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An Estimated DSGE Model to Analyze Housing Market Policies in Hong Kong SAR

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An Estimated DSGE Model to Analyze Housing Market Policies in Hong Kong SAR

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Abstract

During the last decade, Hong Kong SAR has experienced a large increase in house prices and credit, prompting the authorities to respond with several rounds of tightening macro-prudential rules and increasing stamp duty taxes. This paper provides a Dynamic Stochastic General Equilibrium (DSGE) model for Hong Kong SAR and analyzes the effectiveness of these measures, and finds that they have helped reduce house price appreciation and household leverage. A baseline small open economy real business cycle model is extended by including a housing sector, financial frictions, foreign demand for the domestic housing stock, and is estimated using Bayesian methods and data for Hong Kong SAR between 1996 and 2017. The paper finds that, without these policies, house prices would have been 10.5 percent higher, and the household credit-GDP ratio 14 percent higher.

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1 Introduction

House prices and credit have increased substantially in Hong Kong SAR during the last decade. In real terms, house prices have increased by 145 percent since mid-2007, while the household credit-to-GDP ratio has increased by about 20 percent over the same period. In response, the Hong Kong Monetary Authority implemented eight rounds of macroprudential tightening since October 2009. The tightening measures have included reductions in the maximum loan-to-value (LTV) ratio and debt servicing ratio (DSR). Currently, the maximum LTV ratio is 60 percent for the mass market and 50 percent for the luxury market.[1] The maximum DSR ratio is 50 percent. These ratios are tighter for borrowers: (i) whose main source of income is not Hong Kong SAR based, (ii) with multiple mortgages, (iii) who purchase properties for investment purposes (non-owner occupied properties), and (iv) who receive mortgages based on their net worth instead of their income. The Hong Kong Monetary Authority has also applied stricter risk weights for residential mortgages on banks.

The authorities have also implemented several housing market-related tax measures to contain housing prices. The Hong Kong SAR government has implemented several increases in the Ad Valorem Stamp Duty tax since 2013, with a current highest flat rate of 15 percent. In October 2012, the government introduced the 15 percent Buyer's Stamp Duty tax that targets non-resident buyers and company buyers. In November 2010, the Special Stamp Duty tax was implemented, targeting properties resold within 36 months or less with a highest rate of 20 percent.[2]

The contribution of this paper is to evaluate the impact of these housing market related policies using an estimated Dynamic Stochastic General Equilibrium (DSGE) model for Hong Kong SAR. A small open economy real business cycle model is extended with a housing sector, financial frictions, and foreign investors that can purchase the domestic housing stock. The model is estimated using Hong Kong SAR data and Bayesian methods for the period 1996-2017. The model also allows for housing market policies in the form of limits to the LTV ratios as well as stamp duty taxes that affect domestic and foreign purchases. A counterfactual simulation is performed by holding the value of the LTV and stamp duty taxes at their pre-October 2009 levels (before all the tightening occurred), with the result that without these policies, house prices would have been

[1] More specifically, the 50 percent LTV ratio applies to properties whose value is above HKD 10 million.

[2] See International Monetary Fund (2018) for a detailed description and timeline of all the macroprudential measures and stamp duty tax changes since October 2009.

10.5 percent higher, and the household credit-GDP ratio 14 percent higher at the end of 2017. In particular, the LTV cap is more effective at containing leverage, while the stamp duty taxes are more effective at containing house prices.

Other papers have examined the impact of housing market policies using a variety of approaches, and have found that these policies generally have an impact on house price growth. For instance, Craig and Hua (2011) and Rabanal and Shukla (2018) use an error correction model (ECM) for house prices to evaluate the impact of LTV caps and stamp duty taxes, and find that macroprudential and stamp duty tax policies have contributed to slow down house price appreciation in Hong Kong SAR. Nabar and Ahuja (2011) examine the effectiveness of LTV caps using a Vector Autoregressive (VAR) approach for Hong Kong SAR, and find that house prices react with lags to changes in the LTV ratios. He (2014) finds that that caps on LTV ratios have been effective in constraining household leverage, but do not appear to have sustained effects on housing prices. In comparison, higher transaction taxes in the form of additional stamp duties levied by the Government appear to be effective in constraining housing demand and restraining housing price growth. Closely related to this paper is Funke and Paetz (2016), who also estimate a DSGE model for Hong Kong SAR using Bayesian methods and similar features and frictions to the ones studied here. Funke and Paetz (2016) evaluate the performance of different LTV and stamp duty tax rules in terms of welfare, but do not evaluate their impact empirically.

The paper is organized as follows: Section 2 presents the model, Section 3 explains the estimation procedure, while Section 4 presents impulse responses to housing and policy shocks using the estimated model. Section 5 discusses the results of a counterfactual simulation without policy changes since 2009, while Section 6 presents some concluding remarks.

2 The Model

The model is a small open economy real business cycle model which is extended to include a housing sector, financial frictions, and foreign demand for the domestic housing stock. The model assumes flexible prices and that the small open economy takes the world interest rate as given.[3] The government can set macro-prudential policy to affect the LTV cap in new loans, and can also

[3] A baseline RBC small open economy model can be found in Schmitt-Grohe and Uribe (2017). Housing and credit frictions are included as in the contributions by Iacoviello (2005) and Alpanda and Zubairy (2016).

impose stamp duty taxes on both domestic and foreign buyers.

2.1 Savers

Savers consume non-durable goods, housing, and supply labor. They also accumulate capital, have access to international capital markets, and provide credit to borrowers.[4] Their lifetime utility function is given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \gamma \log(C_t^j - hC_{t-1}) + (1-\gamma)\xi_t^D \log(D_t^j) - \frac{\left(N_t^j\right)^{1+\varphi}}{1+\varphi} \right\} \tag{1}$$

subject to:

$$C_t^j + I_t^j + (1+\tau_t^{ADV}) Q_t^D (D_t^j - D_{t-1}^j) + B_t^j + L_t^j = W_t N_t^j + R_t^k K_{t-1}^j + R_{t-1}(B_{t-1}^j + L_{t-1}^j) + T_t \tag{2}$$

E_0 denotes the expectation operator as of time $t = 0$. Savers enjoy utility from the consumption of non-durable goods C_t^j, with external habit parameter h, and from owning housing D_t^j. Savers dislike supplying labor N_t^j, where φ is the inverse Frisch elasticity of labor supply. ξ_t^D is a housing preference shock that follows an AR(1) process in logs. Savers make investment decisions in physical capital I_t^j and can purchase or sell the housing that they own. The real price of housing is Q_t^D, and τ_t^{ADV} is an Ad-Valorem Stamp Duty that is collected on all transactions.[5] T_t is a lump-sum transfer from the government. Savers have access to international capital markets and can purchase bonds B_t^j which pay a domestic interest rate R_t. Savers also extend credit to borrowers L_t^j at the same interest rate. Savers supply labor and rent capital to consumption goods producers, for which they receive a wage W_t and a rental rate R_t^k. Aggregating across savers, the law of motion of capital is given by:

$$K_t = (1-\delta) K_{t-1} + \left[1 - F\left(\frac{I_t}{I_{t-1}} \right) \right] I_t \tag{3}$$

[4]This assumption is introduced for simplicity. Alternatively, it is also possible to assume that savers use bank deposits to save, and that banks lend to borrowers, in a frictionless banking sector.

[5]This paper only evaluates changes in the Ad Valorem Stamp Duty and Buyers Stamp Duty taxes. The Special Stamp Duty was introduced to reduce speculation in the housing market, and the applicable tax rate depends on the length of period that the property is purchased and resold. Studying the effects of this non-linear time-dependent tax rate is not straightforward in the current framework.

where $F = \frac{\varphi_i}{2}(I_t/I_{t-1} - 1)^2$ denotes investment adjustment costs. The relationship between the domestic interest rate R_t and the world interest rate R_t^* is given by:

$$R_t = R_t^* - \psi(e^{B_t} - 1) \tag{4}$$

where B_t is the stock of foreign assets held by the private sector (a negative value would denote net liabilities). The world interest rate is assumed to be exogenous and to follow an AR(1) process in logs.[6]

The savers' first order conditions are as follows. The consumption/savings decision is given by:

$$\lambda_t = \beta E_t \lambda_{t+1} R_t, \tag{5}$$

where E_t is the expectations operator at time t and λ_t is the marginal utility of consumption:

$$\lambda_t = \gamma/(C_t - hC_{t-1}). \tag{6}$$

Housing demand is given by:

$$\lambda_t Q_t^D (1 + \tau_t^{ADV}) = (1-\gamma)\xi_t^D / D_t + \beta E_t \lambda_{t+1} Q_{t+1}^D (1 + \tau_{t+1}^{ADV}),$$

which substituting for the marginal utiility of consumption expression delivers:

$$Q_t^D (1 + \tau_t^{ADV}) = \frac{(1-\gamma)\xi_t^D (C_t - hC_{t-1})}{\gamma D_t} + Q_{t+1}^D (1 + \tau_{t+1}^{ADV})/R_t. \tag{7}$$

The real price of housing is a function of the marginal utility of current housing services in terms of consumption goods (i.e. rents), and its discounted continuation value. The Ad-Valorem Stamp Duty tax also affects the equilibrium house price.

[6]This relationship is suggested by Schmitt-Grohe and Uribe (2017) to ensure that the model has a well-defined steady-state. If $\psi = 0$, the model would not converge to the initial steady-state even with transitory shocks. In practice, ψ is calibrated to a small numerical number such that the model converges to the steady-state, but the friction included in (4) does not affect the business cycle properties of the model.

The labor supply decision by savers is given by:

$$W_t = (N_t)^{\varphi}/\lambda_t. \tag{8}$$

The Euler equations for investing in physical assets are:

$$\lambda_t Q_t^k = \beta E_t \lambda_{t+1}[(1-\delta)Q_{t+1}^k + R_{t+1}^k], \tag{9}$$

where Q_t^k is the multiplier associated to the capital accumulation equation (3), typically referred to as Tobin's Q, and

$$\begin{aligned} 1 = {} & Q_t^k\{[1 - \frac{\varphi_i}{2}(I_t/I_{t-1} - 1)^2] - \varphi_i(I_t/I_{t-1} - 1)(I_t/I_{t-1})\} \\ & + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} Q_{t+1}^k \varphi_i (I_{t+1}/I_t - 1)(I_{t+1}/I_t)^2. \end{aligned} \tag{10}$$

Abstent investment adjustment costs, $\varphi_i = 0$ and $Q_t^k = 1$.

2.2 Borrowers

Borrowers consume non-durable goods, housing, and supply labor. Unlike savers, they do not accumulate capital and have access to international capital markets. Borrowers are more impatient that savers and have a lower discount factor $\beta^B < \beta$. This assumption implies that borrowers want to borrow as much as possible to bring forward consumption, so they face a borrowing constraint based on the value of the housing they own. Following Alpanda and Zubairy (2016), we add more realism to the Iacoviello (2005) model by assuming that loans extended by savers to borrowers are long term and only a fraction κ is refinanced every period. This means that every period, only the flow of new credit, as opposed to the entire stock of credit, is subject to the current LTV cap.[7]

Formally, their problem for borrowers is to maximize their lifetime utility

$$E_0 \sum_{t=0}^{\infty} \left(\beta^B\right)^t \left\{ \gamma \log(C_t^{B,j} - hC_{t-1}^B) + (1-\gamma)\xi_t^D \log(D_t^{B,j}) - \frac{\left(N_t^{B,j}\right)^{1+\varphi}}{1+\varphi} \right\} \tag{11}$$

[7] In Iacoviello (2005), the entire stock of outstanding loans is subject to the LTV cap in each period.

subject to:

$$C_t^{B,j} + (1+\tau_t^{ADV})Q_t^D(D_t^{B,j} - D_{t-1}^{B,j}) + R_{t-1}L_{t-1}^j = W_t^B N_t^{B,j} + L_t^j + T_t^B \tag{12}$$

Borrowers also enjoy utility from the consumption of non-durable goods $C_t^{B,j}$, with external habit parameter h, and from owning housing $D_t^{B,j}$. Borrowers dislike supplying labor $N_t^{B,j}$, where φ is the inverse Frisch elasticity of labor supply. They are also subject to the same housing preference shock as savers ξ_t^D. Borrowers supply labor and receive a wage W_t^B. T_t^B is a lump-sum transfer from the government.

Borrowers receive credit directly from savers, L_t^j. The law of motion of credit is given by:

$$L_t^j = (1-\kappa)L_{t-1}^j + \kappa L_t^{j,new} + \varepsilon_{L,t}. \tag{13}$$

In any given period, borrowers pay a constant, exogenous fraction κ of the outstanding stock of loans to savers. The average duration of a loan is therefore $1/\kappa$. New borrowing (i.e. the flow of new credit) is subject to the LTV cap:

$$L_t^{j,new} \leq LTV_t Q_t^D D_t^{B,j}. \tag{14}$$

In addition, the law of motion of loans includes a credit shock $\varepsilon_{L,t}$ that is iid and Normally distributed. This shock reflects changes in household debt not captured by the model (such as, for instance, defaults or debt write-offs). Setting $\kappa = 1$ brings the model to the one-period debt case in Iacoviello (2005).

The consumption/savings decision is given by:

$$\lambda_t^B = \beta^B E_t \lambda_{t+1}^B R_t + \mu_t^B - (1-\kappa)\beta^B E_t \mu_{t+1}^B, \tag{15}$$

where λ_t^B is the marginal utility of consumption of borrowers:

$$\lambda_t^B = \gamma/(C_t^B - hC_{t-1}^B), \tag{16}$$

and μ_t^B is the Lagrange multiplier to the borrowing constraint (14). It denotes the shadow value of

an additional unit of borrowing in terms of consumption units. Housing demand is given by:

$$\lambda_t^B Q_t^D (1+\tau_t^{ADV}) = (1-\gamma)\xi_t^D / D_t^B + \beta^B E_t \lambda_{t+1}^B Q_{t+1}^D (1+\tau_{t+1}^{ADV}) + \kappa \mu_t^B LTV_t D_t^B, \tag{17}$$

which, compared to the borrowers has an additional term that reflects the additional value of housing because it relaxes the borrowing constraint.

The labor supply decision by borrowers is given by:

$$W_t^B = (N_t^B)^{\varphi} / \lambda_t^B. \tag{18}$$

2.3 Foreign Buyers and Housing Market Equilibrium

In Hong Kong SAR, about 5 percent of housing market purchases are undertaken, on average, by foreign buyers (see International Monetary Fund (2018)). Since 2012, these foreign buyers are subject to a Buyer's Stamp Duty tax of 15 percent. The housing investment decision by foreign investors is modeled with the following optimizing Euler equation, much in the same spirit of equation (7) for domestic buyers. Foreign investors react to Hong Kong SAR house prices, the Buyer's Stamp Duty and the world interest rate when chosing the desired level of investment:

$$(1+\tau_t^{BSD}) Q_t^D = f(\xi_t^{D^*}, D_t^*, C_t^*) + E_t \left[(1+\tau_{t+1}^{BSD}) Q_{t+1}^D \right] / R_t^* \tag{19}$$

where τ_t^{BSD} is the Buyer's Stamp Duty, $f(\xi_t^{D^*}, D_t^*, C_t^*)$ denotes the ratio of marginal utilities of housing and consumption (i.e. rents) for foreign investors. This ratio includes a foreign housing preference shock that follows an AR(1) process in logs.

We assume that housing is in fixed supply to a level $\bar{D}$. This assumption fits the Hong Kong SAR experience well, where housing supply has not reacted to changes in demand at business cycles frequencies, due to the difficulty to find land available for construction (International Monetary Fund (2018)). The housing market equilibrium can be therefore written as:

$$D_t + D_t^B + D_t^* = \bar{D}. \tag{20}$$

2.4 Consumption Goods Producers

The production of consumption goods is performed with a standard Cobb-Douglas technology that uses capital, and hours from both patient and impatient households:[8]

$$Y_t = A_t(K_{t-1})^{\alpha}[(N_t)^{\varepsilon}(N_t^B)^{1-\varepsilon}]^{(1-\alpha)} \tag{21}$$

where A_t is total factor productivity, which follows an AR(1) process in logs. Standard profit maximization conditions equate real wages for each household, and the rental rate of capital, to their marginal product:

$$R_t^k = (1-\alpha)\frac{Y_t}{K_{t-1}}, \tag{22}$$

$$W_t = \alpha\varepsilon\frac{Y_t}{N_t}, \tag{23}$$

$$W_t^B = \alpha(1-\varepsilon)\frac{Y_t}{N_t^B}. \tag{24}$$

2.5 Fiscal Policy

The model has a very simplistic fiscal policy, whereby the government does not accumulate debt, and rebates the revenues generated by the stamp duties to households in a lump-sum fashion:

$$\tau_t^{ADV} Q_t^D(D_t - D_{t-1} + D_t^B - D_{t-1}^B) + \tau_t^{BSD} Q_t^D(D_t^* - D_{t-1}^*) = T_t + T_t^B.$$

2.6 Shock Processes

The model includes five exogenous macroeconomic disturbances (the TFP shock, the world interest rate shock, the domestic and foreign demand shock, and the credit shock) as well as three policy shocks (the LTV ratio, the Ad-Valorem Stamp Duty and the Buyer's Stamp Duty). All macroeconomic disturbances except the credit shock are assumed to follow AR(1) processes in

[8]The assumption that labor between patient and impatient households is not fully substitutable might not necessarily be realistic, but it is a convenient assumption to solve for the steady-state of the model.

logs:

$$\begin{aligned}
\log(A_t) &= (1-\rho_A)\log\left(\bar{A}\right) + \rho_A \log(A_{t-1}) + \varepsilon_{A,t}, \\
\log(R_t^*) &= (1-\rho_{R^*})\log(\bar{R}^*) + \rho_{R^*}\log\left(R_{t-1}^*\right) + \varepsilon_{R^*,t}, \\
\log\left(\xi_t^D\right) &= \rho_D \log\left(\xi_{t-1}^D\right) + \varepsilon_{D,t}, \\
\log\left(\xi_t^{D^*}\right) &= \rho_{D^*}\log\left(\xi_{t-1}^{D^*}\right) + \varepsilon_{D^*,t},
\end{aligned}$$

where the innovations to these shocks, and the credit shock $\varepsilon_{L,t}$, are iid Normally distributed zero-mean innovations.

The model includes three policy shocks, with the following processes:

$$LTV_t = (1-\rho_{LTV})\overline{LTV} + \rho_{LTV} LTV_{t-1} + \varepsilon_{LTV,t},$$

$$\tau_t^{ADV} = (1-\rho_{ADV})\bar{\tau}^{ADV} + \rho_{ADV}\tau_{t-1}^{ADV} + \varepsilon_{ADV,t},$$

and

$$\tau_t^{BSD} = (1-\rho_{BSD})\bar{\tau}^{BSD} + \rho_{BSD}\tau_{t-1}^{BSD} + \varepsilon_{BSD,t}.$$

3 Bayesian Estimation

This section describes the Bayesian estimation of the model. It is divided in three parts. The first subsection describes the dataset employed for the estimation of the model. The second subsection discusses those parameters of the model that are estimated. The third subsection discusses the prior and posterior distributions of the estimated parameters of the model.

3.1 Data

The model is estimated using Hong Kong SAR data between 1996Q1 and 2017Q2. The following series are used:

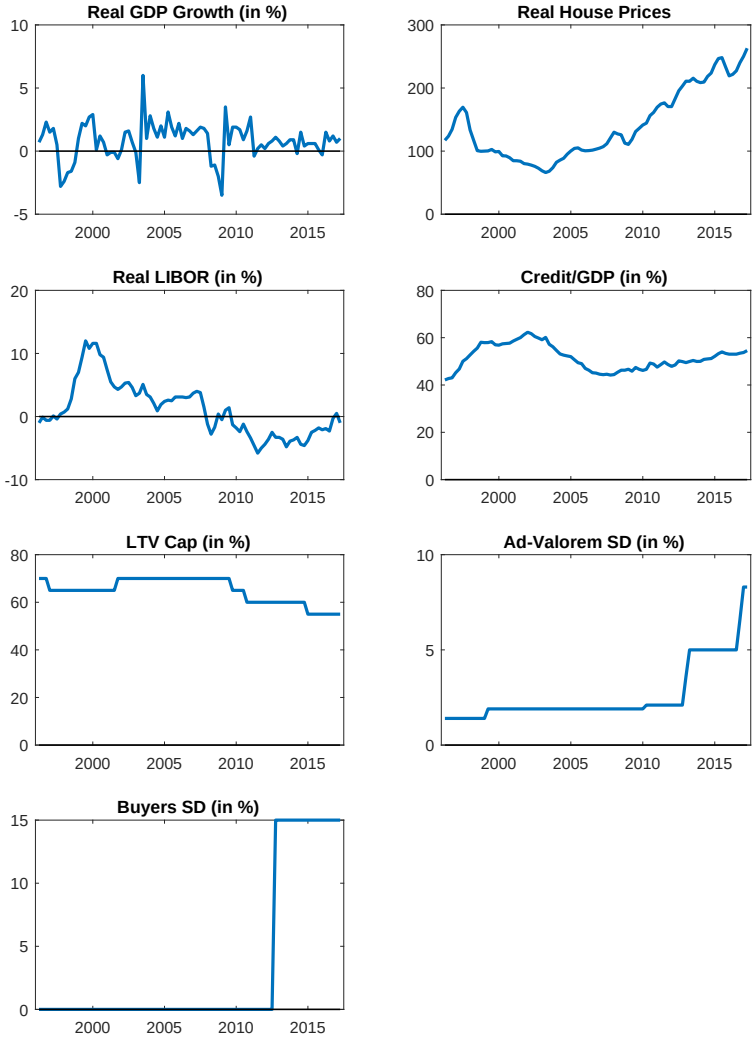
- Real GDP growth (Y_t/Y_{t-1}): Real Gross Domestic Product in 2015 HK Dollars, from the Hong Kong SAR Census and Statistics Department.

- Real house prices (Q_t^D): Property Market Price Index, Private Domestic All Classes, from the Hong Kong SAR Rating and Valuation Department. This series is deflated by the Hong Kong SAR CPI in the IMF's World Economic Outlook Database.

- Household Credit / GDP ratio (L_t/Y_t): Loans and Advances by Professional and Private Individuals, from the Hong Kong Monetary Authority, divided by Nominal Gross Domestic Product from the Hong Kong SAR Census and Statistics Department.

- World real interest rate (R_t^*): 3-month Libor rate deflated by CPI.

Figure 1: Observable Variables



Sources: Hong Kong SAR Census and Statistics Department, Hong Kong SAR Rating and Valuation Department, IMF's World Economic Outlook Database, and Hong Kong SAR Inland Revenue Department.

- LTV ratio (LTV_t): average of lowest and highest LTV cap applicable to a borrower who

applies for a residential property loan for self-use, who has not borrowed or guaranteed other outstanding property mortgage loans, and whose income is mainly derived in Hong Kong SAR. The source is the Hong Kong Monetary Authority.

- Ad Valorem Stamp Duty Tax (τ_t^{ADV}): average of lowest and highest ad valorem stamp duty tax, from the Hong Kong SAR Inland Revenue Department.

- Buyer's Stamp Duty Tax (τ_t^{BSD}): 15 percent starting in 2012Q4, zero otherwise. The source is the Hong Kong SAR Inland Revenue Department.

Figure 1 plots the series that are used for estimation. Real GDP growth, the household credit-to-GDP ratio and real house prices are logged and demeaned. The real Libor rate is divided by 4 to make it a quarterly interest rate. The LTV and Stamp Duty tax series are not transformed.

3.2 Calibrated Parameters

A few parameters of the model are calibrated to either standard parameters in the macro literature or parameters that can be calibrated for Hong Kong SAR. The discount factor for savers is set to 0.997, to match the average real interest rate during the sample period. The discount factor of borrowers is set to 0.99 to reflect their impatience. The capital share of output and the depreciation rate are set at values that are common in the real business cycle literature. The fraction of savers in the economy is set to 0.55, which is about the fraction of residential properties in Hong Kong SAR that do not have a mortgage during the sample period (see Hong Kong Monetary Authority (2017)).[9]

[9]The model only considers households that own a residential property, and hence the relevant fraction for calibrating borrowers and savers are those who live in owner-occupied properties. If the model also included a renting versus owning decision, then the fraction of savers in the economy would have to be calibrated to 0.30, which is the fraction of households that own a property without a mortgage relative to all households in Hong Kong SAR.

Table 1: Calibrated Parameters

β	Discount factor	0.997
β^B	Discount factor borrowers	0.99
α	Capital share of output	0.33
δ	Depreciation rate	0.025
ε	Fraction of savers	0.55
γ	Fraction of consumption in utility	0.8
$D^*/\bar{D}$	Foreign ownership housing stock	0.05
LTV	Steady-state LTV	0.7
$\bar{\tau}^{ADV}$	Steady-state Ad Valorem Stamp Duty Tax	0.03
$\bar{\tau}^{BSD}$	Steady-state Buyer's Stamp Duty Tax	0
ρ_{LTV}	AR(1) coefficient for LTV shock	0.9999
$\rho_{\tau^{ADV}}$	AR(1) coefficient for ADV shock	0.9999
$\rho_{\tau^{BSD}}$	AR(1) coefficient for BSD shock	0.9999

Source: Staff estimates.

The weight of housing in the utility function is set to $1-\gamma = 0.2$, which is about double of the value that Iacoviello and Neri (2010) use for the United States, to reflect the importance of housing expenditure in Hong Kong SAR. Some robustness on this parameter is discussed in the next subsection. The fraction of the housing stock owned by foreign investors is set to 5 percent, based on data published by International Monetary Fund (2018). The steady-state values of all the policy instruments are set to their 2009 values, before all the measures in the housing market were implemented. The steady-state LTV ratio is set at 70 percent, the steady-state Ad-Valorem Stamp Duty tax is set to 3 percent, and the steady state Buyer's Stamp Duty tax is set at zero. The AR(1) coefficients on all policy shocks is set to a number arbitrarely close to one (but smaller than one to avoid non-stationarity issues). The idea is that once the LTV or the stamp duty tax is changed, agents expect it to be permanent.[10]

[10]If the AR(1) coefficient were to be assumed smaller than one, in order to keep the policy instrument at a constant value as is the case in the data, agents would have to be surprised every period with a shock. It is more compelling to assume that agents expect the change to be permanent.

3.3 Estimated Parameters, Prior and Posterior Distributions

The Bayesian parameter estimation is performed using standard methods for the estimation of DSGE models, as in (An and Schorfheide, 2007). The posterior distribution of the estimated parameters is obtained using standard formulas. Denoting by Θ the set of estimated parameters, the posterior distribution is given by:

$$P(\Theta|\{X_t\}_{t=1}^T) \propto Pr(\Theta) L(\{X_t\}_{t=1}^T|\Theta)$$

where $Pr(\Theta)$ is the prior distribution over the model's parameters, and $L(\{X_t\}_{t=1}^T|\Theta)$ is the likelihood function of the observable variables $\{X_t\}_{t=1}^T$, given by the linearized version of the model and the Kalman filter. Table 2 presents the prior and posterior distributions, based on applying the Metropolis-Hastings algorithm with 250,000 draws. The posterior estimates are as follows. First, the amortization rate is estimated at 0.02, which means that the average mortgage duration is about 50 quarters or 12.5 years. The coefficient on habit formation is on the high side, at 0.981, while the parameter that governs labor disutility is also high (22.15). The investment adjustment costs parameter and the interest rate elasticity are close to their prior means, suggesting that more disaggregated data might be needed for identification. All shocks are estimated to be highly persistent, in particular the housing foreign demand shock. In order to better understand the implications of the model, the next section discusses the estimated impluse-response functions.

An important parameter of the model is the fraction of housing services in the utility function. This parameter was problematic to estimate and had to be calibrated at a value of 0.2, which is a value that is higher than other advanced economies, as discussed in the previous subsection. Funke and Paetz (2016) estimated a value of 0.4 for Hong Kong SAR. As a robustness exercise, the present model was reestimated by calibrating the weight of housing services to 0.4. In this case, the (log) marginal likelihood of the model declined from 1559.75 (when $1-\gamma = 0.2$) to 1504.47 (when $1-\gamma = 0.4$). In the Bayesian estimation literature, this is considered to be "very strong" evidence in favor of the model with a weight of 0.2 for housing in the utility function (see Kass and Raftery (1995)).

Table 2: Parameter Estimates

			Prior		Posterior	
	Parameters		Mean	SD	Mean	90% C.S.
κ	Amortization	Beta	0.05	0.01	0.02	[0.013, 0.026]
h	Habits	Beta	0.5	0.05	0.981	[0.978, 0.984]
φ	Labor disutilty	Gamma	5	3	22.15	[14.64, 29.44]
φ_i	Investment adj. cost	Gamma	5	3	5.46	[1.26, 9.6]
ψ	Interest rate elasticity	Gamma	0.01	0.005	0.012	[0.003, 0.02]
ρ_{R^*}	AR(1) World Int. Rate	Beta	0.8	0.01	0.92	[0.88, 0.95]
ρ_D	AR(1) Housing Preference Domestic	Beta	0.8	0.01	0.96	[0.94, 0.98]
ρ_{D^*}	AR(1) Housing Preference Foreign	Beta	0.8	0.01	0.98	[0.95, 0.99]
ρ_A	AR(1) TFP Shock	Beta	0.8	0.01	0.97	[0.95, 0.99]
σ_{R^*}	Std. Dev. World Int. Rate	Gamma	0.01	0.003	0.003	[0.002, 0.004]
σ_D	Std. Dev. Housing Pref. Domestic	Gamma	1	0.2	1.07	[0.75, 1.4]
σ_{D^*}	Std. Dev. Housing Pref. Foreign	Gamma	1	0.2	0.8	[0.51, 1.07]
σ_A	Std. Dev. TFP Shock	Gamma	0.01	0.003	0.015	[0.013, 0.017]
σ_L	Std. Dev. Credit Shock	Gamma	0.001	0.0001	0.0016	[0.0014, 0.0018]
σ_{LTV}	Std. Dev. LTV Shock	Gamma	0.01	0.003	0.012	[0.011, 0.013]
$\sigma_{\tau^{ADV}}$	Std. Dev. ADV Tax Shock	Gamma	0.01	0.003	0.004	[0.003, 0.005]
$\sigma_{\tau^{BSD}}$	Std. Dev. BSD Tax Shock	Gamma	0.01	0.003	0.016	[0.014, 0.018]

Source: Staff estimates.

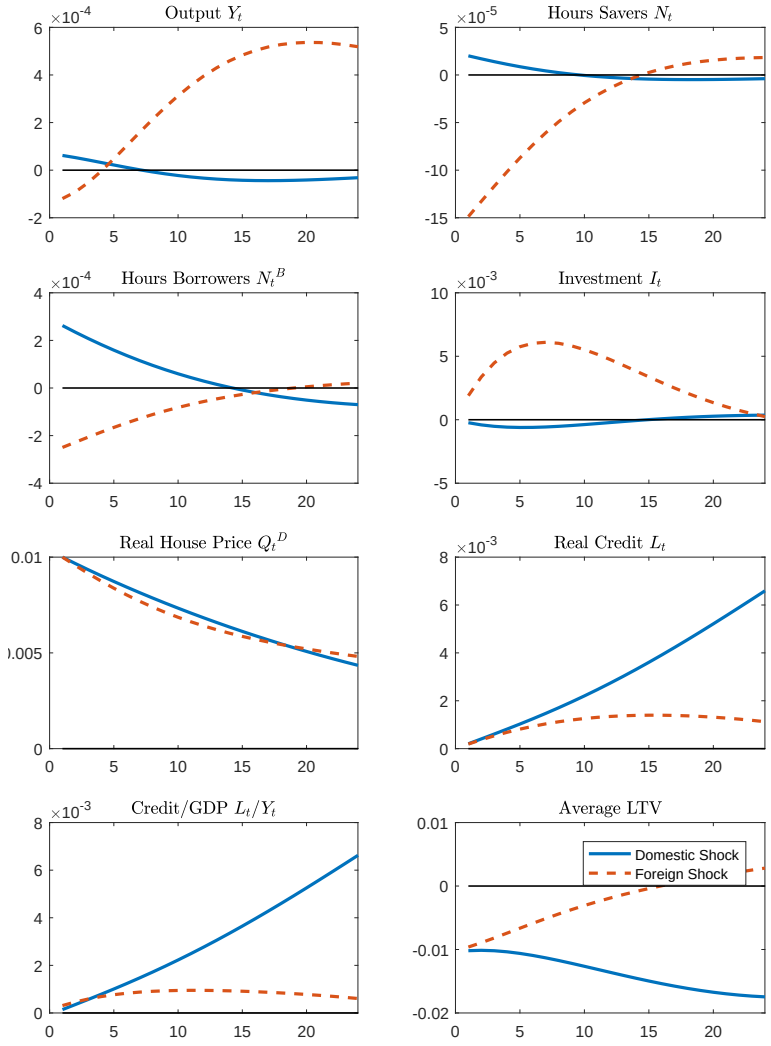
4 Impulse Responses

Since the focus of the paper is on the housing market and housing policies, this section discusses the impulse-responses to the shocks affecting the housing market, using the posterior mode of the estimated parameters to simulate the model.[11] Figure 2 shows the impulse response functions to a domestic (ξ_t^D) and a foreign ($\xi_t^{D^*}$) housing demand shock. Both shocks are normalized such that the increase in house prices is 1 percent on impact. In both cases, the shock increases credit and

[11] The impulse-responses to the remaining shocks in the model are available upon request.

the the credit-to-GDP ratio and lowers the average LTV ratio in the economy: higher house prices increase the amount of collateral in the economy and alleviate borrowing constraints for impatient households.

Figure 2: Effects of Housing Demand Shocks

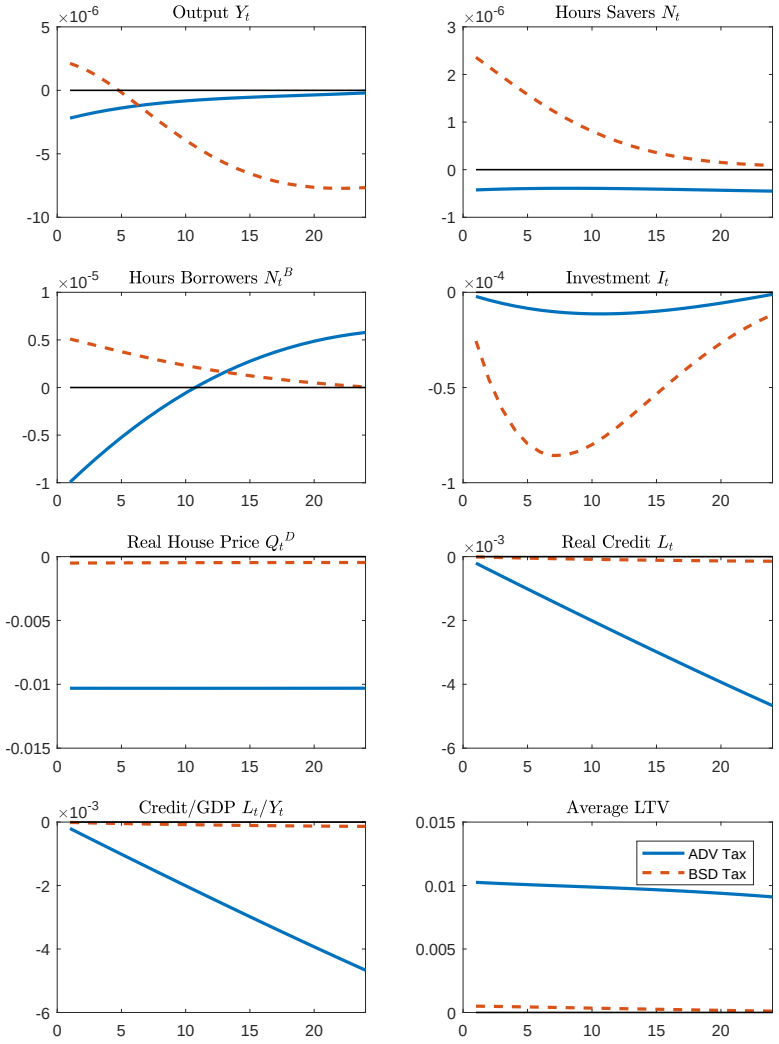


Source: Staff estimates. The x-axis presents quarters after shock, the y-axis presents deviations from steady-state values for each variable.

However, the reaction of GDP is different under both cases: under a domestic housing demand shock, output slightly increases on impact because both savers and borrowers increase their labor supply (as they would want to purchase more housing). But savers also invest less in physical capital in order to direct more resources to purchase housing, so output eventually declines. However, under a foreign demand shock, output initially decreases because borrowers cut their labor supply as the increase in house prices relaxes their borrowing constraint. But as they sell some

of the housing stock to foreign investors, savers have more resources to invest in physical capital, and output ends up recovering after a few quarters. In any event, the reaction of GDP to housing demand shocks is negligible: under the domestic demand shock, output peaks at less than 0.01 percent, while under the foreign shock output peaks at 0.05 percent deviation from its steady-state value.

Figure 3: Effects of Ad-Valorem Taxes

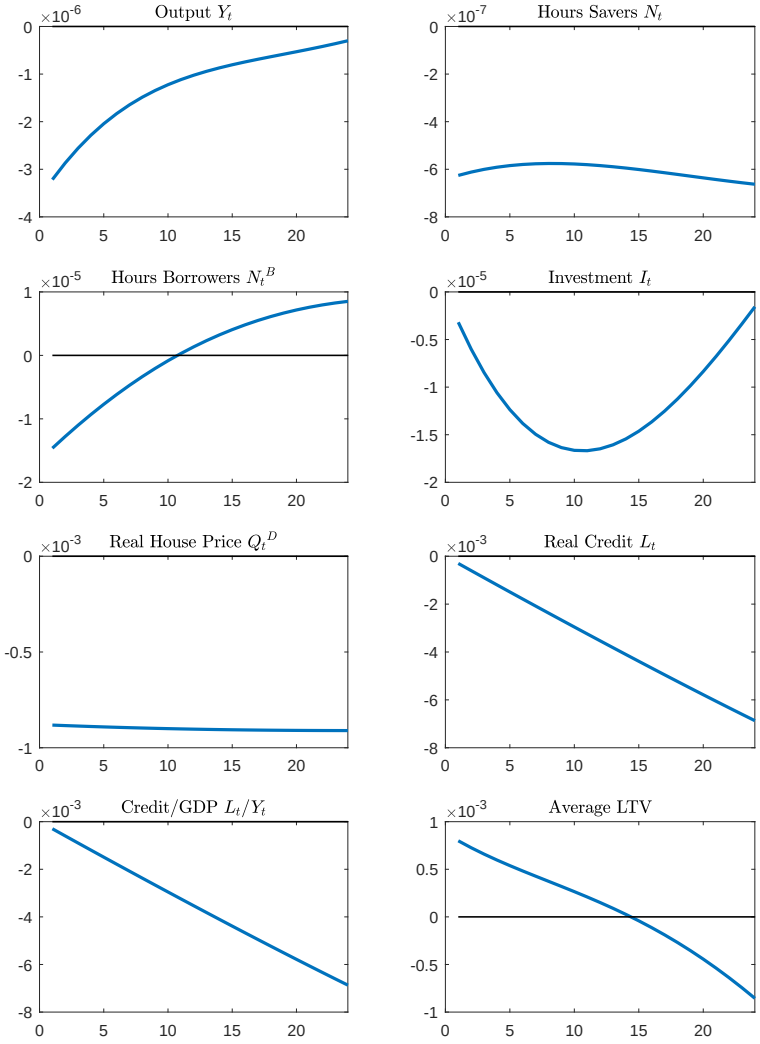


Source: Staff estimates. The x-axis presents quarters after shock, the y-axis presents deviations from steady-state values.

Figure 3 shows the effect of an increase in the Ad Valorem Stamp Duty tax, as well as an increase in the Buyer's Stamp Duty tax of 1 percentage point. The ADV tax lowers real house prices, real credit and the credit-to-GDP ratio. Initially, this tax increases the average LTV in the economy, because credit reacts in a sluggish way while house prices do not. The tax has very minor

quanatitative effects on output, labor supply and investment. The effects of the Buyer's Stamp Duty are much smaller, but are somewhat comparable to the ADV. House prices decline, credit and the credit-to-GDP ratio decrease and the average LTV increases, but by a smaller magnitude because this tax affects a small number of buyers.

Figure 4: Effects of LTV Policies



Source: Staff estimates. The x-axis presents quarters after shock, the y-axis presents deviations from steady-state values.

Figure 4 shows the effects of a 1 percent tightening in the LTV for new loans. The effect on house prices is a reduction of close to 0.1 percent. Because the LTV cap affects new loans only, credit and the credit-to-GDP ratio decline in a sluggish way. The effects on the average LTV ratio display interesting dynamics: in the short run, the average LTV increase slightly, because of the decline in house prices. However, and overtime, the average LTV ratio converges to the LTV cap

for new loans, and becomes negative after about 15 quarters.

5 Counterfactual Simulations

This section presents a counterfactual simulation for the Hong Kong SAR house prices and credit to GDP ratio had the authorities not implemented the several rounds of macroprudential tightening and stamp duty tax increases. The estimated DSGE model is well suited for this task since it is a structural model and therefore less prone to Lucas-critique type of issues.

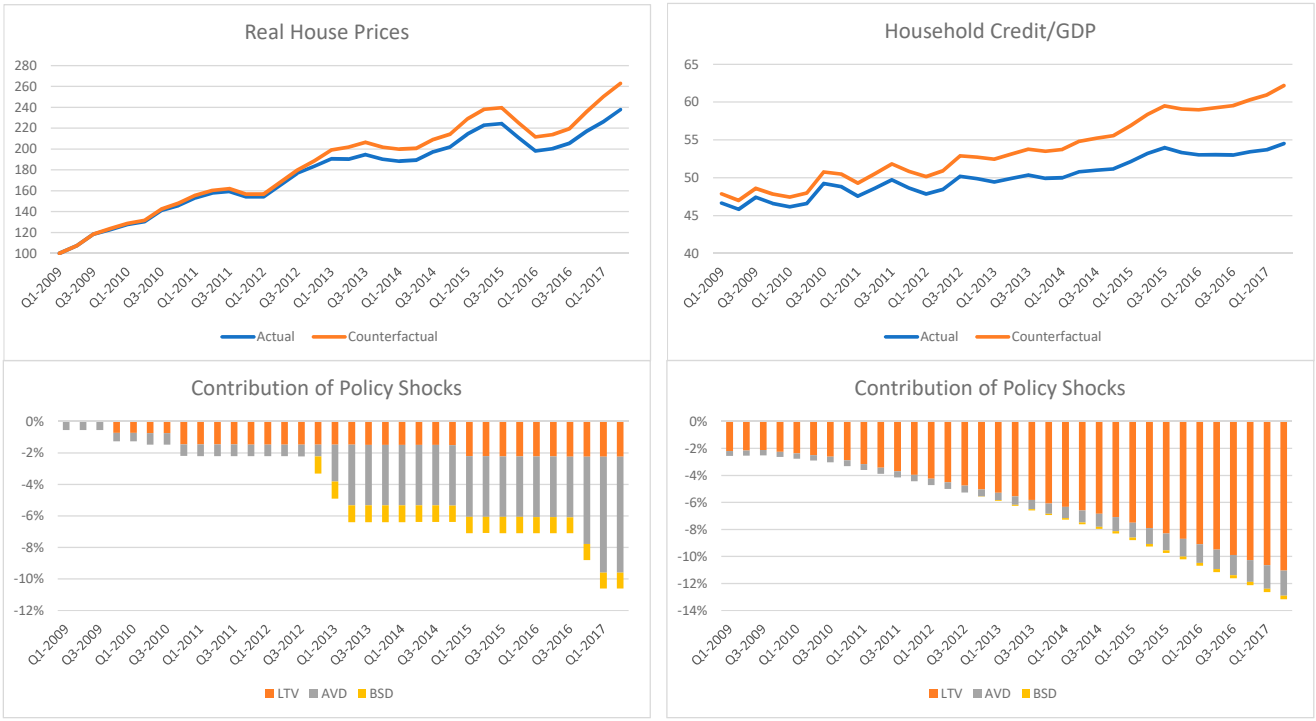
Denote by $\xi_t^{FUN} = [\log(A_t), \log(R_t^*), \log(\xi_t^D), \log(\xi_t^{D^*})]$ the set of macroeconomic fundamental shocks, and by $\xi_t^{POL} = [LTV_t, \tau_t^{ADV}, \tau_t^{BSD}]$ the set of policy shocks. Define $\xi_t = [\xi_t^{FUN}, \xi_t^{POL}]$ as the set of all shocks. Following the methods described in Bauer *et al.* (2003), the Kalman smoother is applied to the observable variables and the law of motion of the model (at the posterior mode) to obtain estimates for the sequence $\{\hat{\xi}_{t|T}\}_{t=1}^T$ (that is, estimates of the shocks of the model conditional on observing the whole sample up to time T). Then, the model is simulated with the following shocks: $\{\tilde{\xi}_t\}_{t=1}^T = \{[\hat{\xi}_{t|T}^{FUN}, \xi_{2009:3}^{POL}]\}_{t=1}^T$, which is the set of estimated macroeconomic fundamental shocks in the previous step but with the policy variables kept at their pre-October 2009 value. This assumption implies that the loan-to-value cap is kept constant at 70 percent, the Ad-Valorem Stamp Duty is at its average rate of 3 percent, and the Buyer Stamp Duty is 0 percent, and allows us to simulate the housing market variables as if the housing market policies had not been in place.

According to this simulation, house prices would have been about 10.5 percent higher, and the household credit-to-GDP ratio about 14 percent higher of the authorities had not implemented all the policy measures. The policy that affects house prices the most is the Ad Valorem Stamp Duty tax, since it is the measure that affects all buyers, except as exempted under the Stamp Duty Ordinance.[12] The LTV policies have a smaller impact than the stamp duties in slowing down house price growth, since they affect only demand by borrowers, who are less than half of the buyers in the model. On the other hand, LTV policies are very effective at containing household leverage, which is the main reason why the Hong Kong Monetary Authority put them in place. Increases in

[12]The Ad-Valorem Stamp Duty tax affects first time buyers as well as those buyers who own more than one property and foreign buyers. There are some exemptions which include: property transactions with the Hong Kong SAR government, gifts of properties received by charitable institutions, or transfers of property to a beneficiary of the estate of a deceased person. The Stamp Duty Ordinance, available at https://www.elegislation.gov.hk/hk/cap117, lists all the relevant exemptions.

the Ad Valorem Stamp Duty also help reduce leverage through their effect on house prices, while the contribution of the Buyer's Stamp Duty is negative but very small.

Figure 5: Counterfactual Simulation



Source: Staff estimates.

6 Concluding Remarks

This paper has used a Dynamic Stochastic General Equilibrium model for Hong Kong SAR to evaluate the impact of housing market policies. A standard small open economy real business cycle model is extended with a housing sector, financial frictions, and foreign investors that can purchase the domestic housing stock, and is estimated using Hong Kong SAR data and Bayesian methods for the period 1996-2017. A counterfactual simulation is performed by holding the value of the LTV and stamp duty taxes at their pre-October 2009 levels (before all the tightening occurred), with the result that without these policies, house prices would have been 10.5 percent higher, and the household credit-GDP ratio 14 percent higher at the end of 2017. Similar to other papers in the literature, such as He (2014), the LTV cap is more effective at containing leverage, while the stamp duty taxes are more effective at containing house prices.

The analysis could be extended in three important directions. First of all, both types of housing market policies entail benefits as well as costs. This paper has focused on quantitatively evaluating some of the benefits (in the form of smaller variability of house prices and credit), but has not evaluated the costs. These would include lack of available credit for borrowers, who might have to cut back current consumption and housing purchases, as well as deadweight losses for buyers and sellers coming from the stamp duty taxes. A comprehensive welfare evaluation would therefore be an interesting exercise. Second, changes in LTV ratios and stamp duty taxes do not happen in a vacuum, as the authorities react to housing market conditions with the tools available to their disposal. In that context, it would be interesting to study the role of LTV and tax rules to achieve the highest welfare. In particular, it would be worthwile to study the indicators to which both instruments should react to, the optimal elasticities, as well as coordination issues. The paper by Funke and Paetz (2016) provides some interesting results, in the context of a somewhat different model to the one presented here.

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