Flight to Housing*

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Abstract

The 2007 global financial crisis has generated episodes of flight to liquidity and quality with lasting high uncertainty, especially in the age of the shortage of safe assets. This is particularly true for developing economies like China, in which financial market is underdeveloped and the financial account is tightly regulated. Moreover, both the household-level and aggregate data suggest a higher economic uncertainty boosts the price of housing with relatively good quality. Motivated by the empirical facts, we embed housings as safe assets into a dynamic general equilibrium model with incomplete markets. With calibration on the Chinese economy, we show that household's holding housing to fight against the increasing uncertainty delivers a housing boom, crowding out resources that could have been allocated to the real sector, and resulting in a recession. We further incorporate the major policy intervention in Chinese housing market, i.e., the house-purchase limit policy, into our baseline model. Policy intervention does effectively curb the house prices and dampen the crowding out effect, but at the cost of restricting households' access to housings as the store of value, and thus lowers welfare by magnifying consumption dispersion. Consequently, the policy intervention faces a trade-off between macro-level stability and micro-level volatility.

Keywords: Safe Assets, Store of Value, Chinese Housing Boom, Household Heterogeneity, Policy Intervention

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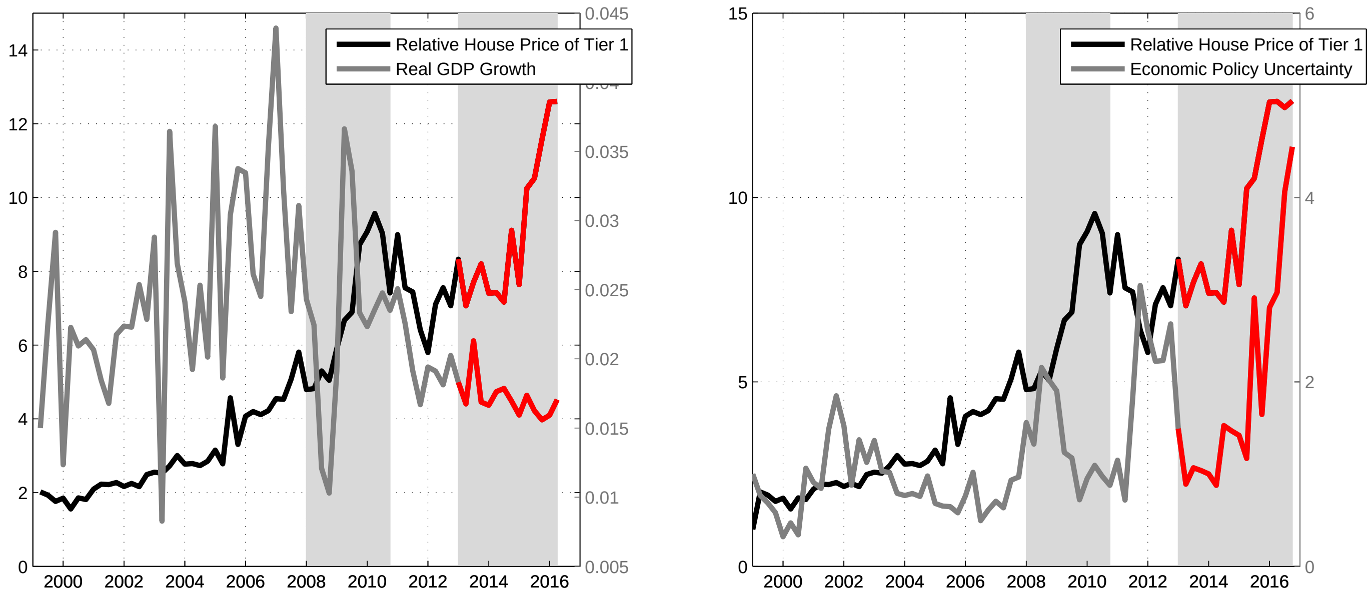
1 Introduction

As the second largest economy and the largest developing economy in the world, China has been not only the major engine of global economic growth during the past decade, but also contributing much to the global saving gluts. Therefore, not surprisingly China has a huge demand for safe assets as the store of value. However the underdevelopment financial market constrains the capacity of the country to produce safe assets. The scarcity of the safe assets in the domestic market is further intensified by the tight financial account regulation as it is costly for the individuals to hold those prime assets produced by the advanced economy (e.g., U.S.). The acute shortage of the safe assets makes the real estate (especially those with better quality) as a desirable candidate for the safe store of value in China.

The underlying mechanism of the global scarcity of safe assets as well as its aggregate consequences has been well documented in the recent literature (e.g., Caballero, Farhi, and Gourinchas, 2008, 2016; Gorton and Ordonez, 2013; He, Krishnamurthy, and Milbradt, 2016a; etc). While the theoretical works mainly focus on the safe assets in the form of debt instruments and their impacts on the advanced economies such as U.S. and European countries, the real assets (specifically the housings) as the store of value and the resulting consequences on the emerging economies such as China are rarely studied. China is the engine for the global saving gluts and the real estate constitutes the largest part of the household wealth in this country. The recent housing boom and the economic slowdown in Chinese economy provide an ideal scenario to identify the mechanism of the prime housing assets as the store of value. Thus we fill the gap in the literature by using Chinese economy as a laboratory to study the safe asset shortage conundrum.

Figure 1 gives a first look at the housing market and the real economy in China. The left panel presents the relative house prices in Beijing and Shanghai to the country-level house prices and the real GDP growth. It can be seen that prior to 2013 the starting point of China's recent economic downturn, the relative house prices in Tier 1 cities grow rapidly along with an average high GDP growth rate. Afterwards the economic growth decelerates, the house prices in Tier 1 cities (comparing to other cities) undertakes a new wave of boost. The upswing in the house prices in Tier 1 cities

Figure 1: Relative House Prices in Tier 1 Cities and Economic Uncertainty[1]



Notes: The house price is the average price of commercial housing. The relative house price is the difference of real house prices in Tier 1 cities (Beijing and Shanghai) and the country-level of real house price. The value in first period is normalized to be 1. The house price and EPU series are from 1999Q1 to 2016Q4, the GDP growth series is from 1999Q1-2016Q1. The shadow bars indicate respectively the financial crisis and 4-trillion fiscal expansion periods (2008Q1-2010Q4) and the recent economic downturn periods (2013Q1-2016Q4). The Data Appendix A.2 provides more details about the construction of these series.

under the adverse economic condition broadly supports the role of prime housing assets as the store of value, in the sense that the safe asset is the one expected to preserve its value during the adverse systemic events (Caballero, Farhi, and Gourinchas, 2017). The shortage of safe asset is further exacerbated by the strong precautionary motive for insuring the economic uncertainties because of the severe financial constraint. The right panel in Figure 1 presents the relative house prices in Tier 1 cities and the Baker-Bloom-Davis (Baker, Bloom, and Davis, 2016) economic policy uncertainty (hereafter EPU) index, a proxy for the aggregate uncertainty. It shows that the house prices in Tier 1 cities negatively comove with the EPU prior to 2013 when the aggregate uncertainty stays at a low level, but afterwards two series present strongly positive comovement when the aggregate uncertainty soars. This provides a general evidence that Chinese households tend to demand more prime housing assets as a store of value when the economic uncertainty rises.

[1]The house price indices we construct do not control the quality. A more reliable construction method is Fang et al. (2016). However, the housing price series in that paper are only up to 2013Q1 which does no cover the recent economic downturn periods. As their housing data is from confidential source, we are not able to extend theirs to

In the empirical analysis, we formally document the fact that the economic uncertainty stimulates the demand of housing assets with relatively good quality. In particular, we employ both household level transaction data in Beijing and the aggregate time series data for the cities with different tiers. The detailed transaction data allows us to consider various dimensions of good quality. The regression analysis shows that the economic uncertainty significantly raises the relative prices of those housings with better quality. The pattern is fairly robust for various dimensions of quality as well as different model specifications. For the aggregate time series data, we build up a structural time-varying-parameter vector autoregressive model (TVP-VAR) to identify the potential impact of the uncertainty shocks on the house prices in Tier 1 cities relative to other cities. The responses show that during the recent economic slowdown a positive economic uncertainty shock elevates the price dispersions between Tier 1 cities and other cities. Furthermore, the aggregate investment series show that the expansion in housing market in Tier 1 cities crowds out the real sectors, which confirms the recent firm-level evidences (Chen et al., 2016).

To quantify the empirical findings, we construct a general equilibrium framework in which the housing assets (corresponding to those with good quality in the real data) emerge as the store of value. Our model features the heterogenous households with incomplete market. The liquidity constraint confines the households' capacity to insure the idiosyncratic uncertainties. As a result, the housing assets play as a role of the liquid wealth (Heathcote and Perri, 2015). The house price (or the value of the house) in current period consists of the expected price and an extra term of liquidity premium. When the economy becomes highly uncertain (an upswing in idiosyncratic uncertainty), the demand for the housing as the store of value is greatly stimulated. The uplifted liquidity premium leads to a boost in house price. We then introduce this mechanism to a comprehensive but tractable dynamic general equilibrium economy with multiple sectors. The expansion of housing sector diverts the resources allocated to real sector, resulting in an aggregate recession. After calibrating the model to the Chinese economy, we find a 25% increase in the uncertainty sharply raises the equilibrium house

most recent date. To verify the validation of our house price series, we compare the relative house price in Tier 1 cities in our data (from 2003Q1-2013Q1) with that in Fang et al. (2016). We find two series track each other closely. The cyclicality of both series presents very similar pattern. The correlation between two series is significantly positive and around 0.6.

price by 20%. The transition dynamics suggest that a rise in uncertainty causes a sizeable decline in the real GDP because of the crowding out effect from the housing sector.

In order to curb the recent housing boom in big cities, the Chinese government implements a strict house-purchase limit policy which confines the quantity of house that the individuals can purchase. We provide a quantitative evaluation on this type of market intervention. The tractability of the model allows us to analytically derive the process of the aggregate house prices as well as the individual optimal decisions after the intervention. We show that the house-purchase limit policy can effectively impede the demand for housings and thus the housing boom. The dampened crowding out effect from the housing sector mitigates the adverse consequence of economic uncertainty on the real sector. However, the policy intervention also circumscribes the capacity that the households can insure the economic uncertainties, resulting in a larger dispersion in the consumption distribution. The social welfare is reduced under the house-purchase limit policy. Therefore, there exists a trade off between the aggregate stability and the household-level consumption volatility for the policy intervention.

Literature Review The current paper is generally related to an extensive volume of literature which we do not attempt to go through here. Instead, we only highlight papers that are most closely related. To begin with, the flight to liquidity and quality in the past financial crisis has created a huge demand for the analysis of the shortage of safe assets. Our paper contributes to the literature on the shortage of safe assets. The empirical work by Krishnamurthy and Vissing-Jorgensen (2012) visit the aggregate demand for US government bond, and decomposes the credit spread between risky assets and Treasury assets into liquidity premium and safety premium. Caballero, Farhi, and Gourinchas (2016) and Caballero and Farhi (2017) explore the macroeconomic implications of safe asset shortages. Benigno and Nisticò (2017) study how monetary policy affects real economy when safe and "pseudo-safe" assets coexist in equilibrium. He, Krishnamurthy, and Milbradt (2016a,b) and Gorton and Ordonez (2013) develop a theory of endogenous safe assets. More broadly speaking, in addition to government bond (issued by US and many OECD countries), money is among the most safe and liquid assets, serving the role of store of value. In particular, our model is well connected with Wen (2015), which develops a tractable Bewley model with micro-founded money demand. Relevantly, Quadrini (2017) show that, in addition to the standard lending channel, the financial intermediation affects the real economy through a novel banking liability channel by issuing liabilities, which is recognized as safe assets by agents facing uninsurable idiosyncratic risk. See Caballero, Farhi, and Gourinchas (2017), Gorton (2017) and Golec and Perotti (2017) for the detailed survey on safe assets.

Secondly, our paper falls into the strand of literature on housing markets in developed and developing economies. Iacoviello (2005), Chaney, Sraer, and Thesmar (2012), and Liu, Wang, and Zha (2013) show that the collateral channel induced by housing can stimulate private investment in US.[2] In contrast, when switching to China, Chen et al. (2016) find that China housing boom turns out to crowd out real investment in net. Moreover, the fast-growing Chinese economy has encouraged a burgeoning literature on housing. Fang et al. (2016) empirically find that housing price has experienced enormous appreciation in the past decade by 2012, which was accompanied by equally impressive growth in household income, except in a few first-tier cities.[3] Moreover, Zhang (2016) empirically and quantitatively address the heterogeneous effects of housing price by investigating the relationship between inequality and housing price. Chen and Wen (2017) argue that China's housing boom is a rational bubble emerging naturally from its economic transition. In contrast, the framework developed by Han, Han, and Zhu (2015) link the house value to fundamental economic variables such as income growth, demographics, migration and land supply.[4] See Glaeser (2017) for a survey on Chinese housing markets.

Our paper is also related to the literature on household heterogeneity in canonical Bewley-Aiyagari-Huggett model. Household heterogeneity has received increasing attention recently, in particular the key channels of household's insurance and the heterogeneous treatment effect of monetary policy. To address the implication of the large decline of household's net worth between 2007 and 2013, Heathcote and Perri (2015) develop a monetary model in which households face idiosyncratic unemployment risk that they can partially self-insure using savings. Kaplan, Moll, and Violante (2016) revisit the transmission mechanism of monetary policy for household consumption in a Het-

[2]See Head, Lloyd-Ellis, and Sun (2014) among others for the recent development of search-based approach to housing markets.

[3]Zhang (2017) undertake a quantitative analysis based on the facts by Fang et al. (2016).

[4]See also Garriga et al. (2017) who analyze how rural-to-urban migration contributes the appreciation of housing price of big cities in China. And Diamond and McQuade (2016) for the discussion of amenity of big cities in US.

erogeneous Agent New Keynesian (HANK) model. Auclert (2017) evaluate the role of redistribution in the transmission mechanism of monetary policy to consumption. See Heathcote, Storesletten, and Violante (2009) for a comprehensive survey.

Finally, our work also belongs to a vibrant literature on the aggregate impact of economic uncertainty. Bloom (2009) and Bloom et al. (2012) construct a heterogeneous-firm model with non-convex capital and labor adjustment cost to show that the wait-and-see effect provides a major channel to propagate uncertainty shocks. Schaal (2017) highlight the role of labor market friction for amplifying the uncertainty shocks. Arellano, Bai, and Kehoe (2016), Christiano, Motto, and Rostagno (2014), Gilchrist, Sim, and Zakrajšek (2014), and Alfaro, Bloom, and Lin (2017) emphasize the financial frictions as a key channel to transmit the firm level uncertainties. In contrast, our paper documents the aggregate consequences of the microeconomic uncertainty through the lens of the shortage of safe assets.

The rest of the paper proceeds as below. To better motivate our work, we devote in Section 2 more empirical facts at both aggregate and disaggregate level. Section 3 presents a two-period toy model to illustrate the key forces behind the fully fledged dynamic model that will be studied in Section 4. In Section 4, we also describe and characterize the generalized model in partial and general equilibrium. We quantify the effects of uncertainty on housing and other variables of interest after calibration in Section 5. In Section 6, we initiate welfare analysis by investigating not only the aggregate implications, but also the heterogeneous treatment effects of policy intervention in housing sector. Section 7 concludes. Data description, details of time-varying-parameter (TVP) VAR, and proofs are relegated in the Appendix.

2 Empirical Facts

The direct consequence of the housing assets as the store of value is that households tend to demand more prime real estate assets when the economy become more uncertain. To test this hypothesis, we conduct empirical analysis based on the micro-level housing transaction data as well as aggregate time series data.

2.1 Evidences from Residential Housing Transaction Data

We first investigate the impact of economic uncertainty on the price dispersion between the housings (apartments) with relatively high quality (will be elaborated in a moment) and others. We use the monthly residential housing transaction data in Beijing from the first month in 2013 to the last month in 2016. The data is a representative sample of Beijing, which covers about 40-50 percent of total second-hand housing transactions in the sample period. The house price growth rate calculated from the sample is very close to the official statistics (i.e., the second-hand house price growth rate in Beijing from the NBS 70-cities house price index). See Appendix A.1 for more details about the representativeness of our data.

Since the quality of one apartment can be captured by a variety of characteristics, we consider five major indicators that represent the *good quality*: the apartment that (i) faces both north and south; (ii) was built less than 15 years; (iii) locates within the second ring of Beijing; (iv) is in the key-school zone; (v) has less than (or includes) two bedrooms.[5] In our empirical analysis, we will divide the whole sample into two subgroups according to each characteristics. To describe the uncertainty for the Chinese economy, we employ the economic policy uncertainty (EPU) index constructed by Baker, Bloom, and Davis (2016). To give a first look at the relationship between the relative demand of housing assets and the economic uncertainty, we compute the rolling correlation between the price dispersion of the quality and the economic policy uncertainty index. If the housing assets play an important role of the store of value, one would observe a positive relationship between the price dispersion between houses with different quality (or the quality premium) and the economic uncertainty. This is because in the underdeveloped financial market, a higher economic uncertainty may lead the households to demand more safe assets. In this sense, the increase in the quality premium, to a great extent, reflects the premium of holding safe assets.

Figure 2 presents the rolling correlation of the growth rate of EPU and the growth rate of the

[5] In China for the big cities like Beijing, the apartments with small size, e.g., less than three bedrooms, are more desirable for the buyers. In this sense, this type of apartments have relatively high quality than others. Also, we do not consider "close to the subway" and "with elevator" as indictors for the good quality. The reason is that for the former one, in our sample almost 93 percent of apartments in the transactions are classified as "close to the subway". For the latter one, as "the apartment with the elevator" is highly correlated with the third characteristics, we incline to not consider this feature as well.

price difference between the apartments with different level of quality. We employ five characteristics to define the good quality (see the aforementioned definitions) of an apartment. The price dispersion for each category of quality is the price ratio of the apartment with the good quality relative to the rest of the sample. From all the panels in Figure 2, we can see that there is a striking upward trend for the rolling correlation between the price dispersion for each category of quality and the economic uncertainty. This suggests that the relationship between the economic uncertainty and the demand for the housing assets with relative good quality becomes more positive. The above pattern remains robust if we look at the HP filtered series (with smoothing parameter 129,600) instead of the growth rate series.

To provide a rigorous analysis, we conduct following regression exercises based on the micro-level transaction data for Beijing's second-hand housing market. We specify the regression equation as

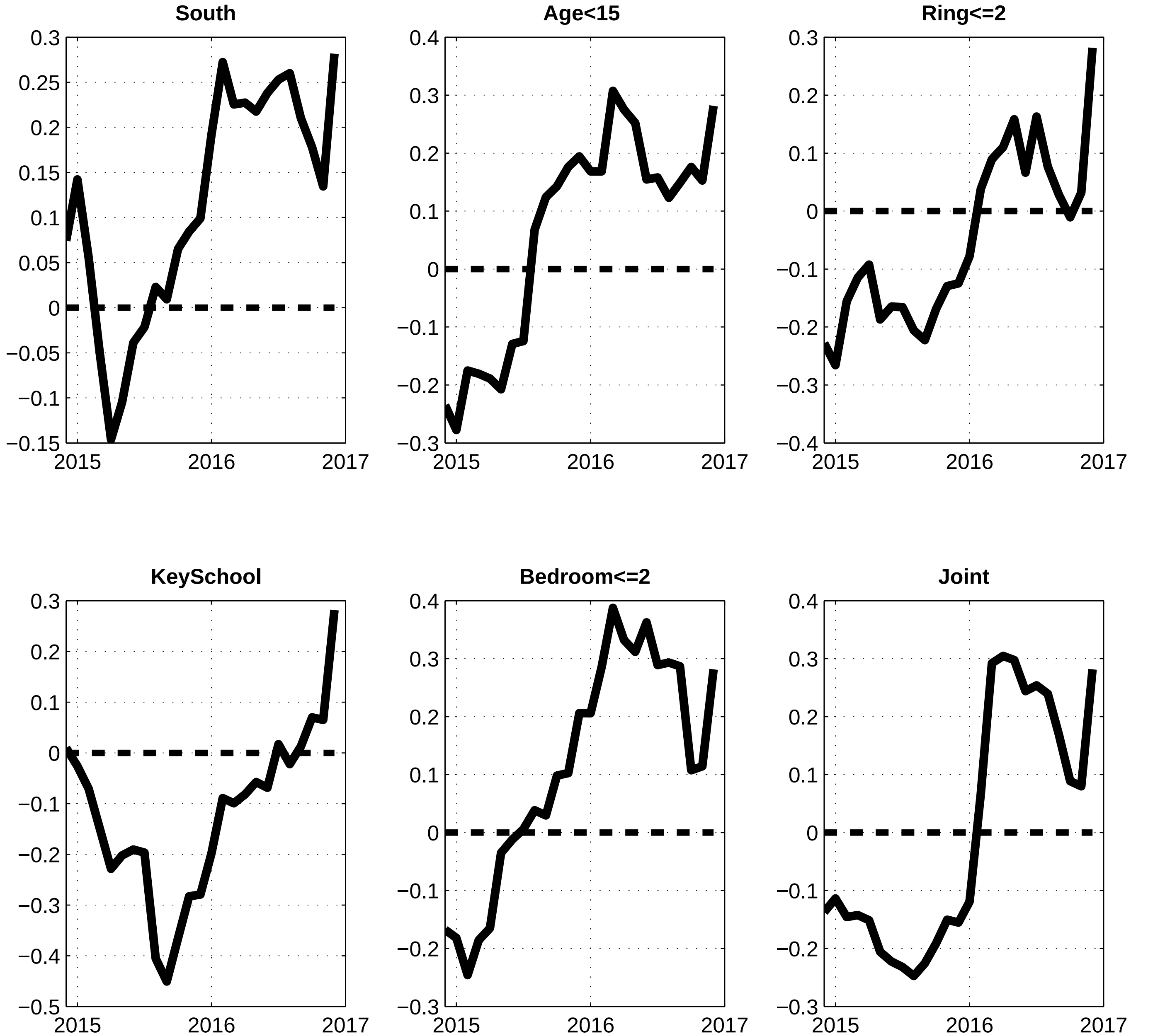
$$\ln p_t^{i,j} = \alpha_1^j + \alpha_2 \mathrm{EPU}_t + \alpha_3 I_{Good}^i \times \mathrm{EPU}_t + \alpha_4 X_t^i + \alpha_5 Z_t + \varepsilon_t^{i,j}. \tag{1}$$

In the above equation, $p_t^{i,j}$ denotes the price per square meter for the house i at time t and region j; α_1^j is the term for the address fixed effect; EPU is the measure of economic policy uncertainty index divided by 1000; I_{good}^i is an indicator for housing with good quality, i.e., aforementioned five categories such as in key-school zone, facing both south and north direction, with the age less than 15 years, with the location within the second ring of Beijing, and with less than three bedrooms; X_t^i indicates a bunch of control variables including quadratic polynomial of size, age of building, the height of the floor, whether the building is close to the subway, whether the building has elevator, and distance to the closest primary school, etc; Z_t denotes the aggregate time dummies that aim to capture the aggregate shocks or the common trend to housing price growth. In the estimation, we also consider year fixed effect, month fixed effect, and the deal date fixed effect.

Table 1 summarizes the baseline estimation results. It shows that the economic uncertainty significantly raises the level of the house prices in Beijing. The houses with relatively good quality (belongs to one of the five categories) generally have higher prices, one exception is the location[6].

[6]The possible reason is that the house price is not monotonic function of distance to the center. There are newly developed areas that attract high-income people, such as the Zhongguancun village where a lot of employee at IT

Figure 2: Rolling Correlation between Uncertainty and Quality Premium



Notes: The quality premium is the ratio computed as the cross-sectional average price of apartments with good quality divided by that of the rest of the sample. Since both the quality premium and the economic policy uncertainty present upward trend, we compute their growth rates. The time series are monthly frequency from 2013M2 to 2016M12. The length of moving window is 24 months (2 years). Five categories for the good quality are considered: "South" for the apartment faces both south and north; "Age$\leq$15" for the apartment with the age less than 15 years; "Ring $\leq$ 2" means the apartment locates within second ring in Beijing; "Key School" for the apartments belongs to key-school zone; "Bedroom $\leq$ 2" for the apartment with at most two bedrooms; "Joint" for the apartment with all above five features.

More importantly, the economic uncertainty has significant positive impact on the relative price between the houses with better quality and those in the rest of the sample. For instance, for the regression in column (5), one unit of increase in economic policy uncertainty would raise the relative price of (i) the house within key-school zone by 8%; (ii) the house facing south by 4%; (iii) the house with age less than 15 years by 4%; (iv) the house locating within the second ring in Beijing by 10% ; (v) the house with less than three bedrooms by 3%. [7] The positive impact of uncertainty on the price dispersion for the houses with good quality provides a direct evidence for the prime houses as safe assets, in the sense that the safe asset is an asset that is expected to preserve its value during the adverse systemic events (Caballero, Farhi, and Gourinchas, 2017).[8]

The above finding is quite robust for the various specifications of the regressions, see columns (5)-(8). The main difference between columns (5)-(8) and (1)-(4) is the newly added deal-date (the month in which the property is sold) dummy. We incorporate this dummy into the baseline regressions because of a concern that the other aggregate factors (e.g., monthly unemployment rate, monthly GDP growth, etc) may also affect the housing price. After controlling for the deal-date fixed effect, we cannot identify the main effect of EPU on the reference group due to the co-linearity problem. However, we can still identify the EPU's impact on the control group by looking at the interaction term. We find that the coefficients before the interaction term hardly change after we control for the deal-date fixed effect.

2.2 Evidences from Aggregate Time Series Data

The micro-level transaction data in Beijing confirms the argument that a higher uncertainty leads to a stronger demand for the housing assets with better quality. As the fundamental of housings in Tier 1 cities is generally better than those in other cities, we would expect to observe a similar positive

industry are living there, and hence raise local housing prices. This explains the coefficient before location is not significantly different from zero at 1 percent confidence level.

[7] Notice that we normalize the Baker-Bloom-Davis economic policy uncertainty index by 1000, so one unit change of this index in the regression corresponds to 1000 points change in the raw index. If we consider the change of one unit of standard deviation of EPU, the regression results correspond to 1% for houses within key-school zone; 0.5% for houses facing south; 0.5% for houses with age ≤ 15; 1.3% for houses within second ring in Beijing; and 0.4% for houses with less than three bedrooms.

[8] The housings with good quality also satisfies the definition of safe asset in Gorton (2017): a safe asset is an asset that can be used to transact without fear of adverse selection.

Table 1: Impact of Economic Uncertainty on the House Prices

Dependent Var.: $\ln p_t^{i,j}$	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
EPU	$.19^{***}$	$.18^{***}$	$.15^{***}$	$.14^{***}$	$.12^{***}$	—	—	—	—	—
	(23)	(17)	(12)	(11)	(9)					
KeySchool	$.03^{***}$	$.03^{***}$	$.03^{***}$	$.04^{***}$	$.04^{***}$	$.03^{***}$	$.03^{***}$	$.03^{***}$	$.04^{***}$	$.04^{***}$
	(14)	(14)	(14)	(15)	(15)	(14)	(15)	(14)	(15)	(15)
EPU×KeySchool	$.09^{***}$	$.09^{***}$	$.10^{***}$	$.08^{***}$	$.08^{***}$	$.09^{***}$	$.09^{***}$	$.10^{***}$	$.09^{***}$	$.09^{***}$
	(11)	(11)	(12)	(10)	(10)	(12)	(12)	(13)	(11)	(11)
South		$.06^{***}$	$.06^{***}$	$.06^{***}$	$.06^{***}$		$.06^{***}$	$.06^{***}$	$.06^{***}$	$.06^{***}$
		(23)	(24)	(24)	(23)		(25)	(25)	(24)	(24)
EPU×South		$.02^{**}$	$.03^{***}$	$.03^{***}$	$.04^{***}$		$.02^{**}$	$.03^{***}$	$.03^{***}$	$.03^{***}$
		(2.2)	(3.1)	(3.9)	(4)		(1.8)	(3.2)	(3.8)	(3.9)
Age$\leq$ 15			$.05^{***}$	$.05^{***}$	$.05^{***}$			$.04^{***}$	$.04^{***}$	$.04^{***}$
			(18)	(18)	(17)			(16)	(16)	(16)
EPU× (Age $\leq$ 15)			$.04^{***}$	$.04^{***}$	$.04^{***}$			$.05^{***}$	$.05^{***}$	$.06^{***}$
			(4.6)	(4.4)	(5.2)			(6.7)	(6.5)	(7.1)
Ring$\leq$ 2				$-.01^{**}$	$-.01^{**}$				$-.01$	$-.01$
				(-2.4)	(-2.2)				(-1.5)	-1.4
EPU× (Ring$\leq$ 2)				$.10^{***}$	$.10^{***}$				$.09^{***}$	$.09^{***}$
				(9)	(9)				(8)	(8)
Bedroom$\leq$ 2					$.01^{***}$					$.01^{***}$
					(4)					(4)
EPU×(Bedroom$\leq$ 2)					$.03^{***}$					$.02^{***}$
					(3.1)					(2.9)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Deal Date dummy						Yes	Yes	Yes	Yes	Yes
No. of Obs	139,163	139,163	139,163	139,163	139,163	139,163	139,163	139,163	139,163	139,163

Notes: The numbers in parentheses are t-statistics; *** p <0.01, ** p<0.05, and * p <0.1.

impact of the economic uncertainty on the house prices in Tier 1 cities relative to those in other cities. In this section, we aim to document this relationship through a structural VAR approach based on aggregate time series data. For the house prices, we particularly employ the quarterly time series of the relative house prices in two Tier 1 cities, Beijing and Shanghai, to the country-level house prices.[9]

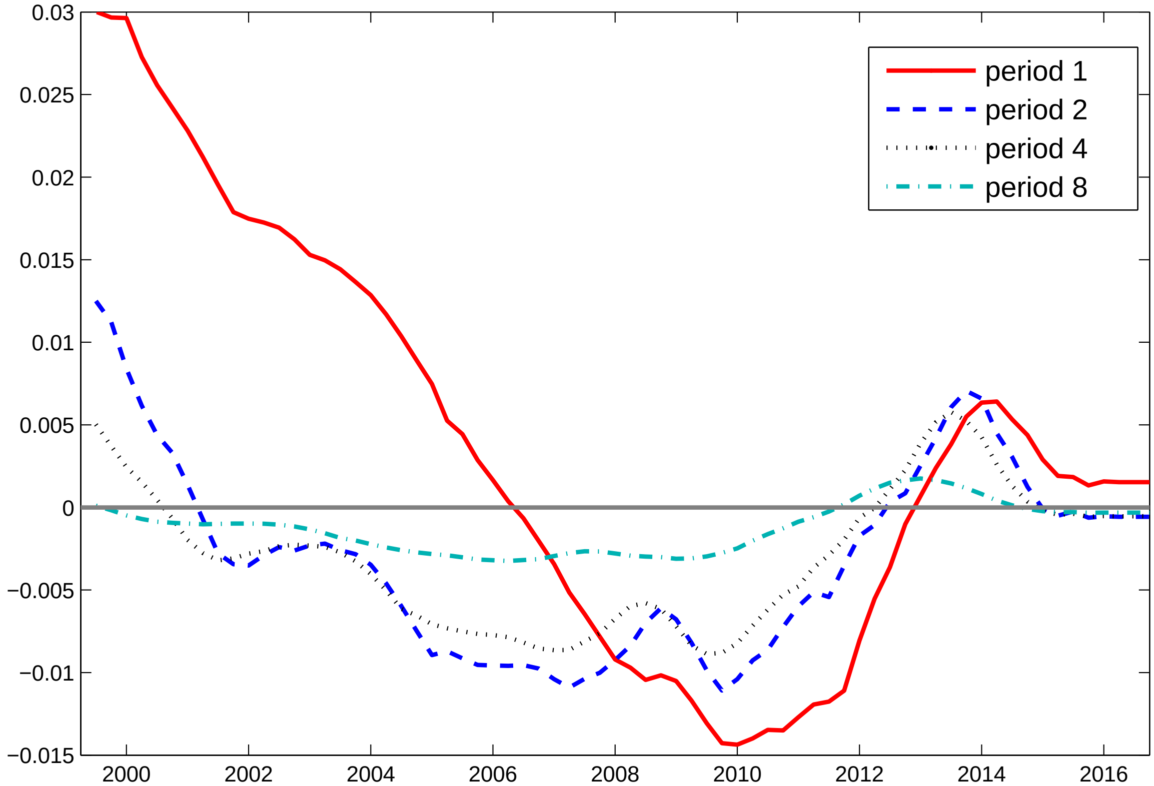
As the relationship between the house prices and the economic uncertainty presents potential structural changes, we employ the time-varying-parameter (TVP) VAR approach to conduct the quantitative analysis of the impact of uncertainty shocks on the house prices, see Appendix B for more details about our TVP-VAR model. In particular, we consider a [House Prices, EPU] two-variable VAR system. Following Bloom (2009), the uncertainty shock is identified via the Cholesky identification scheme, more specifically the second shock in the VAR system which only has impact on the EPU in the first period and will affect the house prices afterwards. To see the dynamic responses of the house prices to the uncertainty shocks along the sample periods, we report the magnitude of impulse responses in periods 1, 2, 4 and 8 (the impact period is period 0) for each date from 1999Q3 to 2016Q4.

Figure 3 shows that in the early 2000 when the Chinese government launched the housing market reform, an upswing in economic uncertainty raises the relative house prices in Tier 1 cities (see the red line for responses of the house prices in period 1). While, the positive impact becomes weaker and weaker, and eventually turns to be negative during the financial crisis and 4-trillion fiscal expansion periods. Afterwards, the responses of house prices to the uncertainty present a strong upward trend that makes the impact of uncertainty more and more positive. After 2013, eventually the responses of house prices turn to be strictly positive, i.e., the price difference between Tier 1 and other cities gets even larger when the economy is more uncertain. The positive relationship between the uncertainty and the price difference is consistent with our previous micro-level evidences. That is, a higher economic uncertainty boosts the demand for the housing with relatively good fundamental and therefore raises the relative prices of these housing assets.

In sum, both of the micro-level and the aggregate time series evidences suggest that the Chinese

[9]The Tier 1 cities also include Guangzhou and Shenzhen, however the time series of house prices for these two cities are relatively short, so in the baseline analysis we only consider Beijing and Shanghai as Tier 1 cities.

Figure 3: Dynamic Impacts of Uncertainty Shock to House Prices



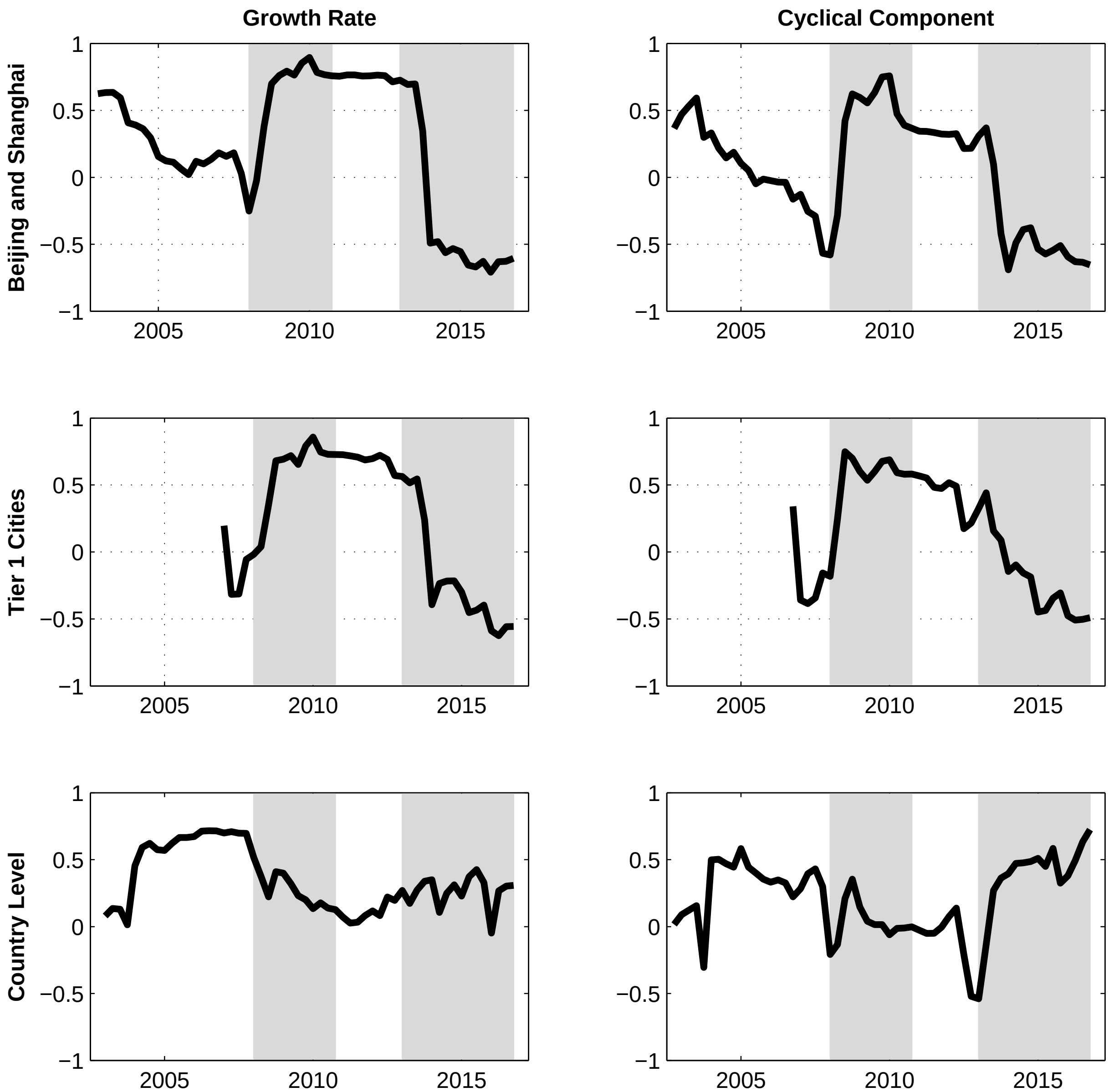
Notes: We consider the two-variable VAR system with the log of house prices ranked as the first, and the log of EPU as the second. The relative house price is the difference of real house prices in Tier 1 cities (Beijing and Shanghai) and the country-level price. The value in first period is normalized to be 1. Both series are from 1999Q1 to 2016Q4. We follow Bloom (2009) to HP filter all the series with smoothing parameter of 1600. The main pattern remains robust for the case of growth rate. We identify the uncertainty shock as the second innovation in the Cholesky decomposition. The number of lag is set to be 2. The estimation procedure of this TVP-VAR model is conducted by using the Matlab program developed by Nakajima (2011). The line for period j corresponds to the level of impulse responses of house prices in the period $j+1$ to a one-standard deviation increase in the EPU index.

people demand more housings with relatively high quality when the economy becomes more uncertain. This suggests that the housing assets may play an important role of safe assets to insure the economic uncertainties.

Aggregate Impact of Housing Booms The housing assets as the store of value may play an important role in the transmission of aggregate fluctuations. The literature suggest that the boom of housing market may stimulate the private investment in the real economy through the collateral channel (Liu, Wang, and Zha, 2013; Chaney, Sraer, and Thesmar, 2012). While, the recent empirical research (Chen et al., 2016) finds that the expansion of Chinese real estate sector may have adverse impact on the private investment due to the crowding out effect. To document the relation between the investments in housing sector and in other sectors, we compute the rolling correlation of cyclical component of fixed asset investment in housing sector and in other sectors in Tier 1 cities. The first line in Figure 4 shows that during the financial crisis and 4-trillion fiscal expansion periods (2008Q1-2010Q4), two investment series for the Tier 1 cities (Beijing and Shanghai) are positively correlated with the correlation around 0.5. While, during the recent economic downturn periods (2013Q1-2016Q4) the correlation of two investment series declines sharply and ultimately achieves -0.5 in the fourth quarter of 2016. For the overall four Tier 1 cities including Beijing, Shanghai, Guangzhou and Shenzhen, two investment series (the second line in Figure 4) present a very similar pattern. The divergent dynamics between the investments in housing sector and in other real sectors, during the recent economic downturn periods, supports the argument that housing sector may adversely affect the real economy by crowding out the resources allocated to real sectors.

For the country level investments in the housing sector and other sectors (the first graph in the last line in Figure 4), however there is no clear relationship between growth rates of two investments. Moreover, the cyclical components of two investment series (the second graph in the last line in Figure 4) even present a positive correlation during the recent economic downturn. The above observation suggests that the real estate market for relatively high quality housing assets, e.g., those in tier 1 cities, may cause more severe crowding out effect on the real economy relative to the markets in other low tier cities.

Figure 4: Rolling Correlation: Real Investment in Housing Sector and in Other Sectors



Notes: Both investment series are real and adjusted by the GDP deflator. For Beijing and Shanghai, the investment series cover periods from 1999Q1 to 2016Q2; for four tier 1 cities, the series cover periods from 2003Q1 to 2016Q4; for country level data, the series cover periods from 1999Q1-2016Q4. For cyclical components, all the series are HP filtered with smoothing parameter of 1600. The width of rolling window is four years, i.e., 16 quarters. The main pattern remains robust for the window width. The shadow bars indicate respectively the financial crisis and 4-trillion fiscal expansion periods (2008Q1-2010Q4) and the recent economic downturn periods (2013Q1-2016Q4).

3 A Toy Model

Motivated by the empirical findings, we embed housing as safe assets into a canonical incomplete market model. To convey the basic intuition, we start with a simple two-period partial equilibrium model. We show that the households would endogenously use housing as the store of value. The rise of economic uncertainty will lead to a housing boom. The economy is populated by heterogeneous households with one unit measure. Each individual lives only two periods indexed by $i \in [0, 1]$. In the first period, the household inelastically provides one unit of labor and receives wage income w which is identical among households. We assume that each household is facing an idiosyncratic shock θ_i that affects the income w, so the eventual income available to individual i is $\theta_i w$. The idiosyncratic income shock θ_i follows CDF $\mathbf{F}(\theta_i)$ on the support $[\theta_{\min}, \theta_{\max}]$. After the realization of θ_i, the household chooses the consumption c_{i1} and the housing holdings h_i given the house price q.[10] Since no aggregate uncertainties are involved, we only consider the stationary equilibrium where the house price is time invariant. In the second period, the households receive a fixed amount of government transfer τ. They finance their consumptions by selling housing holdings to the market (with depreciation rate δ_h) at the price q and by the government transfer τ.[11] So the budget constraint in two periods are $c_{i1} + qh_i = \theta_i w$ and $c_{i2} = q(1 - \delta_h) h_i + \tau$, respectively. In addition, we assume that the housing holdings are subject to liquidity constraint $h_i \geq 0$. Given the realization of θ_i, the household i aims to maximize the lifetime utility $\log c_{it} + \beta \log c_{i2}$, where $\beta \in (0, 1)$, by choosing consumptions $\{c_{i1}, c_{i2}\}$ and housing assets h_i.

Remarks In reality, the housing assets in our model are particularly corresponding to those houses with relative good quality (e.g., apartments with at least one of the five characteristics, or those in Tier 1 cities), since these houses are relatively safe (or easy to sell on the market) comparing to other types of houses. The assumption that the housing with relatively good quality on average

[10] Note that to facilitate the analysis, we do not introduce other types of assets. In the dynamic model, we introduce the physical capital. However, as long as the housings are relatively liquid and safe assets, the main results remain the same.

[11] Here for the simplicity we assume there are some buyers in the housing market purchasing these assets. This partial equilibrium setup can be easily extended to a general equilibrium framework by introducing overlapping-generation structure. The households in young age purchase housings from the old generation and the housing producers. When they are old, they sell all the housing assets to next young generation. In this setup, the property of housing market equilibrium is exactly the same as that in the toy model.

is a relatively safe (and liquid) asset is based on several arguments. First, the Chinese economy is short of safe assets due to the under-developed financial market and the capital control policy. The scarcity of safe assets makes the housing, as a saving instrument, more desirable. Second, among the different types of housing assets, the housings belong to the five categories discussed in the previous empirical analysis (comparing to others) or the housings in Tier 1 cities (comparing to those in Tier 2 or 3 cities) are even more desirable. This is because on the demand side, the housings with these features in terms of residential purpose is more attractive due to the good fundamental, see for instance Davis and Van Nieuwerburgh (2014).[12] The stronger demand makes the housings with good quality relatively safe (or liquid). As a result, the households as investors are more willing to hold these housings.

The optimal condition implies the individual housing demand is

$$qh_i = \frac{\beta}{1+\beta}\theta_i w \max\left\{1 - \frac{\theta^*}{\theta_i}, 0\right\}, \tag{2}$$

where the cutoff satisfies $\theta^* = \frac{\tau}{(1-\delta_h)\beta w}$. The above equation gives the individual housing demand. It indicates that for the high income households (i.e., $\theta_i > \theta^*$), they tend to hold positive level of housing as liquid asset. For those with low income, they just consume all of their income and do not hold housings. Thus, the housing asset plays as a buffer to smooth the consumption. Comparing to the standard saving theory, the saving rate includes an extra term $\max\left\{1 - \frac{\theta^*}{\theta_i}, 0\right\}$ which is convex in θ_i. After the aggregation, we obtain the aggregate housing demand

$$qH = \Phi(\theta^*; \sigma)\frac{\beta}{1+\beta}w. \tag{3}$$

where $H = \int h_i di$ and $\Phi(\theta^*; \sigma) = \int \max\{\theta_i - \theta^*, 0\} d\mathbf{F}(\theta_i; \sigma)$. The term $\Phi(\theta^*; \sigma)$ captures the liquidity premium of holding housing assets. Since the function inside the integral of $\Phi(\theta^*; \sigma)$ is convex in θ_i, the Jensen inequality implies that a higher uncertainty (σ rises) would raise the premium $\Phi(\theta^*; \sigma)$ and therefore the aggregate housing demand.

[12] Indeed, even on the supply side, due to the local government's land control policy in Tier 1 cities, the amount of housing development is limited (Glaeser, 2017). This further exacerbates the shortage of good housing assets (those in Tier 1 cities) in China.

To characterize the supply of housing, we assume that there are two sectors: the real sector and the housing sector. The firms in real sector are competitive and produce consumption goods. For analytical convenience, we assume firms in this sector only use labor as input to produce. The production technology follows a linear function $y_p = a_p n_p$, where a_p is the TFP. The firms hire labor n_p at wage rate w. The profit optimization problem implies $w = a_p$ and zero profit.

The firms in housing sector are also competitive and employ labor, n_h at wage rate w and land, l, at price q_l to produce housings h^s with Cobb-Douglas technology $h^s = a_h n_h^{\gamma} l^{1-\gamma}$, where $\gamma \in (0,1)$ and a_h is the TFP.[13] Given the prices $\{q, w, q_l\}$, the firm chooses labor and land to maximize the profit $q a_h n_h^{\gamma} l^{1-\gamma} - w n_h - q_l l$. The optimal labor decision implies $\gamma q \frac{h^s}{n_h} = w = a_p$, where the second equality comes from the labor demand in real sector. For analytical convenience, we normalize the land supply to be 1, so the supply of new housing can be written as

$$h^s = a_h^{\frac{1}{1-\gamma}} \left(\frac{\gamma q}{a_p}\right)^{\frac{\gamma}{1-\gamma}}. \tag{4}$$

Given the initial stock of housing H_0, the total supply of housing in period 1 is

$$H = a_h^{\frac{1}{1-\gamma}} \left(\frac{\gamma q}{a_p}\right)^{\frac{\gamma}{1-\gamma}} + (1-\delta_h) H_0. \tag{5}$$

The equilibrium house price and quantity are determined by (3) and (5).

It is straightforward to show that a higher uncertainty raises the premium of holding housing $\Phi(\theta^*; \sigma)$, shifting the demand curve upwardly. As a result, the house prices boost and the housing market expands. The housing boom further increases the labor demand in this sector, which in turn crowds out the labor allocated to the real sector. As a result, the real sector shrinks. This captures the crowding out effect of the housing boom on the real economy.

[13] We assume that the labor market is competitive, so firms in housing sector pay the same level of wage rate as those in real sector. We also assume the land is provided by the central government, and the housing firms are take the land price as given.

4 The Fully Fledged Dynamic Model

We now construct a fully fledged dynamic general equilibrium model to quantitatively evaluate the impact of economic uncertainty on the housing market. In particular, we introduce the housing asset into an otherwise standard neo-classical model with incomplete market. Like the toy model, we assume the housing in the model only plays the role of store of value, so when the households are facing larger uncertainty, they demand more housing assets. Then we calibrate the model to Chinese economy and quantitatively evaluate the aggregate impact of housing boom. We also introduce the house-purchase limit policy into the baseline model and conduct the counter-factual policy analysis.

The economy consists of households who are facing idiosyncratic uncertainty, a housing sector that employ capital, labor and land to produce housing assets, a real sector that uses capital and labor to produce consumption and investment goods, as well as a government who controls the land supply. We assume households are owners of the firms in the production sectors. We start with the problem of heterogeneous households.

4.1 Households

The economy is populated by a continuum of households with measure one, who are indexed by $i \in [0, 1]$. In each period, the household i with disposable wealth X_{it} (will be elaborated later) is hit by an idiosyncratic shock, θ_{it}. We assume θ_{it} is independently and identically distributed among households and over time. The cumulative probability density $\mathbf{F}(\theta_{it})$ is on the support $[\theta_{\min}, \theta_{\max}]$ with mean 1 and time-varying standard deviation σ_t. So σ_t captures the household level economic uncertainty. Following Wen (2015), we divide each period into two sub-periods. In the first subperiod, prior to the realization of the idiosyncratic shock θ_{it}, the household makes the decisions of labor supply N_{it} and production asset holdings K_{it+1}; In the second subperiod, the idiosyncratic shock θ_{it} is realized. With the knowledge of θ_{it} the household purchases consumption good C_{it} and housing asset H_{it+1}. The above setup of timing implies that the housing asset can be used as a buffer to smooth the consumption and to ensure the idiosyncratic uncertainties caused by θ_{it}.

We now discuss the household's optimization problem. Following Wen (2015) we specify household's utility as a quasi-linear form in consumption and leisure, i.e., $\log C_{it} - \psi N_{it}$. To make the analysis more transparent, we abstract the residential role of housing. The household aims to maximize the life-time expected utility:

$$\max_{\{C_{it}, H_{it+1}\}} \mathbf{E}_0 \left[\max_{\{N_{it}, K_{it+1}\}} \tilde{\mathbf{E}}_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_{it} - \psi N_{it} \right) \right], \tag{6}$$

where β is discount rate; ψ is the coefficient of the disutility of labor; $\mathbf{E}$ and $\tilde{\mathbf{E}}$ denote, respectively, the expectation operators with and without the knowledge of θ_{it}. The budget constraint is given by

$$C_{it} + q_{ht} H_{it+1} = \theta_{it} X_{it}, \tag{7}$$

where q_{ht} is the real house price; X_{it} is the real disposable wealth excluding the purchase of investment in physical capital, [14]

$$X_{it} = (1 - \delta_h) q_{ht} H_{it} + w_t N_{it} + r_t K_{it} + D_t - \left[K_{it+1} - (1 - \delta_k) K_{it} \right], \tag{8}$$

where δ_k and $\delta_h \in (0, 1)$ are depreciation rates of capitals and housings, respectively; w_t and r_t are respectively the real wage rate and the real rate of return to physical capital; D_t is the profit distributed from the production side.

In addition, the amount of housing is required to larger than zero: [15]

$$H_{it+1} \geq 0. \tag{9}$$

This constraint indeed imposes a liquidity constraint for holding housing asset. As a result, when the household is facing larger economic uncertainty (σ_t increases), the household tends to hold more housing assets in order to reduce the risk of the binding liquidity constraint (9). Note that our model

[14] As discussed in Wen (2015), the disposable wealth defined in equation (8) guarantees an analytical solution of household's optimal decision.

[15] In principle we can allow the minimum requirement of the amount of housing to be a positive number. However, doing so may introduce additional type of friction on housing market and would unnecessarily complicate the model as well as the household's optimal decision on housing demand. Zhang (2016) provides more detailed analysis on this issue.

implicitly assume that the households rely on housing as a saving instrument to provide liquidity. This assumption is not unreasonable especially for Chinese economy. As we discussed previously, due to the under-developed financial market as well as the strict capital control policy, the supply of good-quality asset is limited. As a result, the housing becomes an ideal saving instrument for wealthy people. Technically speaking, we can also introduce other types of liquid assets. However, as long as the supply of these assets is limited, the main mechanism documented in this paper remains valid.

Let λ_{it} and η_{it} denote the Lagrangian multipliers for the budget constraint (7) and the liquidity constraint (9), respectively. The first order conditions with respective to $\{N_{it}, K_{it+1}, C_{it}, H_{it+1}\}$ are given by following equations

$$\psi = w_t \tilde{\mathbf{E}}_t(\theta_{it}\lambda_{it}), \tag{10}$$

$$\tilde{\mathbf{E}}_t(\theta_{it}\lambda_{it}) = \beta \mathbf{E}_t \left[(r_{t+1} + 1 - \delta_k) \tilde{\mathbf{E}}_{t+1}(\theta_{it+1}\lambda_{it+1}) \right], \tag{11}$$

$$\frac{1}{C_{it}} = \lambda_{it}, \tag{12}$$

$$\lambda_{it} = \beta(1 - \delta_h) \mathbf{E}_t \left[\tilde{\mathbf{E}}_{t+1} \left(\theta_{it+1}\lambda_{it+1} \right) \frac{q_{ht+1}}{q_{ht}} \right] + \frac{\eta_{it}}{q_{ht}}. \tag{13}$$

(10) describes the labor supply. (11) is the Euler equation for the inter-temporal decision of physical capital. Since the labor and capital decisions are made prior to the realization of idiosyncratic shock θ_{it}, the expectation operator $\tilde{\mathbf{E}}$ appears in both equations. (12) is the optimal decision for consumption. (13) is the Euler equation for inter-temporal decision of housing purchases. The right hand side of this equation describes the expected benefit of holding housing. Note that in absence of liquidity constraint (e.g., $\eta_{it} = 0$) and idiosyncratic uncertainty (e.g., $\theta_{it} = 1$, for any i), (11) and (13) imply that the household has no incentive to purchase housing asset. In addition, (10) and (11) indicate that we can define the discount factor, Λ_t, analogous to representative agent model, as $\Lambda_t \equiv \tilde{\mathbf{E}}_t(\theta_{it}\lambda_{it})$.

4.2 Housing Sector

There is a representative housing producer. It rents capital K_{ht} at rental rate r_t, hires labor N_{ht} at wage rate w_t, and purchases land L_t at price q_{lt} as inputs to produce housing h_t through a Cobb-Douglas production technology (see Han, Han, and Zhu 2015; Davis and Heathcote 2005 for the similar setup of production function):

$$h_t = \left(K_{ht}^{\alpha_h} N_{ht}^{1-\alpha_h}\right)^{1-\gamma} L_t^{\gamma}, \tag{14}$$

where $\gamma \in (0,1)$ is the land share in production function. Each period the housing producer chooses capital, labor and land to maximize its profit $q_{ht}h_t - r_t K_{ht} - w_t N_{ht} - q_{lt} L_t$. The optimal demands for three inputs are given by

$$r_t = \alpha_h (1-\gamma) q_{ht} \frac{h_t}{K_{ht}}, \tag{15}$$

$$w_t = (1-\alpha_h)(1-\gamma) q_{ht} \frac{h_t}{N_{ht}}, \tag{16}$$

$$q_{lt} = \gamma q_{ht} \frac{h_t}{L_t}. \tag{17}$$

The land supply is controlled by the central government. In the benchmark setup, we consider a simple fixed land supply rule, i.e.,

$$L_t = \bar{L}. \tag{18}$$

4.3 Real Sector

The setup of real sector follows the standard real business cycle literature. There is one representative final good producer. The good market is competitive. The producer hires labor N_{pt} with wage rate w_t and rents capital K_{pt} with rental rate r_t to produce final good Y_{pt}. The production function takes Cobb-Douglas form, $Y_{pt} = K_{pt}^{\alpha_p} N_{pt}^{1-\alpha_p}$, where $\alpha_p \in (0,1)$ is the capital share. The optimal demands for capital and labor are given by

$$r_t = \alpha_p \frac{Y_{pt}}{K_{pt}}, \tag{19}$$

$$w_t = (1-\alpha_p) \frac{Y_{pt}}{N_{pt}}. \tag{20}$$

4.4 Aggregation and General Equilibrium

Define the aggregate variables in $\kappa \in \{p, h\}$ sector as $\chi_{\kappa t}$, where $\chi = \{K, N, Y\}$. Define aggregation of household level variables χ_{it}, where $\chi = \{C, H, N, K\}$, as $\chi_t = \int_0^1 \chi_{it} di$. The market clearing conditions for capital and labor imply

$$\chi_t = \sum_{\kappa \in \{p,h\}} \chi_{\kappa t}, \text{ for } \chi = \{K, N\}. \tag{21}$$

The housing market equilibrium condition implies

$$h_t = H_{t+1} - (1-\delta_h) H_t. \tag{22}$$

Define the aggregate output Y_t as $Y_t = Y_{pt} + q_{ht} h_t$. The aggregate resource constraint is given by

$$C_t + q_{ht} h_t + I_t = Y_t, \tag{23}$$

where $I_t = K_{t+1} - (1-\delta_k) K_t$.

The general equilibrium consists of a set of aggregate variables and prices such that individuals solve their optimization problems and all markets clear.

4.5 Households' Decision Rules

In this section, we discuss the heterogeneous households' optimal decisions. In line with Wen (2015), taking as given the aggregate environment, the individual households' consumption and housing decisions follow trigger strategy. Let θ_{it}^* denote the cutoff of idiosyncratic shock θ_{it}. We consider following two cases for different values of θ_{it}.

Case 1: $\theta_{it} \geq \theta_{it}^*$. In this case, the household has relatively high level of wealth or liquidity, so they tend to hold more housing as a buffer to smooth consumption. As a result, the liquidity constraint for housing (9) does not bind, i.e., $H_{it+1} > 0$ and $\eta_{it} = 0$. In the Appendix C, we show that the cutoff θ_{it}^* satisfies

$$\theta_{it}^* = \frac{1}{X_{it}\beta(1-\delta_h)\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)}. \tag{24}$$

Since $\eta_{it} = 0$, first order conditions (10) and (13) imply that the optimal consumption in this case satisfies $C_{it} = \theta_{it}^* X_{it}$. From the budget constraint (7), the optimal housing decision is given by $H_{it+1} = (\theta_{it} - \theta_{it}^*)X_{it}$. This condition indicates that only those wealthy households (θ_{it} is larger than the cutoff) hold positive level of housing assets as liquidity.

Case 2: $\theta_{it} < \theta_{it}^*$. In this case, the household has relatively low wealth. To smooth the consumption, the household tends to utilize all the liquidity, leading to a binding liquidity constraint (9). Therefore, the housing decision is simply $H_{it+1} = 0$. And the optimal consumption is $C_{it} = \theta_{it}X_{it}$.

To summarize, Proposition 1 below characterizes the household's optimal decisions.

Proposition 1 *Taking as given the aggregate states, the cutoff θ_{it}^* and the wealth X_{it} of the household i are independent with the individual states, that is, $\theta_{it}^* \equiv \theta_t^*$ and $X_{it} \equiv X_t$; the household's optimal consumption and housing decisions are given by following trigger strategy:*

$$C_{it} = \min\{\theta_t^*, \theta_{it}\}X_t, \tag{25}$$

$$H_{it+1} = \max\{\theta_{it} - \theta_t^*, 0\}\frac{X_t}{q_{ht}}; \tag{26}$$

where the wealth X_t satisfies

$$X_t = \frac{1}{\theta_t^*\Lambda_t}\int \max\{\theta_t^*, \theta_{it}\}d\mathbf{F}(\theta_{it};\sigma_t). \tag{27}$$

Proof. See Appendix C. ■

The independence of the individual wealth X_{it} with individual states is mainly due to the specification of quasi-linear utility and the timing of labor decision. Since the disutility of labor takes linear form and the labor choice is made prior to the idiosyncratic shock θ_{it}, the household can adjust her own labor supply to reduce the variations in wealth in hand. As a result, the individual wealth only depends on the aggregate states, and the wealth distribution in our model is degenerated.

4.6 Impact of Uncertainty on Housing Demand

To see how the economic uncertainty (the standard deviation of θ_{it}), σ_t, can affect the housing demand, we conduct a partial equilibrium analysis. Similar to the analysis in the toy model, we define

$$\Phi(\theta_t^*, \sigma_t) \equiv \int \max\{\theta_t^*, \theta_{it}\} d\mathbf{F}(\theta_{it}; \sigma_t). \tag{28}$$

Appendix C shows that the Euler equation for the optimal decision of housing (13) implies that the house price can be expressed as

$$q_{ht} = \Phi(\theta_t^*; \sigma_t)(1 - \delta_h) \frac{\mathbf{E}_t q_{ht+1}}{1 + r_t^i}, \tag{29}$$

where $r_t^i \equiv \frac{1}{\beta \mathbf{E}_t \frac{\Lambda_{t+1}}{\Lambda_t}} - 1$ is the real interest rate. Last equation indicates that the current house price q_{ht} contains a normal component, the discounted expected price in next period, and also a premium term, $\Phi(\theta_t^*; \sigma_t)$. In fact, this extra term reflects the liquidity premium of holding housing, since the housing asset is a buffer to ensure the idiosyncratic uncertainties. More importantly, conditional on aggregate states, the liquidity premium is increasing in the economic uncertainty. This is because $\max\{\theta_t^*, \theta_{it}\}$ is convex in θ_{it}, the Jensen's inequality implies that the premium increases when the uncertainty σ_t rises. Therefore, an upswing in uncertainty may lead to a boom in current house price. Intuitively, when the economy becomes more uncertain, the household would prefer the asset that can be used as a buffer to smooth the consumption: the *flight-to-liquidity* effect. This means that even though the house price is relatively high (or the expected rate of return is low), the households are still willing to hold housing.

Aggregating the individual household's optimal housing decision (26) yields the aggregate housing demand, which is

$$H_{t+1} = \frac{X_t}{q_{ht}} \int \max\{\theta_{it} - \theta_t^*, 0\} d\mathbf{F}(\theta_{it}; \sigma_t);$$

Since the function in the integral is convex in θ_{it}, again the Jensen's inequality implies that a rise in uncertainty σ_t leads to a higher housing demand, taking as given the wealth X_t and the cutoff θ_t^*.

5 Quantitative Analysis

The previous analysis qualitatively shows that the housings are the store of value to smooth the consumption. The demand becomes high when the economic uncertainty is large. To provide the further quantitative analysis, we calibrate the baseline model to Chinese economy.

5.1 Calibration

One period in the model corresponds to one quarter. We partition the parameters into three subsets. The first subset of parameters includes $\{\beta, \psi, \alpha_p, \delta_k\}$ that are standard in the business cycle literature. For the discount factor β, we set it to be 0.995 implying that an annual real deposit rate is 1.8%.[16] For the coefficient in the dis-utility of labor, ψ, as it does not affect model dynamics, we simply normalize it to be 1. For the capital share in the real sector α_p, following the literature Song, Storesletten, and Zilibotti (2011) we set it to be 0.5. For the depreciation rate of physical capital δ_k, following Song, Storesletten, and Zilibotti (2011) we set it to be 0.025.

The second set of parameters related to the housing sector includes $\left\{\delta_h, \gamma, \alpha_h, \bar{L}\right\}$. For the depreciation of housing asset δ_h, we follow Iacoviello and Neri (2010) to set it to be 0.01 (or an annual rate of 4%). We now calibrate the land share γ and capital share $\alpha_h (1-\gamma)$ in the production function for the housing sector. The housing assets in the model are supposed to be those with better quality in the reality (e.g., housings in Tier 1 cities). According to the National Bureau of Statistics in China, for Tier 1 cities the ratio of total spending on land purchases in housing sector to the total revenue in housing sector is around 24.5%, so we specify $\gamma = 0.245$. Regarding the parameter α_h,

[16] The real deposit rate is the annual rate with one-year maturity. This series is annual nominal deposit rate adjusted by the CPI. The series is from 2000 to 2016. The average value is about 1.8%.

Table 2: Parameter Values

Parameter		Value	Target
β	Discount rate	0.995	Annual interest rate (1999Q1-2016Q4)
ψ	Labor dis-utility	1	
α_p	Capital share in real sector	0.5	Song, Storesletten, and Zilibotti (2011)
δ_k	Depreciation of physical capital	0.025	Standard
δ_h	Depreciation of housing	0.01	Iacoviello and Neri (2010)
γ	Land share in H sector	0.245	$\frac{q_l L}{q_h h}$ in Tier 1 cities
α_h	Capital share parameter in H sector	0.7	$\frac{q_l L}{I_h + q_L L}$ in Tier 1 cities
$\bar{L}$	Steady-state land supply	1	
σ	Std of idiosyncratic shock θ_i	0.9775	Gini coefficient of housing holdings, CHFS survey

since the labor and the capital income shares in the housing sector are not available, we use the average ratio of total spending on land purchases in housing sector to the total investment (including land purchases) in housing sector ($\frac{q_l L}{I_h + q_L L}$) in Tier 1 cities to pin down the value of α_h, which is 0.7. This value implies that the capital and the labor shares in housing production function are 52.8% and 22.7% respectively, which are close to the values in the real data. For the land supply in steady state, since it does not affect the model dynamics, we simply normalize it to be 1.

The last set of parameters is related to the distribution of household's idiosyncratic shock, $\mathbf{F}(\theta_{it})$. We assume θ_{it} follows log-normal distribution with mean 1 and standard deviation σ. The CHFS survey data shows that the Gini coefficient of housing asset in 2012 is around 0.6. So we set the value of σ to match the data, which yields a value of 0.9775. Under this parameter value, our model implies the steady-state national saving rate is 0.43, which closely matches that in the real data. [17] Table 2 summarizes the calibrated parameter values.

[17] According to Xie and Jin (2015), the housing asset accounts for almost 80% of total household wealth, and the Gini coefficient of urban households' wealth in 2012 is around 0.7. So, our model implied Gini coefficient of housing holdings also fits their dataset reasonably well.

5.2 Aggregate Effect of Uncertainty

5.2.1 Long-run Equilibrium

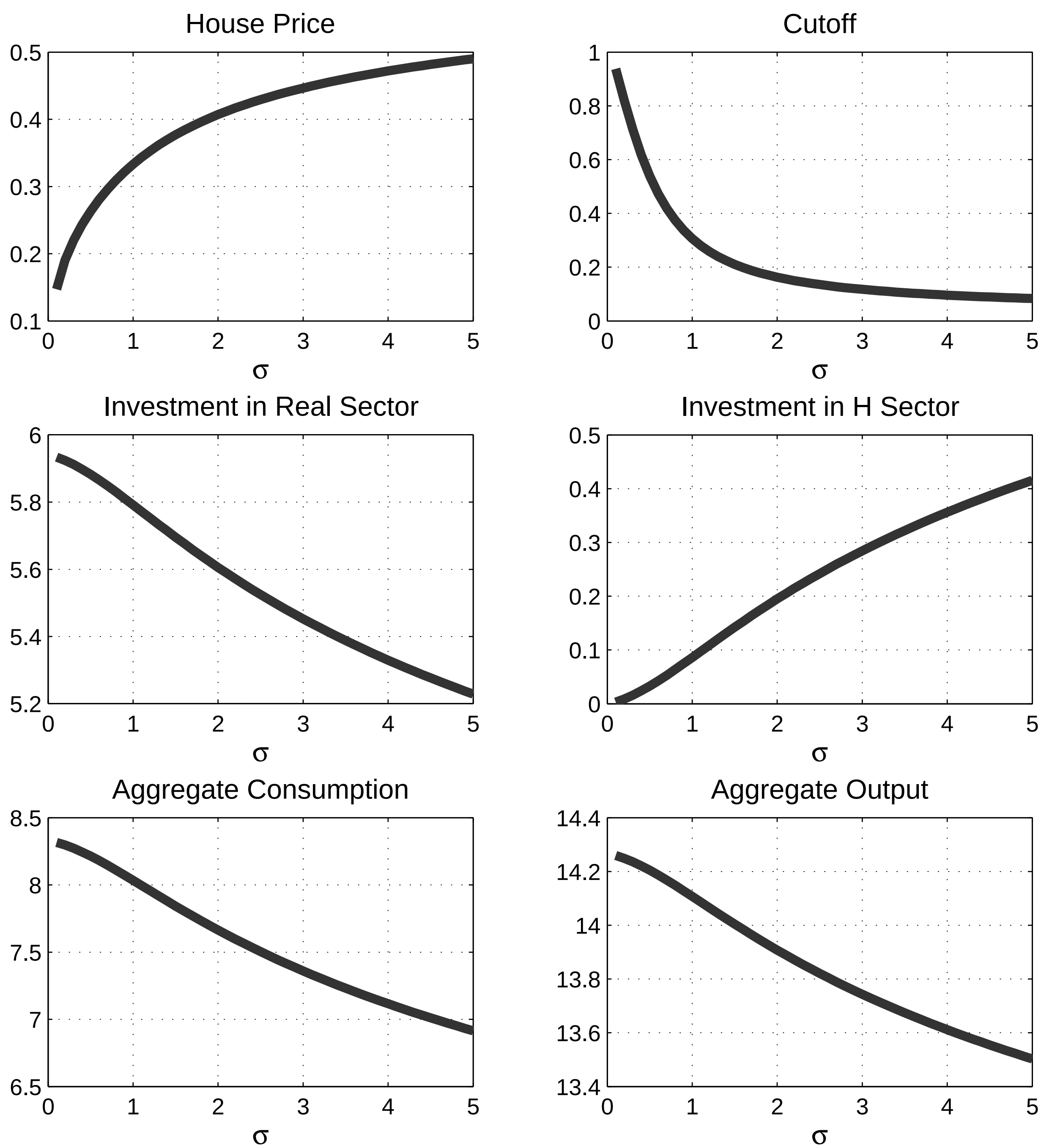
To analyze the aggregate effect of uncertainty, we first conduct the steady-state analysis. Figure 5 describes the relationship between the uncertainty and the key aggregate variables in the stationary equilibrium. It shows that a rise in the uncertainty pushes up the house price in the long run because households demand more housing (or safe) assets as a buffer to smooth their consumptions. This confirms the prediction from the previous partial equilibrium analysis. As a result, the housing sector expands while the real sector shrinks due to the crowding out effect. This pattern is consistent with the empirical findings that when Chinese economy becomes more uncertainty (after 2013), the real investment in the housing sector negatively comoves with that in the real sector. Furthermore, a higher uncertainty also reduces the consumption due to the stronger precautionary saving motive, resulting a decline in aggregate output. Hence, our model is able to explain the phenomenon of housing boom associated with economic recession in the long-run equilibrium.

5.2.2 Transition Dynamics

To evaluate the dynamic impact of uncertainty on the house price as well as aggregate economy, we now discuss the transition dynamics when the economic uncertainty rises. In particular, we assume that the standard deviation of θ_{it} permanently increases by 25%, and the process of the increment follows AR(1) form, i.e., $\sigma_t - \sigma^{new} = \rho(\sigma_{t-1} - \sigma^{new})$, where $\sigma_0 = 0.9775, \sigma_{new} = 0.9775 \times 1.25$, and $\rho = 0.5$. Figure 6 presents the transition dynamics.

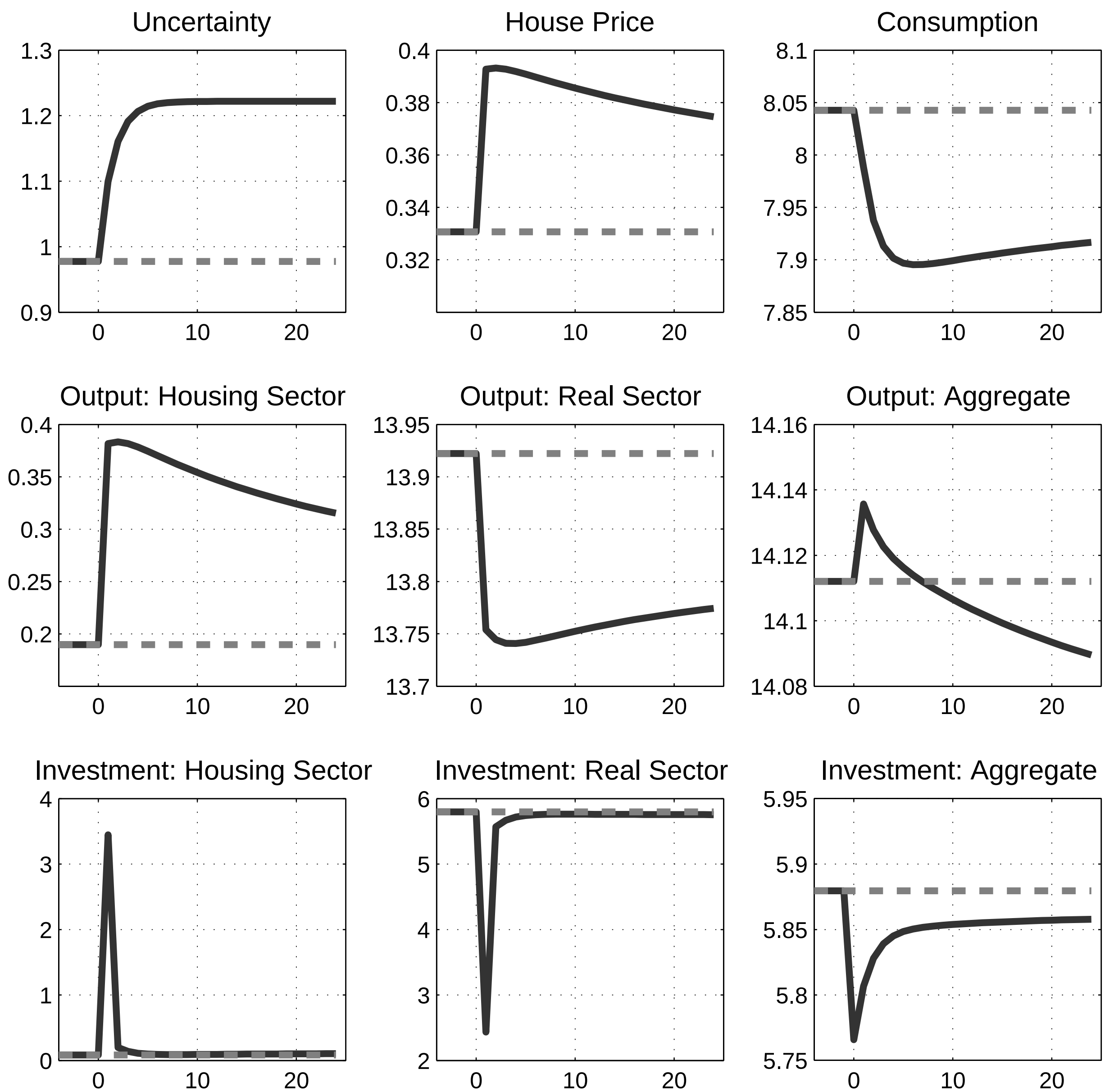
From the figure, it can be seen that after a 25% increase in the uncertainty, the house price rises sharply by around 20% from the level of 0.330 to 0.396. A stronger demand of housing assets as a store of value leads to a boom in housing market. This further stimulates more physical capital investments in housing sector while crowds out those in real sector. As a result, the output in real sector declines. The overall output (GDP) in the long run declines associated with an increase in the short run. The overshoot of aggregate output in the short term is mainly due to the expansion of housing sector. The above transition dynamics are broadly consistent with the two stylized facts discussed previously:

Figure 5: Uncertainty and Aggregate Economy in the Steady State



Notes: The steady state is computed under different values of σ, other parameters are calibrated according to Table 2.

Figure 6: Transition Path after a Rise in Uncertainty



Notes: The transition paths are in levels. We specify the persistence of AR(1) process of σ_t to be 0.5. The dashed lines are the steady-state level prior to the transition.

(i) housing market was experiencing expansion along with the economic recession; (ii) there exists a crowding out effect between the housing sector and the real sector.

6 Policy Intervention in Housing Sector

6.1 Basic Setup

To curb the China's soaring house price in Tier 1 cities, the government tightened the policy rules on the housing market. The major measure is the house-purchase limit policy. In this section, we aim to model this type of policy specifically and evaluate its aggregate consequences as well as the welfare implications.

To model the house-purchase limit policy, we introduce an additional constraint on housing purchase to the benchmark model. In particular, we assume the amount of housing purchased by the household cannot exceed a fraction of the consumption:

$$q_{ht}H_{it+1} \leq \phi C_{it}. \tag{30}$$

The assumption that the purchasing limit is a fraction of consumption guarantees an analytical way to aggregating the economy.[18] Under the setup of a constant purchasing limit, the main insight remains valid. However, the aggregation may become more complicated.

The parameter ϕ governs the tightness of housing regulation policy. When $\phi \to \infty$, the model degenerates to the benchmark model. When $\phi \to 0$, the housing market is completely shut down. Under the house-purchase limit policy, the household's optimal decisions differ from those in the benchmark case. In particular, the individual's optimal policy may include three regimes. When the household's disposable wealth is sufficiently low, to smooth the consumption they may not hold housing asset, i.e., the constraint (9) is binding. When the disposable wealth is sufficiently high, the household would demand large liquidity for the precautionary purpose, as a result, the constraint

[18] Alternatively, we could assume the purchase limit is a function of wealth X_{it}. Indeed, this setup is isomorphic to (30).

(30) is binding. When the disposable wealth is in the middle, with the moderate demand of liquidity, both of (9) and (30) are not binding. In the benchmark model where house-purchase limit is absent, only the first and the third scenarios appear. Therefore, the house-purchase limit policy primarily affects those wealthy (or liquidity abundant) households.

Theoretically, it can be shown that due to the policy intervention there exist two cutoffs of idiosyncratic shock θ_{it}, θ_{it}^* and θ_{it}^{**}, where θ_{it}^* has the same definition as that in (24) and $\theta_{it}^{**} = (1+\phi)\,\theta_{it}^*$. These two cutoffs divide the optimal individual policy into three regimes. The following proposition gives details.

Proposition 2 *Taking as given the aggregate states, the cutoffs θ_{it}^* and θ_{it}^{**}, and the wealth X_{it} of the household i are independent with the individual states, that is, $\theta_{it}^* \equiv \theta_t^*$, $\theta_{it}^{**} \equiv \theta_t^{**}$, and $X_{it} \equiv X_t$; the household's optimal consumption and housing decisions are given by following trigger strategies:*

$$C_{it} = \left[\theta_{it}\mathbf{1}_{\{\theta_{it}\leq\theta_t^*\}} + \theta_t^*\mathbf{1}_{\left\{\theta_{it}^*\leq\theta_{it}<\theta_t^{**}\right\}} + \frac{1}{1+\phi}\theta_{it}\mathbf{1}_{\{\theta_{it}>\theta_t^{**}\}}\right]X_t, \tag{31}$$

$$q_{ht}H_{it+1} = \left[0\times\mathbf{1}_{\{\theta_{it}\leq\theta_t^*\}} + (\theta_{it}-\theta_t^*)\,\mathbf{1}_{\left\{\theta_{it}^*\leq\theta_{it}<\theta_t^{**}\right\}} + \frac{\phi}{1+\phi}\theta_{it}\mathbf{1}_{\{\theta_{it}>\theta_t^{**}\}}\right]X_t; \tag{32}$$

where the wealth X_t satisfies

$$X_t = \frac{1}{\theta_t^*\Lambda_t}\Phi(\theta_t^*;\phi,\sigma_t), \tag{33}$$

and the liquidity premium $\Phi(\theta_t^*;\phi,\sigma_t)$ satisfies

$$\Phi(\theta_t^*;\phi,\sigma_t) = \int\left\{\theta_{it}^*\mathbf{1}_{\{\theta_{it}\leq\theta_t^*\}} + \theta_{it}\mathbf{1}_{\left\{\theta_{it}^*\leq\theta_{it}<\theta_t^{**}\right\}} + \left[\theta_{it}^* + \frac{\phi}{1+\phi}\theta_{it}\right]\mathbf{1}_{\{\theta_{it}>\theta_t^{**}\}}\right\}d\mathbf{F}(\theta_{it};\sigma_t). \tag{34}$$

Proof. See Appendix D. ∎

It can be easily verified that when $\phi\to\infty$, the optimal decisions described in Proposition 2 degenerate to those in the benchmark model. As the house-purchase limit policy restricts the household's access to the housing asset, the premium of holding housing assets (the benefit of store of value) is dampened. The definition of $\Phi(\theta_t^*;\phi,\sigma_t)$ in (34) shows that the house-purchase limit makes the function in the integral less convex comparing to the one in (28). As a result, given the aggregate states, the liquidity premium $\Phi(\theta_t^*; \phi, \sigma_t)$ is decreasing in ϕ.

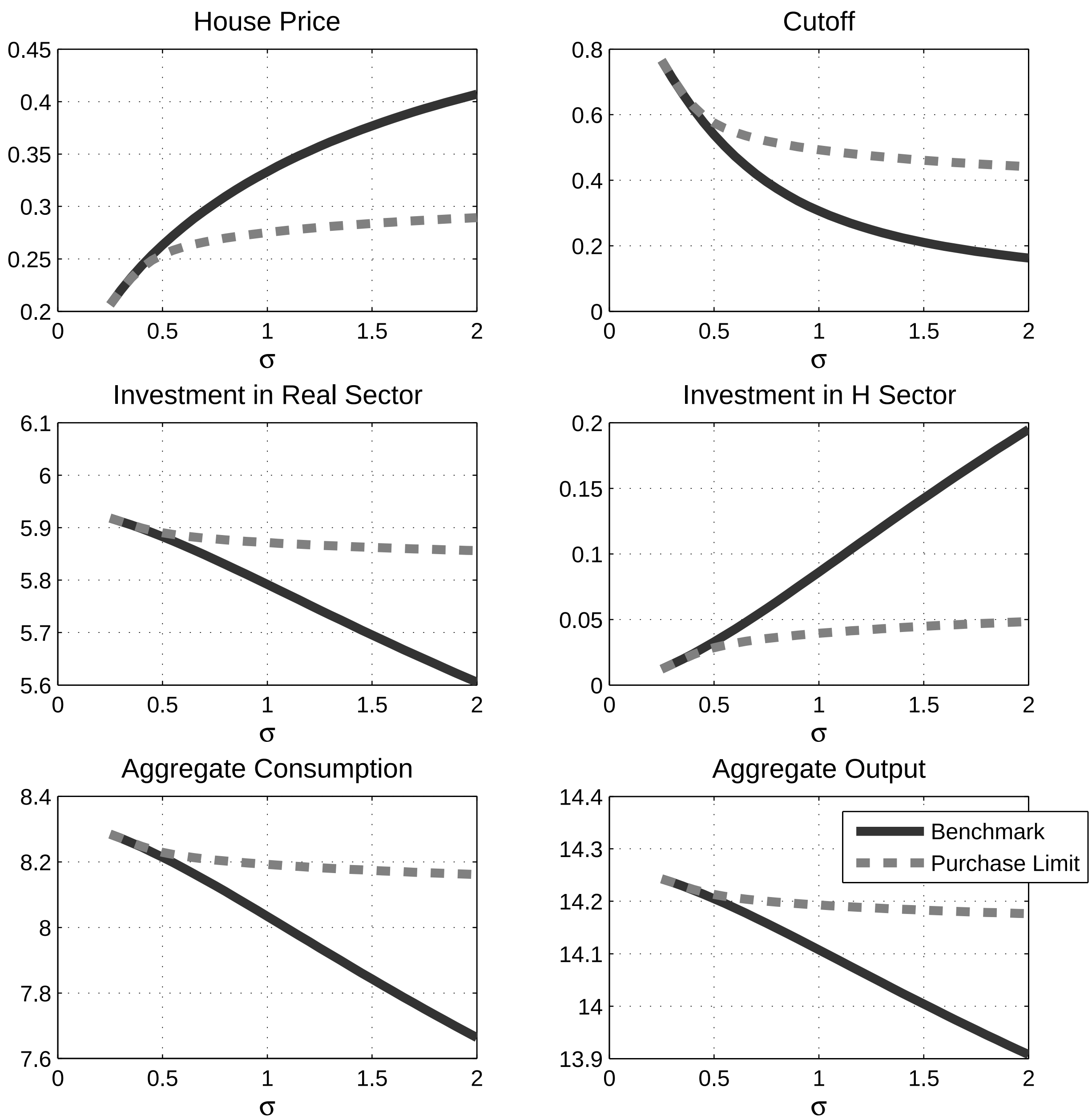
6.2 Aggregate Impacts of Policy Intervention

Long-run Equilibrium and Consumption Misallocation We first quantitatively evaluate the aggregate impact of house-purchase limit policy in the long-run equilibrium. As we discussed in the previous section, this policy curbs the households' demand on the housing assets. It therefore mitigates the general equilibrium crowding out effect of housing sector on the real sector. Figure 7 compares the steady-state equilibrium in the benchmark model and in the model with house-purchase limit policy. It can be seen that in the steady state a higher economic uncertainty may cause a relatively small expansion of housing market comparing to that in the benchmark model. The house price and the physical investment in housing sector rise less. The adverse impact on the real sector is mitigated. As a result, the drop in aggregate consumption and output caused by the higher uncertainty is less severe.

Although the house-purchase limit policy leads to a better performance of the aggregate economy when the economic uncertainty is high, it also circumscribes the households' access to the safe assets that can be used as the store of value. This means the house-purchase limit policy inevitably rises the dispersion of households' consumption and thus exacerbates the consumption misallocation. Figure 8 illustrates the distributional effect of house-purchase limit policy on the households' consumptions (see the solid lines). The stationary distribution of consumption has larger mean and dispersion under the tighter housing purchase limit policy than that in the looser policy regime. For instance, the mean of consumption is 1.6% larger in the tight regime ($\phi = 2.5$) than that in the looser regime ($\phi = 10$). The standard deviation of consumption in the tighter regime is almost 1.5 times larger than that in the looser regime.

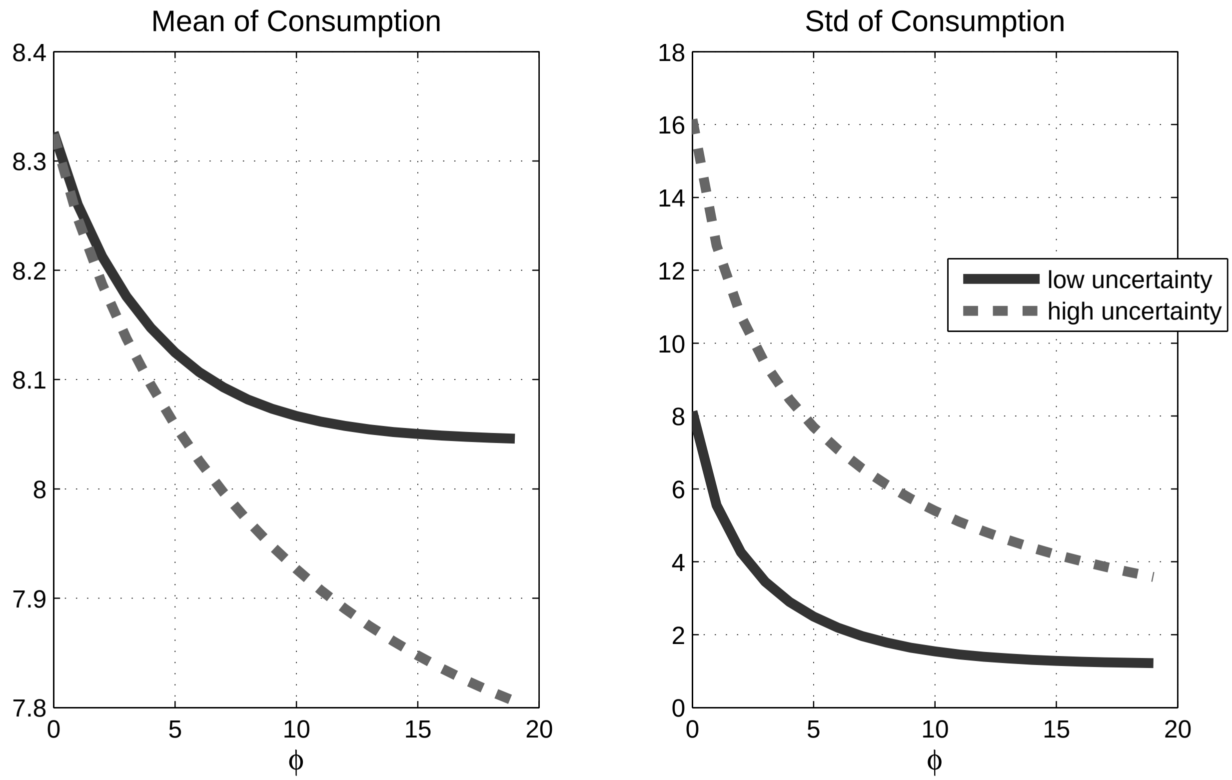
Our quantitative results also show that the distortions of consumption caused by the house-purchase limit policy become even severe when the economic uncertainty is higher. Figure 8 compares the impact of house-purchase limit policy on the mean and the standard deviation of consumption under different level of uncertainty. The solid line and the dashed line represent low uncertainty

Figure 7: Steady-state Equilibrium under House-Purchase limit Policy



Notes: The steady state is computed under different values of σ, the ϕ in house-purchase limit is set to 2.5, and other parameters are calibrated according to Table 2.

Figure 8: Distortion of House-Purchase Limit Policy on Consumption

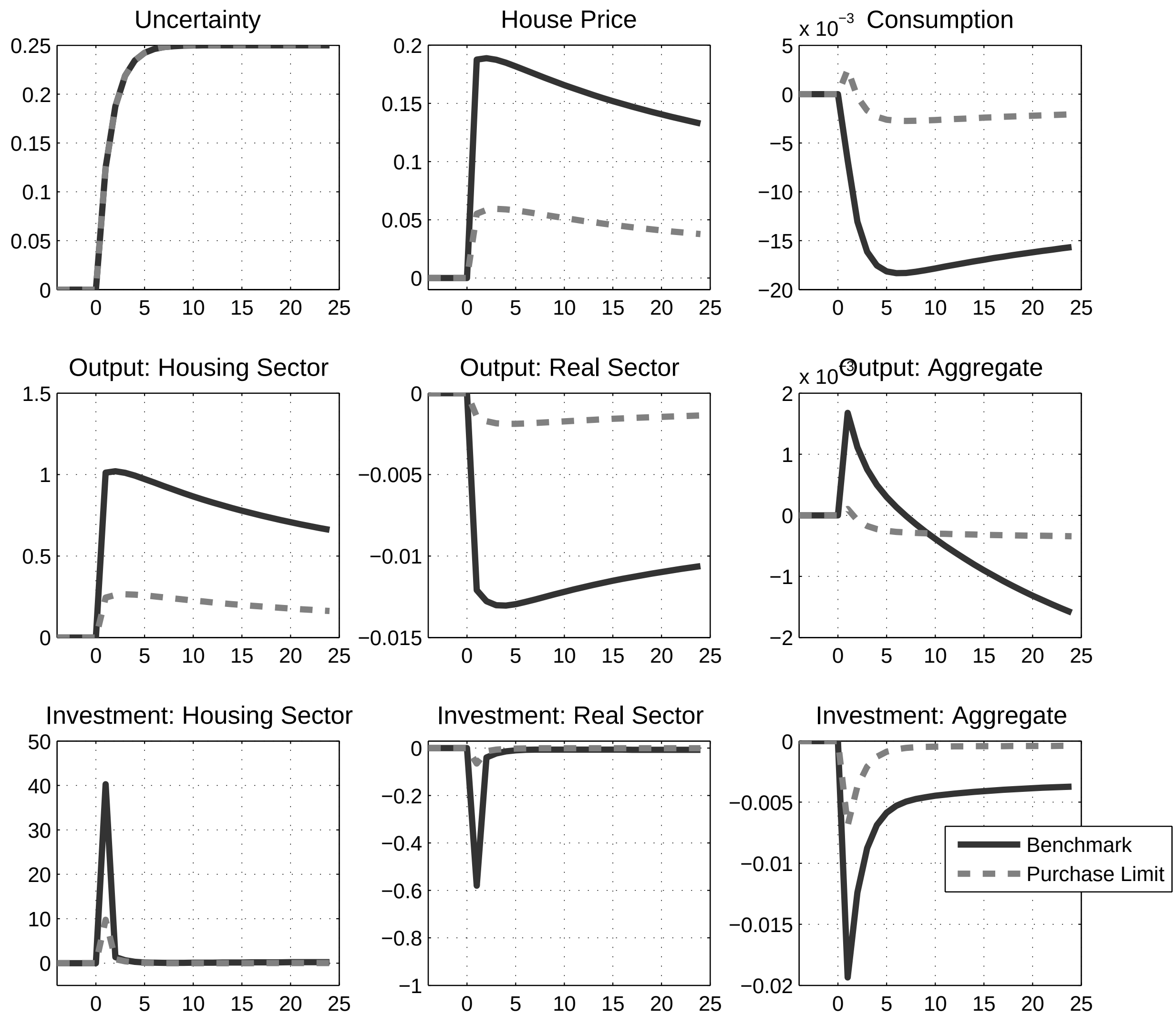


Notes: The distribution of consumption is obtained by computing the consumption expenditure of 100,000 household with i.i.d idiosyncratic shocks θ_i. The parameter values except ϕ and σ are set according to the calibration values in Table 2.

($\sigma = 0.9775$) and high uncertainty ($\sigma = 0.9775 \times 2$) scenarios, respectively. It can be seen that the house-purchase limit policy raises mean and standard deviation of consumption much larger in the former case than in the latter one. This indicates the consumption misallocation caused by the policy increases with the economic uncertainty.

Dynamic Impacts of Policy Intervention To evaluate the dynamic impact of house-purchase limit policy, we compare the transition dynamics after a rise in economic uncertainty under the policy intervention with those in the benchmark model. From Figure 9, it can be seen that a tighter purchase limit policy largely dampens the housing boom after a rise in uncertainty. As a result, the crowding out effect between real sector and housing sector is mitigated.

Figure 9: Transition Path under House-Purchase limit Policy



Notes: The transition is computed by assuming the uncertainty σ_t increases permanently by 25%. For the purchase limit case, the parameter ϕ is set to 2.5, for the benchmark case, $\phi = \infty$. Other parameter values are set according to the calibration values in Table 2.

6.3 Welfare Implication

Despite the mitigation of crowding out effect, the house-purchase limit policy confines the household's access to the assets for the store of value. The more severe consumption misallocation leads to adverse effect on the social welfare. To see this, let W_t denote the social welfare that satisfies

$$W_t = U_t - \psi N_t + \beta W_{t+1} \tag{35}$$

where $U_t = \int \log C_{it} di$ and $N_t = \int N_{it} di$. According to the optimal consumption rule under policy intervention, U_t is

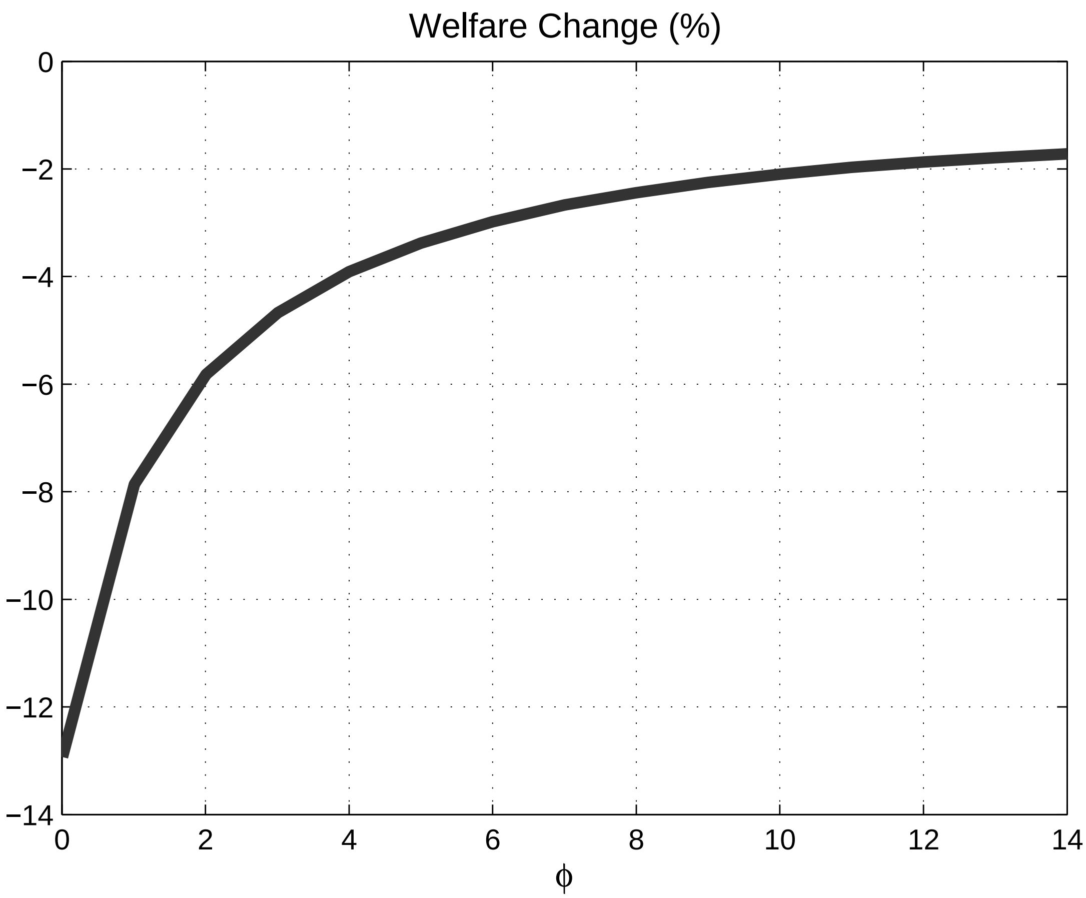
$$U_t = \int \left[\log(\theta_{it}) \mathbf{1}_{\{\theta_{it} \leq \theta_t^*\}} + \log(\theta_t^*) \mathbf{1}_{\left\{\theta_{it}^* \leq \theta_{it} < \theta_t^{**}\right\}} + \log\left(\frac{1}{1+\phi}\theta_{it}\right) \mathbf{1}_{\{\theta_{it} > \theta_t^{**}\}} \right] d\mathbf{F}(\theta_{it}) + \log X_t. \tag{36}$$

Figure 10 compares the welfare effect of economic uncertainty under various tightness of house-purchase limit policies (captured by the value of ϕ). As the higher uncertainty hurts the real economy, the change of welfare is generally negative for a permanent increase in σ. Take the case of $\phi = 4$ as an example. When the economic uncertainty (σ_t) increases by 25%, the welfare (along the transition path) is reduced by around 4%. If the policy becomes tighter, namely $\phi = 2$, a 25% increase in uncertainty would cause a 6% reduction in welfare. This suggests that the adverse effect of uncertainty on the welfare along the transition becomes more severe when the house-purchase limit policy is tighter.

7 Conclusion

The shortage of safe assets, a global syndrome, is acute in the saving gluts like China where the financial market is underdeveloped and the capital account is tightly regulated. The housings with good quality become a desirable store of value when economic uncertainty is high. Based on both the household-level transaction data and the city-level time series data, we find that the economic uncertainty boosts the relative prices for those housings with better quality, especially during the

Figure 10: Welfare Implication under House-Purchase Limit Policy



Notes: The level of welfare is computed for the whole transition path after a 25% permanent increase in σ_t. The change of welfare is the percentage difference between the welfare after transition and that in the original steady state.

recent economic slowdown. The housing boom leads to the adverse impact on the real sector because of the crowding out effect. This paper aims to understand the underlying mechanism of the housings as a safe asset and its aggregate consequences. In particular, we introduce the housing asset as a store of value into a two-sector dynamic general equilibrium model with heterogeneous households and incomplete market. The individuals are facing idiosyncratic uncertainties. Due to the underdeveloped financial market, the housings become liquid wealth that can be used to insure the idiosyncratic uncertainties. A rise in economic uncertainty may lead to a great housing boom due to the stronger precautionary motives. The expansion of housing sector crowds out resources from the real sector, leading to an economic slowdown. So our model provides a theory to understand the recent great divergence between the house price and the economic fundamental in China. To brake the overheated housing market, the Chinese government implements strict house-purchase limit policies that restrict the individuals access to housing market in big cities. In our quantitative exercise, we introduce this type of market intervention into our baseline model. The policy intervention largely reduces the demand for housings under a high economic uncertainty, and thus mitigates the adverse effects on the real economy. However, the policy also limits the individuals' access to the store of value, intensifying the shortage of safe assets. As a result, the consumption misallocation among individuals is exacerbated and the social welfare is reduced. Therefore, there exists a policy trade-off between the macro-level stability and the micro-level volatility.

In contrast to the safe asset literature, we provide empirical and quantitative evidences to identify the real estate as a safe asset through the lens of economic uncertainty. In addition, our paper offers a novel channel for the housing boom to affect the real economy with underdeveloped financial market. The model's tractability allows us to conduct several possible extensions without incurring additional computational burden. For instance, in an extension with open economy environment, the interactions between the internal and external policies (e.g., capital control) can be particularly discussed; or in an extension with multiple types of housing assets, the flight to quality versus the flight to liquidity can be clearly decomposed.

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Appendix

A Data

A.1 Housing transaction data in Beijing

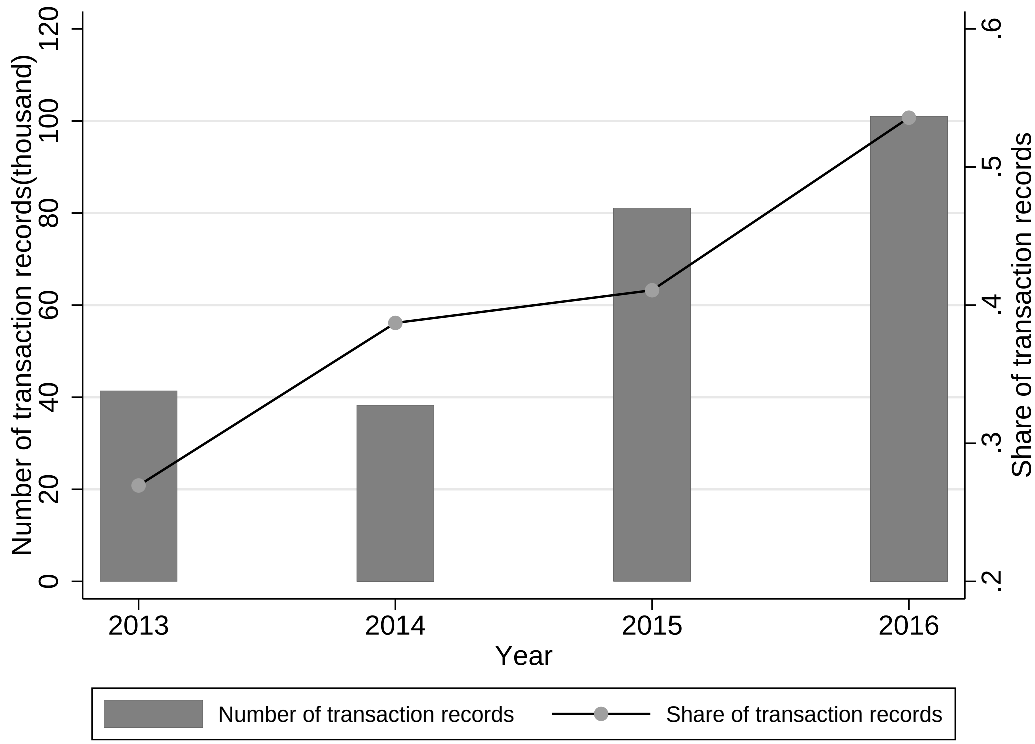
The housing transaction dataset contains the apartment-level second-hand housing transaction records in Beijing from the first month in 2013 to the last month in 2016. It records the housing characteristics and the final deal prices. We drop records that miss either total price or building area, and then winsorize the average price (per square meter) at the 0.1% and 99.9% level. In the end, we are left with 139,200 observations of the second-hand housing transactions, involving up to more than 4,000 communities.

The data is collected from the website of one of the largest real estate agencies in China, named L. In Beijing, the agency L has more than 1,500 stores and over 33 thousands real estate agents in 2016. With a market share reaching 40% in the second-hand housing market in January 2017, the agency L becomes the largest real estate agency in Beijing, based on data released by Beijing Capital Construction Commission.

To evaluate the representativeness of our dataset, we first plot in Figure A.1 the number of transactions carried out by the agency L and the corresponding market share between 2013 and 2016, where the market share is calculated by dividing the agency L's annual total numbers of transactions over the corresponding total number of transactions collected in Beijing Real Estate Statistical Yearbook. There present upward trends both in terms of absolute numbers as well as the market share.

Since Figure A.1 indicates that the agency L has expanded its business in Beijing during this period, we further check the data representativeness by comparing the average price growth rate (month on month) calculated using our data with the Beijing second-hand housing price index calculated by NBS, see Figure A.2. Even though the growth rates in our sample become smaller than those in the Beijing house price index since late 2015, in general the trend in our sample mimics that of the

Figure A.1: Number of Transactions (left) and the Market Share (right)



official data. Therefore, the data from the housing agency L can be considered as representative of the dynamics of Beijing housing market from 2013 to 2016.

We also calculate the summary statistics for the log real housing price in Beijing (deflated by CPI) for different quality categories of apartments. Table A.1 provides details.

A.2 Other Data

1. **Data series in Figure 1.**

   Real house prices: is computed as the ratio between the overall values of total sales of commercial housings and the overall space (square footage) of total sales of commercial housings. The real price index is seasonally adjusted and also adjusted by quarterly GDP deflator. The overall values of total sales is from the WIND database. The overall space of total sales is from National Bureau of Statistics. The GDP deflator is from Chang et al. (2016). Since the data series for Guangzhou and Shenzhen are not available, we construct the house price index for

Figure A.2: Annual House Price Growth Rate and Beijing House Price Index

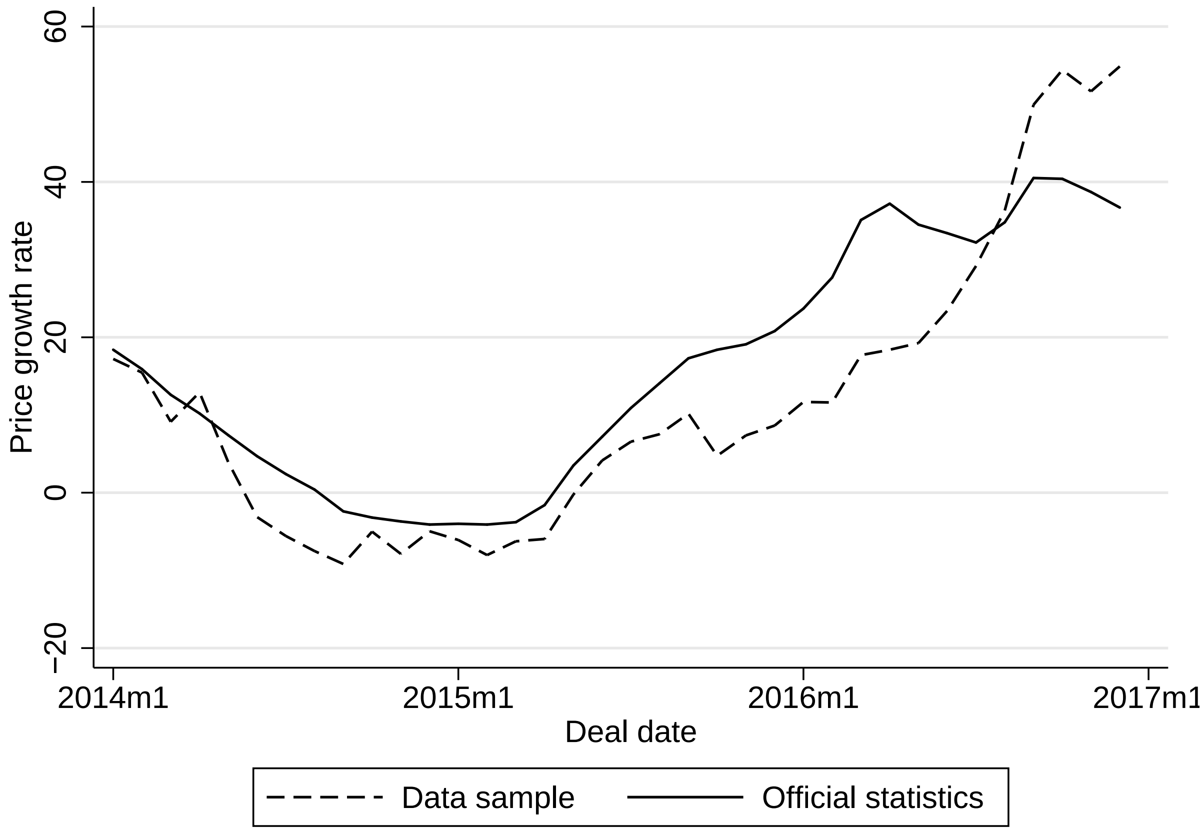


Table A.1: Summary Statistics for Transaction Data in Beijing, 2013-2016

	Mean of log(real prices)	Percent of Obs (%)
Key_school=1	10.8	48.9
Key_school=0	10.6	51.1
South=1	10.7	71.3
South=0	10.6	28.7
age≤15	10.6	45.9
age>15	10.8	54.1
Ring≤2	11.0	14.4
Ring>2	10.7	85.6
Bedroom≤2	10.7	62.1
Bedroom>2	10.7	37.9

Beijing and Shanghai to represent the price in Tier 1 cities. The house price index for the whole country is constructed following the similar method. All the series are from 1999Q1-2016Q4. The relative price of Tier 1 is the difference between the real price in Tier 1 cities and those in other cities.

Real GDP: is from Chang et al. (2016). The series covers from 1999Q1-2016Q1.

Economic Policy Uncertainty (EPU) index: is the constructed by Baker, Bloom, and Davis (2016). The original series is in monthly frequency. The series used in Figure 1 is the quarterly average of the original series.

2. **Data series in Figure 4**.

   Real investment in housing sector: is adjusted fixed asset investments in real estate development adjusted by fixed asset investment (FAI) index and seasonal factors. The series for Beijing, Shanghai and the whole country are collected from NBS, from 1999Q1-2016Q4. The series for Guangzhou and Shenzhen are collected from Bureau of Statistics of the local government, from 2003Q1-2016Q4. The FAI index is from Chang et al. (2016).

   Real investment in other sectors: is fixed asset investments in the sectors excluding real estate sector series adjusted by FAI index and seasonal factors. The series is collected from NBS, from 1999Q1-2016Q4.

3. **Data used in Calibration**.

   Total spending of land purchase in housing sector in Tier 1 cities: The series for Beijing and Shanghai are collected from the WIND database. The series for Guangzhou and Shenzhen are collected from the bureau of statistics of local government.

B Time-Varying Parameter VAR model

Consider a two-variable time-varying parameter (TVP) VAR model with lag of 2. The representation is given by

$$y_t = c_t + B_{1t} y_{t-1} + B_{2t} y_{t-2} + e_t, \; e_t \tilde{} \mathbf{N}(0, \Omega_t), \tag{B.1}$$

for $t = 3, ..., T$, where y_t is a vector of observed variables, which contains the log of relative house price in Tier 1 cities and the log of economic policy uncertainty (EPU); B_{1t} and B_{2t} are 2×2 matrices of time-varying coefficients; and Ω_t is a 2×2 time-varying covariance matrix. The relative house price is the difference of real house prices in Tier 1 cities (Beijng and Shanghai) and the country-level price. The value in first period is normalized to be 1. Both series are from 1999Q1 to 2016Q4. We follow Bloom (2009) to HP filter all the series with smoothing parameter of 1600. We also can use the two growth rates as another alternative. A recursive identification is assumed by the decomposition $\Omega_t = A_t^{-1}\Sigma_t\Sigma_t'A_t'^{-1}$, where A_t is a lower-triangular matrix with diagonal elements equal to one, and Σ_t =diag$(\sigma_{1t}, \sigma_{2t})$. Define β_t as the stacked row vector of B_{1t} and B_{2t}; $a_t = (a_{1t}, a_{2t})'$ is the stacked row vector of the free lower-triangular elements of A_t; and where $h_t = (h_{1t}, h_{2t})$ where $h_{it} = \log \sigma_{it}^2$. The time-varying parameters follow the random walk process: $\beta_{t+1} = \beta_t + u_{\beta t}$, $a_{t+1} = a_t + u_{at}$, $h_{t+1} = h_t + u_{ht}$, and $(\varepsilon_t, u_{\beta t}, u_{at}, u_{ht})'$ follows $\mathbf{N}\left(0, \begin{bmatrix} \mathbf{I} & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_a & 0 \\ 0 & 0 & 0 & \Sigma_h \end{bmatrix}\right)$, for $t = 3, ..., T$, with $e_t = A_t^{-1}\Sigma_t\varepsilon_t$, where Σ_a and Σ_h are diagonal, the coefficient vectors in the first period satisfy $\beta_3 \tilde{} \mathbf{N}(\mu_{\beta_0}, \Sigma_{\beta_0})$, $a_3 \tilde{} \mathbf{N}(\mu_{a_0}, \Sigma_{a_0})$ and $h_3 \tilde{} \mathbf{N}(\mu_{h_0}, \Sigma_{h_0})$. See Nakajima (2011) for the details.

We rank the relative house price as the first variable and the EPU as the second one. The second shock in ε_t is identified as the uncertainty shock, in the sense that in the impact period the uncertainty shock only affects the EPU and afterwards affect the house prices.

C Proof of Proposition 1

Given the aggregate environment, the individual household's consumption and housing decisions follow a trigger strategy. Let θ_{it}^* denote the cutoff of idiosyncratic shock θ_{it}. We consider following two cases for the optimal decisions given the cutoff θ_{it}^*.

Case 1: $\theta_{it} \geq \theta_{it}^*$. In this case, the household has a relatively high level of wealth. They tend to hold more housing as a buffer to smooth consumption. As a result, the liquidity constraint for housing (5) does not bind, i.e., $H_{it+1} > 0$ and $\eta_{it} = 0$.

From the Euler equation for the housing decision (13), we obtain

$$\lambda_{it} = \beta(1-\delta_h)\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right). \tag{C.1}$$

The optimal condition for consumption (12) implies

$$C_{it} = \left[\beta(1-\delta_h)\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1}. \tag{C.2}$$

Putting last equation into the budget constraint yields

$$q_{ht}H_{it+1} = \theta_{it}X_{it} - \left[\beta(1-\delta_h)\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1}. \tag{C.3}$$

Since $H_{it+1} > 0$, we must have the following relation

$$\theta_{it} \geq \left[\beta(1-\delta_h)X_{it}\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1} \equiv \theta_{it}^*, \tag{C.4}$$

This defines the cutoff θ_{it}^*.

Case 2: $\theta_{it} < \theta_{it}^*$. In this case, the household has a relatively low wealth. To smooth the consumption, the household tends to utilize all the liquidity, leading to a binding liquidity constraint, i.e., $H_{it+1} = 0$ and $\eta_{it} > 0$. From the budget constraint, we immediately have

$$C_{it} = \theta_{it}X_{it} = \frac{\theta_{it}}{\theta_{it}^*}\left[\beta(1-\delta_h)\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1}, \tag{C.5}$$

where the second equality comes from the definition of the cutoff θ_{it}^*.

From the Euler equation for the housing decision (13), we get

$$\lambda_{it} = \frac{\theta_{it}^*}{\theta_{it}}\left[\beta(1-\delta_h)\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)\right]. \tag{C.6}$$

Since $\theta_{it} < \theta^*_{it}$, (13) implies $\eta_{it} > 0$.

Plugging (C.4) and (C.6) into the Euler equation for the capital decision (11) yields

$$1 = \beta(1-\delta_h)\Phi(\theta^*_{it};\sigma_t)\mathbf{E}_t\left(\frac{\Lambda_{t+1}}{\Lambda_t}\frac{q_{ht+1}}{q_{ht}}\right), \tag{C.7}$$

where $\Phi(\theta^*_{it};\sigma_t) = \int_{\theta_{\min}}^{\theta_{\max}} \max\{\theta_{it},\theta^*_{it}\} d\mathbf{F}(\theta_{it};\sigma_t)$. Note that last equation can be further expressed as the housing pricing equation

$$q_{ht} = \Phi(\theta^*_{it};\sigma_t)(1-\delta_h)\frac{\mathbf{E}_t q_{ht+1}}{1+r^i_t}, \tag{C.8}$$

where $r^i_t = \frac{1}{\beta E_t \frac{\Lambda_{t+1}}{\Lambda_t}} - 1$ is the real interest rate.

Equation (C.7) further implies the cutoff θ^*_{it} is independent with each household i. So we can simply write θ^*_{it} as θ^*_t. The definition of X_{it} shows that the liquid wealth X_{it} is also identical among households so we can drop the subscript i for X_{it}. The definition of X_{it} implies

$$X_t = \left[\beta(1-\delta_h)\theta^*_t\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1}. \tag{C.9}$$

The optimal consumption rules in previous analysis implies

$$C_{it} = \min\{\theta_{it},\theta^*_t\}X_t. \tag{C.10}$$

Combining last equation and the budget constraint yields

$$H_{it+1} = \max\{\theta_{it}-\theta^*_t, 0\}\frac{X_t}{q_{ht}}. \tag{C.11}$$

From (C.7) and (C.9), we immediately have

$$X_t = \frac{1}{\theta^*_t\Lambda_t}\int_{\theta_{\min}}^{\theta_{\max}} \max\{\theta_{it},\theta^*_t\} d\mathbf{F}(\theta_{it};\sigma_t). \tag{C.12}$$

We thus obtain Proposition 1.

D Proof of Proposition 2

Let ξ_{it} denote the Lagrangian multiplier for house-purchase limit (30). The first order conditions with respective to $\{C_{it}, H_{it+1}\}$ now take the form

$$\lambda_{it} = \frac{1}{C_{it}} + \phi\xi_{it}, \tag{D.1}$$

$$\lambda_{it} + \xi_{it} = \beta(1-\delta_h)\mathbf{E}_t\left[\tilde{\mathbf{E}}_t\left(\theta_{it+1}\lambda_{it+1}\frac{q_{ht+1}}{q_{ht}}\right)\right] + \frac{\eta_{it}}{q_{ht}}. \tag{D.2}$$

Given the aggregate environment, the individual household's consumption and housing decisions follow trigger strategies. Let θ^*_{it} and θ^{**}_{it} denote two cutoffs of idiosyncratic shock θ_{it}. Similar to the proof of Proposition 1, we consider following three cases about different housing decision rules given the cutoff value θ^*_{it}.

Case 1: $\theta^*_{it} \leq \theta_{it} \leq \theta^{**}_{it}$. In this case, the household's liquid wealth is in the middle, with moderate demand of liquidity, both of the liquidity constraint (9) and housing purchase limit constraint (30) are not binding, i.e., $0 \leq H_{it+1} \leq \phi\frac{C_{it}}{q_{ht}}$, $\eta_{it} = 0$ and $\xi_{it} = 0$.

(10) and (D.2) imply

$$\lambda_{it} = \beta(1-\delta_h)\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right). \tag{D.3}$$

From (D.1), we obtain the consumption decision

$$C_{it} = \left[\beta(1-\delta_h)\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1}. \tag{D.4}$$

The resource constraint implies the optimal housing decision is

$$q_{ht}H_{it+1} = \theta_{it}X_{it} - \left[\beta(1-\delta_h)\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1}. \tag{D.5}$$

The relationship $0 \leq H_{it+1} \leq \phi \frac{C_{it}}{q_{ht}}$ implies

$$\theta_{it} \geq \left[\beta(1-\delta_h) X_{it} \mathbf{E}_t \left(\Lambda_{t+1} \frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1} \equiv \theta_{it}^{*}, \tag{D.6}$$

$$\theta_{it} \leq (1+\phi) \left[\beta(1-\delta_h) X_{it} \mathbf{E}_t \left(\Lambda_{t+1} \frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1} \equiv \theta_{it}^{**}, \tag{D.7}$$

which define two cutoffs θ_{it}^{*} and θ_{it}^{**}. The definitions also imply $\theta_{it}^{**} = (1+\phi)\theta_{it}^{*}$.

Case 2: $\theta_{it} < \theta_{it}^{*}$. In this case, the household has a relatively low wealth. To smooth the consumption, the household tends to utilize all the liquidity, leading to a binding liquidity constraint (9). Therefore, the housing decision is simply $H_{it+1} = 0$, $\eta_{it} > 0$ and $\xi_{it} = 0$. The budget constraint implies that the consumption satisfies

$$C_{it} = \theta_{it} X_{it} = \frac{\theta_{it}}{\theta_{it}^{*}} \left[\beta(1-\delta_h) \mathbf{E}_t \left(\Lambda_{t+1} \frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1}. \tag{D.8}$$

From (D.1), we have

$$\lambda_{it} = \frac{\theta_{it}^{*}}{\theta_{it}} \left[\beta(1-\delta_h) \mathbf{E}_t \left(\Lambda_{t+1} \frac{q_{ht+1}}{q_{ht}}\right)\right]. \tag{D.9}$$

Since $\theta_{it} < \theta_{it}^{*}$, (D.2) implies $\eta_{it} > 0$.

Case 3: $\theta_{it} > \theta_{it}^{**}$. In this case, the household has a sufficiently high level of liquid wealth. So they tend to demand more housing as a buffer for the precautionary purpose. As a result, the house-purchase limit constraint (30) is binding, i.e., $H_{it+1} = \phi \frac{C_{it}}{q_{ht}}$, $\eta_{it} = 0$ and $\xi_{it} > 0$.

The budget constraint implies that the consumption satisfies

$$C_{it} = \frac{\theta_{it}}{1+\phi} X_{it} = \frac{\theta_{it}}{\theta_{it}^{*}(1+\phi)} \left[\beta(1-\delta_h) \mathbf{E}_t \left(\Lambda_{t+1} \frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1}. \tag{D.10}$$

From (D.1) and (D.2), we have

$$\lambda_{it} = \left(\frac{\theta_{it}^{*}}{\theta_{it}} + \frac{\phi}{1+\phi}\right) \left[\beta(1-\delta_h) \mathbf{E}_t \left(\Lambda_{t+1} \frac{q_{ht+1}}{q_{ht}}\right)\right]. \tag{D.11}$$

Plugging (D.6), (D.7) and (D.11) into the Euler equation for the capital decision (11) yields

$$1 = \beta(1-\delta_h)\Phi(\theta_{it}^*;\phi,\sigma_t)\mathbf{E}_t\left(\frac{\Lambda_{t+1}}{\Lambda_t}\frac{q_{ht+1}}{q_{ht}}\right), \tag{D.12}$$

where $\Phi(\theta_{it}^*;\phi,\sigma_t) = \int_{\theta_{\min}}^{\theta_{\max}}[\theta_{it}^*\mathbf{1}_{\{\theta_{it}<\theta_{it}^*\}} + \theta_{it}\mathbf{1}_{\{\theta_{it}^*\leq\theta_{it}\leq\theta_{it}^{**}\}} + (\theta_{it}^* + \frac{\phi}{1+\phi}\theta_{it})\mathbf{1}_{\{\theta_{it}>\theta_{it}^{**}\}}]d\mathbf{F}(\theta_{it};\sigma_t)$. Last equation and the definitions of cutoffs imply θ_{it}^* and θ_{it}^{**} are independent with idiosyncratic states. Thus, we can simply drop the subscript i for these two variables.

Also, it is obvious that X_{it} is independent with the idiosyncratic states. So we have

$$X_t = \left[\beta(1-\delta_h)\theta_t^*\mathbf{E}_t\left(\frac{\Lambda_{t+1}}{\Lambda_t}\frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1}. \tag{D.13}$$

Summarizing the consumption rules yields the optimal consumption decision

$$C_{it} = \left[\theta_{it}\mathbf{1}_{\{\theta_{it}<\theta_t^*\}} + \theta_t^*\mathbf{1}_{\{\theta_t^*\leq\theta_{it}\leq\theta_t^{**}\}} + \frac{\theta_{it}}{1+\phi}\mathbf{1}_{\{\theta_{it}>\theta_t^{**}\}}\right]X_t. \tag{D.14}$$

Last equation and the budget constraint imply the optimal housing demand

$$H_{it+1} = \left\{\theta_{it} - \left[\theta_{it}\mathbf{1}_{\{\theta_{it}<\theta_t^*\}} + \theta_t^*\mathbf{1}_{\{\theta_t^*\leq\theta_{it}\leq\theta_t^{**}\}} + \frac{\theta_{it}}{1+\phi}\mathbf{1}_{\{\theta_{it}>\theta_t^{**}\}}\right]\right\}\frac{X_t}{q_{ht}}. \tag{D.15}$$

Finally, (D.12) and (D.13) immediately give

$$X_t = \frac{1}{\theta_t^*\Lambda_t}\Phi(\theta_t^*;\phi,\sigma_t). \tag{F.19}$$

We thus prove Proposition 2.

E Full Dynamic System of Benchmark Model

The full dynamic system for the benchmark model can be summarized as follows.

1. Labor supply

$$\psi = w_t \Lambda_t, \tag{E.1}$$

where $\Lambda_t = \tilde{\mathbf{E}}_t(\theta_{it}\lambda_{it})$.

2. Euler equation for physical capital

$$1 = \beta \mathbf{E}_t \left\{ \frac{\mathbf{\Lambda}_{t+1}}{\Lambda_t} \left[r_{t+1} + (1-\delta_k) \right] \right\}. \tag{E.2}$$

3. Asset pricing for house price

$$q_{ht} = \Phi_t (1-\delta_h) \frac{\mathbf{E}_t q_{ht+1}}{1+r_t^i}. \tag{E.3}$$

where $\Phi_t\left(\theta_t^*; \sigma_t\right) = \int \max\left\{\theta_t^*, \theta_{it}\right\} d\mathbf{F}(\theta_{it}; \sigma_t)$, and $r_t^i \equiv \frac{1}{\beta \mathbf{E}_t \frac{\Lambda_{t+1}}{\Lambda_t}} - 1$.

4. Aggregate consumption:

$$C_t = \int \min\left\{\theta_t^*, \theta_{it}\right\} d\mathbf{F}(\theta_{it}; \sigma_t) X_t. \tag{E.4}$$

5. Aggregate housing demand:

$$H_{t+1} = \frac{X_t}{q_{ht}} \int \max\{\theta_{it} - \theta_t^*, 0\} d\mathbf{F}(\theta_{it}; \sigma_t); \tag{E.5}$$

6. Disposable wealth:

$$X_t = \frac{1}{\theta_t^* \Lambda_t} \int \max\left\{\theta_t^*, \theta_{it}\right\} d\mathbf{F}(\theta_{it}; \sigma_t). \tag{E.6}$$

7. Supply of housing asset:

$$h_t = \left(K_{ht}{}^{\alpha_h} N_{ht}^{1-\alpha_h} \right)^{1-\gamma} L_t^{\gamma}. \tag{E.7}$$

8. Demand for K_{ht} :

$$r_t = \alpha_h (1-\gamma) q_{ht} \frac{h_t}{K_{ht}}. \tag{E.8}$$

9. Demand for N_{ht} :

$$w_t = (1-\alpha_h)(1-\gamma) q_{ht} \frac{h_t}{N_{ht}}. \tag{E.9}$$

10. Demand of land L_t :

$$q_{lt} = \gamma q_{ht} \frac{h_t}{L_t}. \tag{E.10}$$

11. Supply of land

$$L_t = \bar{L}. \tag{E.11}$$

12. Total output in real sector:

$$Y_{pt} = K_{pt}^{\alpha_p} N_{pt}^{1-\alpha_p}. \tag{E.12}$$

13. Demand for K_{pt} :

$$r_t = \alpha_p \frac{Y_{pt}}{K_{pt}}. \tag{E.13}$$

14. Demand for N_{pt} :

$$w_t = (1 - \alpha_p) \frac{Y_{pt}}{N_{pt}}. \tag{E.14}$$

15. Law of motion of H_t :

$$H_{t+1} = (1 - \delta_h) H_t + h_t. \tag{E.15}$$

16. The aggregate resource constraint is given by

$$C_t + q_{ht} h_t + I_t = Y_t, \tag{E.16}$$

    where $I_t = K_{t+1} - (1 - \delta_k) K_t$.

17. Aggregate capital:

$$K_t = K_{pt} + K_{ht}. \tag{E.17}$$

18. Aggregate labor:

$$N_t = N_{pt} + N_{ht}. \tag{E.18}$$

F Steady State in Benchmark Model

We now solve the steady state. According to the definition of r^i, it is easy to obtain $r^i \equiv \frac{1}{\beta} - 1$. From the asset pricing equation, we have

$$\Phi\left(\theta^*\right) = \int \max\left\{\theta^*, \theta_i\right\} d\mathbf{F}(\theta_i;\sigma) = \frac{1}{\beta(1-\delta_h)}, \tag{F.1}$$

which can solve the cutoff θ^* directly. From the Euler equation for physical capital, we can obtain the steady-state $r = \frac{1}{\beta} - 1 + \delta$. From capital demand function (E.13), we then obtain $\frac{Y_p}{K_p}$ and $\frac{K_p}{N_p}$ through

$$r = \alpha_p \frac{Y_p}{K_p} = \alpha_p \left(\frac{K_p}{N_p}\right)^{\alpha_p - 1}. \tag{F.2}$$

And the wage rate is given by

$$w = \left(1 - \alpha_p\right) \frac{Y_p}{N_p} = \left(1 - \alpha_p\right) \left(\frac{K_p}{N_p}\right)^{\alpha_p}. \tag{F.3}$$

From the labor supply function, we have $\Lambda = \frac{\psi}{w}$. From the definition of X, we have

$$X = \frac{1}{\theta^* \Lambda} \int \max\left\{\theta^*, \theta_i\right\} d\mathbf{F}(\theta_i;\sigma). \tag{F.4}$$

And the consumption is

$$C = \int \min\left\{\theta^*, \theta_i\right\} d\mathbf{F}(\theta_i;\sigma) X. \tag{F.5}$$

The aggregate housing demand is

$$q_h H = X \int \max\{\theta_i - \theta^*, 0\} d\mathbf{F}(\theta_i;\sigma). \tag{F.6}$$

According the law of motion of H, we have $h = \delta_h H$, so we can solve $q_h h$.

From (E.8), we have $K_h = \frac{\alpha_h(1-\gamma) q_h h}{r}$. And from (E.9), we have

$$N_h = \frac{r}{w} \frac{1-\alpha_h}{\alpha_h} K_h. \tag{F.7}$$

Since $L = \bar{L}$, we can solve the h according to $h = \left(K_h^{\alpha_h} N_h^{1-\alpha_h}\right)^{1-\gamma} \bar{L}^{\gamma}$. And the house price q_h is easy to solve.

Furthermore, we can obtain land price

$$q_l = \gamma q_h \left(K_h^{\alpha_h} N_h^{1-\alpha_h}\right)^{1-\gamma} \bar{L}^{\gamma-1}. \tag{F.8}$$

Since $I = \delta K = \delta\left(K_p + K_h\right)$, through the resource constraint, we have

$$C = Y_{pt} - \delta_k K = (\frac{K_p}{N_p})^{\alpha_p} N_p - \delta_k \frac{K_p}{N_p} N_p - \delta_k K_h, \tag{F.9}$$

Using the precious results, we can solve K_p and N_p. Aggregate output Y is defined as $Y = Y_p + q_h h$.