Flight to Housing in China *

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Abstract

Using household-level survey and housing transaction data, we detect the flight to safety vis-a-vis housing in China: Great economic uncertainty causes the prices of housing assets to soar, especially those of good quality. To stabilize housing prices, China has imposed purchase restrictions on the housing market. In this paper, we study the aggregate and distributional effects of this housing policy by developing a two-sector macroeconomic model with heterogeneous households. An uncertainty shock generates a countercyclical housing boom by shifting outward households' demand for housing as a store of value. A vibrant housing sector then leads to an economic recession by crowding out resources that could have been allocated to the real sector. Our quantitative analysis suggests that the policy limiting housing purchases effectively curbs surging housing prices. However, the policy restricts households' access to housing that can be used to buffer idiosyncratic uncertainties, creating a larger consumption dispersion. Consequently, the housing policy creates a trade-off between macro-level stability and micro-level consumption risk sharing.

Keywords: Heterogeneous Households, Store of Value, Housing Policy, Aggregate and Distributional Effects, Consumption Risk Sharing

JEL Classification: E21, G11, G18, H31, R21.

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1 Introduction

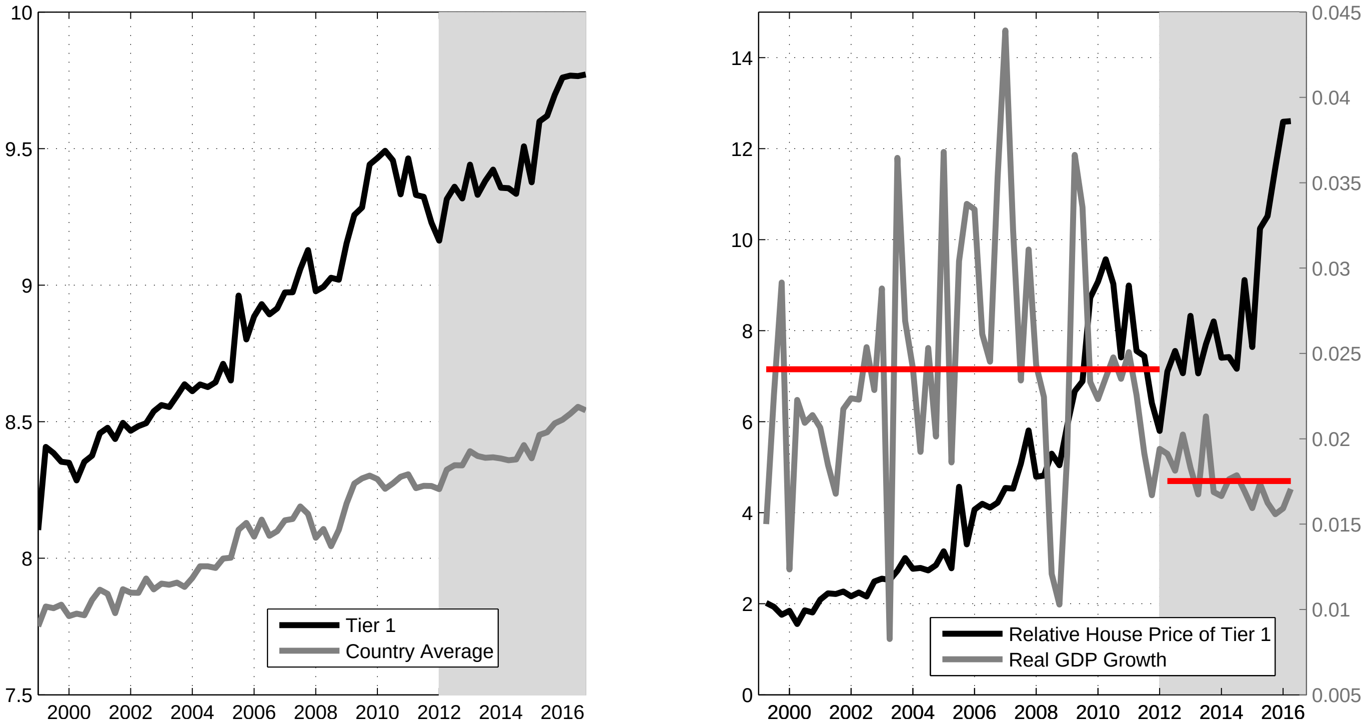
As the second largest economy and the largest developing economy in the world, China has been the major engine of global economic growth in the past decade. Meanwhile, as in other developing economies, China generally suffers from a safe-asset shortage. On the one hand, China has considerable demand for safe assets as a store of value. On the other hand, the underdeveloped financial system constrains the capacity of the country to produce safe assets. Furthermore, tight regulation on financial accounts intensifies the scarcity of safe assets in the domestic market as it is costly for Chinese households to hold prime assets issued by advanced economies like US. The shortage of safe assets naturally causes real estate assets to become desirable safe stores of value in China. Thereby, the Chinese economy serves as an ideal context for studying the flight to safety vis-à-vis housing.

The underlying mechanism of the global scarcity of safe assets and its aggregate consequences has been well documented in the recent literature (e.g., Caballero et al., 2008, 2016; Gorton and Ordonez, 2013; He et al., 2016a; etc). While theoretical works mainly focus on safe assets in the form of debt instruments and their impacts on advanced economies, real assets (especially housing) that are stores of value and their resulting consequences on developing economies are rarely explored. China contributes to the largest global saving glut, and real estate constitutes the largest part of Chinese household wealth. Therefore, the recent Chinese housing boom accompanied by an economic slowdown provides an ideal opportunity for us to evaluate housing assets as a store of value. To this end, we fill the gap in the literature through using Chinese economy as a laboratory to study the conundrum of safe-asset shortage.

Figure 1 provides a first look at the dynamics of Chinese housing prices. The left panel presents housing prices in two Tier 1 cities (Beijing and Shanghai) and the country's average prices. The right panel presents the relative house prices in Tier 1 cities compared to the country's average prices. It can be seen that prior to 2012, i.e., the starting point of China's recent economic slowdown, housing prices in Tier 1 cities and in other cities grew rapidly along with a high average GDP growth rate. Afterwards, economic growth decelerated.[1] In spite of the weak economic condition, housing prices

[1] The real GDP growth reduced from a annual rate of 10% (before 2012) to 6.5% (after 2012).

Figure 1: Housing Prices in Tier 1 Cities and Other cities[2]



Notes: Housing prices are the average real price of commercial housing in Tier 1 cities (Beijing and Shanghai) and for the whole country. The relative housing price is the difference between real housing prices in Tier 1 cities and real housing prices at the country-level. All the time series are from 1999Q1 to 2016Q4. The grey bars indicate the recent economic downturn (2012Q1-2016Q4). The red line in the right panel indicates average GDP growth rates for 1999-2011 and 2012-2016. Appendix A.2 describes the construction of these series in detail.

started to increase. In particular, housing prices in Tier 1 cities grew faster than those of other cities (see the right panel). The upswing in housing prices, especially in Tier 1 cities, under adverse economic conditions, broadly supported the role of housing assets as stores of value (or safe assets), in the sense that a safe asset is the one expected to preserve its value during adverse systemic events (Caballero et al., 2017).

The hypothesis that Chinese housing assets serve as a store of value suggests that great economic uncertainty may stimulate housing prices. Using Chinese household survey data, we document the

[2]The housing price indices we construct do not control for quality. A more reliable construction method is proposed by Fang et al. (2016). However, the housing price series used in that paper is only as recent as 2013Q1, which does not cover the recent economic downturn. As their housing data were obtained from a confidential source, we are not able to extend their series to a more recent date. To validate our housing price series, we compare the relative housing price in Tier 1 cities in our data (from 2003Q1-2013Q1) with that in Fang et al. (2016). We find that the two series track each other closely. The cyclicality of both series presents a very similar pattern. The correlation between the two series is significantly positive and approximately 0.6.

impact of household-level uncertainty (measured by the volatility of income shocks) on the average housing price and households' housing investments. The estimation results show that the uncertainty significantly increases the average housing price and the housing wealth to income ratio. Thereby, greater uncertainty tends to stimulate households' housing investments and boost housing prices. Furthermore, using more detailed housing transaction data from Beijing, we document the impact of economic uncertainty on the average housing price as well as the impact on the average housing price with relatively good quality. The regression analysis reveals that economic uncertainty significantly raises both the average housing price and the relative prices of housing with better quality. This kind of empirical pattern is robust to various measurements of housing quality as well as to different model specifications.

To model and quantify the empirical findings, we construct a two-sector dynamic general equilibrium heterogeneous agent model in which housing assets emerge as a store of value.[3] Liquidity constraints confine the households' capacity to insure idiosyncratic uncertainties. As a result, housing assets endogenously serve as a store of value (Heathcote and Perri, 2018). The Euler equation for asset pricing implies that housing prices in the current period are determined by the expected price and a premium term. As the economy becomes more uncertain, the demand for housing as a store of value increases. Then, an uplifted premium for holding housing leads to a boost in housing prices. The expansion in the housing sector, in turn, diverts resources allocated to the real estate sector, resulting in an aggregate recession. After calibrating the model to the Chinese economy, we find that a 25% increase in uncertainty (standard deviation of idiosyncratic shocks) raises the equilibrium housing 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 an extended model where multiple liquid assets (e.g., government bonds) are introduced, we find that the transmission mechanism in our baseline model remains important as long as the supply of other liquid assets is limited.

To stabilize housing prices, the Chinese government implemented a policy that limits the number of homes households can purchase. Correspondingly, we quantitatively evaluate this kind of policy

[3]The housing in our model can be considered as housing with good quality according to the data.

intervention. The tractability of our model allows us to derive, in a transparent way, the process of housing prices as well as the individual optimal decisions following the government's intervention. We show that the policy limiting home purchases can effectively impede the demand for housing and thus the housing boom. The dampened crowding out effect from the housing sector mitigates the adverse consequences of economic uncertainty on the real sector. However, we also find that the policy intervention prevents households from investing in housing assets as a buffer for consumption risks and reduces the degree of consumption insurance. As a result, social welfare is reduced due to the rising consumption growth dispersion. We conclude that there exists a trade-off between aggregate housing price stability and consumption risk sharing using housing as a safe asset.

Literature Review The current paper is generally related to a large body of the literature, which we do not attempt to go through here. Instead, we highlight only the papers that are most closely related to this study. First, the flight to quality (safety) and liquidity during the last financial crisis has created considerable demand for the analysis of the shortage of safe assets. Our paper contributes to this strand of the literature. The empirical work by Krishnamurthy and Vissing-Jorgensen (2012) analyzes the aggregate demand for US government bonds and decomposes the credit spread between risky assets and treasury assets into the liquidity premium and safety premium. Caballero et al. (2016) and Caballero and Farhi (2017) explore the macroeconomic implications of safe asset shortages. Benigno and Nisticò (2017) study how monetary policy affects the real economy when safe and "pseudo-safe" assets coexist in equilibrium. He et al. (2016a,b) and Gorton and Ordonez (2013) develop a theory of endogenous safe assets. Generally, in addition to government bonds (issued by the US and many OECD countries), money is among the most safe and liquid assets that serve as stores of value. Our model is well-connected with Wen (2015), which develops a tractable Bewley model with micro-founded money demand. Another relevant paper, Quadrini (2017), shows that, in addition to the standard lending channel, financial intermediation affects the real economy through a novel banking liability channel by issuing liabilities, which are recognized as safe assets by agents facing uninsurable idiosyncratic risk. See Caballero et al. (2017), Gorton (2017) and Golec and Perotti (2017) for detailed survey on safe assets.

Second, our paper is related to the strand of the literature on housing markets in developed and developing economies. Iacoviello (2005), Chaney et al. (2012), and Liu et al. (2013) show that the collateral channel induced by housing can stimulate private investment in the US. Miao et al. (2014) introduce housing assets into a heterogeneous-firm model with financial constraints. They show that the liquidity premium generated by the housing assets provides an important channel that amplifies US business cycles.[4] He et al. (2015) study a series of models where housing bears a liquidity premium because it collateralizes loans. They show that the house prices may present rich dynamics such as cyclic, chaotic or stochastic even with fundamentals constant. Zhao (2015) shows in an OLG model that the housing bubble may emerge as a store of value when the equilibrium interest rate is reduced due to the tight financial friction. In contrast, for emerging economies, Chen et al. (2016) find that China's housing boom crowds out real investment. Fang et al. (2016) empirically find that housing prices have experienced enormous appreciation from 2000 to 2012, and this was accompanied by equally impressive growth in household income, except in a few first-tier cities.[5] Moreover, Liang et al. (2016) use city-level panel data to document the impact of land supply policies on China's housing prices. They find the tight land supply policies have led to the rapid growth of housing prices and increased wages in the cities in eastern China. Zhang (2016) empirically and quantitatively address the heterogeneous effects of housing prices by investigating the relationship between inequality and housing prices. 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 et al. (2018) links housing values to fundamental economic variables such as income growth, demographics, migration and land supply.[6] Dong et al. (2019) introduce the firm's housing investment behavior into a New Keyesian DSGE model for the Chinese economy and quantitatively evaluate various types of stabilization policies. See Glaeser (2017) for a more comprehensive survey on the Chinese housing market. Our paper contributes to the housing literature through an anatomy

[4]See Head et al. (2014), among others, for a discussion on the recent development of a search-based approach to housing markets.

[5]Zhang (2017) conducts a quantitative analysis based on the facts provided by Fang et al. (2016).

[6]See also Garriga et al. (2017), who analyze how rural-to-urban migration contributes the appreciation of housing prices in China's large cities, and Diamond and McQuade (2016), for a discussion of amenities in large cities in the US.

of the aggregate and distributional effects of a housing policy that tries to stabilize the countercyclical housing boom in China.

Our paper is also related to the literature on household heterogeneity in the canonical Bewley-Aiyagari-Huggett model. Household heterogeneity has recently received increasing attention, in particular, the key channels of household's insurance and the heterogeneous treatment effect of monetary policy. To address the implications of a large decline in households' net worth between 2007 and 2013, Heathcote and Perri (2018) develop a monetary model in which households face idiosyncratic unemployment risk that they can partially self-insure against by using savings. Kaplan et al. (2018) revisit the transmission mechanism of monetary policy for household consumption in a Heterogeneous Agent New Keynesian (HANK) model. Auclert (2017) evaluates the role of redistribution, in terms of consumption, in the transmission mechanism of monetary policy. See Heathcote et al. (2009) for a comprehensive discussion on the related literature.

Finally, our work belongs to the vibrant stream of the literature on the aggregate impact of economic uncertainty. Bloom (2009) and Bloom et al. (2018) construct a heterogeneous-firm model with nonconvex capital and a labor adjustment cost to show that the wait-and-see effect acts as a major channel that propagates uncertainty shocks. Schaal (2017) highlights the role of labor market friction in amplifying uncertainty shocks. Arellano et al. (2016), Christiano et al. (2014), Gilchrist et al. (2014), and Alfaro et al. (2017) emphasize financial friction as a key channel that transmits firm level uncertainty. In contrast, our paper documents the aggregate consequences of microeconomic uncertainty through the lens of the shortage of safe assets.

The remainder of this paper proceeds as below. To better motivate our research, in Section 2, we present more empirical facts at the disaggregate level. Then, Section 3 and 4 respectively model and quantify the effects of uncertainty on housing and other variables of interest using a two-sector model, where housing is a store of value. In Section 5, we conduct a welfare analysis by investigating both the aggregate and distributional effects of the housing policy. Section 6 provides the conclusion. We provide the data descriptions, more empirical results and proofs in the appendices.

2 Empirical Facts

2.1 Evidence from the Household Survey

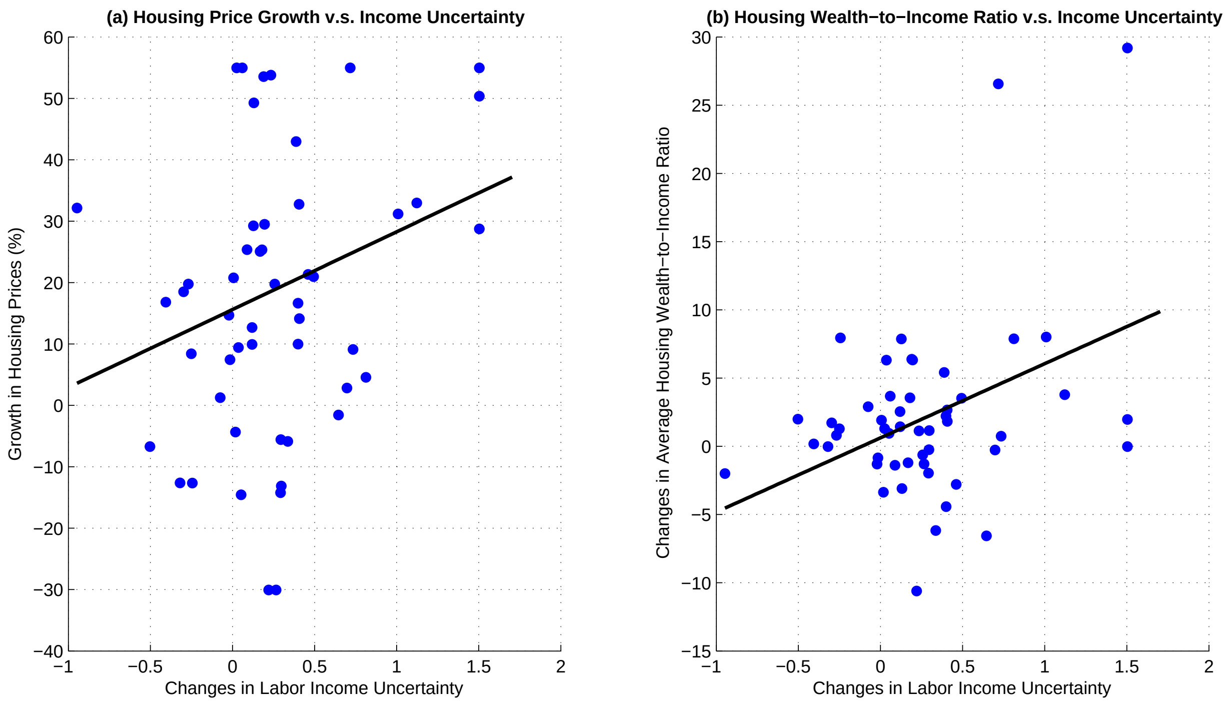
According to the household survey conducted by China Family Panel Studies (CFPS), housing assets account for approximately 80% of households' total assets.[7] Moreover, housing assets are considered to be a relatively safe investment compared to investment in the stock market (Cooper and Zhu, 2017). If housing assets are treated as stores of value, then households tend to demand more housing assets when the economy becomes more uncertain. Therefore, we expect to observe a positive relationship between housing prices and economic uncertainty.

We first document the correlation between household-level uncertainty and the average housing price. Based on the CFPS survey, we construct household income uncertainty as a proxy for the household-level uncertainty and the growth rate of housing prices at the city level. Specifically, we first compute the residual from the income equation using the Mincer regression. City-level household income uncertainty is defined as the variance of the change in the income residual between two subsequent waves of survey. The left panel (Panel a) in Figure 2 shows scatter-plots of the 2-year change in household income uncertainty versus the 2-year growth rate of housing prices in China between 2012 and 2014. The figure shows that there is a significant and positive correlation between household-level uncertainty and the growth rate of housing prices, which suggests that a larger uncertainty is associated with a faster growth of housing prices. We also plot household-level uncertainty against the housing wealth to income ratio. The relationship between these two variables presents a very similar pattern, i.e., a higher households' housing wealth to income ratio is associated with a greater uncertainty.

To provide a rigorous analysis on the impact of uncertainty on the average housing price, we

[7] The share of housing assets in total assets is computed as the ratio between the value of housing to the value of total assets. The average share is computed across households. According to CFPS, the share is 0.83, 0.77, 0.77 and 0.78 respectively for the four waves of the survey (2010, 2012, 2014 and 2016). This pattern is consistent with that proposed in Cooper and Zhu (2017), which uses the China Household Finance Survey conducted in 2012.

Figure 2: Housing and Uncertainty



Notes: Panel (a) plots the 2-year changes in real housing prices versus the 2-year changes in the labor income uncertainty in China between 2012 and 2014. Panel (b) plots the 2-year changes in the housing wealth-to-income ratio against 2-year changes in the labor income uncertainty in China between 2012 and 2014. Each data point in the figure represents one particular city. Data source: CFPS 2012 and 2014. The labor income uncertainty is defined as the variance of households' the growth of labor income residual, which is derived from the standard Mincer regression. The housing price is the city-level average price, which is constructed using the CFPS data. Each city's housing wealth-to-income ratio is defined as the total households' gross value of housing assets divided by total households' labor income in the same city. The sample includes homeowners living in urban China, aged 20-60. We exclude the city with sample size smaller than 30 households. We also winsorize the changes in the labor income uncertainty, the growth in housing prices, and the housing wealth-to-income ratio at 5 and 95 percentiles. In the end, we are left with 51 cities. The solid line denotes the univariate OLS regression line. Each city is weighted by the sum of households' weight in that city. Results would be similar if we use equal weights for every city. Appendix A.1 provides more details about the data construction.

specify the following econometric model

$$p_t^{i,j} = \alpha_1^i + \alpha_2 \times \text{UNC}_t^j + \sum_\kappa \alpha_{3,\kappa} \times I_{\kappa t}^{i,j} + \alpha_4 \times f\left(\text{edu}^{i,j}\right) + \alpha_5 \times g\left(\text{age}_t^{i,j}\right) + \alpha_6 \times \text{FamilySize}_t^{i,j} + \delta_t + \varepsilon_t^{i,j}, \quad (1)$$

where $p_t^{i,j}$ measures the log of the real housing price per square meter for household i in city j and year t. α_1^i captures the household fixed effect. UNC_t^j captures labor income uncertainty in city j and year t. This variable is constructed using the residuals from the standard Mincer regression and measures households' labor income uncertainty in city j and year t. $I_{\kappa t}^{i,j}$, for $\kappa = \{\text{self-employed, employed, agriculture, and soe}\}$, denotes a set of dummy variables indicating the employment status (i.e., self-employed, employed in the agriculture sector, and employed by a state-owned or private-owned enterprise, respectively) of household i in city j and year t. $f\left(\text{edu}^{i,j}\right)$ denotes a quadratic polynomial of the years of education for household i in city j; $g\left(\text{age}_t^{i,j}\right)$ denotes a quadratic polynomial of the age of family head; $\text{FamilySize}_t^{i,j}$ measures the number of family members, and finally, δ_t denotes the year fixed effect. We provide details about the data constructions in Appendix A.1.

Column 1 in Table 1 reports the main results for the fixed-effect panel regression, which shows that the labor income uncertainty has positive and significant impact on individual housing prices. In particular, a one-unit increase in the labor income uncertainty at city level tends to increase housing prices by 5.4%. In our sample, the growth of labor income residual has a standard deviation of 0.49. Therefore, one standard deviation increase in uncertainty will lead to 2.6 (5.4×0.49) percent increase in housing prices.[8] We provide robustness check using log labor income uncertainty and normalized labor income uncertainty (i.e., the labor income uncertainty minus its sample mean and then divide it by its standard deviation in the sample) respectively in Table A.1 in Appendix A.1.

To document the impact of household-level uncertainty on households' investments in housing assets, we use a regression where the dependent variable is the ratio of gross value of housings ($v_t^{i,j}$)

[8]Our finding is generally consistent with that in Hryshko et al. (2010), who find that in the US economy the housings can be used to improve risk sharing and smooth the households' consumption.

Table 1: Impact of the Household-level Uncertainty on the Housing Market

	(1) Housing Price	(2) Housing Wealth/Labor Income
Labor Income Uncertainty	0.054**	0.139***
	(0.0086)	(0.042)
Other controls	Yes	Yes
Family FE	Yes	Yes
Year FE	Yes	Yes
Observations	4,135	4,423
Number of HH	2,221	2,401
Adjusted R^2	0.041	0.022

Notes: Columns 1 and 2 report the results for the fixed effect models, in which the dependent variables are housing prices and the housing wealth to income ratio, respectively. The housing wealth is measured by the gross value of housings. In the fixed effect model, the education variable is removed since the household's education status is time-invariant. The numbers in parentheses are standard errors. The levels of significance are denoted as *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$. The complete estimation results for the control variables are presented in Appendix A.1. Data source: CFPS 2012, 2014 and 2016.

to households' labor income ($y_t^{i,j}$):

$$\frac{v_t^{i,j}}{y_t^{i,j}} = \alpha_1^i + \alpha_2 \times \text{UNC}_t^j + \sum_\kappa \alpha_{3,\kappa} \times I_{\kappa t}^{i,j} + \alpha_4 \times f\left(\text{edu}^{i,j}\right) + \alpha_5 \times g\left(\text{age}_t^{i,j}\right) + \alpha_6 \times \text{FamilySize}_t^{i,j} + \delta_t + \varepsilon_t^{i,j}, \quad (2)$$

Column 2 in Table 1 reports the corresponding estimation results. The table shows that the impact of uncertainty on the households' housing wealth to income ratio is significant and positive. In particular, a one unit increase in city level labor income uncertainty is associated with 13.9% increase in the housing to income ratio. Therefore, one standard deviation increase in uncertainty leads to 6.8 (13.9×0.49) percent increase in the housing wealth to income ratio.[9]

Figure 2 and the regression results in Table 1 suggest that greater household-level uncertainty tends to raise household demand for housing assets and boost housing prices. This finding supports our hypothesis that housing assets in China play a role of store of value, especially when the economy becomes more uncertain.

[9] The estimation of the coefficient of UNC_t^j remains robust but slightly smaller when housing wealth is measured by the gross value net of mortgage.

2.2 Evidence from Residential Housing Transaction Data

Two potential issues regarding the household survey data are that the price of housing is self-reported and the quality of housing asset is hard to control. Next, we conduct an alternative empirical analysis by using a micro-level dataset on housing transactions, which contains detailed information on each housing transaction in Beijing. Because the transaction data is only limited to one city, we cannot further use the geographic variation in household-level uncertainties to identify the impact of uncertainties on the housing price and the housing demand. Instead, we exploit the time variation in uncertainties and study the heterogeneous price responses from housing assets with different quality. More precisely, we estimate the impact of uncertainty on the price dispersion between housing (apartments) with relatively high quality and those with lower quality. If housing assets can act as stores of value, an increase in economic uncertainty would lead to an increase in the average housing price. Our hypothesis is that an increase in the economic uncertainty will induce the price of housing with better quality to increase more.

We get the monthly residential housing transaction data for Beijing from the first month of 2013 to the last month of 2016 from the biggest housing agency in China. The data cover about 40-50 percent of all second-hand housing transactions in the sample period and can be considered as a representative sample of Beijing. See Appendix A.2 for more details about the representativeness of our data.

In order to measure the quality of housing assets, we use four major indicators to represent *good quality*: the apartment (i) faces both north and south; (ii) was built less than 15 years ago; (iii) is located within the second ring of Beijing; and (iv) is in a key-school zone.[10]

Since the measure of household-level uncertainty in monthly frequency is absent in China, we use several popular macroeconomic uncertainty indicators of the Chinese economy as proxies. In particular, we employ the following uncertainty indicators

1. stock market volatility (SV);

[10] We do not consider "close to the subway" and "with an elevator" as indicators of good quality because for the former, in our sample, almost 93% of the apartments in the transactions are classified as "close to the subway", and for the latter, an "apartment with an elevator" is highly correlated with the third characteristic.

2. the macroeconomic uncertainty (MU) index constructed by Huang and Shen (2018); and

3. the economic policy uncertainty (EPU) index constructed by Baker et al. (2016).

Appendix A.2 illustrates the data constructions for these three uncertainty indicators.

In our baseline regression analysis, to document the impact of uncertainty on the average housing price, we specify the regression equation as

$$p_t^{i,j} = \alpha_1^j + \alpha_2 \times \mathrm{UNC}_t + \sum_{\tau=1}^{4} \alpha_{3,\tau} \times I_{Good}^{i,\tau} + \alpha_4 \times X_t^i + \alpha_5 \times Z_t + \varepsilon_t^{i,j}. \tag{3}$$

In the above equation, $p_t^{i,j}$ denotes the log price per square meter for house i at time t and region j in Beijing; α_1^j is the term for the address fixed effect; UNC is the uncertainty index measured by SV, MU or EPU; and $I_{Good}^{i,\tau}$ indicates housing with the τ-th good-quality characteristic, i.e., the aforementioned four categories. X_t^i indicates other control variables for individual characteristics, including a quadratic polynomial of size, age of the building, height of the floor, whether the building is close to the subway, whether the building has an elevator, distance to the closest primary school, and dummies for district, subdistrict and block. Z_t denotes indicators for the aggregate economy that aim to control for aggregate shocks, macroeconomic conditions and the common trend of housing price growth.[11] In some specifications, Z_t also includes the year fixed effect and the month fixed effect.

Table 2 summarizes the results of the baseline estimation. Columns 1-3 correspond to three cases where uncertainty is measured by stock market volatility (SV), macroeconomic uncertainty (MU) and economic policy uncertainty (EPU), respectively. The results show that economic uncertainty significantly increases the average level of housing prices in Beijing. More specifically, if economic uncertainty increases by one standard deviation, the average price of a second-hand apartment in Beijing increase by 0.8% for the SV case (Column 1), 5% for the MU case (Column 2), and 8% for the EPU case (Column 3).[12] Moreover, the homes with relatively good quality (those belonging to

[11] Z_t includes the Keqiang index, growth rate of fixed investments, monthly inflation rate, Shibor rate, and A-share index. Appendix A.2.3 provides more details.

[12] The standard deviation of the stock market volatility indicator is 0.12. Therefore, a one-standard-deviation increase in uncertainty would lead to an $0.0689 \times 0.12 \simeq 0.8\%$ increase in the average housing price. The standard

Table 2: Impact of Economic Uncertainty on Housing Prices

VARIABLES	(1) UNC=SV $p_t^{i,j}$	(2) UNC=MU $p_t^{i,j}$	(3) UNC=EPU $p_t^{i,j}$	(4) UNC=SV $p_t^{i,j}$	(5) UNC=MU $p_t^{i,j}$	(6) UNC=EPU $p_t^{i,j}$
UNC	0.0689***	0.935***	0.219***	–	–	–
	(0.0141)	(0.0333)	(0.0081)	–	–	–
EliteSchool=1	0.0576***	0.0574***	0.0573***	0.0444***	0.0931***	0.0389***
	(0.0016)	(0.0016)	(0.0016)	(0.0047)	(0.0089)	(0.0025)
South=1	0.0646***	0.0643***	0.0643***	0.0485***	0.1150***	0.0561***
	(0.0014)	(0.0014)	(0.0014)	(0.0048)	(0.0094)	(0.0024)
Age≤15	0.0586***	0.0584***	0.0585***	0.0499***	0.0887***	0.0459***
	(0.0021)	(0.0021)	(0.0021)	(0.0049)	(0.0090)	(0.0028)
Ring≤2	0.0213***	0.0208***	0.0211***	-0.00967	0.0572***	0.0035
	(0.0036)	(0.0036)	(0.0036)	(0.0069)	(0.0124)	(0.0044)
(EliteSchool=1)×UNC	–	–	–	0.0271***	0.0799***	0.0808***
	–	–	–	(0.0089)	(0.0199)	(0.0082)
(South=1)×UNC	–	–	–	0.0299***	0.1170***	0.0307***
	–	–	–	(0.0093)	(0.0211)	(0.0087)
(Age≤15)×UNC	–	–	–	0.0153*	0.0707***	0.0490***
	–	–	–	(0.0088)	(0.0199)	(0.0082)
(Ring≤2)×UNC	–	–	–	0.0606***	0.0829***	0.0738***
	–	–	–	(0.0119)	(0.0271)	(0.0112)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Closing Date	No	No	No	Yes	Yes	Yes
Observations	123,663	123,663	123,625	123,663	123,663	123,625
R-squared	0.675	0.687	0.688	0.695	0.695	0.696

Notes: Columns 1-3 respectively correspond to the cases where economic uncertainty is measured respectively by stock market volatility (SV); macroeconomic uncertainty (MU), as constructed by Huang and Shen (2018); and economic policy uncertainty (EPU), as constructed by Baker et al. (2016). Since the economic uncertainty indicators are based on an aggregate time series, in this regression, we cannot control for the deal date fixed effect. In columns 4-6, we control for the deal date fixed effect, so the aggregate time series variables are removed in this regression due to the colinearity issue. EliteSchool=1 indicates that the housing is located in a key school zone; South=1 indicates that the housing faces both south and north; Age $\leq$ 15 indicates the age of the housing is less than or equal to 15 years; and Ring $\leq$ 2 indicates the housing is located in the second ring of Beijing city. The numbers in parentheses are standard errors. The levels of significance are denoted as *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

one of the four categories) tend to have higher prices for both measurements of uncertainty.[13]

If housing assets act as stores of value, then the price of housing with relatively good quality may increase even more when economic uncertainty becomes larger. Therefore, we expect to observe that economic uncertainty has a positive impact on the relative price of houses with better quality and those of all other housing. To test this hypothesis, we introduce interaction terms $I^{i,\tau}_{Good}\times\text{UNC}_t$ into the baseline regression. For brevity, we report only the estimation of the coefficients of the interaction terms $I^{i,\tau}_{Good}\times\text{UNC}_t$.[14] Columns 4-6 in Table 2 present the main results. This table shows that economic uncertainty has a significant and positive impact on the relative price of houses with better quality and that of the rest of the sample. For instance, for the case of SV (Column 1), a one standard deviation increase in SV would raise the relative price of: (i) housing located in a key-school zone by 0.3%; (ii) housing facing south by 0.35%; (iii) housing less than 15 years old by 0.2%; and (iv) housing located within the second ring of Beijing by 0.7%. The positive impact of uncertainty on the price dispersion of housing with good quality provides direct evidence that prime houses act as safe assets, in the sense that a safe asset is an asset that is expected to preserve its value during adverse systemic events (Caballero et al., 2017).[15]

In summary, the evidence from both the household survey data and housing transactions data suggests that when the economy becomes more uncertain, Chinese demand more housing, especially housing with relatively high quality. This result implies that housing assets may play an important role as stores of value for households to insure against economic uncertainty.

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deviations of the MU and EPU indicators are 0.06 and 0.36, respectively, so the marginal increases in housing prices caused by a one-standard-deviation increase in MU or EPU are approximately 5% and 8%, respectively.

[13]We also conduct estimations where four interaction terms are added sequentially, and the main results remain unchanged.

[14]In this regression, we also control for the deal date fixed effect. After doing this, we cannot identify the main effect of uncertainty on the reference group due to the colinearity problem. However, we can still identify the impact of uncertainty on the control group by looking at the interaction term. We find that the coefficients before the interaction term barely change after we control for the deal date fixed effect.

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

3 Baseline Model

Motivated by the aforementioned empirical facts, we now construct a dynamic general equilibrium model to quantitatively evaluate the impact of economic uncertainty on the housing market. In particular, we introduce housing assets into an otherwise standard neoclassical model with incomplete market. We assume that in the model, housing plays only the role of a store of value. Therefore, when households face greater uncertainty, they demand more housing assets. Then, we calibrate the model to the Chinese economy and quantitatively evaluate the aggregate impact of the housing boom. We also introduce the policy limiting home purchases into the baseline model and conduct a counter-factual policy analysis.

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

3.1 Households

The economy is populated by a continuum of households with a unit measure. Each household is indexed by $i \in [0, 1]$. In each period, household i with disposable wealth X_{it} (this will be elaborated later) is hit by an idiosyncratic shock, θ_{it}. We assume that 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 a mean of 1 and a time-varying standard deviation σ_t. Therefore, σ_t captures household-level economic uncertainty. Following Wen (2015), we divide each period into two subperiods. In the first subperiod, prior to the realization of the idiosyncratic shock θ_{it}, the household makes decisions regarding the 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 goods C_{it} and housing assets H_{it+1}. The above setup of timing implies that housing assets can be used as a buffer to smooth consumption and to insure the idiosyncratic uncertainties caused by θ_{it}.

We now discuss the household's optimization problem. Following Wen (2015), we specify the household's utility as a quasilinear form of 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 its life-time expected utility:

$$\max_{\{C_{it}, H_{it+1}\}} \mathbf{E}_0 \left[\max_{\{N_{it}, K_{it+1}\}} \tilde{\mathbf{E}}_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_{it} - \psi N_{it} \right) \right], \tag{4}$$

where β is the discount rate and 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

$$C_{it} + q_{ht} H_{it+1} = \theta_{it} X_{it}, \tag{5}$$

where q_{ht} is the real housing price, and X_{it} is real disposable wealth, excluding the purchase of investment in physical capital.[16]

$$X_{it} = (1 - \delta_h) q_{ht} H_{it} + w_t N_{it} + r_t K_{it} + D_t - \left[K_{it+1} - (1 - \delta_k) K_{it} \right], \tag{6}$$

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

In addition, we impose a no-short-selling constraint on housing assets; i.e., the amount of housing is required to be nonnegative:[17]

$$H_{it+1} \geq 0. \tag{7}$$

The last inequality indeed imposes a liquidity constraint on holding housing assets. As a result,

[16] As discussed in Wen (2015), the disposable wealth defined in equation (6) guarantees that there is an analytical solution for a household's optimal decision, which further allows the tractable aggregation of heterogeneous households.

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

when the household is facing greater economic uncertainty (σ_t increases), the household tends to hold more housing assets to reduce the risk of the binding of the liquidity constraint (7). Note that our model implicitly assumes that households rely on housing as a saving instrument to provide liquidity. This assumption is broadly consistent with the stylized fact that in China, housing assets are a major saving instrument used by households (housing assets account for almost 80% of household total wealth). Alternatively, we can introduce other types of liquid assets, for instance, government bonds. However, as long as the supply of these assets is limited (which is indeed the reality in China), the main mechanism in our paper remains valid. Section 4.3 provides further discussions of this issue.

Let λ_{it} and η_{it} denote the Lagrangian multipliers for the budget constraint (5) and the liquidity constraint (7), respectively. The first order conditions with respect to $\{N_{it}, K_{it+1}, C_{it}, H_{it+1}\}$ are given by the following equations

$$\psi = w_t \tilde{\mathbf{E}}_t(\theta_{it}\lambda_{it}), \tag{8}$$

$$\tilde{\mathbf{E}}_t(\theta_{it}\lambda_{it}) = \beta \mathbf{E}_t\left[(r_{t+1} + 1 - \delta_k)\tilde{\mathbf{E}}_{t+1}(\theta_{it+1}\lambda_{it+1})\right], \tag{9}$$

$$\frac{1}{C_{it}} = \lambda_{it}, \tag{10}$$

$$\lambda_{it} = \beta(1-\delta_h)\mathbf{E}_t\left[\tilde{\mathbf{E}}_{t+1}\left(\theta_{it+1}\lambda_{it+1}\right)\frac{q_{ht+1}}{q_{ht}}\right] + \frac{\eta_{it}}{q_{ht}}. \tag{11}$$

Condition (8) describes the labor supply. (9) is the Euler equation for the intertemporal decision regarding physical capital. Since labor and capital decisions are made prior to the realization of the idiosyncratic shock θ_{it}, the expectation operator $\tilde{\mathbf{E}}$ appears in both equations. (10) is the optimal decision for consumption. (11) is the Euler equation for the intertemporal decision for housing purchases. The right-hand side of this equation describes the expected benefit of holding housing. Note that in the absence of the liquidity constraint (e.g., $\eta_{it} = 0$) and idiosyncratic uncertainty (e.g., $\theta_{it} = 1$ for any i), (9) and (11) imply that the household has no incentive to purchase housing assets. In addition, (8) and (9) indicate that we can define the discount factor, Λ_t, which is similar to that in the representative agent model, as $\Lambda_t \equiv \tilde{\mathbf{E}}_t(\theta_{it}\lambda_{it})$.

3.2 Housing Sector

There is a representative housing producer that rents capital K_{ht} at the rental rate r_t, hires labor N_{ht} at the wage rate w_t, and purchases land L_t at price q_{lt}, which are all inputs used to produce housing h_t. Following Davis and Heathcote (2005) and Han et al. (2018), we specify the production technology as

$$h_t = \left(K_{ht}^{\alpha_h} N_{ht}^{1-\alpha_h}\right)^{1-\gamma} L_t^{\gamma}, \tag{12}$$

where $\gamma \in (0,1)$ is the land share and $\alpha_h \in (0,1)$ describes the capital share. 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 the three inputs are given by

$$r_t = \alpha_h (1-\gamma) q_{ht} \frac{h_t}{K_{ht}}, \tag{13}$$

$$w_t = (1-\alpha_h)(1-\gamma) q_{ht} \frac{h_t}{N_{ht}}, \tag{14}$$

$$q_{lt} = \gamma q_{ht} \frac{h_t}{L_t}. \tag{15}$$

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

$$L_t = \bar{L}. \tag{16}$$

3.3 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} at the wage rate w_t and rents capital K_{pt} with the rental rate r_t to produce the final good Y_{pt}. The production function takes the form of a Cobb-Douglas function, $Y_{pt} = K_{pt}^{\alpha_p} N_{pt}^{1-\alpha_p}$, where $\alpha_p \in (0,1)$ is the capital share. The optimal demand for both capital and labor is given by

$$r_t = \alpha_p \frac{Y_{pt}}{K_{pt}}, \quad (17)$$

$$w_t = (1-\alpha_p)\frac{Y_{pt}}{N_{pt}}. \quad (18)$$

3.4 Aggregation and General Equilibrium

We define the aggregate variables in the $\kappa \in \{p,h\}$ sector as $\chi_{\kappa t}$, where $\chi = \{K, N, Y\}$. We define the aggregation of the 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

$$K_t = \sum_{\kappa\in\{p,h\}} K_{\kappa t} \text{ and } N_t = \sum_{\kappa\in\{p,h\}} N_{\kappa t}. \quad (19)$$

The housing market equilibrium condition implies

$$h_t = H_{t+1} - (1-\delta_h)H_t. \quad (20)$$

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

$$C_t + q_{ht}h_t + I_t = Y_t, \quad (21)$$

where $I_t = K_{t+1} - (1-\delta_k)K_t$. We also define the sectoral investment as $I_{\kappa t} = K_{\kappa t+1} - (1-\delta_k)K_{\kappa t}$, where $\kappa = \{p,h\}$.

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

3.5 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 household's consumption and housing decisions follow a trigger strategy. Let θ_{it}^* denote the cutoff of the 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 households have a relatively high level of wealth, so they tend to hold more housing as a buffer to smooth consumption. As a result, the no-short-selling constraint for housing (7) does not bind; i.e., $H_{it+1} > 0$ and $\eta_{it} = 0$. In Appendix B.1, we show that the cutoff θ_{it}^* satisfies

$$\theta_{it}^* = \frac{1}{X_{it}\beta(1-\delta_h)\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)}. \tag{22}$$

Since $\eta_{it} = 0$, the first order conditions (8) and (11) imply that the optimal consumption in this case satisfies $C_{it} = \theta_{it}^* X_{it}$. Because of the budget constraint (5), the optimal housing decision is given by $H_{it+1} = (\theta_{it} - \theta_{it}^*)X_{it}$. This condition indicates that only wealthy households (θ_{it} is larger than the cutoff) hold a positive level of housing assets.

Case 2: $\theta_{it} < \theta_{it}^*$. In this case, the household has a relatively low level of wealth. To smooth consumption, the household will sell all of the housing at hand, $(1-\delta_h)H_{it}$, to obtain extra liquidity, leading to a binding constraint (7). Therefore, the housing decision is simply $H_{it+1} = 0$, and the optimal consumption is $C_{it} = \theta_{it}X_{it}$.

Proposition 1 below characterizes the household's optimal decisions.

Proposition 1 *Conditional on the aggregate states, the cutoff θ_{it}^* and the wealth X_{it} of 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 the following trigger strategy:*

$$C_{it} = \min\{\theta_t^*, \theta_{it}\}X_t, \tag{23}$$

$$H_{it+1} = \max\{\theta_{it} - \theta_t^*, 0\}\frac{X_t}{q_{ht}}; \tag{24}$$

where wealth X_t satisfies

$$X_t = \frac{1}{\theta_t^*\Lambda_t}\int \max\{\theta_t^*, \theta_{it}\}d\mathbf{F}(\theta_{it};\sigma_t). \tag{25}$$

Proof. See Appendix B.1. ■

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

3.6 Impact of Uncertainty on Housing Demand

To study how economic uncertainty (the standard deviation of θ_{it}), σ_t, can affect housing demand, we conduct a partial equilibrium analysis. In particular, we define

$$\Phi(\theta_t^*; \sigma_t) \equiv \int \max\{\theta_t^*, \theta_{it}\} d\mathbf{F}(\theta_{it}; \sigma_t). \tag{26}$$

Appendix B.1 shows that the Euler equation for the optimal decision of housing (11) implies that the housing price can be expressed as

$$q_{ht} = \Phi(\theta_t^*; \sigma_t)(1 - \delta_h) \frac{\mathbf{E}_t q_{ht+1}}{1 + r_t^i}, \tag{27}$$

where $r_t^i \equiv 1/(\beta \mathbf{E}_t \Lambda_{t+1}/\Lambda_t) - 1$ is the real interest rate. The last equation indicates that the current housing price q_{ht} contains a normal component, the discounted expected price in the next period, and a premium term, $\Phi(\theta_t^*; \sigma_t)$. In fact, this extra term reflects the liquidity premium of holding housing, since the housing asset acts as a buffer to insure against idiosyncratic uncertainty. When the household has a low level of wealth ($\theta_{it} < \theta_{it}^*$), selling the housing on hand could provide the household extra liquidity to smooth consumption. More importantly, conditional on the aggregate states, the premium term $\Phi(\theta_t^*; \sigma_t)$ is increasing in economic uncertainty.[18] Therefore, an upswing in uncertainty may lead to a boom in current housing prices. Intuitively, when the economy becomes more uncertain, the household would prefer the asset that can be used as a buffer to smooth consumption: the *flight-*

[18] This occurs because the term $\max\{\theta_t^*, \theta_{it}\}$ in $\Phi(\theta_t^*; \sigma_t)$ is convex in θ_{it}; Jensen's inequality implies that the premium increases when uncertainty σ_t increases.

to-liquidity effect. As a result, the option value of holding housing assets becomes higher when economic uncertainty increases, which means that even though housing prices are relatively high, households are still willing to hold housing assets.

Aggregating the individual household's optimal housing decision (24) yields the aggregate housing demand, which is

$$H_{t+1} = \frac{X_t}{q_{ht}} \int \max\{\theta_{it} - \theta_t^*, 0\} d\mathbf{F}(\theta_{it}; \sigma_t). \tag{28}$$

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

4 Quantitative Analysis

The previous analysis qualitatively shows that housing is a store of value that can smooth consumption. The demand for housing becomes higher when economic uncertainty increases. To provide a further quantitative analysis, we calibrate the baseline model to the Chinese economy.

4.1 Calibration

One period in the model corresponds to one quarter. We partition the parameters into three subsets. The first subset of parameters includes $\{\beta, \psi, \alpha_p, \delta_k\}$, which are standard in the business cycle literature. We set the discount factor β to be 0.995, implying that the annual real deposit rate is 1.8%.[19] The coefficient of the disutility of labor ψ does not affect the model's dynamics; therefore, we simply normalize it to be 1. Following Song et al. (2011), we set the capital share in the real sector α_p to be 0.5 and the depreciation rate of physical capital δ_k to be 0.025.

The second set of parameters related to the housing sector includes $\left\{\delta_h, \gamma, \alpha_h, \bar{L}\right\}$. We follow Iacoviello and Neri (2010) to set the depreciation of housing assets δ_h to be 0.01, implying an annual depreciation rate of 4%. We now calibrate the land share γ and the capital capital $\alpha_h (1-\gamma)$ for

[19]To calibrate β, we use the real deposit rate, which is the annual rate with one-year maturity. This series is the annual nominal deposit rates adjusted by the CPI from 2000 to 2016. The average value is approximately 1.8%.

Table 3: Parameter Values

Parameter		Value	Target
β	Discount rate	0.995	Annual interest rate (1999Q1-2016Q4)
ψ	Labor disutility	1	
α_p	Share of capital in the real sector	0.5	Song et al. (2011)
δ_k	Depreciation of physical capital	0.025	Standard
δ_h	Depreciation of housing	0.01	Iacoviello and Neri (2010)
γ	Share of land in the H sector	0.245	$\frac{q_l L}{q_h h}$ in Tier 1 cities
α_h	Parameter of the share of capital in the 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 idiosyncratic shock θ_i	0.9775	Gini coefficient of housing holdings, CHFS survey

the housing sector in the production function. The housing assets in the model are assumed to be those with better quality in reality, such as housing 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 the housing sector to the total revenue in housing sector is approximately 24.5%, so we specify $\gamma = 0.245$. Regarding the parameter α_h, since data on the shares of labor and the capital income in the housing sector are not available, we use the average ratio of total spending on land purchases in the housing sector to total investment (including land purchases) in the housing sector $(q_l L / (I_h + q_L L))$ in Tier 1 cities to pin down the value of α_h, which is 0.7. This value implies that the shares of capital and labor in the housing production function are 52.8% and 22.7%, respectively. Since the land supply in steady state does not affect the model's dynamics, we simply normalize it to be 1.

The last set of parameters is related to the distribution of the households' idiosyncratic shock, $\mathbf{F}(\theta_{it}; \sigma_t)$. We assume that θ_{it} follows a log-normal distribution with a mean of 1 and a standard deviation of σ in the steady state. The CHFS survey data show that the Gini coefficient of housing assets in 2012 is approximately 0.6, so we set the value of σ such that the model-implied Gini coefficient of housing assets matches the value in data, which yields a value of 0.9775. Under this value, our model implies that the steady-state national savings rate is 0.43, which closely matches the real data.[20] Table 3 summarizes the calibrated parameter values.

[20] According to Xie and Jin (2015), housing assets account for almost 80% of total household wealth, and the Gini coefficient of urban households' wealth in 2012 is approximately 0.7. Therefore, our model-implied Gini coefficient of housing holdings also fits their dataset reasonably well.

4.2 Aggregate Effect of Uncertainty

4.2.1 Long-run Equilibrium

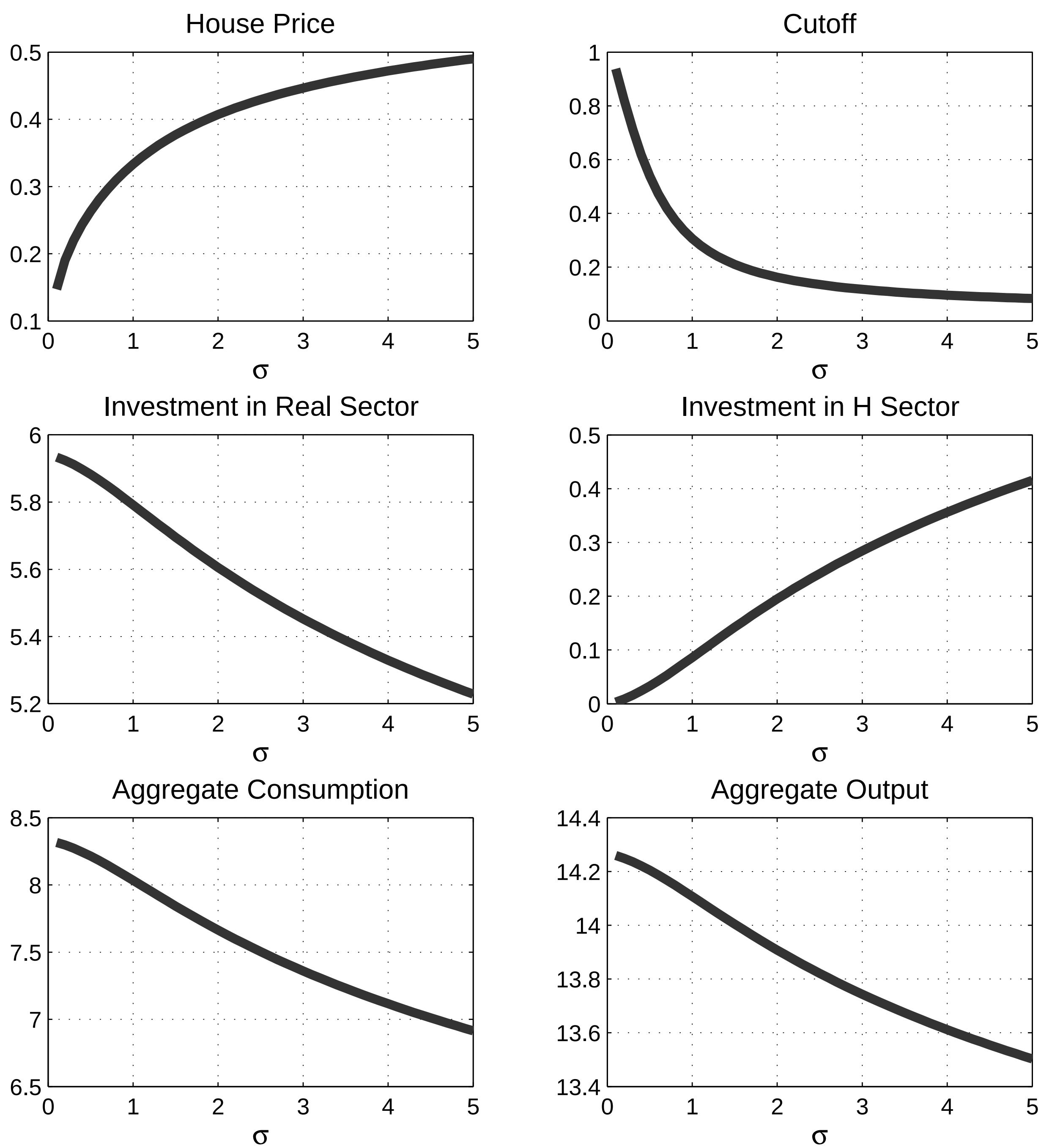
To analyze the aggregate effect of uncertainty, we first conduct a steady-state analysis. Figure 3 describes the relationship between uncertainty and the key aggregate variables at stationary equilibrium. The figure shows that an increase in uncertainty drives up housing prices in the long run because households demand more housing (or safe) assets as a buffer to smooth their consumption, which confirms our prediction based on the previous partial equilibrium analysis. Furthermore, Figure 3 shows that the housing sector expands but the real sector shrinks due to the crowding out effect. This pattern is consistent with the empirical finding that in Chinese economy, the real investment in the housing sector negatively comoves with that in the real sector (Chen et al., 2016). Furthermore, greater uncertainty reduces consumption due to the stronger motive for precautionary saving. Hence, our model is able to explain the phenomenon of a housing boom associated with an economic recession in the long-run equilibrium.

4.2.2 Transition Dynamics

To evaluate the dynamic impact of uncertainty on housing prices and the aggregate economy, we now discuss the transition dynamics when economic uncertainty increases. In particular, we assume that the standard deviation of θ_{it} permanently increases by 25%, and the increment follows the AR(1) process; 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 4 presents the transition dynamics.

Figure 4 shows that after a 25% increase in uncertainty, the housing prices rise sharply by approximately 20% from 0.330 to 0.396. Increased demand for housing assets as stores of value leads to a boom in the housing market, which further stimulates more physical capital investment in the housing sector but crowds out those in the real sector. As a result, the output in the 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 the housing sector. The above transition dynamics are broadly consistent with two stylized facts regarding the Chinese

Figure 3: Uncertainty and the Aggregate Economy in the Steady State



Notes: The steady state is computed using different values of σ; the other parameters are calibrated according to Table 3.

economy: (i) the housing market experiences an expansion while the economy slows down, and (ii) there is a crowding out effect between the housing sector and the real sector (Chen et al., 2016).

4.3 Further Discussion: Model with Multiple Stores of Value

In the baseline model, housing is considered as the only safe store of value, and transactions related to housing do not incur any cost. To make the model more realistic, we introduce an alternative asset, namely, government bonds, which can be used as a store of value. In addition, to further differentiate between housing and bonds, we assume that holding housing involves a convex transaction (or adjustment) cost, and housing assets earn a positive rate of return (e.g., rental rate). In the extended model, the budget constraint faced by the households can be written as

$$C_{it} + q_{ht}H_{it+1} + B_{it+1} = \theta_{it}X_{it}, \tag{29}$$

where q_{ht} is the real housing price; B_{it+1} represents bonds holdings. The real disposable wealth X_{it} is written as

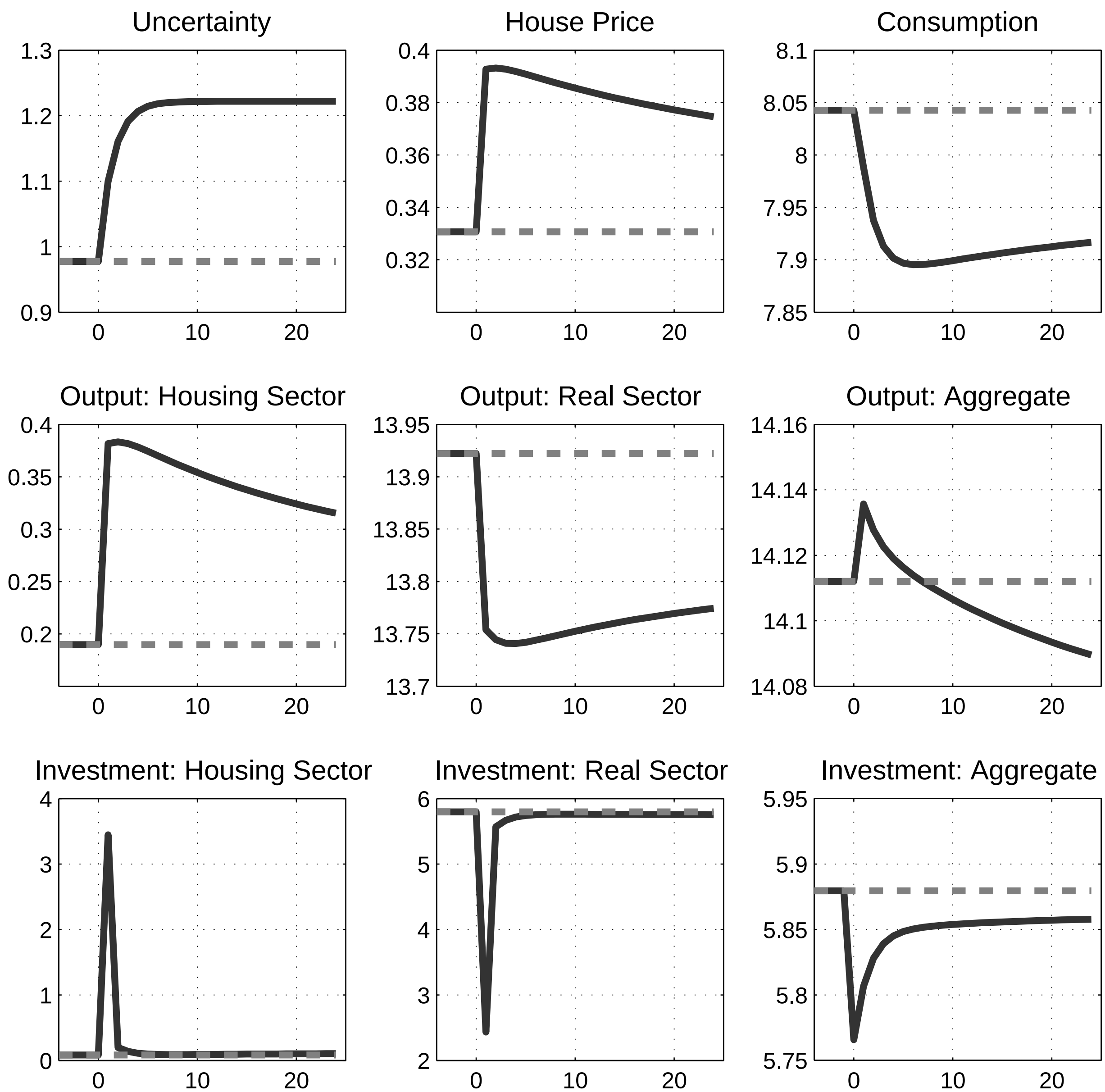
$$X_{it} = \left[(1-\delta_h)q_{ht} + r_{ht}\right]H_{it} - \gamma_b\frac{\left(q_{ht-1}H_{it}\right)^{1+\chi}}{1+\chi} + R_{bt-1}B_{it} + w_tN_{it} + r_tK_{it} + D_t - \left[K_{it+1} - (1-\delta_k)K_{it}\right], \tag{30}$$

where r_{ht} is the rental rate of housing and R_{bt} is the interest rate for the bonds. The term $\gamma_b\left(q_{ht-1}H_{it}\right)^{1+\chi}/(1+\chi)$ ($\gamma_b > 0$ and $\chi > 0$) captures the transaction cost for the housings. For simplicity, we assume that r_{ht} is exogenously given.[21] The above setup implies that in the model economy, the government bonds are more liquid than housing. To model market incompleteness, in addition to the non-short-selling constraint for housing (7), we impose a liquidity constraint for the entire holding of housing and bonds. In particular, we assume that total holdings of housing and bonds are required to higher than a lower bound, which is proportional to household wealth $\theta_{it}X_{it}$

$$q_{ht}H_{it+1} + B_{it+1} \geq \zeta\theta_{it}X_{it}, \tag{31}$$

[21] Alternatively, we can consider an additional type of households, who are hand-to-mouth and only rent houses. This setup provides a way to endogenize the rental rate r_{ht}.

Figure 4: Transition Path after an Increase in Uncertainty



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

where the parameter $\zeta \in (-1, 1)$ reflects the tightness of the liquidity constraint of the household.[22] A larger value of ζ indicates that the household faces a tighter liquidity constraint. The remaining parts of the model are identical to those in the baseline model. Appendix B.5 provides more details about the households' optimal decisions.

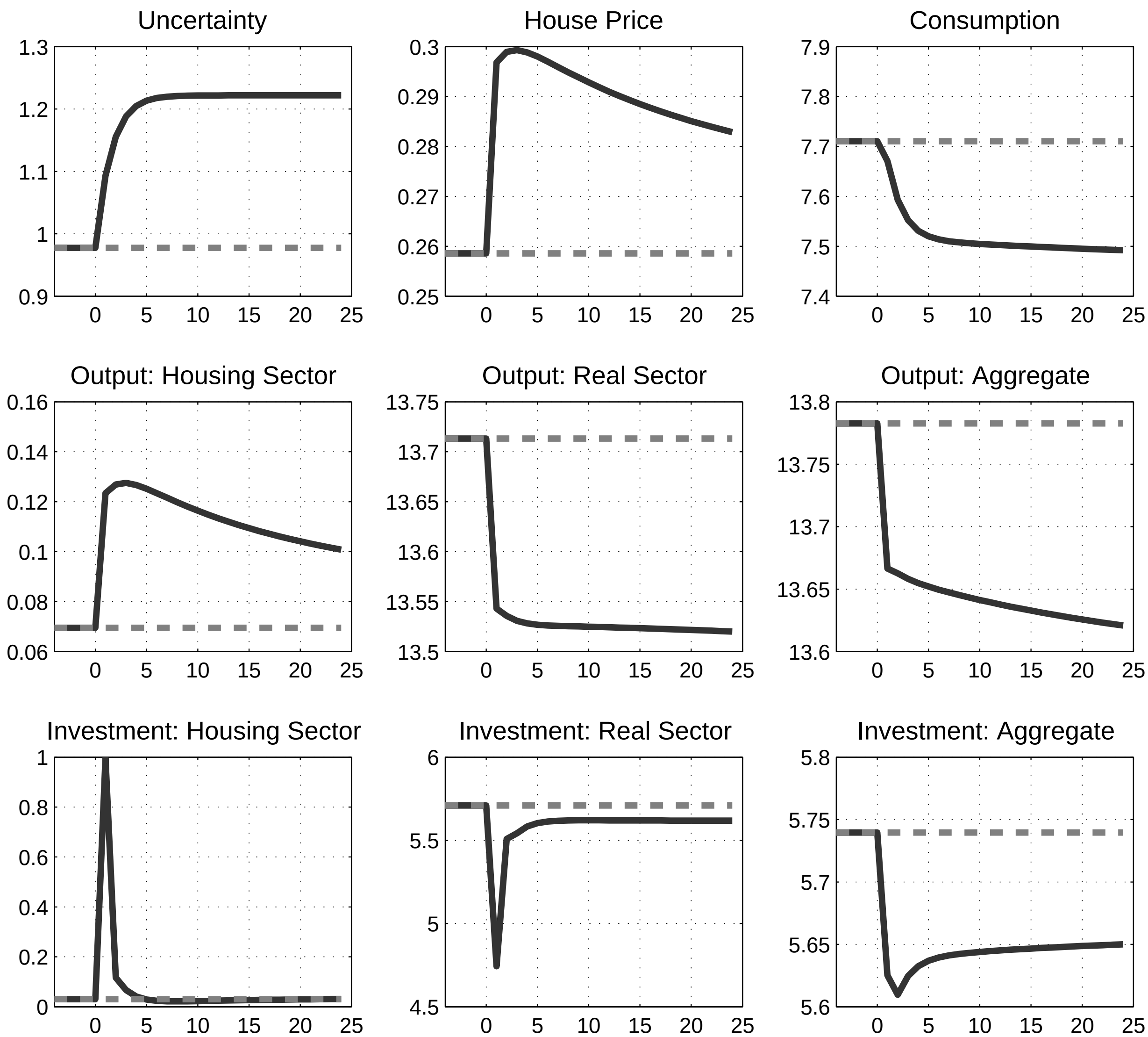
Based on the extended model, we conduct the same quantitative exercises as used in the baseline model. Figure 5 reports the transition dynamics and shows that the dynamic impacts of uncertainty on the housing market and the real economy present very similar patterns to those in the baseline model. An increase in economic uncertainty boosts the housing sector but dampens the real economy, though the magnitude is relatively small. This occurs because in the extended model, the households choose to hold both liquid bonds and housing as stores of value, resulting in a relatively weak response of the housing market to the uncertainty shock.[23]

Liquidity Constraint and Housing Prices One important prediction in the extended model is that if the households' liquidity constraint tightens, i.e., ζ becomes larger, their demand for bonds and housing as stores of value will increase, which translates into higher housing prices. Appendix B.5 provides a more rigorous analysis regarding this issue. To document the impact of the liquidity constraint on the housing and real sectors, we compute the steady state of the aggregate economy under different values of ζ. Figure 6 shows that a tighter liquidity constraint (ζ is larger) induces higher housing prices, which confirms our previous analysis. Furthermore, Figure 6 shows that aggregate output declines when ζ increases. This occurs because higher demand for housing leads to a more severe crowding-out effect of the housing sector on the real sector.

[22] A negative value of ζ indicates that the household is allowed to hold a negative portion of liquid assets. In this case, the household is a net borrower.

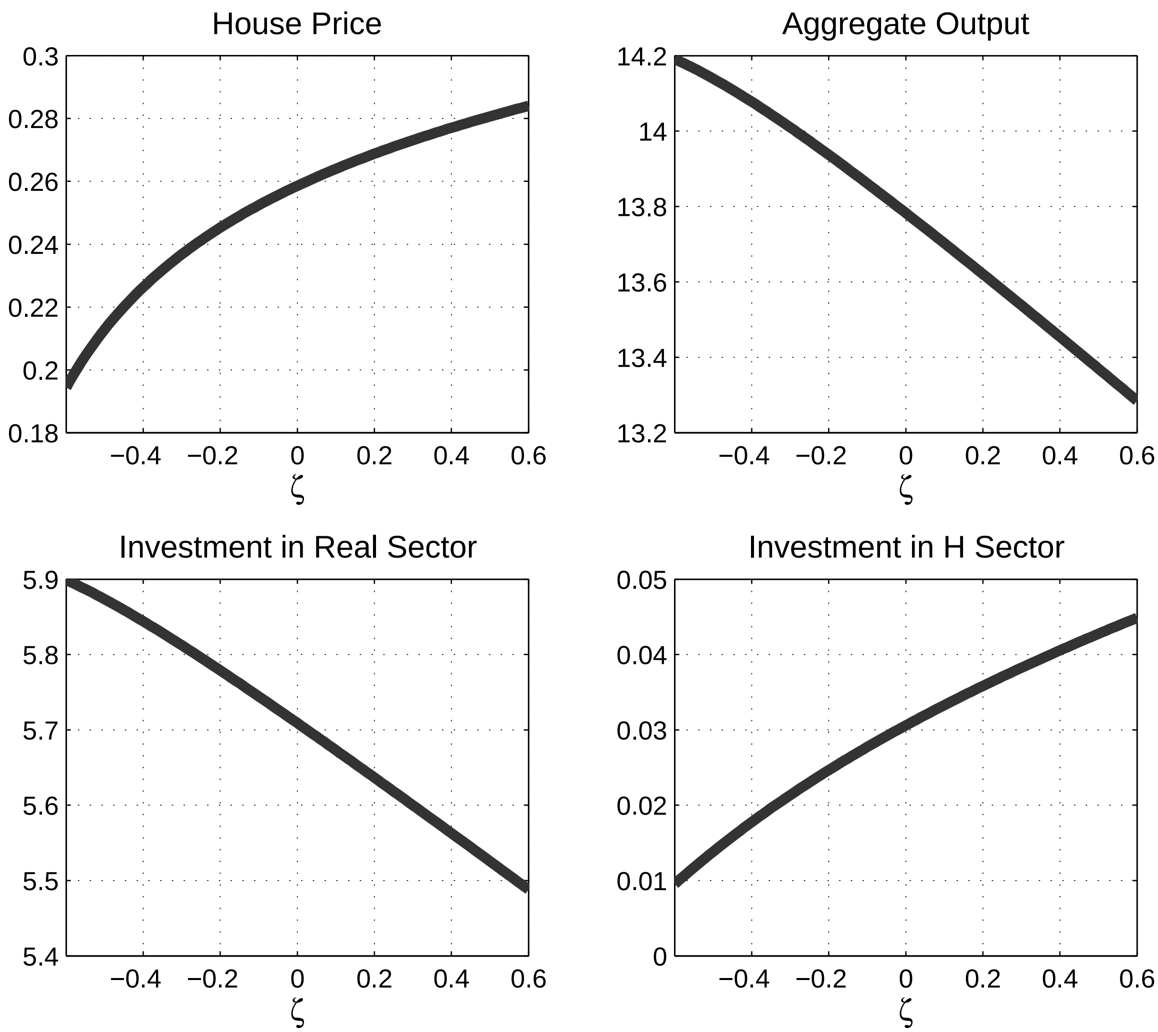
[23] Our model also implies that a positive uncertainty shock reduces the interest rate of the bonds. This prediction is consistent with Chinese data. The correlation between economic uncertainty (measured by economic policy uncertainty, EPU) and the Shibor rate is -0.6 over the periods of 2013M1-2018M9.

Figure 5: Transition Path after an Increase in Uncertainty: Extended Model



Notes: The transition paths are shown in levels. The parameter γ_b is set to be 0.01, and the supply of the bonds $\bar{B}$ is set to be 1.95, implying a steady-state bond to GDP ratio of 15%. We set the liquidity constraint parameter ζ to 0, and set the quarterly rent to price ratio to 0.01, which is consistent with data for Shanghai and Beijing. The dynamic pattern is fairly robust to the values of the above parameters. The dashed lines represent the steady-state level prior to the transition.

Figure 6: Liquidity Constraint and the Aggregate Economy under Multiple Assets



Notes: The steady state is computed under different values of ζ; the other parameters take the same values as those in Figure 5.

5 Housing Policy

5.1 Setup

To curb the soaring housing prices in Tier 1 cities, the Chinese government has intervened in housing markets from time to time. The policy that limits housing purchases is the most relevant one. In this section, we aim to model this type of housing policy. We then use the extended model to evaluate both the aggregate and distributional consequences of this kind of housing policy.

To model the policy that limits housing purchases, we introduce an additional constraint on housing purchases into the benchmark model. In particular, we assume the amount of housing purchased by a household cannot exceed a limit, which is proportional to its consumption:

$$q_{ht}H_{it+1} \leq \phi C_{it}. \tag{32}$$

Assuming that the limit of housing purchase is proportional to the household's consumption provides an analytical way to aggregate the economy. The constraint (32) is equivalent to the setup where the purchase limit is a function of wealth $\theta_{it}X_{it}$, i.e., $q_{ht}H_{it+1} \leq \bar{\phi}\theta_{it}X_{it}$ and $\bar{\phi} = \frac{\phi}{1+\phi}$. [24]

The parameter ϕ governs the tightness of the housing policy. When $\phi \to \infty$, the model degenerates to the baseline model. When $\phi \to 0$, the housing market is completely shut down. Under the policy that limits housing purchases, the household's optimal decisions differ from those in the baseline case. In particular, the individual household's optimal decisions may include three regimes. When the household's disposable wealth is sufficiently low, to smooth consumption it will sell the housing assets on hand, i.e., the constraint (7) is binding. When disposable wealth is sufficiently high, the household will demand a large amount of housing for precautionary purposes, resulting in a binding constraint for (32). When disposable wealth is in the middle range, with a moderate demand for housing, neither (7) nor (32) is binding. In the baseline model where the policy that limits housing purchases is absent, only the first and the third scenarios emerge. Therefore, the policy that limits housing purchases primarily affects wealthy households (or those with an abundance of liquidity).

[24] The main insight remains valid under the setup of a constant purchase limit. However, the aggregation in this case may become more complicated.

Theoretically, it can be shown that due to the policy intervention, there are two cutoffs of the idiosyncratic shock θ_{it}; i.e., θ_{it}^{*} and θ_{it}^{**}, where θ_{it}^{*} has the same definition as that in (22) and $\theta_{it}^{**} = (1+\phi)\,\theta_{it}^{*}$. These two cutoffs divide the optimal individual decision into three regimes. The following proposition gives the 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 of 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 the following trigger strategies:*

$$C_{it} = \left[\theta_{it}\mathbf{1}_{\{\theta_{it}\leq\theta_t^{*}\}} + \theta_t^{*}\mathbf{1}_{\left\{\theta_{it}^{*}\leq\theta_{it}<\theta_t^{**}\right\}} + \frac{1}{1+\phi}\theta_{it}\mathbf{1}_{\{\theta_{it}>\theta_t^{**}\}}\right]X_t, \tag{33}$$

$$q_{ht}H_{it+1} = \left[0\times\mathbf{1}_{\{\theta_{it}\leq\theta_t^{*}\}} + \left(\theta_{it}-\theta_t^{*}\right)\mathbf{1}_{\left\{\theta_{it}^{*}\leq\theta_{it}<\theta_t^{**}\right\}} + \frac{\phi}{1+\phi}\theta_{it}\mathbf{1}_{\{\theta_{it}>\theta_t^{**}\}}\right]X_t; \tag{34}$$

where wealth X_t satisfies

$$X_t = \frac{1}{\theta_t^{*}\Lambda_t}\Phi(\theta_t^{*};\phi,\sigma_t), \tag{35}$$

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

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

Proof. See Appendix B.2. ■

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 policy that limits housing purchases restricts the household's access to housing assets, the premium of holding housing assets (the benefit of a store of value) is dampened. The definition of $\Phi(\theta_t^{*};\phi,\sigma_t)$ in (36) shows that the limit on housing purchases makes the function in the integral less convex than the one in (26). As a result, given the aggregate states, the premium term $\Phi(\theta_t^{*};\phi,\sigma_t)$ is decreasing in ϕ.

5.2 Aggregate Impacts of the Policy Intervention

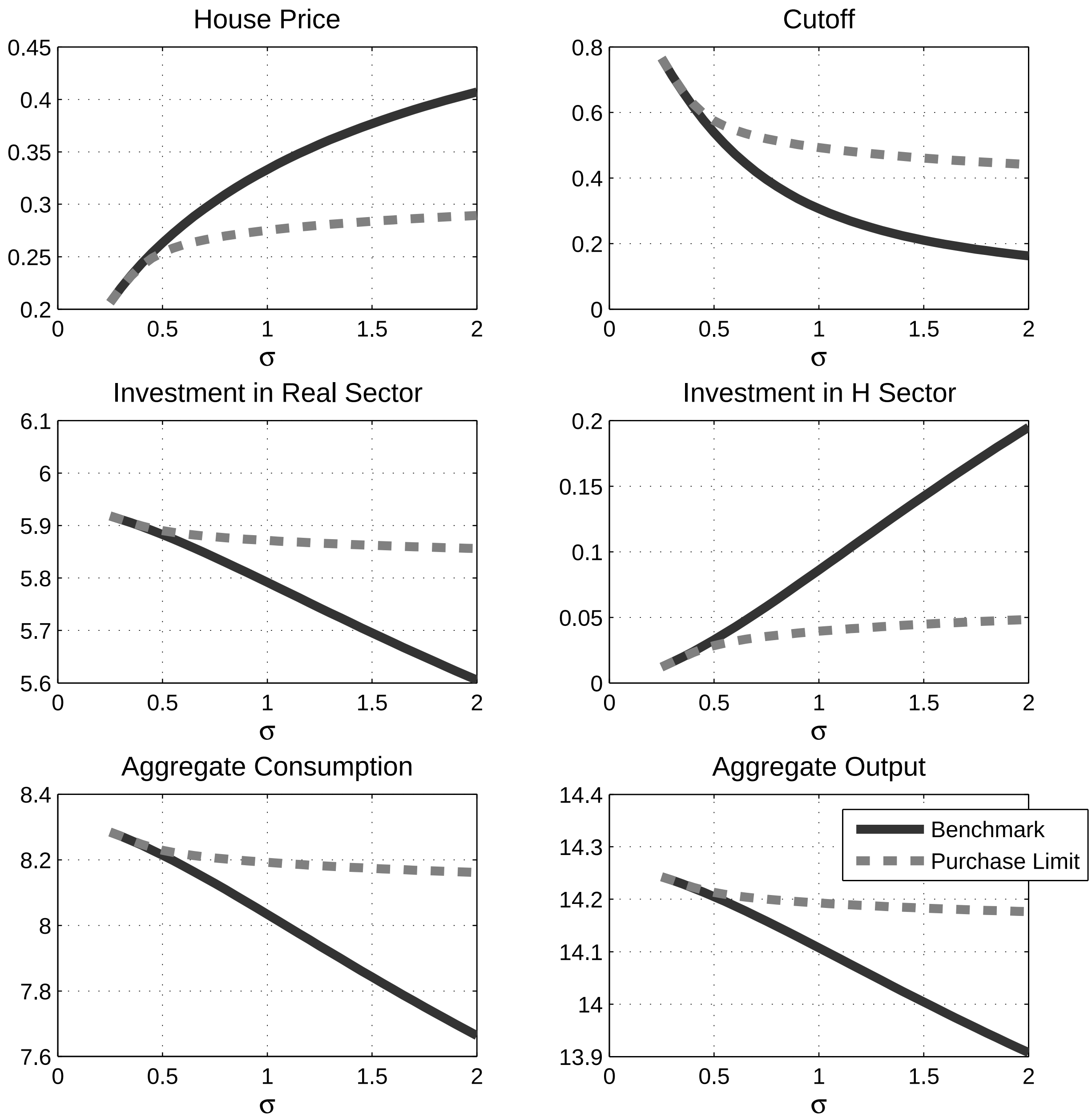
Long-run Equilibrium and Consumption Risk Sharing We first quantitatively evaluate the aggregate impact of the policy that limits housing purchases in the long-run equilibrium. As we discussed in the previous section, this policy curbs household demand for housing assets and therefore mitigates the crowding out effect of the housing sector on the real sector in the general equilibrium. Figure 7 compares the steady-state equilibrium in the baseline model and that in the model with the policy that limits housing purchases. It can be seen that in the steady state, greater economic uncertainty may cause a relatively small expansion of the housing market compared to that in the baseline model. Therefore, housing prices and physical investment in the housing sector increase less, and the adverse impact on the real sector is mitigated. As a result, the drop in aggregate consumption and output caused by greater uncertainty is less severe.

Although the policy that limits housing purchases improves the performance of the aggregate economy when economic uncertainty is high, it also reduces households' access to safe assets that can be used as stores of value. This means that the policy that limits housing purchases inevitably reduces household's ability to insure idiosyncratic uncertainty, and thus increases the dispersion of household consumption. The first panel in Figure 8 computes the partial insurance coefficient as suggested by Blundell et al. (2008) under the housing policy. A smaller partial insurance coefficient indicates a weaker ability for households to insure idiosyncratic uncertainties. There presents a negative relationship between the tightness of regulation and the partial insurance coefficient: a tighter regulation (ϕ is smaller) leads to a lower partial insurance coefficient.[25] In an extreme case where the housing market is completely shut down ($\phi = 0$), the partial insurance coefficient becomes zero, therefore the household cannot insure the uncertainty at all due to the lack of store of value. The figure also shows that an increase in uncertainty reduces the partial insurance coefficient under our calibration.

The second and third panels in Figure 8 illustrate the distributional effect of the policy that

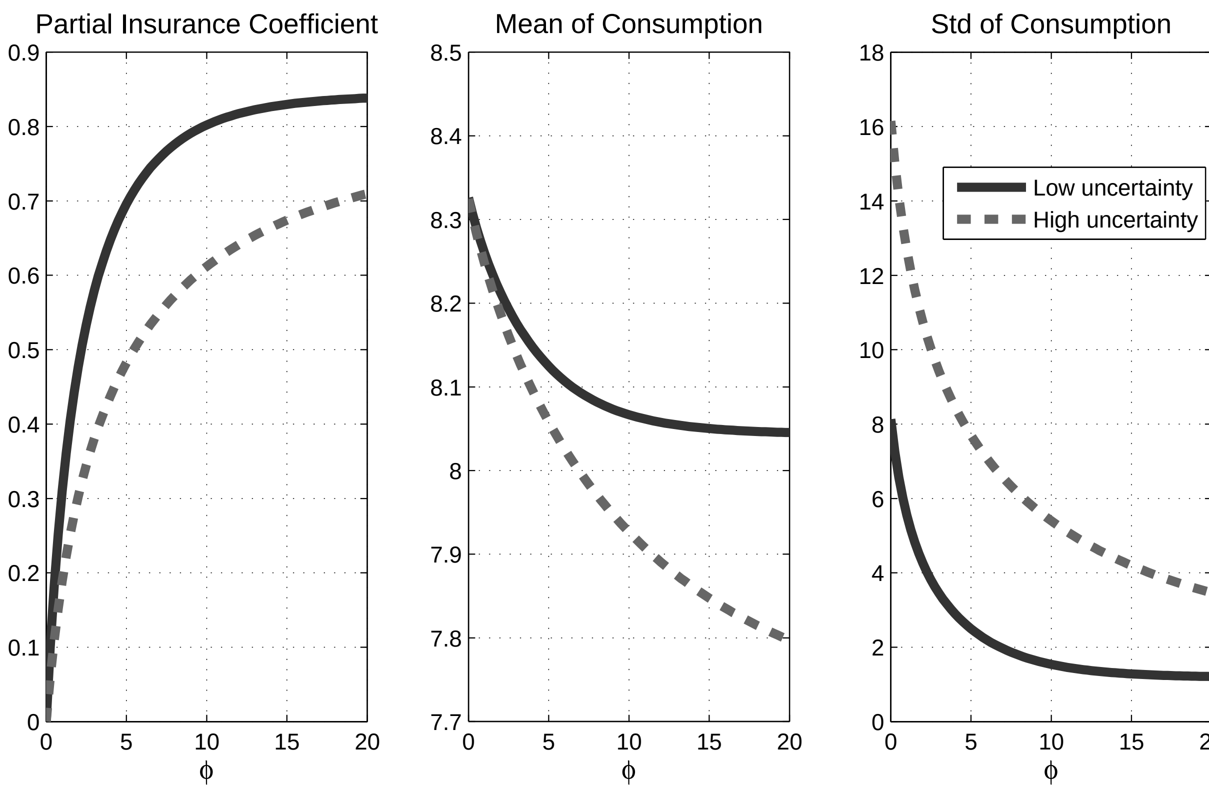
[25] We also compute the partial insurance coefficients for the different tightness of liquidity (ζ) or different supply of government bonds $\bar{B}$. The quantitative results show that a tighter liquidity constraint or a smaller supply of government bonds lead to a lower partial insurance coefficient. The above results support our theory that an excessive demand for (or a shortage of) safe assets may hinder the households' ability to insure their idiosyncratic uncertainties.

Figure 7: Steady-state Equilibrium under the Policy that Limits Housing Purchases



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 3.

Figure 8: Consumption Distortion caused by the Policy that Limits Housing Purchases



Notes: The distribution of consumption is obtained by computing the consumption expenditures of 100,000 households with i.i.d idiosyncratic shocks θ_{it} in the stationary equilibrium. The parameter values except ϕ and σ are set according to the calibration values shown in Table 3. In the low and high uncertainty cases, we set σ to be 0.9775 and 0.9775×2, respectively. The partial insurance coefficient is computed according to Blundell et al. (2008), which is the estimation coefficient obtained through regressing individual consumption growth $\Delta \log(C_{it})$ on the log of idiosyncratic shock θ_{it}.

limits housing purchases on household consumption (see the solid lines). The stationary distribution of consumption has a higher mean and greater dispersion under a tighter policy than that in the looser policy regime. For instance, the mean of consumption is 1.6% higher 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 show that the consumption distortion caused by the policy that limits housing purchases becomes even severe when economic uncertainty is higher. Figure 8 compares the impact of the policy that limits housing purchases on the mean and standard deviation of consumption under different levels of uncertainty. The solid line and the dashed line represent low uncertainty ($\sigma = 0.9775$) and high uncertainty ($\sigma = 0.9775 \times 2$) scenarios, respectively. It can be seen that the policy that limits housing purchases increases the mean and standard deviation of consumption to levels that are much higher in the former case than in the latter one. This result indicates that the reduction in the degree of consumption insurance caused by the housing policy increases with economic uncertainty.

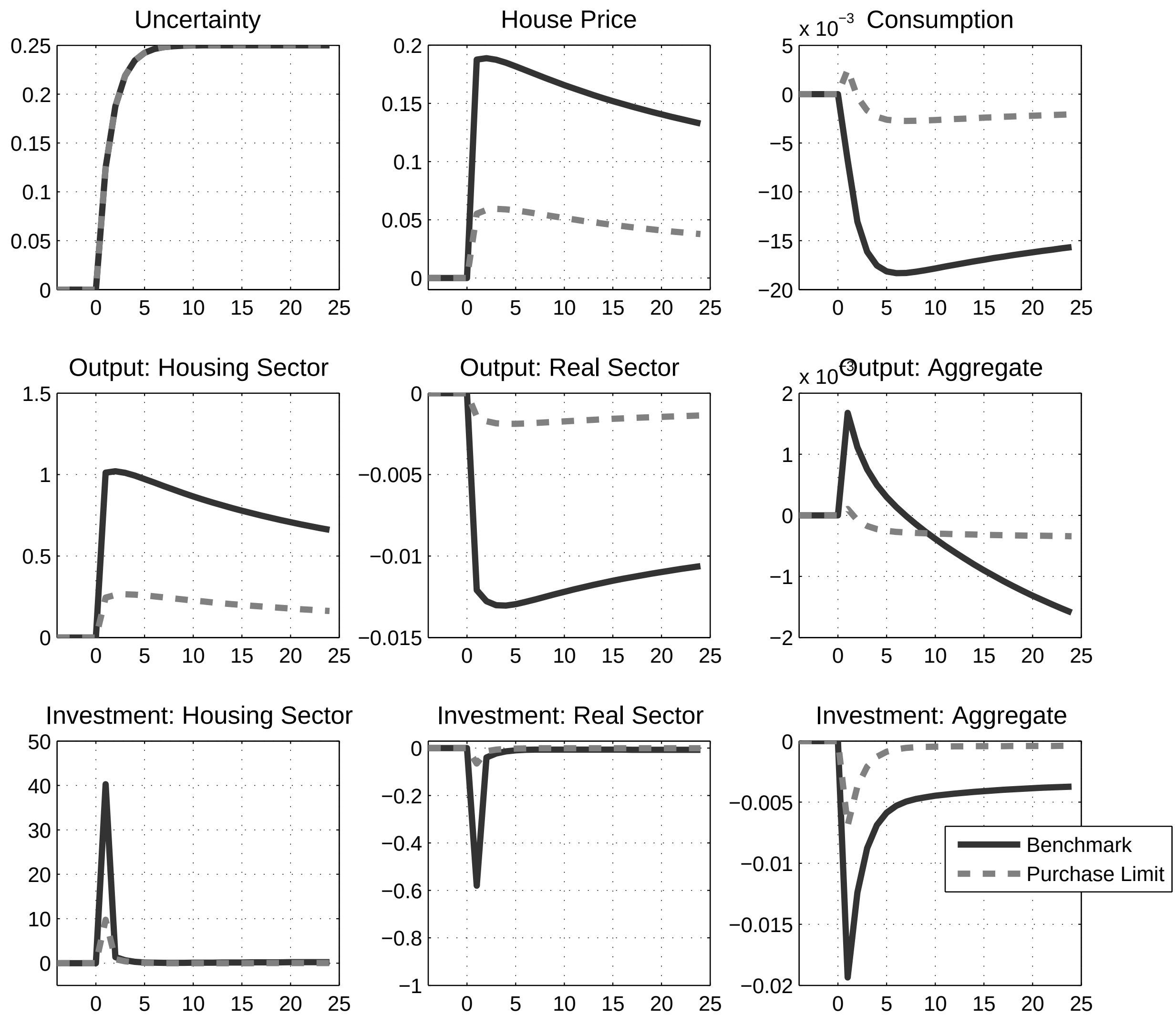
Dynamic Impacts of the Policy Intervention To evaluate the dynamic impact of the policy that limits housing purchases, we compare the transition dynamics after an increase in economic uncertainty under the policy intervention with those in the baseline model. Figure 9 shows that a tighter purchase limit policy largely dampens the housing boom after an increase in uncertainty. As a result, the crowding out effect between the real sector and housing sector is mitigated.

5.3 Welfare Implications

Despite the mitigation of the crowding out effect, the policy that limits housing purchases confines households' access to assets that can act as stores of value. A larger reduction in the degree of consumption insurance leads to adverse effects on social welfare. To illustrate this, we let W_t denote social welfare, which satisfies

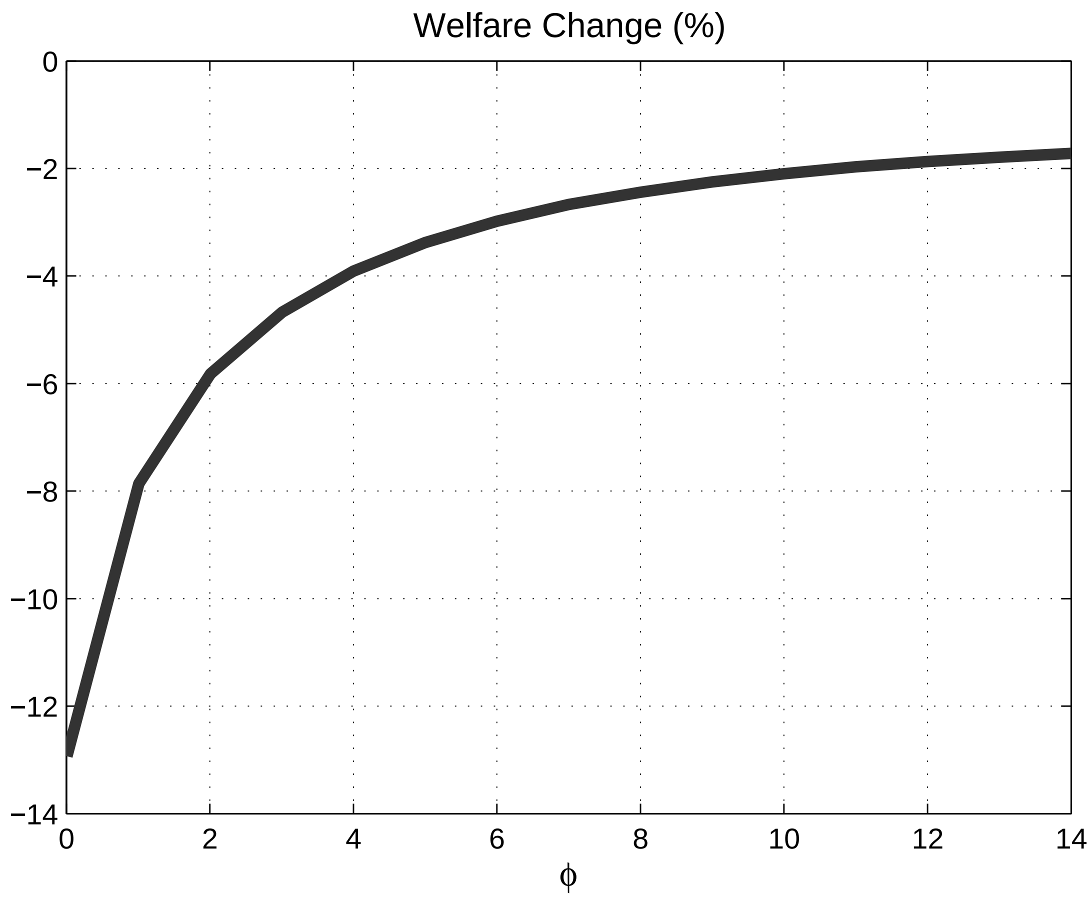
$$W_t = U_t - \psi N_t + \beta W_{t+1}, \tag{37}$$

Figure 9: Transition Path under the Policy that Limits Housing Purchases



Notes: The transition is computed by assuming that uncertainty σ_t increases permanently by 25%. For the purchase limit case, the parameter ϕ is set to 2.5, and for the baseline case, $\phi = \infty$. The other parameter values are set according to the calibration values shown in Table 3.

Figure 10: Welfare Implications of the Policy that Limits Housing Purchases



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

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

$$U_t = \int \left[\log (\theta_{it}) \mathbf{1}_{\{\theta_{it} \leq \theta_t^*\}} + \log (\theta_t^*) \mathbf{1}_{\left\{\theta_{it}^* \leq \theta_{it} < \theta_t^{**}\right\}} + \log \left(\frac{1}{1+\phi} \theta_{it} \right) \mathbf{1}_{\{\theta_{it} > \theta_t^{**}\}} \right] d\mathbf{F} (\theta_{it}) + \log X_t. \quad (38)$$

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

6 Conclusion

This paper aims to analyze how housing acts as safe assets by investigating the aggregate and distributional consequences of the housing policy in China. The shortage of safe assets, a global syndrome, is acute in developing economies such as China, whose financial market is underdeveloped and capital accounts are tightly regulated. Based on both household survey and household-level transaction data, we find that economic uncertainty boosts housing prices, especially during the recent economic slowdown when economic uncertainty increases. The results suggest that housing assets especially those with relative high quality become desirable stores of value when economic uncertainty is high.

To quantify the economic consequences of housing boom, we introduce housing assets as stores of value into a two-sector macroeconomic model with household heterogeneity and market incompleteness. Due to financial underdevelopment, housing acts as a major safe asset used to buffer idiosyncratic uncertainty. An increase in economic uncertainty leads to a housing boom due to precautionary motives. An expansion in the housing sector crowds out resources that could have been allocated to the real sector, leading to an economic slowdown. Therefore, our model makes sense of the recent great divergence between housing prices and the economic fundamentals of China macroeconomy.

To curb the exaggerated housing boom, the Chinese government has implemented a policy that limits housing purchases to restrict individual access to the housing market in big cities. Our quantitative exercise reveals that the housing policy largely depresses the aggregate demand for housing when there is great economic uncertainty and thus alleviates the adverse effects of the housing boom on the real economy. However, the housing policy also limits individual's access to housing as a store of value, reducing the degree of consumption insurance. Consequently, the dispersion in consumption is exacerbated and social welfare is reduced. Therefore, the housing policy creates a trade-off between macro-level stability and micro-level consumption risk sharing.

Complementary to the safe-asset literature, we provide both empirical and quantitative evidence to identify housing as safe assets through the lens of economic uncertainty. In addition, our paper offers a novel channel through which the housing boom affects a real economy with an underdeveloped financial market. The model's tractability allows us to conduct a potentially intriguing extension in a transparent way. For instance, by introducing rental market friction and hand-to-mouth households that only rent housing, we can explain the phenomenon that high housing prices are accompanied by high vacancy rates. We could evaluate the dynamic interactions between internal and external policies (e.g., capital control) by extending the model to an open economy. We could also extend the model to decompose the flight to quality (safety) and the flight to liquidity by introducing multiple types of housing assets. We leave these analyses for future research.

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Appendix

A Data and Empirics

A.1 CFPS Household Survey Data

In section 2.1, we present the relationship between household-level uncertainty and the growth of housing prices. Here, we provide more details about the data constructions. The dataset we employ is the Chinese Family Panel Studies (CFPS) conducted by Peking University. The CFPS is conducted every two years. We use all the waves (2010, 2012, 2014 and 2016) of CFPS.

Household Income Uncertainty We follow Blundell et al. (2008) and Santaeulàlia-Llopis and Zheng (2018) to construct the household-level income uncertainty. The procedure includes two steps. First, we apply the following sample selection criteria: (1) drop observations with negative household labor income; (2) retain only urban homeowners; (3) keep households aged 20-60. We then run the standard Mincer regression on the households' labor income and obtain the residual labor income

$$\log\left(\text{income}_t^i\right) = \alpha + \sum_{\kappa} \beta_{2,\kappa} \times I_{\kappa,t}^i + \beta_3 \times f\left(\text{edu}^i\right) + \beta_4 \times g\left(\text{age}_t^i\right) + \delta_t + z_t^i, \tag{A.1}$$

where i denotes the household's ID, and t denotes time. $I_{\kappa,t}^i$ are the dummy variables indicating the employment status (i.e., self-employed, employed, employed in the agriculture sector, and employed by a state-owned or private-owned enterprise). $f\left(\text{edu}^i\right)$ is a quadratic polynomial of the years of education, and $g\left(\text{age}_t^i\right)$ is a quadratic polynomial of the age of the family head. δ_t denote the year fixed effects.

Second, we construct city-level labor income uncertainty. We drop cities that contain a limited number of observations (less than 30). We define labor income uncertainty in year t city j as

$$\sigma_{j,t}^2 = var\left(z_t^{i,j} - z_{t-2}^{i,j}\right), \text{ for } t = \{2012, 2014, 2016\}. \tag{A.2}$$

We winsorize city-level the labor income uncertainty at 5 and 95 percentiles. Ultimately, we obtain data on 108 cities used in the regression.

We define the 2-year changes in the households labor income growth uncertainty as

$$\Delta\sigma^2_{j,t} = \sigma^2_{j,t} - \sigma^2_{j,t-2},, \text{ for } t = \{2014, 2016\} \tag{A.3}$$

City-Level Housing Prices We calculate the average housing price in city j at year t, P^j_t, as the total weighted sum of gross value of housing assets divided by the total weighted sum of housing area (in square meters). We define real price growth as

$$\Delta p^j_t = \log\frac{P^j_t}{\mathrm{CPI}^j_t} - \log\frac{P^j_{t-2}}{\mathrm{CPI}^j_{t-2}}, \text{ for } t = \{2012, 2014, 2016\}, \tag{A.4}$$

where CPI^j_t is the consumer price index in city j and year t. Figure 2 presents the scatter plot $(\Delta p^j_t, \Delta\sigma^2_{j,t})$, for $t = \{2014, 2016\}$.

More Results from the Estimations We now present more estimation results from our empirical analysis. Columns 1-2 in Table A.1 correspond to the regressions with log housing price as dependent variable. Columns 3-4 in correspond to the regressions with housing wealth-to-income ratio as dependent variables. The table shows that the positive relationship between income uncertainty and housing prices (or the housing wealth-to-income ratio) remains robust for various definitions of uncertainties.

A.2 Regression using Transaction Data from Beijing

A.2.1 Measurement of Uncertainty

In the empirical regressions, we consider three measurements of economic uncertainty in the Chinese economy.

1. **Stock market volatility (SV) index**: The stock market volatility index is based on all listed firms on the A Share market (listed either on the Shanghai or Shenzhen Stock Exchanges). We

Table A.1: Housing and Uncertainty: Robustness

	(1)	(2)	(3)	(4)
Dependent Variable	$p_t^{i,j}$	$p_t^{i,j}$	$\frac{v_t^{i,j}}{y_t^{i,j}}$	$\frac{v_t^{i,j}}{y_t^{i,j}}$
Log Income Uncertainty	0.065***		0.119***	
	(0.021)		(0.037)	
Normalized Income Uncertainty		0.026**		0.068***
		(0.11)		(0.020)
Other Controls	Yes	Yes	Yes	Yes
Family FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	4,423	4,135	4,423	4,423
Number of HH	2,221	2,221	2,401	2,401
Adjusted R^2	0.043	0.041	0.022	0.022

Notes: In columns 1-2 and 3-4, the dependent variables are log of housing prices, $p_t^{i,j}$, and the housing wealth to income ratio, $\frac{v_t^{i,j}}{y_t^{i,j}}$, respectively. The housing wealth is measured as the gross value of housing. Other controls are the same as those in the baseline regressions (1) and (2). For the normalized income uncertainty, we first minus the labor income uncertainty by its sample mean, and then divide it by its standard deviation in the sample. The numbers in parentheses are standard errors. The levels of significance are denoted as *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

first compute their daily price growth rates and then compute the standard deviation for each trading day across all stocks. Second, we compute the sum of the standard deviations in each month and use this value as a measure of stock market volatility.

2. **Macroeconomic uncertainty index (MU)**: This index is constructed by Huang and Shen (2018), who use 224 monthly time series variables to construct the aggregate uncertainty index based on the methodology proposed by Jurado et al. (2015). The above two uncertainty indices are highly correlated. The correlation of the SV and MU indices (after HP filtered) in our sample period (2013M1-2016M12) is 0.60.

3. **Economic policy uncertainty index (EPU)**: This index is constructed by Baker et al. (2016) (**BBD**), which is a scaled frequency count of articles on policy-related economic uncertainty in the South China Morning Post (SCMP), Hong Kong's leading English-language newspaper. The data series can be downloaded from the website:

http://www.policyuncertainty.com/china_monthly.html.

A.2.2 Housing Transaction Data in Beijing

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

The data were collected from the website of one of the largest real estate agencies in China (labelled by L). In Beijing, the agency L had more than 1,500 stores and over 33 thousand real estate agents in 2016. With a market share reaching 40% in the second-hand housing market in January 2017, this agency has become 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. Market share is calculated by dividing the agency L's annual total number of transactions by the corresponding total number of transactions reported in the Beijing Real Estate Statistical Yearbook. Figure A.1 shows an upward trend both in terms of absolute numbers and market share.

Since Figure A.1 indicates that the agency L has expanded its business in Beijing during this period, we further check 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 are smaller than those in the Beijing housing price index since late 2015, in general, the trend in our sample mimics that of the official data. Therefore, the data from the agency L can be considered as representative of the dynamics of the 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 (see Table A.2).

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

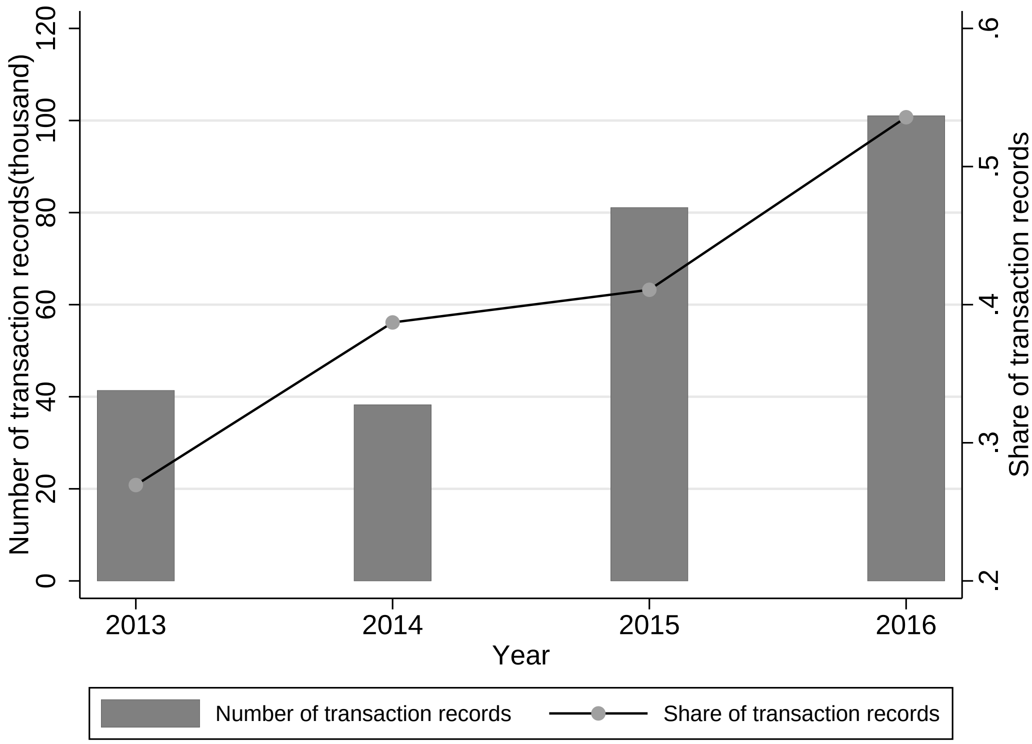
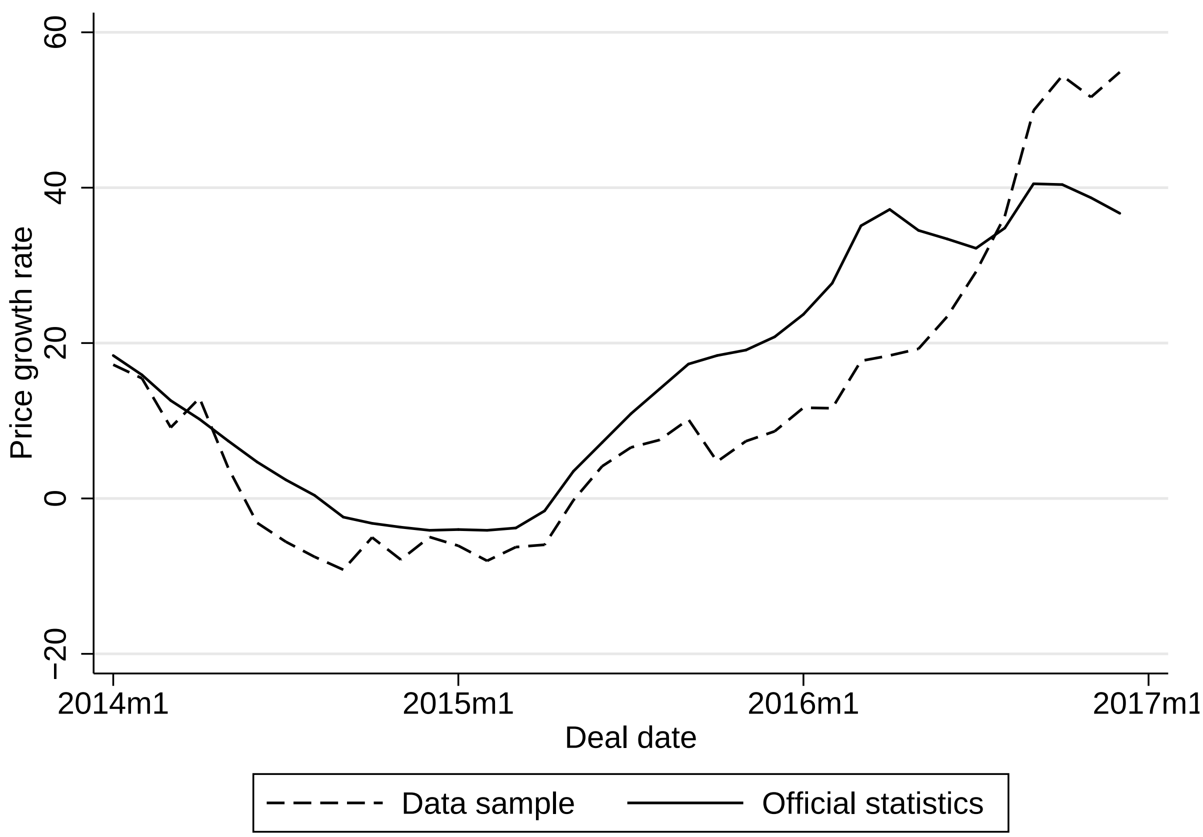


Table A.2: Summary Statistics for Transaction Data from Beijing, 2013-2016

	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

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



A.2.3 Controls used in the Regressions

In the baseline regression (3), we employ several key aggregate indicators to control for the macroeconomic conditions, which are summarized in Z_t. We now introduce each control included in Z_t.

1. **Keqiang index** is equal to 0.40 $\times$ the industrial consumption of electricity+ 0.35 $\times$ the growth rate of the mid/long-term loan+0.25 $\times$ the growth rate of the railway cargo volume. This index was first suggested by the current Premier of People's Republic of China, Keqiang Li, to monitor the condition of the real economy.

2. **Growth rate of fixed investment** is the monthly growth rate of fixed asset investment.

3. **Inflation rate** is the monthly Consumer Price Index.

4. **Shibor rate** is the 1-month Shanghai interbank market rate. We compute the average for each month.

5. **A-share index** is the monthly average A-share market index.

6. In some specifications, Z_t further include the year fixed effect and the month fixed effect.

All the series were obtained from the CEIC database and seasonally adjusted.

A.3 Other Data

1. Data series in Figure 1: (**i**) Real housing prices are computed as the ratio between the total sales of commercial housing and the overall space (square meters) for the total sales of commercial housing. The real price index is seasonally adjusted and also adjusted by a quarterly GDP deflator. The data on total sales were obtained from the WIND database. Data on the overall space for the total sales were obtained from the National Bureau of Statistics. The GDP deflator was obtained from Chang et al. (2016). Since the data series used for Guangzhou and Shenzhen are not available for a longer time period, we construct the housing price index for Beijing and Shanghai to represent the price in Tier 1 cities. The housing price index for the whole country is constructed following a similar method. All the series are for the time period 1999Q1-2016Q4. The relative price of Tier 1 cities is the difference between the real price in Tier 1 cities and that for the whole country. (**ii**) Data on the real GDP were obtained from Chang et al. (2016). The series covers the period from 1999Q1-2016Q1.

2. Data used in the Calibration: Data on total land purchases in the housing sector in Tier 1 cities for Beijing and Shanghai were collected from the WIND database. The data series in Tier 1 cities for Guangzhou and Shenzhen were collected from the Bureau of Statistics of the local governments.

B Proofs and Dynamic System

B.1 Proof of Proposition 1

Taking as 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 (11), we obtain

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

The optimal condition for consumption (10) implies

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

Putting last equation into the budget constraint yields

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

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

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

which 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

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

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

From the Euler equation for the housing decision (11), we get

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

Since $\theta_{it} < \theta_{it}^*$, (11) implies $\eta_{it} > 0$.

Plugging (B.4) and (B.6) into the Euler equation for the capital decision (9) yields

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

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

$$q_{ht} = \Phi(\theta_{it}^*; \sigma_t)(1-\delta_h) \frac{\mathbf{E}_t q_{ht+1}}{1 + r_t^i}, \tag{B.8}$$

where $r_t^i = 1/\left(\beta \mathbf{E}_t \Lambda_{t+1}/\Lambda_t\right) - 1$ is the real interest rate.

Equation (B.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

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

The optimal consumption rules in previous analysis implies

$$C_{it} = \min\{\theta_{it}, \theta_t^*\} X_t. \tag{B.10}$$

Combining last equation and the budget constraint yields

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

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

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

We thus obtain Proposition 1.

B.2 Proof of Proposition 2

Let ξ_{it} denote the Lagrangian multiplier for house-purchase-limit (32). The first order conditions with respective to $\{C_{it}, H_{it+1}\}$ now take the form

$$\lambda_{it} = \frac{1}{C_{it}} + \phi\xi_{it}, \tag{B.13}$$

$$\lambda_{it} + \xi_{it} = \beta(1-\delta_h)\mathbf{E}_t\left[\tilde{\mathbf{E}}_t\left(\theta_{it+1}\lambda_{it+1}\frac{q_{ht+1}}{q_{ht}}\right)\right] + \frac{\eta_{it}}{q_{ht}}. \tag{B.14}$$

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: $\theta_{it}^* \le \theta_{it} \le \theta_{it}^{**}$. In this case, the household's liquid wealth is in the middle, with moderate demand of liquidity, both of the liquidity constraint (7) and housing purchase limit constraint (32) are not binding, i.e., $0 \le H_{it+1} \le \phi C_{it}/q_{ht}$, $\eta_{it} = 0$ and $\xi_{it} = 0$.

(8) and (B.14) imply

$$\lambda_{it} = \beta(1-\delta_h)\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right). \tag{B.15}$$

From (B.13), we obtain the consumption decision

$$C_{it} = \left[\beta(1-\delta_h)\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1}. \tag{B.16}$$

The resource constraint implies the optimal housing decision is

$$q_{ht}H_{it+1} = \theta_{it}X_{it} - \left[\beta(1-\delta_h)\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1}. \tag{B.17}$$

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

$$\theta_{it} \geq \left[\beta(1-\delta_h)X_{it}\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1} \equiv \theta^*_{it}, \tag{B.18}$$

$$\theta_{it} \leq (1+\phi)\left[\beta(1-\delta_h)X_{it}\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1} \equiv \theta^{**}_{it}, \tag{B.19}$$

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 (7). 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

$$C_{it} = \theta_{it}X_{it} = \frac{\theta_{it}}{\theta^*_{it}}\left[\beta(1-\delta_h)\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)\right]^{-1}. \tag{B.20}$$

From (B.13), we have

$$\lambda_{it} = \frac{\theta^*_{it}}{\theta_{it}}\left[\beta(1-\delta_h)\mathbf{E}_t\left(\Lambda_{t+1}\frac{q_{ht+1}}{q_{ht}}\right)\right]. \tag{B.21}$$

Since $\theta_{it} < \theta^*_{it}$, (B.14) 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 (32) is binding, i.e., $H_{it+1} = \phi C_{it}/q_{ht}$, $\eta_{it} = 0$ and $\xi_{it} > 0$.

The budget constraint implies that the consumption satisfies

$$C_{it} = \frac{\theta_{it}}{1+\phi} X_{it} = \frac{\theta_{it}}{\theta_{it}^*(1+\phi)} \left[\beta(1-\delta_h) \mathbf{E}_t \left(\Lambda_{t+1} \frac{q_{ht+1}}{q_{ht}} \right) \right]^{-1}. \tag{B.22}$$

From (B.13) and (B.14), we have

$$\lambda_{it} = \left(\frac{\theta_{it}^*}{\theta_{it}} + \frac{\phi}{1+\phi} \right) \left[\beta(1-\delta_h) \mathbf{E}_t \left(\Lambda_{t+1} \frac{q_{ht+1}}{q_{ht}} \right) \right]. \tag{B.23}$$

Plugging (B.18), (B.19) and (B.23) into the Euler equation for the capital decision (9) yields

$$1 = \beta(1-\delta_h) \Phi(\theta_{it}^*; \phi, \sigma_t) \mathbf{E}_t \left(\frac{\Lambda_{t+1}}{\Lambda_t} \frac{q_{ht+1}}{q_{ht}} \right), \tag{B.24}$$

where $\Phi(\theta_{it}^*; \phi, \sigma_t) = \int_{\theta_{\min}}^{\theta_{\max}} [\theta_{it}^* \mathbf{1}_{\{\theta_{it} < \theta_{it}^*\}} + \theta_{it} \mathbf{1}_{\{\theta_{it}^* \le \theta_{it} \le \theta_{it}^{**}\}} + (\theta_{it}^* + \frac{\phi}{1+\phi}\theta_{it}) \mathbf{1}_{\{\theta_{it} > \theta_{it}^{**}\}}] d\mathbf{F}(\theta_{it}; \sigma_t)$. 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

$$X_t = \left[\beta(1-\delta_h) \theta_t^* \mathbf{E}_t \left(\frac{\Lambda_{t+1}}{\Lambda_t} \frac{q_{ht+1}}{q_{ht}} \right) \right]^{-1}. \tag{B.25}$$

Summarizing the consumption rules yields the optimal consumption decision

$$C_{it} = \left[\theta_{it} \mathbf{1}_{\{\theta_{it} < \theta_t^*\}} + \theta_t^* \mathbf{1}_{\{\theta_t^* \le \theta_{it} \le \theta_t^{**}\}} + \frac{\theta_{it}}{1+\phi} \mathbf{1}_{\{\theta_{it} > \theta_t^{**}\}} \right] X_t. \tag{B.26}$$

Last equation and the budget constraint imply the optimal housing demand

$$H_{it+1} = \left\{ \theta_{it} - \left[\theta_{it} \mathbf{1}_{\{\theta_{it} < \theta_t^*\}} + \theta_t^* \mathbf{1}_{\{\theta_t^* \le \theta_{it} \le \theta_t^{**}\}} + \frac{\theta_{it}}{1+\phi} \mathbf{1}_{\{\theta_{it} > \theta_t^{**}\}} \right] \right\} \frac{X_t}{q_{ht}}. \tag{B.27}$$

Finally, (B.24) and (B.25) immediately give

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

We thus prove Proposition 2.

B.3 Full Dynamic System of Baseline Model

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

1. Labor supply

$$\psi = w_t \Lambda_t, \tag{B.28}$$

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

2. Euler equation for physical capital

$$1 = \beta \mathbf{E}_t \left\{ \frac{\mathbf{\Lambda}_{t+1}}{\Lambda_t} \left[r_{t+1} + (1 - \delta_k) \right] \right\}. \tag{B.29}$$

3. Asset pricing for housing price

$$q_{ht} = \Phi_t (1 - \delta_h) \frac{\mathbf{E}_t q_{ht+1}}{1 + r_t^i}. \tag{B.30}$$

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 $r_t^i \equiv 1/\left(\beta \mathbf{E}_t \Lambda_{t+1}/\Lambda_t\right) - 1$.

4. Aggregate consumption:

$$C_t = \int \min\left\{\theta_t^*, \theta_{it}\right\} d\mathbf{F}(\theta_{it}; \sigma_t) X_t. \tag{B.31}$$

5. Aggregate housing demand:

$$H_{t+1} = \frac{X_t}{q_{ht}} \int \max\{\theta_{it} - \theta_t^*, 0\} d\mathbf{F}(\theta_{it}; \sigma_t); \tag{B.32}$$

6. Disposable wealth:

$$X_t = \frac{1}{\theta_t^* \Lambda_t} \int \max\left\{\theta_t^*, \theta_{it}\right\} d\mathbf{F}(\theta_{it}; \sigma_t). \tag{B.33}$$

7. Supply of housing asset:

$$h_t = \left(K_{ht}{}^{\alpha_h} N_{ht}^{1-\alpha_h}\right)^{1-\gamma} L_t^{\gamma}. \tag{B.34}$$

8. Demand for K_{ht} :

$$r_t = \alpha_h (1-\gamma) q_{ht} \frac{h_t}{K_{ht}}. \tag{B.35}$$

9. Demand for N_{ht} :

$$w_t = (1-\alpha_h)(1-\gamma) q_{ht} \frac{h_t}{N_{ht}}. \tag{B.36}$$

10. Demand of land L_t :

$$q_{lt} = \gamma q_{ht} \frac{h_t}{L_t}. \tag{B.37}$$

11. Supply of land

$$L_t = \bar{L}. \tag{B.38}$$

12. Total output in real sector:

$$Y_{pt} = K_{pt}^{\alpha_p} N_{pt}^{1-\alpha_p}. \tag{B.39}$$

13. Demand for K_{pt} :

$$r_t = \alpha_p \frac{Y_{pt}}{K_{pt}}. \tag{B.40}$$

14. Demand for N_{pt} :

$$w_t = (1-\alpha_p) \frac{Y_{pt}}{N_{pt}}. \tag{B.41}$$

15. Law of motion of H_t :

$$H_{t+1} = (1-\delta_h) H_t + h_t. \tag{B.42}$$

16. The aggregate resource constraint is given by

$$C_t + q_{ht} h_t + I_t = Y_t, \tag{B.43}$$

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

17. Aggregate capital:

$$K_t = K_{pt} + K_{ht}. \tag{B.44}$$

18. Aggregate labor:

$$N_t = N_{pt} + N_{ht}. \tag{B.45}$$

B.4 Steady State in Baseline 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

$$\Phi(\theta^*) = \int \max\{\theta^*, \theta_i\} d\mathbf{F}(\theta_i; \sigma) = \frac{1}{\beta(1-\delta_h)}, \tag{B.46}$$

which can solve the cutoff θ^* directly. From the Euler equation for physical capital, we can obtain the steady-state $r = 1/\beta - 1 + \delta$.

From capital demand function (B.40), we then obtain Y_p/K_p and K_p/N_p through

$$r = \alpha_p \frac{Y_p}{K_p} = \alpha_p \left(\frac{K_p}{N_p}\right)^{\alpha_p - 1}. \tag{B.47}$$

Moreover, the wage rate is given by

$$w = (1-\alpha_p) \frac{Y_p}{N_p} = (1-\alpha_p) \left(\frac{K_p}{N_p}\right)^{\alpha_p}. \tag{B.48}$$

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

$$X = \frac{1}{\theta^* \Lambda} \int \max\{\theta^*, \theta_i\} d\mathbf{F}(\theta_i; \sigma). \tag{B.49}$$

In turn, aggregate consumption and housing demand are respectively given by

$$C = \int \min\{\theta^*, \theta_i\} d\mathbf{F}(\theta_i; \sigma) X, \tag{B.50}$$

$$q_h H = X \int \max\{\theta_i - \theta^*, 0\} d\mathbf{F}(\theta_i; \sigma). \tag{B.51}$$

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

From (B.35), we have $K_h = \alpha_h(1-\gamma)q_h h/r$. And from (B.36), we have

$$N_h = \frac{r}{w}\frac{1-\alpha_h}{\alpha_h}K_h. \tag{B.52}$$

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 housing price q_h is easy to solve.

Furthermore, we can obtain land price

$$q_l = \gamma q_h \left(K_h^{\alpha_h} N_h^{1-\alpha_h}\right)^{1-\gamma} \bar{L}^{\gamma-1}. \tag{B.53}$$

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

$$C = Y_{pt} - \delta_k K = \left(\frac{K_p}{N_p}\right)^{\alpha_p} N_p - \delta_k \frac{K_p}{N_p} N_p - \delta_k K_h, \tag{B.54}$$

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

B.5 Extended Model with Multiple Stores of Value

In the extended model, we introduce risk free bond as an alternative store of value. The household's problem is essentially the same as that in the baseline model. The budget constraint now becomes

$$C_{it} + q_{ht} H_{it+1} + B_{it+1} = \theta_{it} X_{it}, \tag{B.55}$$

where q_{ht} is the real housing price; B_{it+1} is the stock of bond; X_{it} is the real disposable wealth excluding the purchase of investment in physical capital,

$$X_{it} = [(1-\delta_h)q_{ht} + r_{ht}]\, H_{it} - \gamma_b \frac{(q_{ht-1}H_{it})^{1+\chi}}{1+\chi} + R_{bt-1}B_{it} + w_t N_{it} + r_t K_{it} + D_t - [K_{it+1} - (1-\delta_k)K_{it}]\,, \tag{B.56}$$

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; r_{ht} is the rental rate of the housing and R_{bt-1} is the interest rate for the bond. For simplicity, we assume both of r_{ht} is exogenously given.

In addition, similar to the baseline setup the amounts of housing and bond are assumed to be greater than zero:

$$q_{ht}H_{it+1} + B_{it+1} \geq \zeta\theta_{it}X_{it}, \tag{B.57}$$

$$q_{ht}H_{it+1} \geq 0. \tag{B.58}$$

Denote λ_{it}, μ_{it} and η_{it} respectively as the Lagrangian multipliers for the budget constraint (B.55), the liquidity constraints (B.57) and (B.58). The first order conditions with respective to $\{N_{it}, K_{it+1}, C_{it}, H_{it+1}, B_{it+1}\}$ are given by following equations

$$\psi = w_t \Lambda_t, \tag{B.59}$$

$$\Lambda_t = \beta \mathbf{E}_t \left[(r_{t+1} + 1 - \delta_k)\Lambda_{t+1}\right], \tag{B.60}$$

$$\frac{1}{C_{it}} = \lambda_{it}, \tag{B.61}$$

$$\lambda_{it} = \beta \mathbf{E}_t \left[\Lambda_{t+1} \frac{(1-\delta_h)\, q_{ht+1} + r_{ht+1}}{q_{ht}}\right] - \beta\gamma_b \mathbf{E}_t \Lambda_{t+1} \left(q_{ht}H_{it+1}\right)^{\chi} + \mu_{it} + \eta_{it}, \tag{B.62}$$

$$\lambda_{it} = \beta \mathbf{E}_t \Lambda_{t+1} R_{bt} + \mu_{it}. \tag{B.63}$$

(B.59) and (B.60) indicate that we can define the discount factor, Λ_t, analogous to representative agent model, as $\Lambda_t \equiv \tilde{\mathbf{E}}_t(\theta_{it}\lambda_{it} - \zeta\theta_{it}X_{it}) = \frac{\psi}{w_t}$. Define $\theta^*_{it} = 1/\left(\beta \mathbf{E}_t \Lambda_{t+1} R_{bt} X_{it}\right)$.

The household's optimal decisions follow trigger strategy as those in the baseline model.

Case 1. $\theta_{it} > \theta_{it}^*$. In this case, household would like to hold positive amount of safe assets, i.e., $q_{ht}H_{it+1} + B_{it+1} > \zeta\theta_{it}X_{it}$. So we have $\mu_{it} = 0$ and $\eta_{it} \geq 0$. From the FOCs, we have

$$q_{ht}H_{it+1} = \max\left\{\left\{\frac{\mathbf{E}_t\Lambda_{t+1}\left[\frac{(1-\delta_h)q_{ht+1}+r_{ht+1}}{q_{ht}} - R_{bt}\right]}{\mathbf{E}_t\Lambda_{t+1}\gamma_b}\right\}^{\frac{1}{\chi}}, 0\right\}. \tag{B.64}$$

For the moment, we assume the following condition is always satisfied,

$$\frac{(1-\delta_h)\, q_{ht+1} + r_{ht+1}}{q_{ht}} > R_{bt}, \tag{B.65}$$

so that $\eta_{it} = 0$ and the housing demand is given by

$$q_{ht}H_{it+1} = \left\{\frac{\mathbf{E}_t\Lambda_{t+1}\left[\frac{(1-\delta_h)q_{ht+1}+r_{ht+1}}{q_{ht}} - R_{bt}\right]}{\mathbf{E}_t\Lambda_{t+1}\gamma_b}\right\}^{\frac{1}{\chi}}. \tag{B.66}$$

Since $\mu_{it} = \theta_{it} = 0$, from (B.63) we further have $C_{it} = \theta_{it}^* X_{it}$ and

$$q_{ht}H_{it+1} + B_{it+1} = (\theta_{it} - \theta_{it}^*)\, X_{it}. \tag{B.67}$$

Case 2. $\theta_{it} \leq \theta_{it}^*$. The household has no incentive to hold assets, i.e., $q_{ht}H_{it+1} + B_{it+1} = \zeta\theta_{it}X_{it}$ and $C_{it} = (1-\zeta)\,\theta_{it}X_{it}$. In this case, for $\theta_{it} = \theta_{it}^*$ we have the relationship $1/\left(\theta_{it}^* X_{it}\right) = \beta\mathbf{E}_t\Lambda_{t+1}R_{bt}$, which defines the cutoff θ_{it}^*. So we can solve μ_{it} as

$$\mu_{it} = \left[\frac{1}{(1-\zeta)\,\theta_{it}} - \frac{1}{\theta_{it}^*}\right]\frac{1}{X_{it}}. \tag{B.68}$$

The FOCs for housing and bonds imply

$$q_{ht}H_{it+1} = \left\{\frac{\mathbf{E}_t\Lambda_{t+1}\left[\frac{(1-\delta_h)q_{ht+1}+r_{ht+1}}{q_{ht}} - R_{bt}\right]}{\mathbf{E}_t\Lambda_{t+1}\gamma_b}\right\}^{\frac{1}{\chi}} + \eta_{it}, \tag{B.69}$$

therefore $q_{ht}H_{it+1} \geq 0$ under the assumption $\frac{(1-\delta_h)q_{ht+1}+r_{ht+1}}{q_{ht}} \geq R_{bt}$. It further implies $\eta_{it} = 0$. So the housing holding for any household is obtained as

$$q_{ht}H_{it+1} = \left\{ \frac{\mathbf{E}_t \Lambda_{t+1} \left[\frac{(1-\delta_h)q_{ht+1}+r_{ht+1}}{q_{ht}} - R_{bt} \right]}{\mathbf{E}_t \Lambda_{t+1} \gamma_b} \right\}^{\frac{1}{\chi}}. \tag{B.70}$$

From (B.63), we can further have

$$1 = \beta \mathbf{E}_t \frac{\Lambda_{t+1}}{\Lambda_t} R_{bt} \Phi_t \left(\theta_{it}^*; \sigma_t \right), \tag{B.71}$$

where the premium of holding housings $\Phi_t \left(\theta_{it}^* \right)$ satisfies

$$\Phi_t \left(\theta_{it}^* \right) = \int_{\theta_{it} < \theta_{it}^*} \left(\theta_{it}^* + \zeta \theta_{it} \right) d\mathbf{F} \left(\theta_{it}; \sigma_t \right) + \int_{\theta_{it} \geq \theta_{it}^*} \theta_{it} d\mathbf{F} \left(\theta_{it}; \sigma_t \right). \tag{B.72}$$

Last equation implies the cutoff is irrelevant to the individual state. So for simplicity, we can write $\theta_{it}^* \equiv \theta_t^*$. It is straightforward to show that the premium $\Phi_t \left(\theta_{it}^* \right)$ increases with ζ. This is because a larger ζ implies a more severe liquidity constraint, thereby holding housing produces a large premium. The asset pricing equation of housings (B.71) further implies that a larger ζ induces a lower interest rate. Since the housing demand is decreasing in the interest rate R_{bt}, a tighter liquidity constraint (ζ is larger) may lead to a higher housing price.

The individual household's optimal decision is summarized as follows.

Proposition B.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, housing and bond decisions are given by following trigger strategy:*

$$C_{it} = \left[(1-\zeta)\theta_{it} \mathbf{1}_{\{\theta_{it} \leq \theta_t^*\}} + \theta_t^* \mathbf{1}_{\{\theta_{it} > \theta_t^*\}} \right] X_t, \tag{B.73}$$

$$q_{ht}H_{it+1} = \left\{ \frac{\mathbf{E}_t \Lambda_{t+1} \left[\frac{(1-\delta_h)q_{ht+1}+r_{ht+1}}{q_{ht}} - R_{bt} \right]}{\mathbf{E}_t \Lambda_{t+1} \gamma_b} \right\}^{\frac{1}{\chi}}, \tag{B.74}$$

$$B_{it+1} = \theta_{it} X_{it} - C_{it} - q_{ht} H_{it+1}, \tag{B.75}$$

where the wealth X_t satisfies

$$X_t = \frac{1}{\theta_t^* \Lambda_t} \int \left\{ (\theta_t^* + \zeta \theta_{it}) \mathbf{1}_{\{\theta_{it} \leq \theta_t^*\}} + \theta_{it} \mathbf{1}_{\{\theta_{it} > \theta_t^*\}} \right\} d\mathbf{F}(\theta_{it}; \sigma_t). \tag{B.76}$$

In the deterministic equilibrium, the aggregate housing demand is given by

$$H_{t+1} = \frac{1}{q_{ht}} \left\{ \frac{1}{\gamma_b} \left[\frac{(1-\delta_h)\, q_{ht+1} + r_{ht+1}}{q_{ht}} - R_{bt} \right] \right\}^{\frac{1}{\chi}}. \tag{B.77}$$

(B.72) implies that when the uncertainty σ_t increases, R_{bt} decreases. This will shift the housing demand curve upwardly. Therefore, it would be expected that uncertainty raises housing price even though the liquid bond is introduced. Moreover, as long as the total bond supply is limited (i.e., the financial market is incomplete) and the adjustment cost γ_b is small, the main results in our baseline model still hold.