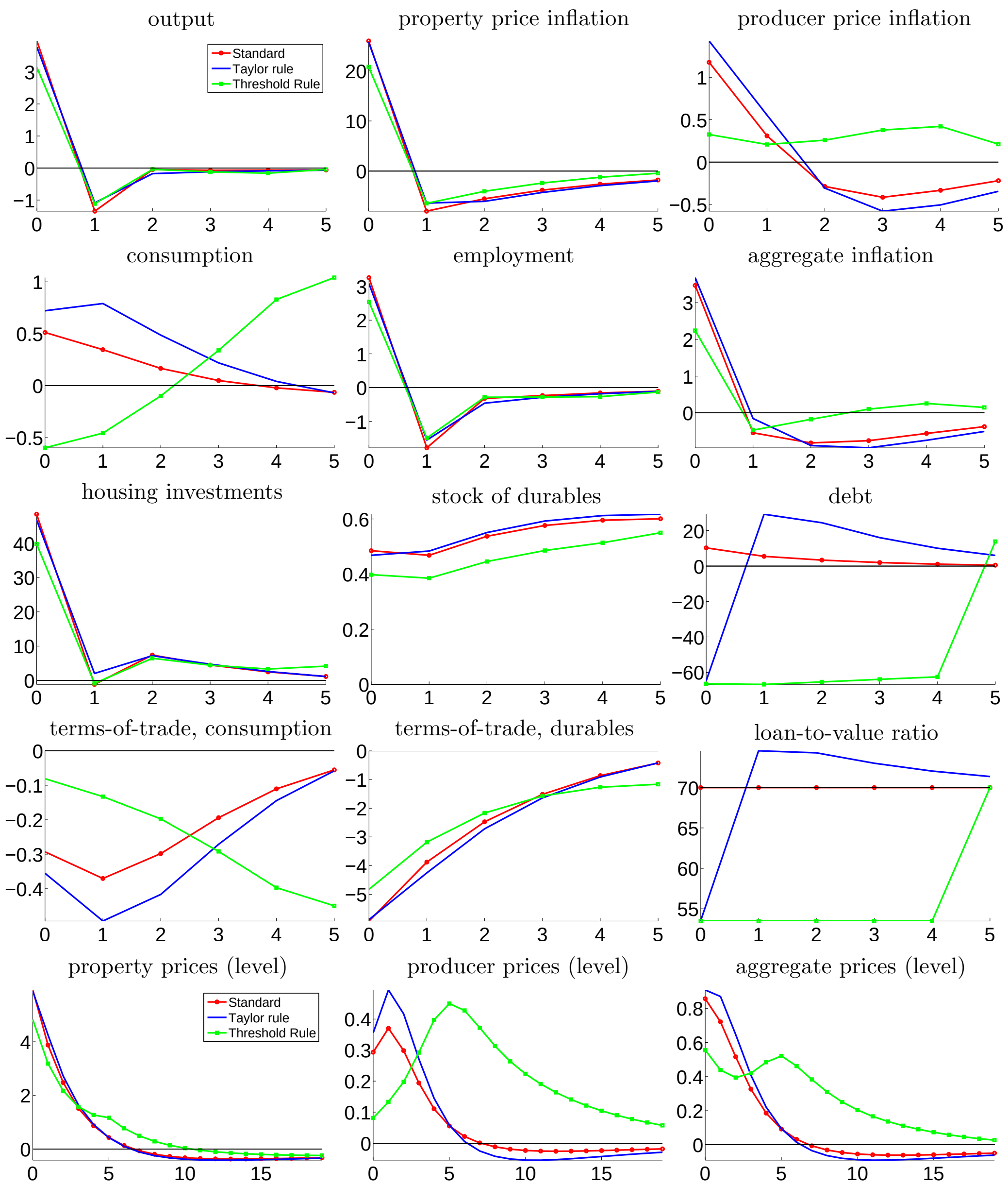
subject to $\alpha \geq 0$ and $v + M^* \alpha \geq 0$, where M^* is the upper square $T \times T$ submatrix of M, and m is the steady state of the bounded variable (which is zero in our model), and v is the vector of the unconstrained impulse response of the bounded variable. The resulting α determines the linear combination of shocks $\left(\sum_{s=0}^{t=T-1} \alpha_{s+1}^* \epsilon_{s,t-s}^{SP,j}\right)$ that are exactly the size needed to push the bounded variable back to zero whenever the bound is hit. Since $\alpha^{*\prime}\left(m + v + M^* \alpha^*\right) = 0$, either $\alpha_{s+1}^* = 0$ (implying a zero weight to $\epsilon_{s,\cdot}^{SP,j}$) or the bound is binding in period s. The impulse responses for each variable i of the model are now simply given by $v_i + M_i \alpha^*$, where v_i and M_i are the corresponding unconstrained impulse responses and the impulse responses matrix of i, respectively.

[15] Note that ϕ'_{ltv} is much higher. The policymaker reacts only to the fraction of property price inflation that lies above the threshold value.

[16] Note that each shock is known in period 0, but hits the equation in period s. Hence, these shocks are consistent with a rational expectations solution of the model.

Figure 2 illustrates the impulse responses of our simulation exercise for the standard model with no interventions (red line), the time-varying Taylor-type policy (blue line) and the threshold rule (green line), respectively.

Figure 2. Impulse Responses, Positive Saver's Housing-Preference Shock



Note: The reactions of all variables are given in percentage deviations from equilibrium, except the inflation rates (which represent annual deviations from equilibrium in percentage points), and the LTV ratio (which represents the actual ratio).

The general response to the increase in the saver's housing preference is straightforward. A positive preference shock increases the demand for housing and consumption goods. This leads to a boom in the economy, accompanied by an increase in both inflation rates. The higher value of houses relaxes the borrowing constraint and 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, leading to a fall in output and a return to equilibrium of all variables over the medium term.[17]

Three results deserve comment. First, macroprudential policies are no silver bullet. Even when the LTV ratio is decreased sharply from 70% to slightly above 55%, housing price inflation decreases only slightly no matter if we assume a time-varying or a threshold policy. Nevertheless, the reduction in property price inflation at impact equals 0.23% with a time-varying policy and 5.17% with a non-linear policy. Moreover, the LTV policy seems to have a strong impact on household debt. Thus, if reducing debt levels is the policy goal, our simulation results suggest that LTV policies are quite successful. In addition, the dynamics of household consumption expenditures differ substantially when the LTV ratio is decreased. Since the increase in inflation is dampened, the real interest rate increases, implying a dampening effect on the consumption-savings decision via the household's Euler equation. A second, more pleasant, result is that LTV policies strongly dampen the deviations from equilibrium for nearly all other variables. The third insight from Figure 1 is our most policy-relevant result. Apart from the question how a countercyclical LTV rule could be designed, the graphs illustrate that non-linear interventions are not only more realistic but also perform better. Although the LTV ratios are decreased by the same amount at impact, housing prices increase to a lesser extent as all agents know that in the next period the LTV ratio will not be raised above the equilibrium value of 70%.

The last row of Figure 2 illustrates the dynamics of the price levels. Due to the fixed exchange rate regime, price levels have to return to their pre-shock equilibrium value.[18] Analysing the price level dynamics, confirms our previous results: the threshold rule combines both other scenarios and leads to the lowest increase in prices at impact, as well as the smoothest return to equilibrium for property prices and the aggregate price level. Only producer prices increase more strongly than under the baseline scenario as inflation stays above equilibrium for a longer time horizon.

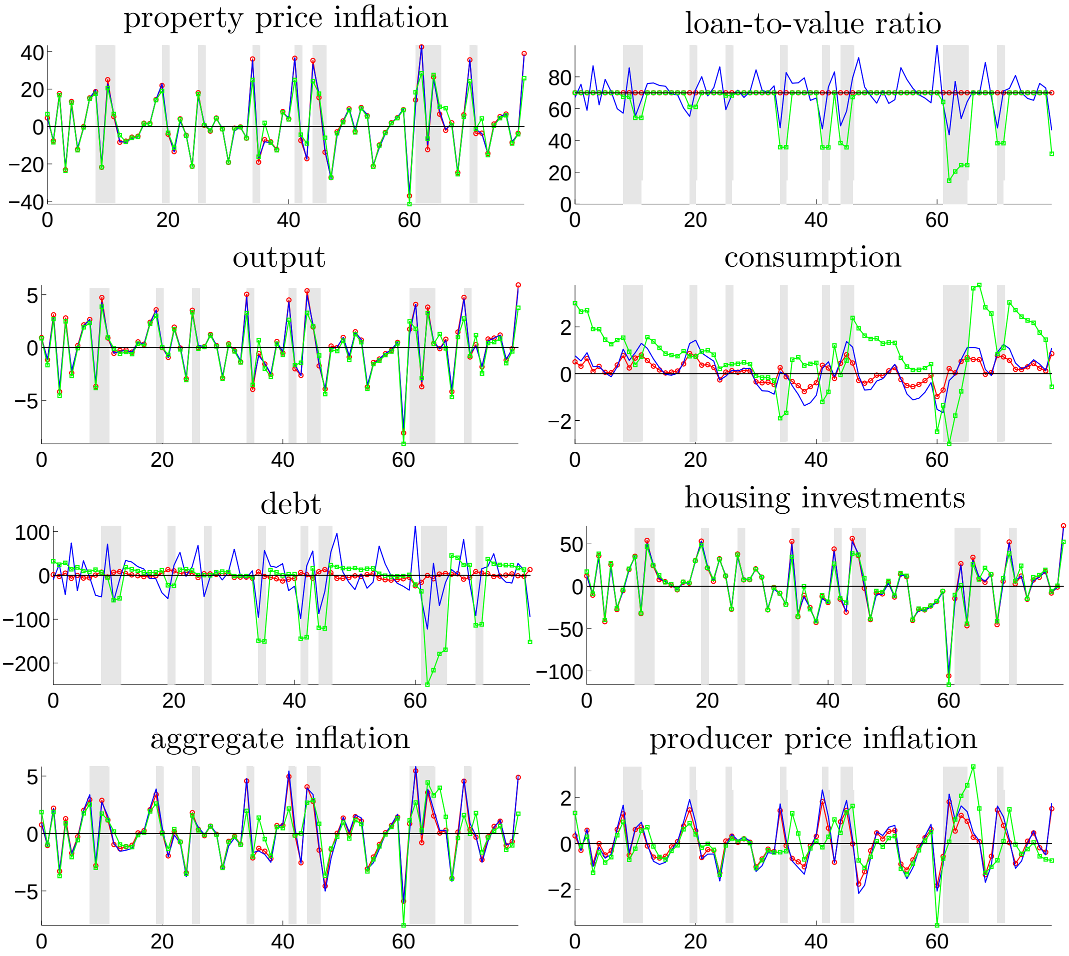
Taken as a whole, our simulation exercise supports the use of threshold-based LTV policies, although their direct impact on property price inflation is limited. They dampen the effects of the increase in property prices on real variables and consumer prices to a non-negligible extent and reduce private debt. Moreover, the concerns that these policies could do more harm than good if they act automatically and in a countercyclical way are eliminated as we simulate the model using a more realistic non-linear rule that only reacts to extreme events.

Having shown how LTV limits work in general, we now analyse different threshold levels for different calibrations of the model. For this purpose, we simulate the model

[17]Since the exchange rate is fixed, the domestic interest rate reacts only negligibly due to the influence of the preference shock on risk-sharing via (15).

[18]This is a standard result in models of small, open economies with an exchange rate peg (see e.g. Galí and Monacelli (2005)). For a realistic result, we would have to add a trend inflation rate.

Figure 3. Simulations of the Model for $\sigma_{d,s} = 2.2$



Red line: Standard, **Blue line:** Taylor rule, **Green line:** Threshold rule

for 1,000 quarters, drop the first 150 periods and derive the standard deviations for our different policy scenarios. Simulating the model under a threshold rule works in a similar way as deriving impulse responses, i.e. we must first find the vector of shadow shocks and imply the bound to be satisfied for all periods. Thus, the corresponding quadratic optimisation problem needs to be solved in each period. Suppose, for example, that the model is simulated up to period t. To ensure that the constraint binds, we need to simulate the model for T more periods to observe whether the bound is hit. If this is the case, we then need to find α, which determines the combination of shocks of the exact size needed to push the bounded variable to zero. Using this value for α, we can simulate the next period and repeat the procedure.

To illustrate the working of this approach, Figure 3 shows simulations of the model for the calibration described above and a time span of 80 quarters. For the standard deviation, we again rely on the estimations of Funke and Paetz (2011), where $\sigma_{d,s} = 2.2$ for the corresponding scenario. The shaded areas denote those periods where the threshold is surpassed. The simulations nicely illustrate that the positive peaks of the property price inflation, output, housing investments and aggregate inflation are all dampened under the threshold rule, while there seems to be no visible effect of the Taylor rule. In addition, the graphs confirm that the dampening effect on property prices works via the debt channel, and that the dynamics of producer prices and consumption differ substantially under the threshold rule.

Table 1 provides the standard deviations for different calibrations, thresholds levels (3,4,5) and policy scenarios.[19] 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, when property price inflation increases by 25%. 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. The tables provide the results for four scenarios taken from the estimations of Funke and Paetz (2011): a baseline estimation with a fairly low share of borrowers (0.09), an estimation with a fixed low share of borrowers (0.2), an estimation with a fixed high share of borrowers (0.35), and an estimation with a uniformly distributed prior for γ and ω (the estimated share of borrowers here is 24%). The corresponding estimated standard deviations of the shocks are 2.24, 2.07, 1.51, and 2.2, and the AR(1) parameters are given by 0.85, 0.87, 0.75, 0.69, respectively. For the different thresholds, we adjust the Taylor-rule reaction parameter ϕ_{ltv} so that the impact reduction of the LTV ratio is identical to the reduction of the threshold rule for an increase in property prices of 25%. For the additional scenarios, we first keep the Taylor rule coefficient and adjust the threshold rule parameter for our baseline threshold of 4% so that the impact reactions of the LTV ratios are equal. This ensures that the rules differ only in their dynamics and retain the same initial reduction.

The table provide several insights. First, and most important, both types of LTV policies moderate the housing price cycle, independent of scenario or threshold. In addition, the table shows that the threshold rule is much more successful in reducing property price inflation, especially for low threshold values. Second, in most scenarios both types of LTV policies decrease the volatility of most other variables (or lead only to minor increases). The obvious exception is the standard deviation of debt; a drop in the volatility of property price inflation is always accompanied with an increase in the volatility of debt. This stems from the strong impact of the LTV ratio on the ability of borrowing households to take mortgage-secured loans. Variations in the LTV ratio are transmitted via the private debt channel and the volatility of household debt increases strongly when the LTV ratio is used as a policy

[19] In the literature on optimal monetary policy, a representative household is typically considered so there is no conflict of interest among households. In the modelling framework of this paper, however, there are two distinct types of households: borrowers and savers. These households presumably have different preferences over optimal monetary policy. Analysing this conflict of interest among households, a worthy research topic, is beyond the scope of the present discussion.

Table 1. Standard Deviation of Different Policy Scenarios and Calibrations

Funke/Paetz(2011), Baseline Estimation ($\omega = 0.09, \sigma_{d,s} = 2.24, \rho_{d,s} = 0.85$)

variable	property infl.			producer infl.			aggregate infl.			output			employment			investments			debt			ϕ_{ltv}	$\phi^{'}_{ltv}$
threshold	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)		
3	4.04	4.03	3.92	0.09	0.09	0.08	0.36	0.36	0.34	1.22	1.22	1.21	0.15	0.16	0.15	19.43	19.70	19.38	8.93	76.89	79.36	4.35	10.40
4	4.04	4.03	3.95	0.09	0.09	0.08	0.36	0.36	0.34	1.22	1.22	1.21	0.15	0.15	0.15	19.43	19.60	19.37	8.93	48.56	63.05	2.80	10.40
5	4.04	4.04	3.98	0.09	0.09	0.08	0.36	0.36	0.35	1.22	1.22	1.21	0.15	0.15	0.15	19.43	19.50	19.38	8.93	20.49	48.72	1.23	10.40

Funke/Paetz(2011), Fixed Low Share of Borrowers ($\omega = 0.2, \sigma_{d,s} = 2.07, \rho_{d,s} = 0.87$)

variable	property infl.			producer infl.			aggregate infl.			output			employment			investments			debt			ϕ_{ltv}	$\phi^{'}_{ltv}$
threshold	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)		
3	4.21	4.16	3.84	0.12	0.13	0.13	0.40	0.40	0.36	1.30	1.32	1.29	0.22	0.24	0.24	27.14	28.27	27.29	8.05	81.38	93.90	4.45	16.00
4	4.21	4.18	3.93	0.12	0.12	0.12	0.40	0.40	0.36	1.30	1.31	1.29	0.22	0.23	0.23	27.14	27.83	26.98	8.05	50.45	72.75	2.80	16.00
5	4.21	4.19	4.00	0.12	0.12	0.12	0.40	0.40	0.37	1.30	1.31	1.29	0.22	0.22	0.22	27.14	27.43	26.98	8.05	20.82	55.91	1.20	16.00

Funke/Paetz(2011), Fixed High Share of Borrowers ($\omega = 0.35, \sigma_{d,s} = 1.51, \rho_{d,s} = 0.75$)

variable	property infl.			producer infl.			aggregate infl.			output			employment			investments			debt			ϕ_{ltv}	$\phi^{'}_{ltv}$
threshold	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)		
3	2.39	2.37	2.27	0.19	0.19	0.17	0.40	0.38	0.37	0.37	0.38	0.38	0.19	0.24	0.20	6.16	6.47	6.09	4.82	45.70	28.98	4.45	16.00
4	2.39	2.38	2.33	0.19	0.18	0.18	0.40	0.39	0.39	0.37	0.38	0.38	0.19	0.22	0.19	6.16	6.35	6.12	4.82	28.15	17.83	2.80	16.00
5	2.39	2.38	2.36	0.19	0.18	0.18	0.40	0.40	0.40	0.37	0.37	0.38	0.19	0.20	0.19	6.16	6.24	6.14	4.82	11.40	10.97	1.20	16.00

Funke/Paetz(2011), ω **and** γ **Uniformly Distributed** ($\omega = 0.24, \sigma_{d,s} = 2.2, \rho_{d,s} = 0.69$)

variable	property infl.			producer infl.			aggregate infl.			output			employment			investments			debt			ϕ_{ltv}	$\phi^{'}_{ltv}$
threshold	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)		
3	4.34	4.26	4.02	0.24	0.35	0.47	0.62	0.70	0.70	2.77	2.51	2.53	2.46	2.22	2.26	33.15	31.77	32.20	8.43	81.40	112.01	4.35	20.00
4	4.34	4.28	3.95	0.24	0.31	0.29	0.62	0.67	0.57	2.77	2.60	2.51	2.46	2.30	2.21	33.15	32.21	31.17	8.43	51.62	75.86	2.80	20.00
5	4.34	4.31	4.02	0.24	0.27	0.25	0.62	0.64	0.56	2.77	2.68	2.56	2.46	2.38	2.26	33.15	32.67	31.44	8.43	23.90	55.38	1.35	20.00

Note: (1) refers to the standard scenario without LTV policy, (2) refers to the time-varying Taylor rule, and (3) refers to the threshold rule.

tool.[20] Since LTV ratios are kept below 70% for one year when using a threshold rule, the collateral constraint also tightens for one year. Consequently, debt decreases for a longer time horizon, although the impact reduction might be the same under both rules.

Interestingly, output volatility also decreases for all scenarios, but the one with a high share of borrowers, when using a threshold rule. For many cases, the threshold rule tends to lower the volatility of inflation and output, thereby avoiding the typical inflation-output trade-off of the New Keynesian model. In contrast, the countercyclical policy tends to increase the output volatility for all scenarios except the last.[21] Moreover, by studying the last scenario, we observe that the non-linearity of the model under a threshold rule may imply a non-linear relationship between the reduction of property price inflation and the threshold value. In the last scenario, the standard deviation of property price inflation is higher for the lowest threshold of 3% than for the medium threshold of 4%.

The overall conclusion of this modelling exercise is that prudent application of LTV ratios can be effective in taming property price booms and contain the associated risks.[22]

5 Conclusions

The global financial crisis of 2008–2009 drew attention to the important issues of dealing with escalating housing prices and the need for pro-active policies that avert, or at least mitigate, future crises. Or are such crises inevitable? This topic is now an active area of macroeconomic research. Here, we offered a quantitative evaluation as to whether and to what extent LTV policies might help dampen the effects of housing price bubbles. A key strength of the threshold model presented above is that it facilitates a more nuanced view of what LTV policies do. Our claim, or at least our hope, is that this threshold policy approach is a productive conceptual tool for confronting key empirical facts.

Hong Kong's long experience with LTV rules is partly the outgrowth of its lack of an independent monetary policy under its currency board system and the strong link between its housing market and macroeconomic business cycles. Nevertheless, our examination of nonlinear LTV policies through the lens of a DSGE model indicates

[20]Recall that we assume very strong shocks to create high inflation rates in the housing market. The average volatility of mortgage secured debt is of course smaller as the LTV ratio does not change as long as the inflation rate stays below the threshold.

[21]The impact on employment volatility is ambiguous (but small) for both rules. Notably, the direction of the impact is the same for both types of rules.

[22]A caveat for our calibration results is in order here. In housing markets, expectations may lead to the settling in of rational and self-fulfilling price bubbles. We have ruled out such bubble solutions in our model. Thus, our conclusions are subject to this restriction. In other words, we are not saying LTV tools are a cure-all. At best, they relieve certain pressures created through the use of more traditional macroeconomic tools.

that preventive LTV policies have a good chance of containing some of the risk of boom-bust cycles. Furthermore, the narrow design and focus reduces negative side effects and costs. In assessing the general lessons of our calibration results, one should consider whether our nonlinear LTV policy rule results are driven by conditions specific to Hong Kong. We believe this is not the case, meaning our findings can be generalised to other advanced economies.

Here, we exclusively analyse pre-emptive LTV policies. However, Jeanne and Korinek (2010) have suggested an alternative approach to reining in booms and busts, noting that collateralised borrowing gives rise to an externality and a free-market equilibrium that is excessively volatile. When credit is collateralised, the interaction between debt accumulation and asset prices magnifies the impact of booms and busts, i.e. borrowing and asset prices feed into each other during booms and busts. The responses that provide the best outcome for the economy are bolstering of the regulatory regime and counter-cyclical taxation on debt.[23]

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