House-price crash and macroeconomic crisis: a Hong Kong case study

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Abstract

The crash of house prices has become an important feature of macroeconomic crisis. We argue that the crash of house prices driven by contractionary monetary policy is not only a reaction, but also accelerates and amplifies the fluctuations of major macroeconomic variables. The impulse response of consumption to the house price shock estimated from Bayesian VAR is of same level as that of investment in Hong Kong, which is distinct from the United States. Therefore, in this paper we conduct a case study of Hong Kong in the 1997-1998 financial crisis and quantitatively analyze the mechanism by developing a general equilibrium model incorporating financial accelerator in both household and entrepreneur sectors. In addition, we introduce real estate producers in order to modify the unrealistic mechanism in existing literature. After estimating the parameters with a combination of calibration and Bayesian method, the simulated impulse responses imply that our model can explain the co-movement of house prices, consumption and investment much better than alternative ones. Moreover, the results of variance decomposition show that interest rate shock can explain most of the house price fluctuations, and a substantial fraction of fluctuations in major macroeconomic variables.

I. Introduction

The fluctuations of house prices have become one increasingly prominent characteristic of economic crisis. For example, the recent financial crisis in the United States was caused by the collapse of the housing market, which propelled the U.S. economy into the Great Recession. In fact, researchers have already noted that conditions in the real estate market played a major role in the rapid meltdown during the 1997-1998 Southeast Asian financial crisis (John Quigley, 2001). A notable fact in Hong Kong during this crisis is a slump in consumption and investment in tandem with a sharp decline in house prices (Figures 1 and 2). However, quantitative studies based on a general equilibrium framework on this issue are still rare. This paper aims to delve into this area by establishing and estimating a general equilibrium model incorporating financial accelerator to understand the interactions between real estate market fluctuations and the aggregate economic dynamics during the Hong Kong financial crisis. Throughout this paper, we will focus on the following two questions: (1) What kind of mechanism causes the crash of house prices? (2) How do house prices influence the macroeconomic variables, including output, consumption, and investment?

We find two empirical observations that are related to the questions that we wish to address. The first concerns the source of the continuing decline in property prices during a recession. Getler et al.(2004) argued that the increase in the world interest rate forced the central bank to raise the domestic interest rate in order to maintain the fixed exchange rate regime. Therefore, the unexpected uplift of the world interest rate is the root that provoked the Southeast Asian financial crisis. There is no fundamental or institutional problem in Hong Kong, hence we argue that the shock that dampened the Hong Kong housing market in that crisis might also come from monetary policy. To verify the above idea, a bivariate Bayesian vector autoregression (BVAR) model with Minnesota prior is used to estimate the impulse responses of both private house price index and private office price index following a shock to interest rate based on a sample period from 1995 to 1999 (Figures 3 and 4). A positive shock to interest rate leads to persistent decrease in house price indices, which is in line with the findings of Getler et al. (2004). Therefore, it is reasonable to use the monetary policy shock as the main shock in our analysis.

The second piece of evidence relates to how property prices impact macroeconomic variables. We argue that their interactions exist not only in Southeast Asian financial crisis, but also for the entire sample period from the 1980s to 2010. Figures 5 to 7 display the estimated impulse responses of output, consumption, and investment following a shock to house prices. These impulse responses are also estimated from a BVAR model. A positive shock to house prices stimulates a persistent increase in macroeconomic variables, among which the response of investment is the most significant, followed by consumption and output. Particularly, the impulse response of consumption is of the same level as investment, which is distinct from the United States.

To understand these salient features of the data, we propose a general equilibrium model based on Bernanke et al. (1999) (BGG hereafter), which describes how the credit market channel may form part of the monetary transmission mechanism. We introduce two distinctive features into the Dynamic New Keynesian sticky price model. The first one is that we assume credit constraints exist for both households and entrepreneurs. Thus, both of them face the optimal financial contracts and use real estate as collateral to reduce the agency costs associated with borrowing to finance consumption and investment. When there is an exogenous interest rate shock, this unanticipated rise depresses the demand for houses, which in turn decreases the investment and house prices. The unanticipated decline in house prices dampens the net worth of both homeowners and entrepreneurs, stimulating the external finance premium, which in turn further depresses investment. Then, a kind of multiplier effect arises. Moreover, the crash in house prices could directly influence consumption through transfers, and output through the decrease in office input. Thus, a shift in housing demand caused by an interest rate shock can lead to large fluctuations in house prices, and produce a broad impact on consumption, investment, and output.

Another feature of our model, compared with other studies, is the introduction of real estate producers into the model. Being different from final goods producers, real estate producers manufacture housing services using investment (final goods) and lands without being constrained on borrowing. This more convincing assumption improves the treatment of the supply of housing in existing literature which assumes that housing supply is fixed.

To evaluate our model quantitatively, we estimate the model using calibration and Bayesian method with Hong Kong aggregate time-series data. Compared to models that only have financial accelerator in either households or firms, our benchmark model provides a much better explanation for the co-movements of house prices, investment, and consumption, as well as the persistence of fluctuations observed in Hong Kong. Our estimation also indicates that propagated through financial accelerators, an interest rate shock alone accounts for about 95% of house prices fluctuations, and more than 70% of fluctuations in macroeconomic variables, including consumption and investment.

A strand of recent DSGE literature on property prices assumes that either households or entrepreneurs are credit constrained, and they use houses or lands as collateral to finance consumption or investment expenditures (Aoki et al., 2004; Iacoviello, 2005; Iacoviello and Neri, 2010; Liu, Wang and Zha, 2011). Aoki et al. (2004) assume that houses provide housing services to consumers and serve as collateral to lower borrowing cost for homeowners. They show that this financial friction amplifies and propagates the effects of the monetary policy shock on housing investment, house prices, and consumption. Similarly, Iacoviello (2005) and Iacoviello and Neri (2010) analyze the relationship between house prices and consumption based on the idea that consumers are credit constrained, and they use houses as collateral to finance their consumption. On the other hand, Liu, Wang, and Zha (2011) introduce a credit constraint into the producer side and explain the positive co-movement between land prices and investment. Although these models are capable of explaining the interaction between land prices and consumption or house prices and investment, they have difficulty in delivering positive co-movements of all the three variables simultaneously. Our model can overcome this difficulty since we establish financial market frictions in both household and entrepreneur sectors, and thus form the transmission channels for both consumption and investment.

Also, our model is different from the literature focusing on the long-run trend of house prices by employing the life cycle model (Ortalo–Magne et al., 2006; Li et al., 2007; Kiyotaki et al., 2010). In contrast, we aim to explain the crash of house prices in the short run, especially during a recession. Our model is also distinctive from the studies of the interaction between housing market and the macro economy (Case and Shiller, 1988; DiPasquale and Wheaton, 1992). Their concern is the response of the housing market to aggregate fluctuations. Instead, we are interested in explaining the fact that the housing market could exert great impact on macroeconomic variables rather than the other way round.

The rest of the paper is organized as follows. Section 2 presents our benchmark model based on Dynamic New Keyesian sticky price model. Section 3 estimates structural parameters of the model. Section 4 presents the simulation results, drawing comparisons between alternative models and evaluate the relative importance of shocks. Conclusions are contained in Section 5.

II. The Benchmark Model

In this section we build a New Keynesian sticky price model incorporating financial accelerator mechanism in order to explain the features of the data. The mechanism is anticipated to be developed that a positive shock from monetary policy will generate the crash of house prices, which amplifies and propagates major macroeconomic variables fluctuations. Also, fluctuations in macroeconomic variables will further exacerbate house prices decline. The economy consists of five types of representative agents: household, entrepreneur, real estate producer, retailer, and monetary authority. There are three types of commodities: houses (or offices for the entrepreneur), nondurable goods and labor. Each household is treated as a composite of two behavioral types: homeowner and consumer. Homeowners purchase houses, and then rent them to consumers. Consumers' utility depends on nondurable goods consumption, housing services and leisure. Entrepreneurs demand office and input them as a production factor to produce wholesales goods. Real estate producers supply houses and offices. Retailers differentiate wholesales goods to gain pricing power. Finally, the monetary authority supports some kind of interest rate rule. Most importantly, borrowing constraints exist in both household and entrepreneur sectors. As their activities are somewhat conventional, we start with households' decision problem.

A. The representative household

The major difference between our model and basic New Keynesian model in household sector lies on the borrowing constraint in purchasing housing services. To avoid the complexity inherent in modeling the dynamic optimization problem of heterogeneous consumers under different borrowing constraints, we follow the method of Aoki et al.(2004). That is, each household is a combination of two behavioral agents: homeowner and consumer. According to Aoki et al.(2004), this separation has the advantage of making the analysis simple, but without losing the essence of the financial accelerator mechanism.

In case of being confused, we first introduce some useful notations in the model.

1. The CES aggregator of consumption.—Consumers demand nondurable consumption goods c_t and house services h_t. C_t denotes a CES consumption aggregator of the form

$$C_t = [\lambda^{1/\eta} c_t^{(\eta-1)/\eta} + (1-\lambda)^{1/\eta} h_t^{(\eta-1)/\eta}]^{\eta/(\eta-1)} \tag{1}$$

Here nondurable consumption goods c_t is a Dixit-Stiglitz aggregator of differentiated consumption goods $c_t(i)$, indexed by $i \in (0,1)$ as

$$c_t = [\int_0^1 c_t(i)^{(\varepsilon-1)/\varepsilon} di]^{\varepsilon/(\varepsilon-1)} \tag{2}$$

Hence the corresponding price index for nondurable consumption goods is given by

$$P_{c,t} = [\int_0^1 p_t(i)^{1-\varepsilon} di]^{1/(1-\varepsilon)} \tag{3}$$

Let P_t denotes the composite price index of C_t, which is defined as

$$P_t = [\lambda P_{c,t}^{1-\eta} + (1-\lambda) P_{h,t}^{1-\eta}]^{1/(1-\eta)} \tag{4}$$

2. Homeowner's economic behavior.—The house purchase decisions of the household sector are made by homeowners. At the end of each period, homeowners purchase houses at price Q_t from real estate producers, and then rent them to their consumers at a rental price $P_{h,t+1}$ in the subsequent period. Homeowners finance the purchase of houses partly with their own net worth available at the end of period t, N_{t+1}^H and partly by borrowing, b_{t+1}. That is,

$$\begin{aligned} q_t h_{t+1} &= N_{t+1}^H + b_{t+1} \\ q_t &= Q_t / P_t \end{aligned} \tag{5}$$

Homeowners' demand for houses depends on expected marginal return on housing and expected marginal financial costs. The expected marginal return $R_{h,t+1}$ is given by

$$E_t[R_{h,t+1}] = E_t[\frac{X_{h,,t+1} + (1-\delta) q_{t+1}}{q_t}] \tag{6}$$

where $0 < \delta < 1$ is the depreciate rate of houses, and $X_{h,t+1}$ is the rental price relative to the composite price index.

Then we switch to the expected marginal financial costs. The first assumption here is that homeowners are risk neutral. In the environment with asymmetric information, homeowners face an external finance premium caused by financial market imperfection when borrowing. For individual homeowners, the return to houses is sensitive to idiosyncratic risk. When borrowers announce that they cannot repay the debt, the lenders cannot observe the realized return unless they pay a fixed "auditing cost". Hence the uncollateralized external financial cost may be more expensive than internal finance due to this "costly state verification" problem. Thus the optimal contract will be a debt contract. That is when the borrower announces he is unable to repay, the lender takes possession of all the borrower's assets. Following BGG's derivation, the external finance premium can be expressed as a decreasing function of the net worth to asset ratio, $N^H_{t+1}/q_t h_{t+1}$, according to the optimal contract. The optimality condition for homeowners' demand for houses is given by

(7)
$$\begin{aligned} E_t[R_{h,t+1}] &= f(N^H_{t+1}/q_t h_{t+1})R_{t+1} \\ f' &< 0 \end{aligned}$$

where R_{t+1} is the riskless real interest rate. The assumption of risk neutrality guarantees that (7) holds for the aggregate level.

Since external financial premium depends on homeowners' financial condition, the evolution of net worth is the key to determine homeowners' demand on houses. Let V^H_t denote the value of homeowners at the beginning of period t, given by

(8)
$$V^H_t = R_{h,t} q_{t-1} h_t - f(N^H_t / q_{t-1} h_t) R_t (q_{t-1} h_t - N^H_t)$$

Then homeowners' net worth can be defined as

(9)
$$N_{t+1} = V_t - D_t$$

where D_t is homeowners' transfer to consumers. The transfer D_t in our model represents the distribution of housing equity between homeowners and consumers. This setting is to capture the important economic behavior in the reality that households use their housing equity to finance consumption. Thus the link between house prices and consumption has been established. Households face the trade-off between current consumption and future finance premium. The rise of house prices can increase the transfer and hence consumption and utility today. However, this also implies a decrease in homeowners' net worth, and an increase in the future finance premium. The optimal allocation should depend on some factors such as the elasticity of intertemporal substitution and future income uncertainty. Following Aoki et al.(2004), to make it simple, we set the transfer to be an increasing function in the net worth of household relative to their assets. That is,

$$
\begin{aligned}
D_t &= \chi(N_{t+1}^H / q_t h_{t+1}) \\
\chi^{'} &> 0
\end{aligned}
\tag{10}
$$

3. Consumer's economic behavior.—There are two types of consumers in our economy: normal consumers and Rule-of-Thumb(ROT) consumers. Normal consumers have accumulated enough wealth, thus they make standard intertemporal and intratemporal decisions. ROT consumers don't have sufficient wealth to smooth consumption. Their marginal propensity to consume is higher than that of the former due to borrowing constraints or impatience. In general, ROT consumers can represent young people in the society.

3.1. The representative normal consumers' utility maximization problem is

$$
\max E_t \sum_{k=0}^{\infty} \beta^k [\log C_{t+k}^p - \xi \frac{(M^p)_{t+k}^{1+\varphi}}{1+\varphi}] \tag{11}
$$

$$
s.t. \; P_t C_t^p + B_{t+1} = W_t C_t^p + R_t^n B_t + \Pi_t
$$

where superscript p denotes normal consumers, C_t^p is the consumption of composite goods, M_t^P is labor supply, R_t^n is the riskless nominal interest rate, W_t is the nominal wage.

3.2. The income of ROT consumers come from wage income and the transfer paid out by homeowners. And they will consume all their current income and save none at the end of each period (Campell and Mankiw, 1989). In order to guarantee enough income, ROT consumers supply labor inelastically. The consumption of the ROT consumers is given by

$$C_t^r = w_t + D_t \tag{12}$$

where superscript r denotes ROT consumers, w_t is the real wage.

3.3 The fraction of normal consumers in the economy is $0 < n_p < 1$. Thus, aggregate consumption is then

$$C_t = n_p C_t^p + (1 - n_p) C_t^r \tag{13}$$

Correspondingly, the aggregate labor supply is

$$M_t = n_p M_t^p + (1 - n_p) \tag{14}$$

B. The representative entrepreneur

Entrepreneurs combine offices with labor to produce wholesale products according to a constant return to scale production function. We describe entrepreneurs' production process with a Cobb-Douglas production function, given by

$$Y_t = F(M_t, O_t) = A_t M_t^{1-\alpha} O_t^{\alpha} \tag{15}$$

where A_t is an exogenous technology, O_t is the aggregate amount of offices purchased by entrepreneurs in period $t-1$, M_t is the labor input.

Similarly, entrepreneurs have the borrowing constraint problem as homeowners in purchasing houses. Entrepreneurs purchase offices at price Q_t in each period for the use in the subsequent period. However, entrepreneurs can't finance the purchase of offices solely with their own net worth. For individual entrepreneurs, the return to offices is sensitive to idiosyncratic risk, which is not observable for lenders. Therefore, entrepreneurs face the external finance premium when borrowing. And the optimal borrowing contract guarantees riskless real interest rate for lenders' expected return. The demand for offices depends on expected return and expected marginal financial costs. The expected return of office $R_{o,t+1}$ is defined as

$$(16) \qquad E_t[R_{o,t+1}] = E_t[\frac{\frac{X_{c,t+1}}{X_{t+1}}\frac{\alpha Y_{t+1}}{O_{t+1}} + (1-\delta)q_{t+1}}{q_t}]$$

where $X_{c,t}$ is the price of nondurable goods relative to composite goods, X_t is the gross markup of retail goods over wholesale goods, δ is the depreciate rate.

Following BGG, external finance premium is the decreasing function of the ratio of net worth to assets value in the optimal contract. Be analogous to homeowners, the optimal demand for office is given by

$$(17) \qquad \begin{aligned} E_t[R_{o,t+1}] &= \Phi(N^E_{t+1}/q_t O_{t+1})R_{t+1} \\ \Phi' &< 0 \end{aligned}$$

The dynamic behavior of office demand depends on the evolution of entrepreneurs' net worth, N_{t+1}. The more net worth entrepreneurs have, the more mortgage they can get. Thus in the equilibrium entrepreneurs can postpone their consumption to accumulate enough net worth until they don't need to borrow. In order to prevent this, entrepreneurs are assumed to have a probability ν to survive into next period at the end of each period. Entrepreneurs' net worth is defined as

$$(18) \qquad N^E_{t+1} = \nu V^E_t + W^E_t$$

$$V_t^E = R_{o,t}q_{t-1}o_t - \Phi(N_t^E/q_{t-1}o_t)R_t(q_{t-1}o_t - N_t^E) \tag{19}$$

where N_t^E is entrepreneurs' net worth, V_t^E is entrepreneurs' equity. Then entrepreneurs who fail in period t consume the residual equity which is

$$C_t^E = (1-\nu)V_t^E \tag{20}$$

C. The representative real estate producer

One feature of our model is the elastic housing supply, which distinguishes our model from other literature that assumes fixed housing supply (Iacoviello 2005, Liu, Wang and Zha 2011). Real estate producers input land and final goods to produce housing services. Then real estate producers sell housing services to homeowners and entrepreneurs at a nominal price Q_t. The production function of houses is given by

$$Z_t = L^{1-\gamma}I_{z,t}^{\gamma} \tag{21}$$

where Z_t is the flow of houses, L is the land input, $I_{z,t}$ is the final goods input. Following the method of Kiyotaki et al. (2011), the supply of land is fixed. This assumption generates the following mechanism: the more fraction the land value takes in housing value, the more violently house prices response to the exogenous shock. Peng and Wheaton (1994) provided empirical evidence supporting this in Hong Kong by econometric tests under the restriction of land supply set by Hong Kong government. According to the principle of profit maximization, the house price Q_t is given by

$$Q_t = \frac{1}{\gamma}P_{c,t}L^{\gamma-1}I_{z,t}^{1-\gamma} \tag{22}$$

The stock of houses T_t is

$$T_t = (1-\delta)T_{t-1} + Z_t \tag{23}$$

T_t can be used as houses or offices interchangeably. The real estate market clear condition is

$$T_t = h_t + O_t \tag{24}$$

D. Retailer

As is standard in literature, to motivate sticky prices we modify the model to allow for monopolistic competition retailers. Retailers buy wholesale goods from entrepreneurs, and then differentiate them. Retailers have the power of pricing and sell their products $Y_t(i)$ at the price $P_{c,t}(i)$. In each period, only a fraction $1-\theta$ of retailers are allowed to change their prices (Calvo,1983). Hence, retailer i choose the optimal price $P^*_{c,t}$ to maximize the expected discounted profits

$$\max \sum_{k=0}^{\infty} \theta^k E_{t-1}[\Lambda_{t,k} \frac{P^*_{c,t} - P^w_t}{P_t} Y^*_{t+k}(i)] \tag{25}$$

where $\Lambda_{t,k} = \beta \frac{c_t}{c_{t+k}}$ is the household intertemporal marginal rate of substitution, $P^w_t = \frac{P_{c,t}}{X_t}$ is the nominal price of wholesale goods. The aggregate price evolves according to

$$P_{c,t} = [\theta P^{1-\varepsilon}_{c,t-1} + (1-\theta)(P_{c,t})^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}} \tag{26}$$

In the economy, final goods can be defined as a CES aggregator of retail goods.

$$Y^f_t = [\int_0^1 Y_t(i)^{(\varepsilon-1)/\varepsilon} di]^{\varepsilon/(\varepsilon-1)} \tag{27}$$

Final goods can be used as nondurable goods consumption, entrepreneurs' consumption, investment and government expenditure. The economy resource constraint is

$$Y_t^f = c_t + C_t^e + I_{z,t} + G_t \tag{28}$$

E. Monetary Authority

Since our mode aims to quantify the responses of house prices and macroeconomic variables to the monetary policy shock, the existence of monetary authority is necessary. The monetary authority in our model is assumed to support a Taylor rule. Monetary authority adjusts the interest rate to meet two aims: targeted inflation rate and smoothed interest rate. When there is an exogenous interest rate shock, the unanticipated rise in nominal interest rate depresses the demand of houses, which in turn decreases the investment and house prices. The unanticipated decline in the asset prices decreases net worth in both homeowners and entrepreneurs part, stimulating the external finance premium, which in turn further depresses investment. Then a kind of multiplier effect arises. The crash in house prices directly influence consumption through transfers D_t and output through the decrease in office input O_t.

Until now, the complete DSGE model has been established. We will log-linearize the first order conditions and market clear conditions to study the responses of economic system to exogenous shocks.

III. Calibration and Bayesian Estimation

The time unit in the model is meant to be a quarter. We assign values to the structural parameters using a combination of calibration and econometric estimation techniques.

We calibrate most parameters using long-run data relations from Hong Kong as well as parameter values that are common in related studies. We set the quarterly discount factor β to 0.99, which also pins down the steady state quarterly riskless rate $R = \beta^{-1}$. The values assigned to $C/Y, I^z/Y, G/Y$ are $0.6, 0.25$ and 0.2 respectively, which are in accord with the history average of Hong Kong. The share of consumption accruing to entrepreneurs' labor accordingly equals to 0.05. The value assumed for λ implies that housing rent expenditure accounts for 12% of total consumption at the steady state. According to statistics from Hong Kong Rating and Valuation Department, the annual rate of return for private houses and private offices are 4.8% and 8.4% respectively. We therefore set $R^h = 1.012$ and $R^o = 1.021$. As is also within convention, the capital share α is 0.35. We assume firms' quarterly survival rate is 0.973 according the bankruptcy and merge data of listed companies in Hong Kong. We set the probability a firm does not change its price within a given period, θ, equal to 0.75, implying that the average time between price adjustment is four quarters. In the monetary policy rule, we set the autoregressive parameter, ρ, to 0.95 and the coefficient ζ on inflation equal to 2, which are standard and make the interest rate smooth.

The parameters governing the financial accelerator are similar to those used in BGG. We define households' leverage ratio ϕ^h as one minus debt to disposable income ratio. We calibrate it as 1/1.4, which is in line with the average value observed in Hong Kong. Firms' leverage ratio is set as 0.5, the same as BGG. The elasticity of the external finance premium with respect to leverage is an important parameter in our model as it determines the borrowing ability for firms and households. Since there is no way to identify it in the factual data, we set this elasticity for households equal to 0.1 following Aoki et al. (2004), and set it as 0.05 for firms according to BGG. The appendix table presents the calibrated parameter values.

We estimate the remaining parameters of the model using Bayesian methods and Hong Kong data on output, private consumption and house price index over the period 1980Q1 to 2010Q4. Specifically, we estimate seven structural parameters, namely, the five ratios or elasticity parameters that can not be calibrated accurately, $O/T, \omega = w/c^r, n_p, s, \gamma$, and parameters defining the stochastic process of shocks, ρ_g and ρ_a. As Liu et al. (2011), we impose Beta prior distributions on all structure parameters except s. The mean of these prior distributions are set as the calibrated values in Aoki et al. (2004). Aoki et al. (2004) argued that the elasticity of transfer with respect to housing equity changed from 3 to 30 based on UK history; therefore, we assume that the prior for adjustment factor s in the dividend rule follows a uniform distribution over $[3, 30]$. We also estimate three nonstructural parameters, $\sigma_{er}, \sigma_{eg}, \sigma_{ea}$, representing the standard deviations of i.i.d. errors with inverse gamma prior distributions. The prior distributions are summarized in Table 1.

Table 1 also reports the estimates of structural and shock parameters at the posterior mode along with standard deviations. The steady ratio O/T is estimated as 0.4275, implying that private offices occupy 42.75% of the total produced houses. The estimated ratio of wage to consumption for ROT consumer, ω, is 83.36%. The ratio of common consumer, n_p, is estimated to 74.02%. These parameters are broadly in line with those reported in literature (Aoki et al., 2004; Iacoviello, 2005). The estimated parameter γ (0.1060) in housing production function implies that land value accounts for nearly 90% of housing values. Davis and Heathcote's (2007) empirical evidence shows that fluctuations in real estate values are primarily driven by changes in land prices. Liu et al.(2011) also regards land as the main factor in the housing market that their DSGE model focus on land prices and macroeconomic fluctuations. Therefore, we believe the housing production function in our model is reasonable estimated. Finally, the estimation reveals that the two common shocks—government expenditure shock and technology shock— are persistent and have a modest deviation.

IV. Model Results Analysis

A. Effects of amplification and persistence

So how well does the financial accelerator work in our world? In this section, we present some impulse responses of the model to a contractionary monetary policy shock. There are two ways to evaluate the amplification and persistence effects of our benchmark model.

The first one is to compare the impulse responses of our model to those of actual data. From the results of BVAR model in section 2, the responses of investment to the house price shock has the largest magnitude, followed by the responses of consumption, and that of output is the last. Besides that, private house price index and private office price index response negatively to a positive shock in interest rate. Those are the results we want to match in our model.

Figure 8 displays the impulse responses of major macroeconomic variables in our benchmark model. The shadow areas represent the 68% posterior probability bands. In the linear equilibrium system, we introduce a positive interest rate shock and generate the impulse responses of house price, output, consumption and investment. From the perspective of amplification effect, house price, output and consumption all drop by 20%. And investment drops most, more than 25%. As we switch to the persistence effect, consumption takes 10 periods to recover and output takes 15 periods, and house prices and investment need more than 25 periods to return to steady state. These impulse responses match the BVAR evidence well.

The second way to examine the effects of the model is to compare impulse responses generated by the benchmark model to those of alternative models which turn off financial accelerator in either household sector or entrepreneur sector. The parameters in alternative models take the same values of those estimated in benchmark model. Figure 9 highlights the effect on house price, output, consumption and investment when financial accelerator turns off in the household sector. Investment drops almost 25%, which is the same as the benchmark model, whereas the amplification effect on house price, output and consumption is much weaker, which drops by 17%, 17%, and 15% respectively. Surprisingly, the persistence of impulse response that takes all variables 40 periods to recover contradicts with our intuition. In the other alternative model which is showed in figure 10, we correspondingly turn off financial accelerator in entrepreneur sector. Both the amplification and persistence effects become weaker than our benchmark model. The peak responses of house price, output, consumption and investment to monetary policy shock are 14%, 15%, 17%, and 18%. As is expected, all variables only need 10 periods to return to steady state. Obviously, compared with these alternative models, our benchmark model has advantages in both amplification and persistence.

B. What shocks drive the house prices?

Our estimated model helps us assess the relative importance of the shocks in driving fluctuations in house prices and macroeconomic variables. We do this through variance decompositions. Table 2 reports the results of house prices and several key macroeconomic variables across the 3 types of structural shocks at forecasting horizons between the impact period (1Q) and six years after the initial shocks (24Q).

A neutral technology shock (i.e., a TFP shock) contributes little to house price fluctuations, though it accounts for a substantial fraction of fluctuations in investment, consumption and output. The reason lies in the fact that it can only move house prices in entrepreneur sector, thus its impact is much less amplified through financial acceleration. This finding is consistent with Liu et al. (2011), who report weak amplification and propagation effects of macroeconomic variables following a TFP shock after incorporating financial frictions into their DSGE model. A shock to government demand explains little of the fluctuations in house prices and key macroeconomic variables. This is intuitive based on the reason that it can only influence variables through the increase in demands for final goods, which is both indirect and weak.

In contrast, the interest rate shock drives more than 97% of house price fluctuations. Working through financial accelerators in both households and firms, the interest rate shock causes a substantial fraction of fluctuations in investment (about 80%), consumption (about 83-90%) and output (about 82-90%). This finding corroborates the results obtained by Jermann and Quadrini (2009) and Aoki et al. (2004), which showed that financial shocks can impact the borrowing ability of firms and households, and thus play an important role in business cycles.

V. Concluding Remarks

In this paper, we study the crash of house prices and its influence on major macroeconomic variables through the case of Hong Kong during the Southeast Asian financial crisis. First, we establish the responses of output, consumption, and investment to the house price shock using bivariate Bayesian VAR models and identify the interest rate shock as the one that results in the crash of house prices. Then in order to implement quantitative studies in a general equilibrium framework, we build a model with financial accelerator mechanism exits both in the household and entrepreneur sectors. The model focuses on the macroeconomic effects of imperfections in credit markets due to asymmetric information. Such imperfections generate external financial premium on households and entrepreneurs when they raise funds to finance their housing purchase. Moreover, the external financial premium is a function of net worth, which heavily depends on house prices. When a positive interest rate shock comes, the decline in house prices raises the external financial premium, which leads to a reduction in housing demand. Thus, the financial accelerator in both sectors amplifies and propagates the fluctuations in house prices and macroeconomic variables.

We use the combination of calibration and Bayesian estimation to assign values to the structural parameters and compare the impulse responses of our benchmark model with those of two alternative models. We conclude that our model can match the data well and exert better effects in both amplification and persistence than models with financial accelerator solely exits in household sector or entrepreneur sector.

In the subsequent research we will extend our model to a small open economy. Given the important role of the foreign exchange rate regime in economic activities not only in Hong Kong, but also in Thailand, South Korea, and Indonesia, with sufficient data preparation in these emerging countries, we would like to investigate the influence of foreign exchange rate regime on house prices and other macroeconomic variables.

Table 1 Prior and Posterior Distribution

	Prior			Posterior		
Parameter	Distribution	Mean	S.D.	Mode	S.D.	T stat.
O/T	Beta	0.4	0.1	0.4275	0.1473	2.9028
ω	Beta	0.6	0.1	0.8336	0.0619	13.4607
n_p	Beta	0.5	0.1	0.7402	0.0589	12.5654
s	Uniform	3(min)	30(max)	3.0000	0.0557	53.8546
γ	Beta	0.4	0.1	0.1060	0.0337	3.1513
ρ_g	Beta	0.85	0.1	0.7415	0.0449	16.5037
ρ_a	Beta	0.85	0.1	0.7458	0.0430	17.3546
σ_{er}	Inv. Gamma	0.2	2	0.0236	0.0003	77.2450
σ_{eg}	Inv. Gamma	0.2	2	0.2339	00161	14.5079
σ_{ea}	Inv. Gamma	0.2	2	0.1266	0.0218	5.8028

Table 2 Variance decompositions of aggregate quantities

Horizon	Interest Rate	Government Demand	TFP (Technology)
		House Price	
1Q	96.39	0.33	3.28
4Q	98.18	0.21	1.61
8Q	97.92	0.16	1.93
16Q	97.70	0.11	2.18
24Q	97.68	0.10	2.22
		Investment	
1Q	88.57	0.05	11.38
4Q	79.63	0.11	20.26
8Q	77.57	0.12	22.31
16Q	78.97	0.11	20.92
24Q	80.09	0.10	19.81
		Consumption	
1Q	97.56	0.00	2.44
4Q	88.14	0.03	11.83
8Q	83.86	0.06	16.09
16Q	83.44	0.06	16.51
24Q	83.74	0.06	16.21
		Output	
1Q	94.08	0.97	4.95
4Q	85.58	0.74	13.68
8Q	82.62	0.63	16.75
16Q	83.10	0.56	16.33
24Q	83.82	0.53	15.65

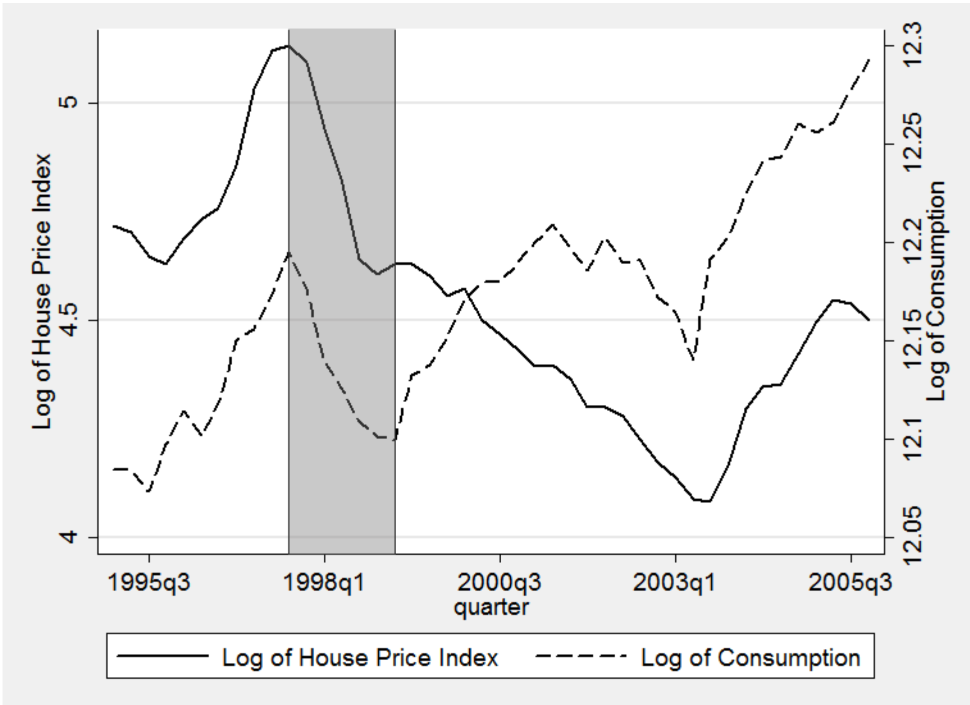

Figure 1: Seasonal adjusted House Prices Index and Consumption from 1995 to 2005, with the financial crisis phase represented by the shaded part (i.e., from 1997 Q3 to 1999 Q4).

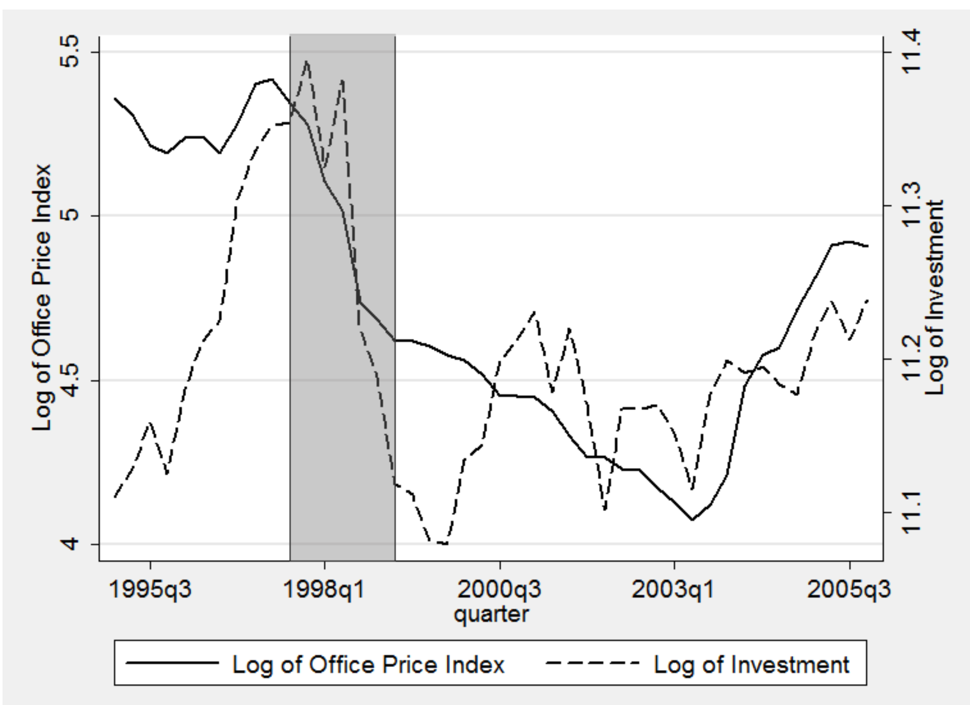

Figure 2: Seasonal adjusted Office Price Index and Investment from 1995 to 2005, with the financial crisis phase represented by the shaded part (i.e., from 1997 Q3 to 1999 Q4).

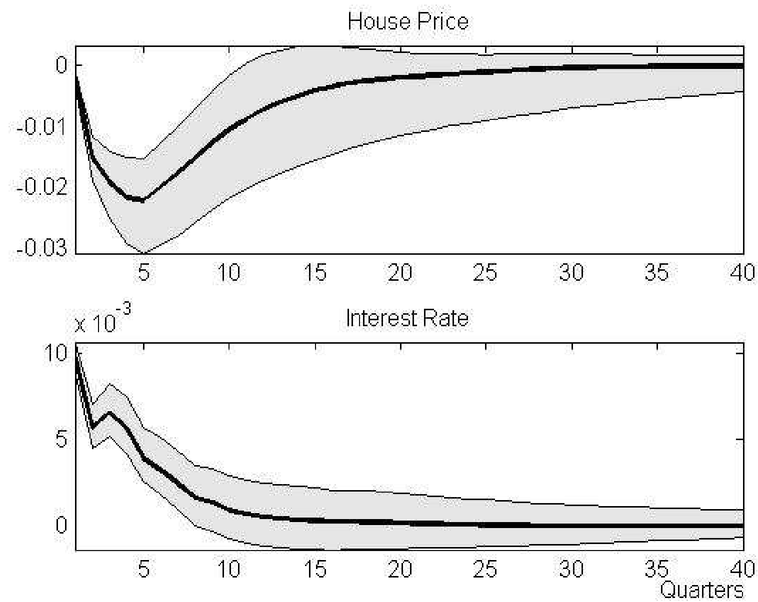

Figure 3: Impluse response to a shock to the interest rate. Note: House price is measured with the private house price index. Interest rate is measured with the six-month foreign exchange funds rate. Solid lines represent the estimated responses from a bivariate BVAR model based on monthly data from January 1995 to December 1999. Darked parts represent the 68% posterior probability bands.

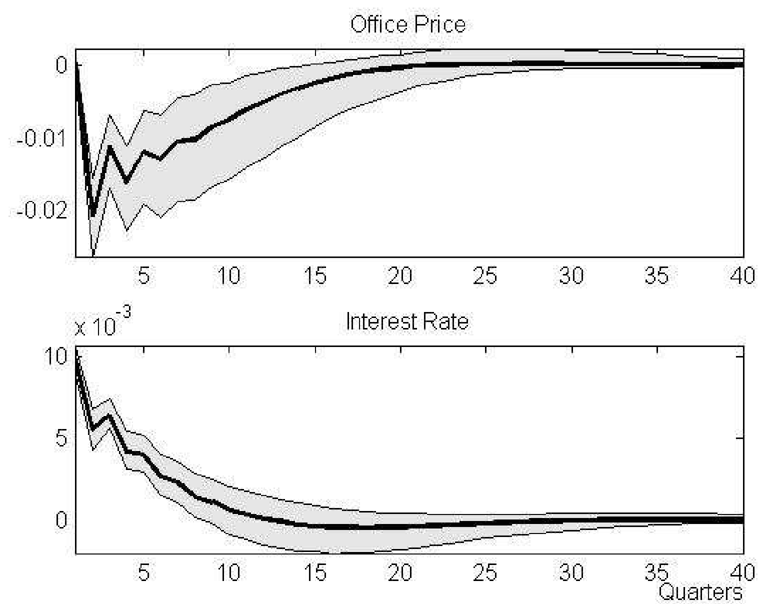

Figure 4: Impulse responses to a shock to the interest rate. Note: Office price is measured with the private office price index. Interest rate is measured with the six-month foreign exchange funds rate. Solid lines represent the estimated responses from a bivariate BVAR model based on monthly data from January 1995 to December 1999. Darked parts represent the 68% posterior probability bands.

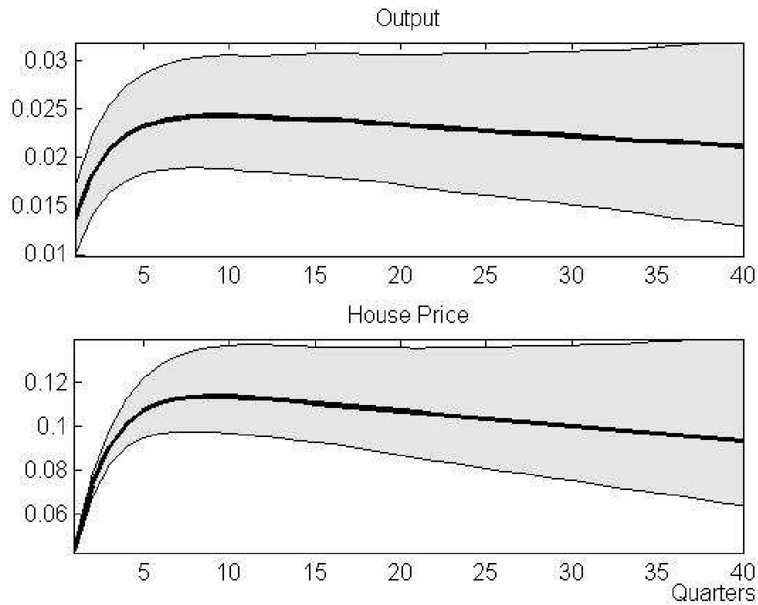

Figure 5: Impulse responses to a shock to the house price index. Note: House price is measured with the private house price index. Solid lines represent the estimated responses from a bivariate BVAR model based on quarterly data from 1980 Q1 to 2010 Q4. Darked parts represent the 68% posterior probability bands.

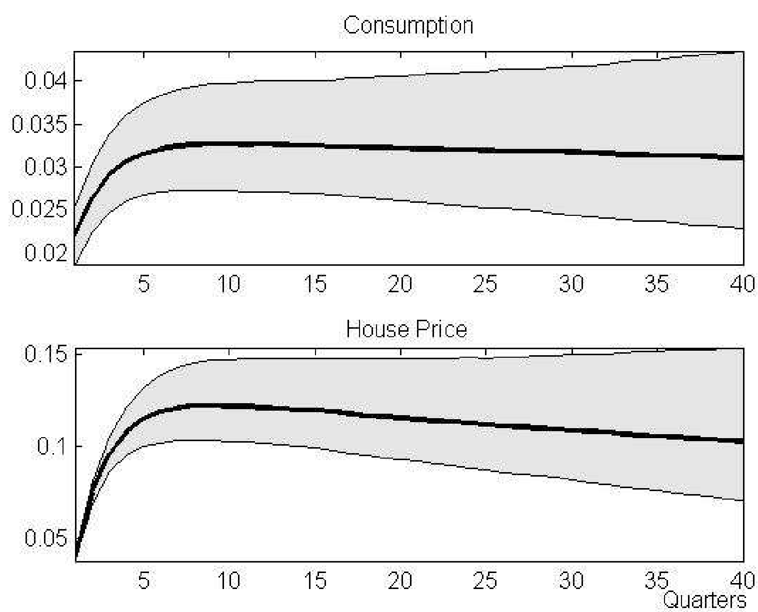

Figure 6: Impulse response to a shock to the house price index. Note: House price is measured with the private house price index. Solid lines represent the estimated responses from a bivariate BVAR model based on quarterly data from 1980 Q1 to 2010 Q4. Darked parts represent the 68% posterior probability bands.

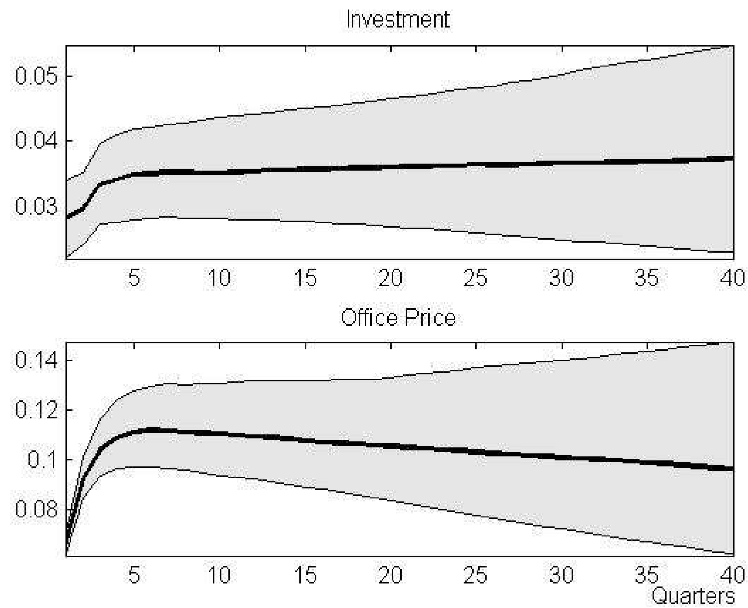

Figure 7: Impulse responses to a shock to office price index. Note: Office price is measured with the private office price index. Solid lines represent the estimated responses from a bivariate BVAR model based on quarterly data from 1986Q1 to 2010Q4. Darked parts represent the 68% posterior probability bands.

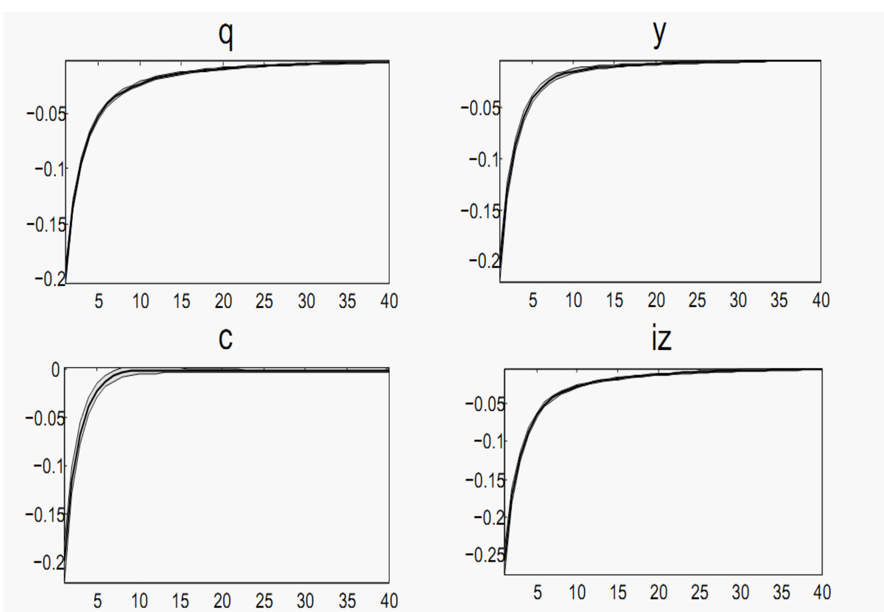

Figure 8: Impulse responses to a shock to the interest rate

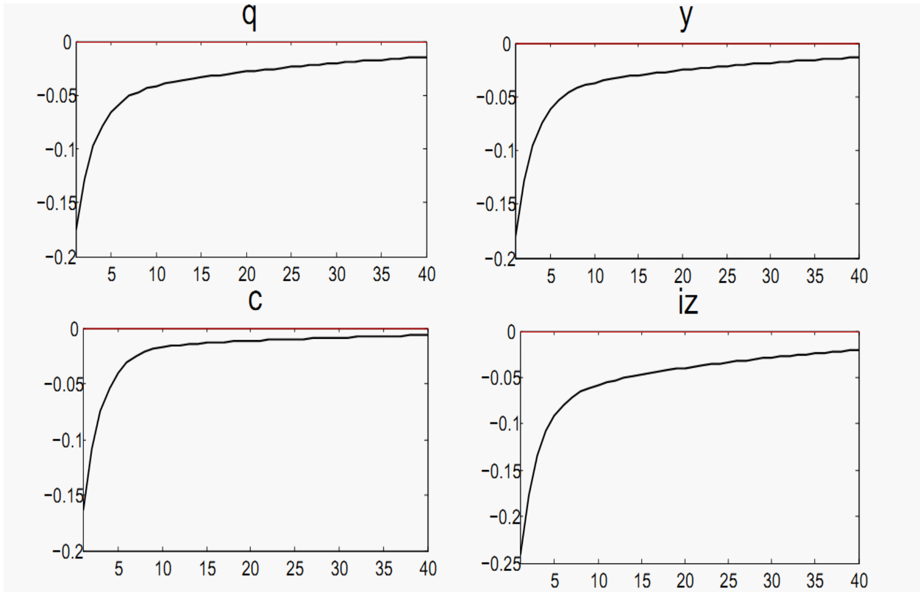

Figure 9: Impulse responses to a shock to the interest rate after turning off the financial accelerator in household sector

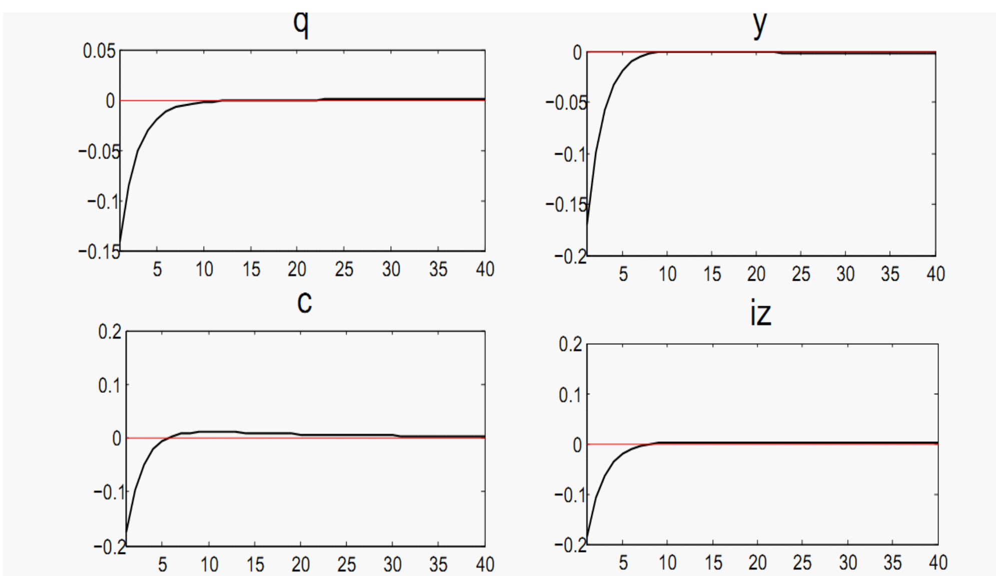

Figure 10: Impulse responses to a shock to the interest rate after turning off the financial accelerator in entrepreneur sector

A Appendix: The Complete Log-Linearized Model

1. Aggregate demand

$$y_t = \frac{c}{Y} c_t + \frac{C^e}{Y} c^e_t + \frac{I_z}{Y} i_{z,t} + \frac{G}{Y} g_t \tag{A1}$$

$$C^p_t = -r_{t+1} + C^p_{t+1} \tag{A2}$$

$$C^r_t = \omega w_t + (1-\omega) d_t \tag{A3}$$

$$C_t = n_p C^p_t + (1-n_p) C^r_t \tag{A4}$$

$$c_t = C_t - \eta x_{c,t} \tag{A5}$$

$$h_t = C_t - \eta x_{h,t} \tag{A6}$$

$$x^c_t = \vartheta x^h_t \tag{A7}$$

$$r^h_{t+1} = r_t - \nu^h \left(n^h_{t+1} - q_t - h_{t+1} \right) \tag{A8}$$

$$r^h_{t+1} = (1-\mu^h) x^h_t + \mu^h q_{t+1} - q_t \tag{A9}$$

(A10) $$d_t = s(n^h_{t+1} - q_t - h_{t+1})$$

(A11) $$r^h_{t+1} = r_t - \nu^o \left(n^e_{t+1} - q_t - o_{t+1}\right)$$

(A12) $$r^h_{t+1} = (1-\mu^o)(y_{t+1} - o_{t+1} + x^c_{t+1} - x_{t+1}) + \mu^o q_{t+1} - q_t$$

(A13) $$q_t = (1-\gamma) i_{z,t} + x_{c,t}$$

(A14) $$t_t = \frac{O}{T} o_t + \frac{h}{T} h_t$$

(A15) $$c^e_t = (1/\phi^o) r^o_t + (1 - 1/\phi^o)\, r_t + \left(1 + \mu^o \frac{\phi^o - 1}{\phi^o}\right) n^e_{t-1} - \mu^o \frac{\phi^o - 1}{\phi^o} (q_{t-1} + o_t)$$

2. Aggregate supply

(A16) $$y_t = a_t + (1-\alpha) m_t + \alpha o_t$$

(A17) $$w_t = y_t - m_t - x_t + x_{c,t}$$

(A18) $$C^p_t + \varphi m^p_t = w_t$$

(A19) $$m_t = m^p_t$$

(A20) $$z_t = \gamma i_{z,t}$$

(A21) $$\pi_t = \kappa(-x_t) + \beta\pi_{t+1}$$

3. The evolution of state variables

(A22)
$$n^h_{t+1} = R^h[(1/\phi^h)r^h_t + (1-1/\phi^h)r_t + (1+\nu^h\frac{\phi^h-1}{\phi^h})n^h_{t-1} - \nu^h\frac{\phi^h-1}{\phi^h}(q_{t-1}+h_t)] - (R^h-1)d_t$$

(A23) $$n^e_{t+1} = \nu * R^o[(1/\phi^o)r^o_t + (1-1/\phi^o)r_t + (1+\nu^o\frac{\phi^o-1}{\phi^o})n^e_{t-1} - \nu^o\frac{\phi^o-1}{\phi^o}(q_{t-1}+o_t)]$$

(A24) $$t = (1-\delta)t_{t-1} + \delta z_t$$

4. Monetary policy and shock processes

(A25) $$r^n_t = \rho r^n_{t-1} + (1-\rho)\zeta\pi_{t-1} + e^{rn}_t$$

(A26) $$g_t = \rho_g g_{t-1} + e^g_t$$

(A27) $$a_t = \rho_a a_{t-1} + e^a_t$$

(A28) $$r^n_t = r_t + \pi_{t+1}$$

(A1) is the goods market clearing. (A2) and (A3) are the consumer's first-order conditions for consumption. (A4) is the aggregate consumption of normal consumers and ROT consumers. The demand for nondurable goods and house services are (A5) and (A6). (A7) is the price relationship. The external finance premium for homeowners and entrepreneurs are (A8) and (A11). The definitions of return for house and office are respectively (A9) and (A12). (A10) represents the transfer rule. (A13) is the house price definition and (A14) is the house market clearing. The entrepreneur's consumption is (A15).

(A16) is the production function. The combination of (A17), (A18) and (A19) is the labor market clearing conditions. (A20) is the house production function. The New Keynesian Phillips Curve is (A21). (A22), (A23) and (A24) are the law of motions for homeowner's net worth, entrepreneur's net worth and house stock. (A25) is Taylor rule. The exogenous process of government expenditure and productivity are (A26) and (A27). (A28) is the definition of real interest rate.

B Appendix: Parameters Calibration

$\frac{c}{Y}$	0.6
$\frac{C^e}{Y}$	0.05
$\frac{I_Z}{Y}$	0.25
$\frac{G}{Y}$	0.1
η	1
$\vartheta = -\frac{1-\lambda}{\lambda}$	-0.14
$\nu^h = \frac{f'(\phi^h)}{f(\phi^h)}\phi^h$	0.1
$\nu^o = \frac{\Phi'(\phi^o)}{\Phi(\phi^o)}\phi^o$	0.05
ϕ^h	1/1.4
ϕ^o	0.5
$\mu^h = \frac{1-\delta}{R^h}$	0.978
$\mu^o = \frac{1-\delta}{R^o}$	0.969
α	0.35
δ	0.01
υ	0.973
θ	0.75
β	0.99
κ	0.0858
ζ	2
φ	1
R^h	1.012
R^o	1.021

C Appendix: Household Credit Constrain and Real Estate Producer

In this part we would demonstrate the distinct features of the correlation between residential and commercial housing market in Hong Kong, and provide additional motivation for modeling real estate producers explicitly in our paper. All our data are officially issued by Hong Kong Government, and therefore are of high quality. Particularly, the data of the residential and commercial land usage comes from first hand land auction record documented by Land Department in Hong Kong. The building data comes from the Building Department in Hong Kong.

Is housing equity an important asset in Hong Kong?

In Hong Kong, the net housing equity takes a large share of households wealth. Figure A1 displays the ratio of net housing wealth to nominal GDP. The net housing equity in private residential sector, estimated as the total market value of the private housing stock minus the total outstanding mortgage balance, was 3.7 trillion in 1997. At the same time, the total market value of stock market in Hong Kong was 5 trillion. Though the house prices have declined dramatically since 1997, the net housing equity was still 1.8 trillion in 2000. Another fact is that the property-related loans accounts for the largest share of total domestic credit since 1990s. The property-related loans comprise mortgage loans for the purchase of private residential property and loans for building and construction, property development and investment. Figure A2 shows this relationship. The actual share of property-related loans should be higher than the figure shown here because it doesn't include the consumer and corporate loans extended against property collateral. Although the data on the latter is not available, the Quarterly Bulletins of Hong Kong Monetary Authority (May 2001, March 2004) argued that there is a widespread practice of using property as collateral for consumer and business loans in Hong Kong.

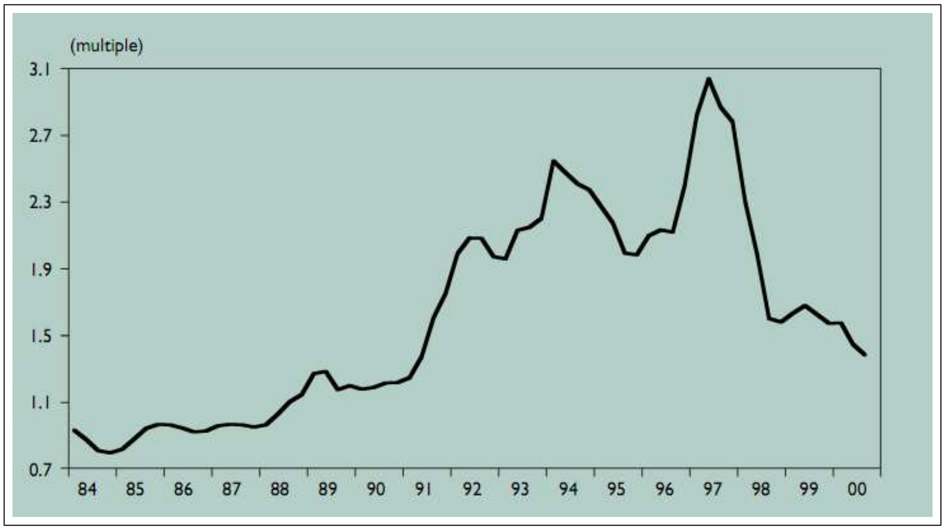

Figure A1: Ratio of Net Housing Wealth to Nominal GDP

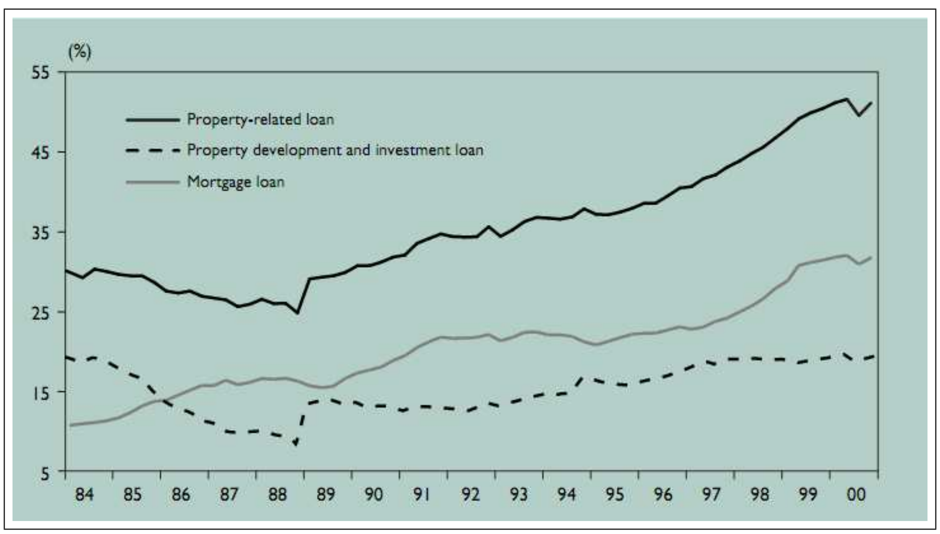

Figure A2: Share of Property-related Loan to Total Dometic Credit

Why should we focus on houses rather than land?

We argue that land cannot reflect the fluctuations in the housing market of Hong Kong. First, a considerable proportion of new houses are supplied in the form of building upon the old ones rather than building on the new land. Figure A3 shows the area ratio of old extension building to new building for residential and commercial usage. Though changing sharply from year to year, the average ratio for residential structure is 0.71 while it is 0.82 for commercial structure. Thus, land can't reflect the fluctuations of the old extension building, which accounts for a large fraction of the housing market.

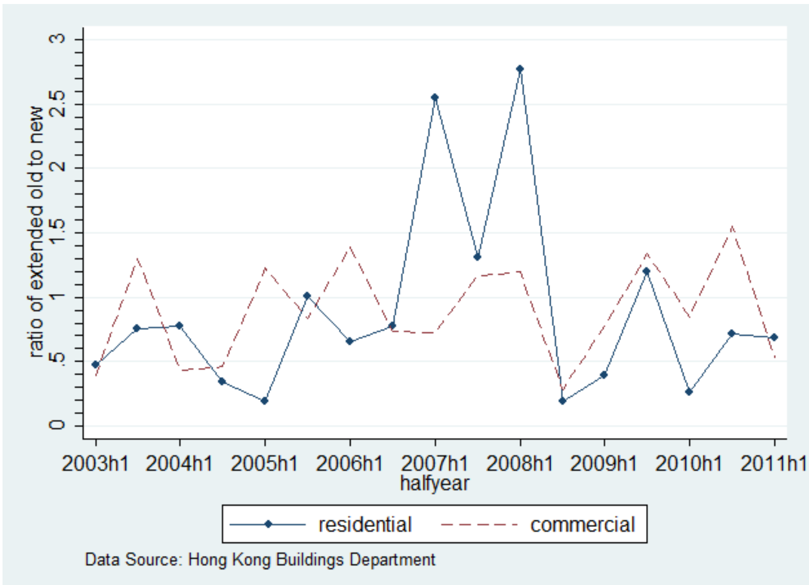

Figure A3: Area Ratio of Old Extension to New Building

Secondly, Being different from American, people of Hong Kong do not buy land and then build houses by themselves; instead, they buy apartments in high buildings and large mansions. According to the data from Hong Kong Building Department and Land Department, the average floor is 29 for commercial buildings and 10 for dwelling buildings from the 2000 to 2010. It would be far from reality if we put land rather than house into the utility function of representative household.

Clearly, based on the above two reasons, it is more natural to model the HOUSING market for Hong Kong rather than the LAND market. Specifically, to introduce houses, we should have real estate producers who use land and other final goods to build houses. In the next section, we turn to the land market of Hong Kong.

Hong Kong land policy: fixed land supply

Hong Kong is a city with small amount of land (1,100 sq.km.) relative to its large population (7,108,100). To preserve enough land for future, the authority auctions its land user rights every year according to a long-run land program. Most land contracts last for 75 years with some exception of 99 years or 999 years. According to Figure A4, the land auctioned by the government every year remains at the same level before and after the year of 2000 respectively, but dropped sharply in 2000. This is mainly because of some political reasons due to the sovereignty transfer from UK to China and the influence of SARS. If we ignore these political and exogenous shocks, it can be argued that there is a certain amount of new land supplied in the land market, and the amount maintains at the same level every year. This is the motivation for us to model a fixed supply of land, L, for real estate producers each period.

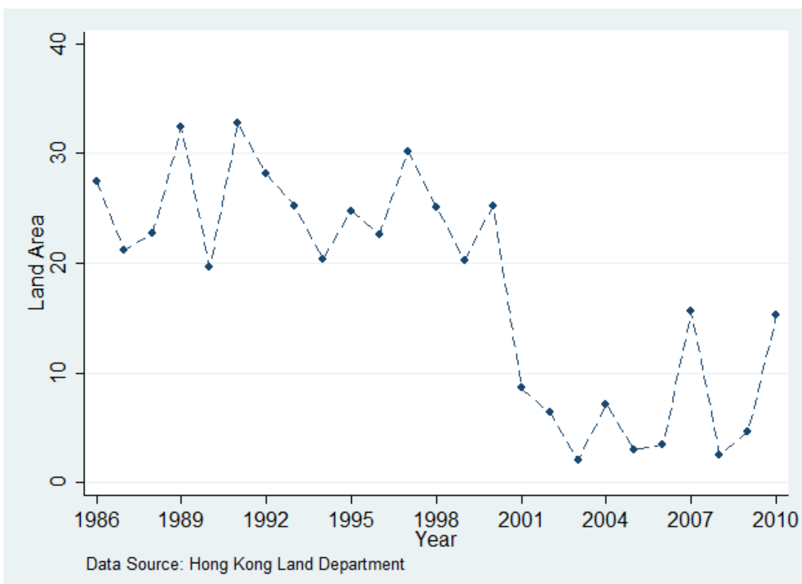

Figure A4: Yearly Land Area Auctioned by the Government

(Notes: Before the sovereignty transfer in 1997, the prior authority aimed to sell more land to return funds back to the UK Government. Moreover, owing to the impacts of SARS in 2003, the local authority began to use the list system to sell land user rights instead of the regular land auctions.)

Residential and commercial usage: no substitution

The distinct difference between our model and the prominent work of Liu, Wang, and Zha (2011) is that we do not depend on the conversion between commercial land and residential land. Rather, we have a supply of new houses every period produced by the real estate producer. The new houses are added to the housing stock and then reallocated among households and entrepreneurs. The transform from residential houses to business offices is not likely to happen since we have the credit constrain both in the household sector and entrepreneur sector. We would show that our mechanism is much better at least for the case of Hong Kong.

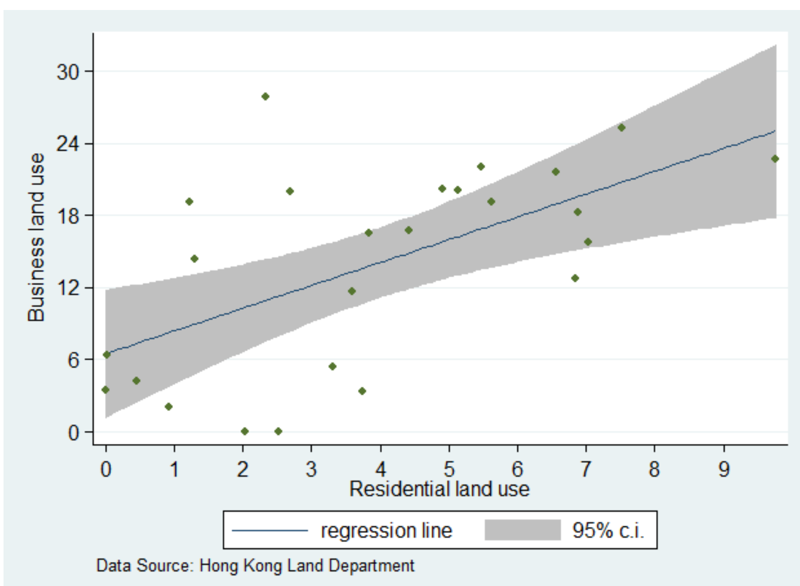

Figure A5: Land Area for Residential Usage and Business Usage

We first check the land data. Figure A5 shows the scatter between land areas for residential use and business use. This is a yearly data from 1986 to 2010, and each point in the figure represents a specific year. As the fitted line shows, there is a positive correlation between two distinct land purposes. The correlation is 0.5891 and significant at the 1% level. This means there is no substitution between two land styles.

As we have argued before, it is more nature to focus on the buildings rather than land for Hong Kong housing market. Therefore, we turn to the relationship between residential and commercial building areas. Figure A6 illustrated the monthly time series of building areas for two usages from May 2000 to September 2010. Though the variance of business area is larger than the residential one, their fluctuations are generally similar. Figure A7 shows the scatter of residential and commercial housing area. Clearly, they do not own a negative correlation; instead, the calculated correlation coefficient is 0.0814 and insignificant at any normal level. This can be understood as a reaction to the common aggregate economic environments. When the economy is booming, demands for both residential and commercial structure might be aroused, and vice versa. Thus, a negative relation as in Liu, Wang, and Zha (2011) is not likely to happen.

Figure A6: Building Areas for Commercial and Residential Usage (time series)

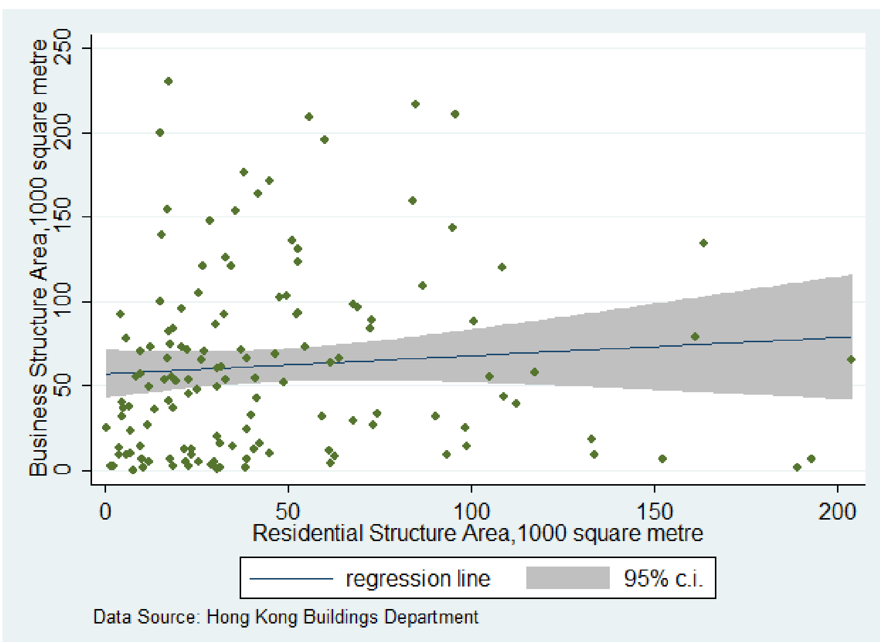

Figure 11: Figure A7: Housing Areas for Commecial and Residential Usage (scatter)

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Notes