

Liquidity Constraints, Transition Dynamics, and the Chinese Housing Return Premium

Yu Zhang*

Princeton University

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Abstract

Home price movements received increasing academic and public attention in recent years. In this paper, I propose a novel explanation for large housing booms in emerging markets that highlights the effect of household wealth accumulation on housing prices under liquidity constraints, using the recent Chinese housing boom as an example. In China, housing prices grew 170% during 2003–2012 in real terms. Returns on housing commanded a 12% premium annually over the risk-free rate. Across Chinese cities, increases in the value of housing are closely associated with increases in household wealth, whether measured with or without housing. I argue that the high Chinese housing return premium results from an upward transition in household wealth from a low initial condition, interacted with liquidity constraints. Specifically, low initial household wealth, under liquidity constraints, limits housing prices to be low in 2003; but as household wealth quickly rises aided by high household savings, housing prices also quickly increase. I assess the quantitative plausibility of this explanation using an otherwise standard consumption-housing two-asset dynamic portfolio choice model, augmented with realistic liquidity constraints and low initial wealth, with housing priced in industry equilibrium. This model matches the high housing return premium and explains 92% of the observed increase in housing prices. This model also generates other intriguing predictions, including an investment motive that helps explain the high Chinese household saving rate puzzle. It also predicts that a permanent slowdown in Chinese economic growth might only lead to a temporary dip in Chinese housing prices. The analysis in this paper also provides insights for understanding other episodes in emerging housing markets for which there are both liquidity constraints and low initial household wealth.

JEL codes: D14, D91, E21, G11, G12, O53, R21, R31.

Keywords: housing market, wealth accumulation, transition dynamics, liquidity constraints.

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1 Introduction

Home price movements received increasing academic and public attention in recent years. The Chinese housing boom is central in this attention, in part because of its spectacular nature. Real housing prices grew 170% from 2003 to 2012 in China, more than doubling the 68% increase in the U.S. from 1997 to 2006.¹ Housing commands a large return premium relative to low interest rates: The average annualized price return on housing is 12.4% in real terms. In comparison, the average real return on bank savings is -0.2%, and the average mortgage interest rate is 3.5%. What made housing prices in 2003 so different from housing prices in 2012? What sustained the large gap between the return on owning housing and the return on alternative assets?

To address these two questions, I propose a novel explanation that centers on the upward transition of household wealth from a low initial condition, under liquidity constraints. This explanation contributes to the understanding of forces that underpin housing price movements. This explanation operates as follows. First, there are substantial liquidity constraints in China that limit arbitrage between different asset returns, and that tie housing prices to household wealth. Second, given that the generous former social welfare system was only phased out in late 1990s, household wealth is initially low in China in 2003, limiting housing prices to a low level relative to the net present value of future rents. But as household wealth quickly rises aided by high household savings, housing prices also quickly increase.

A key piece of motivating evidence for this explanation comes from an examination of the cross-city pattern in the extent of the housing boom. Specifically, I construct a city-level panel dataset that includes measures of price, quantity, housing value, purchasing power, and household wealth, and then document a tight comovement: increases in housing value at the city level are closely associated with increases in household wealth, whether measured with or without housing. This comovement is almost one-to-one: after I control for measures of purchasing power, the regression coefficient is around one between the growth rate of housing value and the growth rate of household wealth, whether measured with or without housing. Liquidity constraints provide a parsimonious mechanism to rationalize this strong comovement between household wealth and housing value.

¹The national average housing price index is from [Fang et al. \(2015\)](#), weighted by the value of housing in each city. The national average housing price index for the U.S. is from Case-Shiller.

To assess the quantitative plausibility of my explanation for the Chinese housing boom, I develop a rational expectations dynamic portfolio choice model with endogenous housing prices, augmented with realistic liquidity constraints and a low initial wealth. In the model, there are two goods: non-housing and housing consumption. A representative household receives endowment income in non-housing consumption, and the endowment process features risks in trend growth. The representative household also consumes both non-housing and housing consumption, and can borrow in the form of loans, invest in a bank savings account, and buy homes. The interest rate on loans and the bank savings account is specified exogenously. Homes, meanwhile, yield housing consumption. The supply of homes is given by an upward-sloping supply curve. The price of homes is determined endogenously in the model in an industry equilibrium.

I consider the effects of two types of liquidity constraints on home price dynamics, evolution of wealth and household portfolio compositions. I start the model at the empirical value of the initial household wealth-to-income ratio and calibrate the model to match the increase in the household wealth-to-income ratio. The two types of liquidity constraints I consider are borrowing constraints and illiquidity.

Absent these liquidity constraints, the model cannot match the level of the housing return premium and the increase in housing prices in the data, for households will borrow and invest substantially at the beginning, bidding up prices and lowering subsequent returns. Realistically, this borrowing and investing is neither feasible nor optimal in the Chinese housing market: not feasible because Chinese households face stringent borrowing constraints, and not optimal because housing is illiquid and households need to set aside funds for emergency expenditures.

With borrowing constraints only, the model is successful in matching the level and the trend in the housing return premium and generates 92% of the increase in housing prices observed in the data. That said, this particular model predicts households in China will not hold bank deposits in periods of high housing return premia, whereas in the data, they in fact do hold substantial low-return bank deposits.

The model with borrowing constraints and illiquidity, modeled as emergency consumption needs that must be met with liquid bank deposits, retains success in explaining the housing return premium and the increase in housing prices and generates a third to a half of empirical

holdings of bank deposits by households. The extended model's inability to completely match the household portfolio echoes the finding in [Telyukova \(2013\)](#), and [Pagel and Vardardottir \(2016\)](#).

Overall, the model with borrowing constraints only offers a parsimonious account of both the high housing price return and the high premium of the housing price return relative to interest rates in China's housing market during the sample period of 2003-2012. The model with borrowing constraints and illiquidity provides a more complete picture and matches not only the high housing price return and the high premium of housing price returns relative to interest rates, but also to some extent the observed household portfolio.

The model highlights key features of China that strongly influence the main results. The results rely on two crucial features of China: (1) a low required rate of return as a result of financial repression, and (2) the government's releasing vast amounts of new supply into the housing market. First, the low required rate of return makes the net present value of future rents extremely high in China, and also makes liquidity constraints bind even given a seemingly high value-to-income ratio. Second, the government captures much of the price appreciation by releasing vast amounts of new supply of housing in this period. If households own all housing from the beginning, then the feedback from housing price appreciation on an initial increase in household wealth would be so strong that the transition out of liquidity constraints would be instantaneous.

Two intriguing predictions emerge from the model that help answer important unresolved questions.

First, the model in this paper helps explain the high Chinese saving rate puzzle. Specifically, the model generates an investment motive for owning housing, and this investment motive raises the household saving rate during the transition. Transition dynamics generate an expected appreciation on housing faster than the growth rate of income, especially at the beginning of the housing boom. Facing housing returns that exceed expected income growth, households save with high-return housing and trade off less current consumption with more capital gains and more consumption in the future. This new explanation for high household savings in China contrasts with the negative finding in the model without the investment motive in [Wang and Wen \(2012\)](#).

Second, the model provides a framework for predicting the effect of a growth slowdown on

the Chinese housing market. Specifically, the model predicts a rebound and a subsequent increase in housing prices following an initial drop when the growth rate of the economy has permanently slowed to zero. This pattern occurs because housing prices under liquidity constraints are tightly connected to household wealth. When the expected growth rate of income permanently drops, the target household wealth-to-income ratio increases. As aggregate household wealth converges upward toward this higher target, housing prices increase with it.

1.1 Literature Review

This paper makes several contributions to the literature.

First, this paper contributes to a line of literature that points to mechanisms underlying the movement of housing prices by proposing a novel mechanism that highlights the effect of household wealth accumulation on housing price movements under liquidity constraints. Some of the mechanisms already highlighted in this literature are user cost ([Poterba \(1984\)](#)), demographics ([Mankiw and Weil \(1989\)](#)), behavioral biases ([Case and Shiller \(1990\)](#)), geographical constraints ([Glaeser et al. \(2008\)](#)), and credit expansion ([Favara and Imbs \(2015\)](#)).

Second, this paper also contributes to a stream of literature that examines equilibrium models of housing prices. Studies in this literature include the static model in [Stein \(1995\)](#), and the dynamic models in [Davis and Heathcote \(2005\)](#), [Ortalo-Magne and Rady \(2006\)](#), [Kiyotaki et al. \(2011\)](#), and [Favilukis et al. \(Forthcoming\)](#). This paper studies a dynamic equilibrium model of housing prices.

Within this literature, the closest are [He et al. \(2015\)](#) and [Favilukis et al. \(Forthcoming\)](#), both of which interpret the recent U.S. housing boom as the result of an *exogenous* relaxation of borrowing constraints. The main difference here is that my explanation relies on *endogenous* increases in liquidity through household wealth accumulation, instead of exogenous changes in constraints.

Third, this paper contributes to the growing study of liquidity constraints on asset prices and household portfolio choice.² Relative to this literature, I use this paper to focus on

²Some examples of papers on liquidity constraints and asset pricing include [Black \(1972\)](#), [Allen and Gale \(1994\)](#),

an environment with low wealth and a large asset class (i.e., China's housing market in transition) for which liquidity constraints are plausibly binding for the aggregate household sector and generate particularly large effects on asset prices and household portfolio choice. Finally, this paper contributes to an emerging branch of literature on the Chinese housing boom, which includes empirical descriptive studies such as [Wang and Zhang \(2014\)](#), [Fang et al. \(2015\)](#), [Wu et al. \(2015\)](#), [Feng and Wu \(2015\)](#), [Wu et al. \(2016\)](#), [Glaeser et al. \(2016\)](#). This paper adds to the empirical descriptive studies of the Chinese housing boom by constructing a city-level panel dataset of housing values and then documenting a tight comovement between city-wide housing value and city-wide household wealth, whether measured with or without housing.

Two other papers that model the Chinese housing boom are [Chen and Wen \(Forthcoming\)](#) and [Garriga et al. \(2016\)](#).³ Neither paper explains the large housing return premium relative to other assets, which this paper highlights and explains. Furthermore, these two papers focus on either the store of value role or the consumption role of housing. In the model of this paper, housing is realistically modeled as both a consumption and an investment good. Finally, in sharp contrast to the bubble perspective in [Chen and Wen \(Forthcoming\)](#), this paper shows that a faster-than-income increase in housing value and an investment motive in holding housing arise naturally in an empirically supported and quantitatively feasible framework without bubbles.⁴

The remainder of this paper is organized as follows. Section 2 documents stylized facts that motivate the explanation in this paper. Section 3 illustrates the mechanism and provides relevant institutional background. Section 4 develops a dynamic model of the housing market for a quantitative assessment of the mechanism. Section 5 reports the results of the quantitative assessment. Section 6 discusses additional predictions of the model. Section 7 concludes this paper.

[Aiyagari and Gertler \(1999\)](#), [Constantinides et al. \(2002\)](#), [Kogan et al. \(2007\)](#), [Brunnermeier and Pedersen \(2009\)](#), [Lagos \(2010\)](#) and [Frazzini and Pedersen \(2014\)](#). Some examples of papers on liquidity constraints and household portfolio choice include [Cocco \(2005\)](#), [Davis et al. \(2006\)](#), [Telyukova \(2013\)](#), [Kaplan and Violante \(2014\)](#), and [Campbell and Cocco \(2015\)](#).

³[Chen and Wen \(Forthcoming\)](#) use a rational bubble framework, in which housing is an intrinsically worthless asset and entrepreneurs hold housing with an investment motive, to explain the faster-than-income increase in housing value.

[Garriga et al. \(2016\)](#) illustrate that income growth and urbanization increase housing value in Chinese cities in a model where housing is purely a consumption good. However, once investment in housing is allowed, prices no longer grow as fast as in the data.

⁴Also, in this paper high housing returns arise and cease endogenously, while the rational bubble in [Chen and Wen \(Forthcoming\)](#) cannot get started within the model (as is well known in the bubble literature, rational bubbles can never emerge within a model; they must already be present when the asset starts trading.)

2 Stylized Facts

In this section, I document stylized facts that motivate the analysis in this paper.

2.1 Data construction

To document the motivating facts, I construct a panel dataset of housing values, prices, quantities, household purchasing power, and household wealth for Chinese cities, building on the work in Fang et al. (2015), which offers a constant-quality housing price index that covers 120 cities from 2003 to 2012. To construct housing values I use the perpetual inventory method, and combine information from the 2005 1% Mini Census microdata, the housing price index, and information on new home sales.⁵ I measure housing quantities in efficiency units (i.e. the ratio of housing values and housing prices). Measures of household purchasing power include disposable income, retail sales, and population; I also consider other proxies for the level of economic activities, including electricity use and the profits of industrial firms. Finally, I compute a measure of household wealth by combining city-level information on household bank deposits and mortgages with my constructed measure of housing values. This measure of household wealth in Chinese cities takes into account its two largest components—home equity and bank deposits—which together make up 80 to 90% of urban household wealth, according to calculations derived from two national household surveys that become available only around the end of my sample, the Chinese Household Finance Survey (CHFS) and the Chinese Family Panel Studies (CFPS).⁶ I describe in detail the procedure and assumptions for constructing the city-level panel dataset in Appendix A.

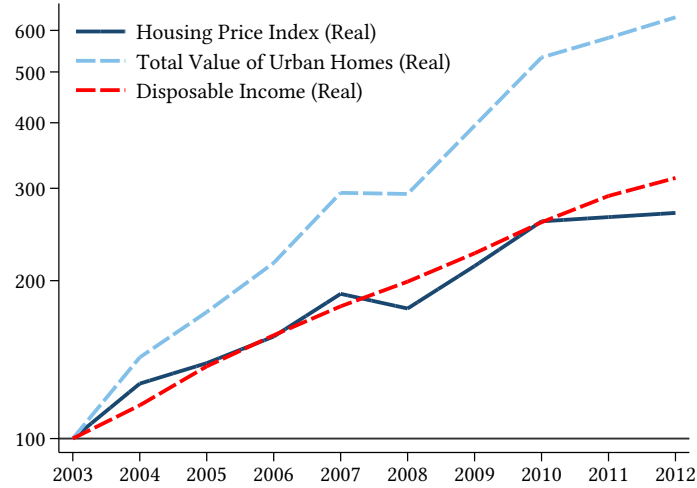
2.2 The Faster-than-Income Increase in Housing Value

The increase in housing values greatly exceeded the increase in household income. Aggregating over cities in my sample, Figure 1 plots the increase in housing values, housing prices, and household income. In addition to the 2.7 times growth in the real value-weighted housing

⁵Data on housing value and housing quantities are scant, even in the aggregate: The National Bureau of Statistics has yet to carry out a systematic housing census. Further, the flow-of-funds tables contain no measure of housing values.

⁶Data on holdings of other financial assets do not exist for the cities in my sample. Fortunately, non-bank financial markets are underdeveloped in China, and the majority of the household financial assets are in bank deposits. This measure also does not include value of personal businesses. However, this omission should not matter for checking the liquidity constraint mechanism, given that it is hard to borrow against (or cash out of) the value of personal businesses in China.

Figure 1: Fast growth in price and quantity of urban homes



Note: The top dashed line plots increases in real urban housing values. The solid line plots increases in the real national value-weighted average housing price index. The gap between the top dashed line and the solid line represents increases in the quantity of housing in efficiency units. The lower dashed line plots increases in real aggregate urban disposable income for comparison.

price index, there is a 2.2 times growth in the quantity of housing in efficiency units. In total, real housing values increased by 5.6 times, surpassing the 3.4 times growth in real aggregate urban disposable income, which already takes into account migration and population growth. Any model used to explain the Chinese housing boom needs to address the faster growth of housing values relative to household income.

2.3 The Large and Decreasing Housing Return Premium

The return on housing commanded a substantial premium over interest rates. Table 1 summarizes the average price return on housing and the average housing return premium over interest rates, weighted by the value of housing at different cities. I focus on the price return on housing (p_{t+1}/p_t) because data on the rents and imputed service flows on housing are not available. The annualized price return on housing is, on average, 12.4% in real terms. In comparison, the average real return on bank deposits, the largest financial asset class in terms of portfolio holdings by households, is -0.2%, and the average mortgage interest rate is 3.5%.

Table 1: Housing return premium over risk-free rates, national weighted average, 2003–2012

	Mean	Standard deviation
Real housing price appreciation	12.4% (3.9%)	11.6%
Real interest rate on deposits	-0.2% (0.5%)	1.6%
Real interest rate on mortgages	3.5% (0.5%)	1.5%
Excess return over deposit rate	12.6% (3.8%)	11.4%
Excess return over mortgage rate	8.9% (3.8%)	11.4%

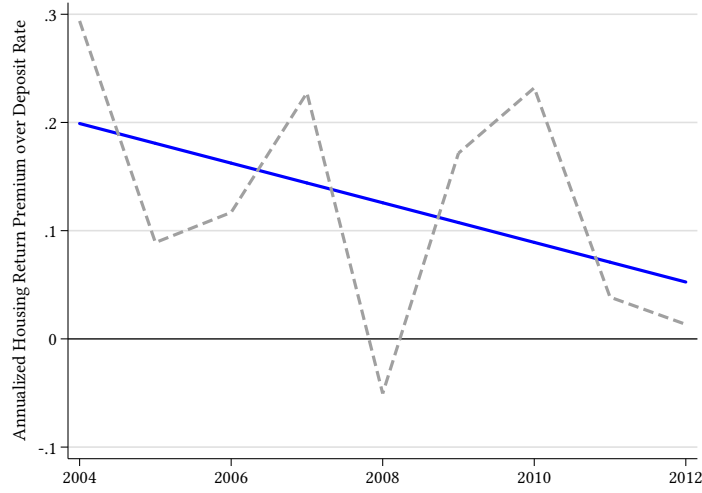
Note: This table summarizes the average price return on housing and the average housing return premium over interest rates, weighted by the value of housing in different cities. Standard error of sample mean in parentheses. Nobs = 9.

A high return premium is puzzling, in part because an investor can gain much by reallocating funds to the asset with a higher return, especially if the volatility of the return premium is not very large compared to the average return premium. This is indeed the case here, as the Sharpe ratio (the ratio between the average return and the standard deviation) of housing relative to the deposit rate is 110%, and the Sharpe ratio of housing relative to the mortgage rate is 78%.

Moreover, during the period 2003–2012, the housing return premium seems to trend downward over time. A downward trend in the housing return premium could suggest some kind of convergence between the return on housing and interest rates. The average housing return premium over the deposit rate during 2003–2007 is 18.2%, while the average housing return premium over the deposit rate during 2007–2012 is 8.1% (excluding 2007–2008, the year of the global financial crisis, the average is 11.4% during 2008–2012).

The downward trend is graphically illustrated in Figure 2, in which the dashed line is the actual realization of the housing return premium over the deposit rate, and the solid line is an estimated linear trend of the housing return premium.

Figure 2: The housing return premium trends downward over time



Note: The dashed line plots the actual realization of the (value-weighted national average) housing return premium over the deposit rate. The solid line plots an estimated linear trend of the housing return premium.

Figure 3: Statistical significance of the downward trend in the housing return premium

	Housing Return Premium over Deposit Interest Rate					
	(1)	(2)	(3)	(4)	(5)	(6)
Sample	Full	Excluding First Year	Excluding Last Year	Tier 1	Tier 2	Tier 3
Time Trend	-0.0124***	-0.0031**	-0.0063***	-0.0162**	-0.0187***	-0.0098***
Observations	891	792	792	36	234	621
R^2	0.064	0.004	0.013	0.052	0.143	0.043
Number of Cities	99	99	99	4	26	69

Note: In this table I regress the city-level housing return premium over the deposit interest rate on a linear time trend. Column (1) reports the result for the full sample, which indicates a significant and large downward trend in the housing return premium. Columns (2) and (3) report robustness of the downward trend to removing the first or the last year of observations, respectively. Columns (4)-(6) report robustness of the downward trend for cities in each tier in China. Standard errors are clustered at the city level. *** indicates significance at the 1% level. ** indicates significance at the 5% level.

To check further on the statistical significance of the trend in the housing return premium, Table 3 reports the results of regressing the city-level housing return premium over the deposit interest rate on a linear time trend. The linear time trend is statistically significant. The statistical significance of the downward time trend is robust when I remove the first year or the last year of observations and is also robust for cities of all tiers in China.⁷

2.4 Across Cities: A One-to-One Relationship Between Value of Housing and Household Wealth, Including or Excluding Housing

The cities that experienced the largest housing boom in 2003–2012 tend to be the cities that experiences the largest increase in household wealth, whether including or excluding housing.

To more fully understand the mechanism that underlies the Chinese housing boom, I explore the characteristics of Chinese cities that experienced the largest housing boom in 2003–2012. In particular, I use the city panel dataset to estimate the following panel regressions:

$$\log(p_{it}) = \alpha_i + \beta \log(wealth_{it}) + \gamma_1 \log(income_{it}) + \gamma_2 \log(population_{it}) + \varepsilon_{it}, \quad (1)$$

$$\log(p_{it}q_{it}) = \alpha_i + \beta \log(wealth_{it}) + \gamma_1 \log(income_{it}) + \gamma_2 \log(population_{it}) + \varepsilon_{it}. \quad (2)$$

I include city fixed effects in the panel regressions to focus on the *movement* of both the housing market and the right-hand side variables. To make sure the coefficient on $\log(wealth)$ is not just due to regressing housing on housing, I use two different wealth measures: wealth including housing and wealth excluding housing (which is simply household bank savings).

Table 2 reports the results of the panel regressions. The results suggest that cities that have seen the biggest increases in housing prices and in housing value also tend to be cities that have seen the biggest increase in household wealth, whether that measure of wealth includes or excludes housing. The magnitude of the association is large: a one percent higher growth in household wealth is associated with around a half percent higher price appreciation in housing and a one percent higher increase in the overall value of homes. The coefficients on $\log(wealth)$ are similar whether I include or exclude housing from household wealth,

⁷The decrease in the housing return premium raises some doubts about explanations based on risks of a bubble collapsing. To the extent that such an explanation involves a bubble that is growing, households' exposure to the risk of a bubble collapsing should increase over time, which should be expected to increase the housing return premium over time.

suggesting that the estimated tight relationship is not due simply to regressing housing on housing.

Table 2: City-level panel regression results

	(1)	(2)	(3)	(4)
Dependent Variables	Log(Home Price Index)		Log(Total Value of Housing)	
Household Wealth	Net Worth	Bank Deposits	Net Worth	Bank Deposits
Measures	(Including Housing)	(Excluding Housing)	(Including Housing)	(Excluding Housing)
Log(Household Wealth)	0.604***	0.492***	1.107***	1.062***
Log(Income)	-0.0656	0.265***	0.0574	0.524***
Log(Population)	0.0871	0.187	-0.0301	0.128
Observations	990	990	990	990
Adjusted-R ²	0.94	0.89	0.99	0.99
Number of Cities	99	99	99	99
City FE	YES	YES	YES	YES

Note: This table reports results of the following city panel regressions:

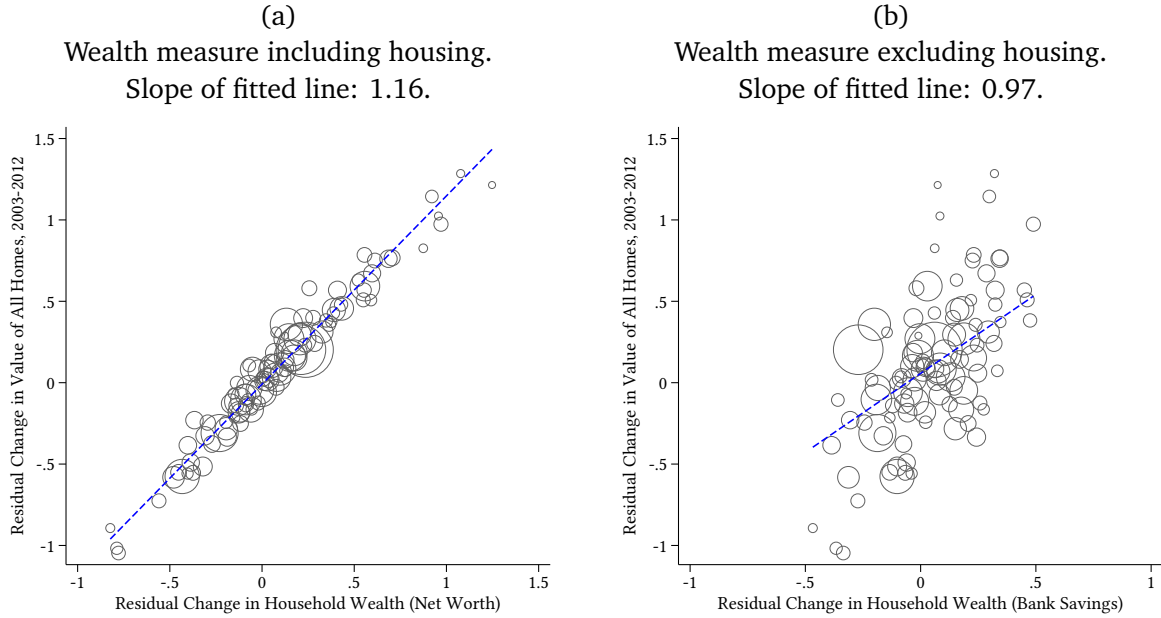
$$\begin{aligned}\log(p_{it}) &= \alpha_i + \beta \log(\text{wealth}_{it}) + \gamma_1 \log(\text{income}_{it}) + \gamma_2 \log(\text{population}_{it}) + \varepsilon_{it}, \\ \log(p_{it}q_{it}) &= \alpha_i + \beta \log(\text{wealth}_{it}) + \gamma_1 \log(\text{income}_{it}) + \gamma_2 \log(\text{population}_{it}) + \varepsilon_{it}.\end{aligned}$$

The regressions include city fixed effects. All variables are deflated by the consumer price index at the province level. Two different wealth measures are used: wealth including housing and wealth excluding housing (which is simply household bank savings). Standard errors are clustered at the province level. *** indicates significance at the 1% level.

Figure 4 graphically illustrates the tight relationship between increases in the total value of homes and increases in household (total or non-housing) wealth. Log housing value and log household wealth are first regressed on log income and log population. I take the regression residuals and plot the 2003–2012 growth rate in (residual) housing value over the growth rate in (residual) household wealth, including or excluding housing. Again, the slope of the fitted line representing the association between increases in the total value of homes and increases in household wealth is similar and close to one, whether I include or exclude housing from household wealth.

The one-to-one association between increases in the total value of homes and increases in

Figure 4: Growth in the overall value of homes is positively associated with growth in household (non-housing) wealth



Note: This figure plots the 2003-2012 growth rate in (residual) housing value over the growth rate in (residual) household wealth. The residuals are constructed by regressing log housing value and log household wealth on log income and log population. Left: Wealth including housing. Right: Wealth excluding housing (which is simply household bank savings).

household (total or non-housing) wealth is quite robust. Specifically, it is robust to: (1) additional proxies of purchasing power and of levels of economic activity as controls in the panel regressions (e.g., retail sales, electricity use, profit of industrial firms), which address to some extent omitted variable bias; (2) exclusion of three Northeastern provinces that are reputed to be more prone to statistical manipulation; and (3) inclusion of time fixed effects in the panel regressions, which further addresses the concern that coefficients could be picking up common aggregate time trends shared by the housing market and the right-hand-side variables. Appendix Tables A1-A3 reports results from these robustness checks.

2.5 Summary of Stylized Facts

To summarize, I document four stylized facts on the Chinese housing boom:

Fact 1: A substantial housing return premium exists, for the price return on housing is much higher than interest rates on financial saving and borrowing.

Fact 2: The housing return premium trends downward over time.

Fact 3: The increase in housing prices and housing quantities are both large. The increase in the total value of housing in the Chinese housing boom is beyond the increase in purchasing power during 2003–2012.

Fact 4: The increase in the total value of housing at the city level is associated one-to-one with the increase in household wealth, whether including or excluding housing.

3 Proposed Mechanism and Institutional Background

Liquidity constraints together with an upward transition in Chinese household wealth provide a mechanism that potentially explains the large increase in housing prices, the large and declining housing return premium, and the faster-than-income-growth increase in housing values that is linked one-to-one with the increase in household wealth.

The mechanism operates as follows. Liquidity constraints and low initial household wealth limit housing demand, thereby generating the low housing prices in 2003. Subsequently, household savings from low initial household wealth generate a transitional increase in household wealth, which lifts housing demand, driving up both housing prices and quantities. The increase in housing demand is amplified by a feedback loop through which appreciation of existing housing generated by the initial increase in household wealth leads to a further increase in household wealth, and so on.

This mechanism explains the aforementioned stylized facts naturally. For example, liquidity constraints, especially in the form of constraints on borrowing, provide a natural explanation for Fact 1 (level of housing return premium) and Fact 4 (cross-city association). Liquidity constraints create a tight connection between Chinese household wealth and how much Chinese households can invest in housing, which accounts for Fact 4. Liquidity constraints also create limits to arbitrage between the high return on housing and the low return on financial saving and borrowing, which accounts for Fact 1.

Further, when liquidity constraints are initially binding, a large increase in Chinese household wealth, coupled with a growth rate of wealth faster than the growth rate of income, can explain Fact 2 (downward trend in housing return premium) and Fact 3 (increase in housing

value beyond increase in income). Housing values also increase one-to-one with household wealth under the binding liquidity constraints, at a rate faster than the growth rate of income, which accounts for Fact 3. Finally, the increase in household wealth also makes binding liquidity constraints less tight, reducing limits to arbitrage between the high return on housing and the low return on financial saving and borrowing, which accounts for Fact 2. This explanation is consistent with, and relies upon, institutional details in the Chinese housing market and with the dynamics of Chinese household wealth. In this section, I show that (1) institutional details in China indeed imply influential liquidity constraints, and (2) Chinese household wealth indeed saw a large transitional increase from a low initial value in the sample period aided by both savings and capital gains, following the phasing out of the generous old social welfare system.

3.1 Liquidity Constraints for Chinese Home Buyers

Liquidity constraints limit the amount of funds in the Chinese housing market relative to household wealth. When household wealth is low, liquidity constraints lower the price of housing below the net present value of future rents. I focus on two types of liquidity constraints most relevant to Chinese households: borrowing constraints and illiquidity. I describe the extent to which they are relevant for Chinese households in their housing investment.

3.1.1 Borrowing constraints

Constraints on borrowing limit the amount of funds a household *can* invest in housing relative to the amount of household wealth. Access to borrowing for the purchase of homes in China is limited to mortgage borrowing, and mortgage regulations are very stringent in China. The regulatory constraints on mortgage borrowing are multi-faceted, impacting a wide range of potential borrowers. I describe some of these constraints here:

- **Downpayment constraint:** The China Banking Regulatory Commission (CBRC) imposes a minimum downpayment ratio on mortgage borrowings in China. For most of the period I study, the minimum downpayment ratio is 30%. In comparison, zero downpayment mortgages are widespread during the U.S. housing boom.

- **Payment-to-income constraint:** The CBRC also constrains mortgage borrowing relative to the current income of borrowers, as a monthly mortgage payment cannot exceed 50% of the monthly income of the borrower at the time of borrowing. Although payment-to-income constraints are not unique to China, the high expected income growth in China makes the constraint especially restrictive in China, given that the constraint is set in terms of current income, which is potentially very low relative to future income.
- **Inflexible repayment schedule:** The CBRC requires mortgage loans to be repaid in either equal installments of principal, or in equal installments of principal and interest. This makes it impossible to avoid the payment-to-income constraint by choosing an increasing repayment schedule.
- **Limits on refinancing:** Mortgage refinancing, the act of taking out a new mortgage to pay off the old one, is not allowed. On a similar note, mortgage maturity cannot be extended through refinancing.
- **Limits on borrowing for investment homes:** Rich households that want to buy multiple homes face more stringent borrowing constraints. The minimum downpayment ratio for a second home is substantially higher than that for a first home. Mortgage borrowing on a third home and beyond are not allowed.
- **Difficulty in borrowing against older homes:** Many homes constructed before the sample period, especially those built by work units as in-kind benefits, are poor quality and have been improperly maintained, and some times without proper titles. As a result, banks are unwilling to extend credit on those homes and imposes stringent building age requirements.

In sum, substantial constraints on mortgage borrowing limit the amount of funds that Chinese households can use in addition to household wealth for the purchase of housing.

3.1.2 Illiquidity

Illiquidity of housing reduces the fraction of household wealth that households are *willing to* invest in housing in the presence of emergent expenditure needs. Extraction of wealth

in housing is costly in terms of time costs and/or pecuniary costs, and households would optimally withhold some wealth in liquid assets that are more easy to access, even if the return on housing is much higher than the return on liquid assets. Illiquidity of housing then, plays a more important role if there are strong needs for expenditures that cannot be covered by regular paychecks. I describe some types of such expenditures that seem to be important for Chinese households:

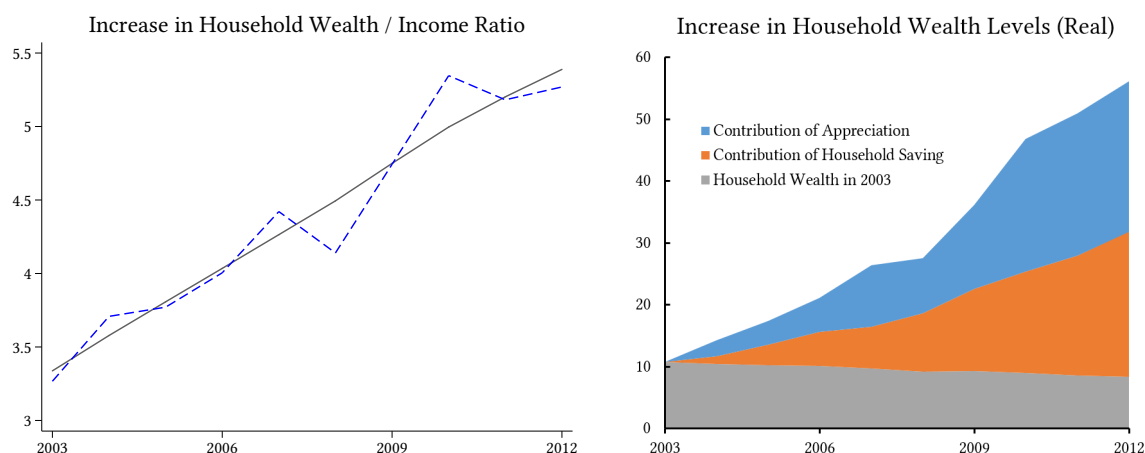
- **Out-of-pocket medical expenses:** Out-of-pocket medical expenses are not billed, and must be paid on the spot in Chinese hospitals during the day or week of treatment. This creates a strong incentive for households to withhold some wealth in liquid assets rather than in high-return housing. The magnitude of out-of-pocket medical expenses is large. In the CFPS microdata in 2012, the share of out-of-pocket medical expenses relative to total annual expenditures is, on average, 11%, with a highly skewed distribution: for 3% of the households, out-of-pocket medical expenses exceed 55% of total annual expenditures; for 1% of the households, out-of-pocket medical expenses exceed 83% of total annual expenditures.
- **Expenses during unemployment:** Unemployment benefits in China are regulated to be below the local minimum wage, which is already set at a very low level and can in no way be considered a living wage. Since the extraction of housing wealth remains costly, this creates another incentive to withhold some wealth in liquid assets instead of in high-return housing.

In sum, the chance of large emergency expenditures conditional on illiquidity of housing further limits the amount of funds relative to household wealth that Chinese households will use for the purchase of housing.

3.2 Upward Transition in Chinese Household Wealth

Since liquidity constraints create a tight link between household wealth and the amount of funds in the housing market, a large increase in Chinese household wealth can drive large increases in housing prices and quantities by increasing the amount of funds in the constrained housing market. This feeds back to the increase in household wealth through the appreciation of households' existing housing holdings.

Figure 5: Left: Increase in level of real household wealth and composition of the increase. Right: Increase in household wealth-to-income ratio



Note: The left panel plots the increase in the level of urban aggregate household wealth, deflated by the consumer price index. The bottom part represents household wealth in 2003. The middle part represents new household savings, including saving in financial assets and the purchase of new homes. The top part represents the appreciation on both existing housing owned prior to 2003 and new housing bought since 2003. The right panel plots the increase in the urban household wealth-to-income ratio. The income measure is disposable income. The dashed line plots the time series of the urban household wealth-to-income ratio. The solid line plots smoothed values obtained by applying the Hodrick-Prescott filter.

Chinese household wealth was arguably still in transition in 2003. Unique institutional features of the Chinese economic system at that time are important factors that help explain this transition. China used to be a communist/socialist economy in which personal property had a minimal role. A generous social welfare system provided housing, healthcare, education, and pension benefits. Households needed minimal savings. The economic reform, which started in 1978, initially did not touch the social welfare system, until budgetary pressures forced social welfare reform in the 1990s, which greatly cut education and health benefits, eliminated in-kind housing benefits, and lowered the pension replacement rate. Household saving rates rose from 10% to 20% in the 1990s and continued to increase in the 2000s. Still, household wealth was only 3.2 times disposable income in the initial sample year of 2003, which is 30% lower than the lowest wealth-to-income ratio among advanced economies studied in [Piketty and Zucman \(2014\)](#).

From 2003 to 2012, the data show a large upward movement in household wealth, both in levels and in the wealth-to-income ratio. Adjusted for inflation, household wealth increased 5.2 times. Half of the increase in wealth levels comes from two types of saving: saving in financial assets and the purchase of new homes. Another half of the increase in wealth

levels comes from the appreciation on both existing housing owned prior to 2003, and new housing bought since 2003. The wealth-to-income ratio increased from 3.2 to 5.2 (Figure 5), reaching the range of wealth-to-income ratios studied in [Piketty and Zucman \(2014\)](#).

In sum, following the phasing out of the generous former social welfare system, Chinese household wealth indeed saw a large transitional increase from a low initial value in the sample period.

4 Model and Equilibrium

In this section, I develop a model of China's housing market during 2003–2012 that emphasizes the effects of transition dynamics in the aggregate household wealth from a low initial condition, under liquidity constraints, on the Chinese housing market. Features of this model are specially designed to capture key aspects of the reality in China.

The model is a dynamic portfolio choice model with two goods, non-housing and housing, and three assets: housing, bank deposits, and mortgages, which capture the largest asset classes accessed by urban Chinese households. There is a representative family consisting of a continuum of member households that receive endowment income in the non-housing good. The endowment process features a high trend growth state and a low trend growth state, which captures the high trend growth in China and the long-run risks of a slowdown in fundamentals.

Housing is priced in an industry equilibrium, with households as the demand side. A member household in the representative family is potentially constrained with respect to the amount of funds it can use to purchase housing, as reflected by the level of household wealth combined with liquidity constraints. I consider two types of liquidity constraints: borrowing constraints and illiquidity. Borrowing constraints are modeled as exogenous constraints on mortgage borrowing. Illiquidity is modeled via a within-period shock that creates a need for emergency expenditures for some member households of the representative family; because this need cannot be financed with wealth in housing, it must be financed with bank deposits.

To focus on transition dynamics in household wealth under liquidity constraints, the supply side of the housing market is intentionally stylized, and is modeled as an upward-sloping

supply curve in the stock of housing; as such, the total quantity of housing supplied increases with the price of housing.

4.1 Model

4.1.1 Endowment

There is a representative family with a continuum of member households. For the moment, all member households are identical, and the subscript indexing households within the representative family is suppressed for clarity.

Households receive a stochastic endowment y_t of the non-housing good at the beginning of the period. The endowment process y_t captures the high trend growth in China, as well as a stark long-run risk of future slowdown. Specifically:

$$y_t = \Gamma_t z_t. \quad (3)$$

The first component of y_t , Γ_t represents the cumulative product of past trend growth $\{g_0, \dots, g_t\}$:

$$\Gamma_t = g_t \Gamma_{t-1} = \prod_{s=0}^t g_s, \quad (4)$$

In particular, trend growth g_t follows a two-state Markov chain:⁸

$$g_t \sim \text{Markov}\left(\begin{bmatrix} g_H \\ g_L \end{bmatrix}, \begin{bmatrix} 1 - \pi_g & \pi_g \\ 0 & 1 \end{bmatrix}\right). \quad (5)$$

The Markov chain for trend growth g_t in (5) implies that the slowdown is permanent: the economy never emerges from low growth once a slowdown occurs. In Section 6, I exploit this specification of the long-run trend growth risk to explore the model's prediction for housing price dynamics when a slowdown occurs.

The second component z_t represents a stationary shock to the stochastic endowment process that captures short run risks in fundamentals, and is modeled as another two-state Markov

⁸The nature of change in trend growth is likely to be less discrete in reality. Here I keep the specification of g_t simple, to make the model results easier to interpret; that said, I will consider richer growth processes in future research.

chain:

$$z_t \sim \text{Markov}\left(\begin{bmatrix} z_H \\ z_L \end{bmatrix}, \begin{bmatrix} 1 - \pi_z & \pi_z \\ \pi_z & 1 - \pi_z \end{bmatrix}\right). \quad (6)$$

4.1.2 Markets

The non-housing good is the numeraire. There is a market for ownership of housing. Housing ownership trades at price p_t . Housing is divisible and depreciates at rate δ each period.

Households have access to risk-free saving a_t in bank deposits and risk-free borrowing b_t in mortgages (subject to borrowing constraints) at exogenous interest rates. The interest rate on bank deposits is R_a . The interest rate on mortgages is R_b . I choose the setup with exogenous interest rates to reflect the complex nature of the monetary system in China.⁹

Liquidity Constraints

The first type of liquidity constraint that households face is an exogenous borrowing constraint on mortgages. In Section 5, the model's dynamics on housing prices and wealth dynamics is mostly driven by liquidity constraints of this type. Specifically, the constraint on mortgage borrowing is the following:

$$b_t \leq \psi(p_t) \cdot p_t h_t. \quad (7)$$

The function $\psi(\cdot)$ is increasing in p_t , and bounded by $\bar{\psi}$. The upper bound $\bar{\psi}$ reflects a standard loan-to-value (LTV) constraint on collateral borrowing against housing values.¹⁰ The ratio $\psi(\cdot)/\bar{\psi}$ reflects that some urban homes in China cannot be borrowed against in mortgages. Many older homes, especially those built by work units as in-kind benefits, are poor quality and have been improperly maintained. As a result, banks are unwilling to extend credit on those homes. Newer commercial homes are more easily borrowed against; therefore, the fraction of homes that can be borrowed against increases over time. However, modeling ψ as a function of time adds time as a state variable. To economize on the number of state variables, I model $\psi(\cdot)$ as a function of the price of housing, which increases over time in the data.

⁹Credit quotas and monetary aggregate targeting more closely describe the monetary system in China than market clearing in the interest rate margin. See [Chen et al. \(2016\)](#) for a discussion.

¹⁰The constraint on mortgage borrowing (7) does not explicitly reflect the no-refinancing restriction in Chinese housing. Modeling long-term mortgages in the model is an extension that I am currently working on.

The second type of liquidity constraint that households face is illiquidity. Illiquidity is modeled via within-period emergency consumption shocks, where the amount of emergency consumption to be made is limited by the amount of bank deposits.

The emergency consumption shock is realized within each period. At the start of each period and before the within-period emergency consumption shocks are realized, each member household receives endowments y_t , makes portfolio choices h_t , a_t , b_t , and chooses the planned amount of normal consumption $\tilde{c}_t^n$.

When the within-period emergency consumption shock is realized, with a probability of π a member household has to make an emergency consumption c_t^m . Emergency consumption can be obtained by converting some of the planned normal consumption $\tilde{c}_t^n$. But the member household faces a limit on the amount of planned consumption that can be converted. Specifically, I assume that the amount of emergency consumption that can be converted is limited by the amount of bank deposits held by the member household:

$$c_t^m \leq a_t. \quad (8)$$

Equation (8) is the liquidity constraint due to illiquidity in this model, or in other words the emergency consumption constraint. A member household hit with the emergency consumption shock consumes emergency consumption c_t^m subject to (8), and also consumes normal consumption $c_t^n = \tilde{c}_t^n - c_t^m$. A member household not hit with the emergency consumption shock consumes normal consumption $c_t^n = \tilde{c}_t^n$ only.

The motivation for adding illiquidity as another type of liquidity constraint is to create another incentive for Chinese households in the model to limit their investments in housing in face of high housing price returns. Because households value emergency consumption and the amount of emergency consumption is limited by the amount of bank deposits, households will optimally set aside some of their wealth in bank deposits and not in housing.

Another motivation for adding illiquidity is that I observe households holding substantial bank deposits in their respective portfolios during the Chinese housing boom. Illiquidity via the emergency consumption constraint, then, is a channel to generate bank deposit holdings in the model.

4.1.3 Household Preferences

The utility function of each member household is of the Epstein-Zin-Weil form:

$$V_t = \left\{ \left[E_{t-} (c_t^{1-\theta} h_t^\theta)^{1-\gamma} \right]^{\frac{1-\frac{1}{\sigma}}{1-\gamma}} + \beta \left[E_t (V_{t+1})^{1-\gamma} \right]^{\frac{1-\frac{1}{\sigma}}{1-\gamma}} \right\}^{\frac{\sigma}{\sigma-1}} \quad (9)$$

where E_{t-} denotes the expectation at the beginning of period t , before the within-period emergency consumption shock is realized, and where c_t is an aggregator over normal and emergency consumption that depends on the realization of the emergency consumption shock:

$$c_t = \begin{cases} c_t^n & \text{with prob } 1 - \pi \\ (c_t^n)^{1-\kappa} (c_t^m)^\kappa & \text{with prob } \pi. \end{cases} \quad (10)$$

I choose an Epstein-Zin-Weil utility function so that the model may more easily capture high household savings in China during a period of high growth by separating the elasticity of intertemporal substitution and the relative risk aversion.¹¹

In the special case that $\gamma = 1/\sigma$, the utility function of the member household reduces to

$$V_0 = \begin{cases} E_0 \sum_{t=0}^{\infty} \beta^t \frac{(c_t^{1-\theta} h_t^\theta)^{1-\gamma}}{1-\gamma} & \text{if } \gamma \neq 1, \\ E_0 \sum_{t=0}^{\infty} \beta^t \log(c_t^{1-\theta} h_t^\theta) & \text{if } \gamma = 1, \end{cases} \quad (11)$$

where c_t is again the aggregator over normal and emergency consumption given by (10).

4.1.4 Household Budget Constraint

The member household start with an initial wealth w_0 , and maximize utility V_0 defined in (9), subject to the liquidity constraints

$$\begin{aligned} b_t &\leq \psi(p_t) \cdot p_t h_t, \\ c_t^m &\leq a_t, \end{aligned}$$

¹¹See Choi et al. (Forthcoming) for a discussion.

and the following budget constraints:

$$c_t^m + c_t^n + a_t + p_t h_t - b_t \leq y_t + w_t, \quad (12)$$

$$w_{t+1} = R_a a_t + p_{t+1}(1 - \delta)h_t - R_b b_t. \quad (13)$$

Also, a_t , b_t cannot be negative, implying that households cannot have negative deposits or negative mortgages. This setup reflects that some households in China hold deposits and borrow in mortgages simultaneously.

Budget constraints (12) and (13) illustrate the relationship between dynamics in household wealth and household choices of housing. When households save by forgoing consumption, household wealth w_t is expected to grow. When household wealth w_t grows, households have more resources to buy housing h_t for investment and consumption, given liquidity constraints (7) and (8). Household choice of housing h_t further influences the dynamics of household wealth w_t through changes in the price of housing p_t over time.

4.1.5 Housing Supply

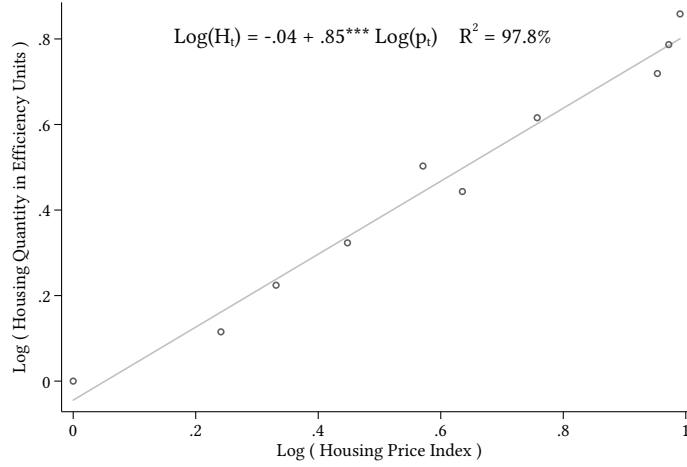
To focus on liquidity constraints and transition dynamics in household wealth, the supply side of the housing market is intentionally stylized and modeled as an upward-sloping supply curve, governed by a single parameter ε :

$$H^S = \bar{H} \cdot p^\varepsilon. \quad (14)$$

The parameter ε has a clear interpretation as the price elasticity of housing supply (in terms of the stock of housing). This helps disciplining the parameter ε in the quantitative analysis.

Furthermore, this parsimonious specification of the housing supply curve provides a good fit of the aggregate price and quantity of housing in the data. 14 indicates a linear fit between $\log(H_t)$ and $\log(p_t)$. Figure 6 plots $\log(H_t)$ and $\log(p_t)$ in the aggregate data, as measured by efficiency units of housing and the housing price index, respectively. The R-squared statistic of the linear regression of $\log(H_t)$ on $\log(p_t)$ is 97.8%.

Figure 6: Linear fit of $\log(H_t)$ and $\log(p_t)$ in the aggregate data



Note: This figure plots $\log(H_t)$ and $\log(p_t)$ in the aggregate data, as measured by efficiency units of housing and the housing price index, respectively. The solid line plots a linear fit of $\log(H_t)$ on $\log(p_t)$ estimated in the regression $\log(H_t) = \beta_0 + \beta_1 * \log(p_t) + u_t$. The plotted equation reports the regression coefficients and the R-squared statistic. *** indicates significance at the 1% level.

4.2 Equilibrium

In this subsection, I restate the household maximization problem recursively and define the recursive equilibrium of the model.

The state vector of the household maximization problem consists of individual household wealth w , aggregate household wealth W , trend aggregate income Γ , and transitory aggregate income state z . Aggregate housing H^S is not a state variable because it is a function of aggregate household wealth W ; this is due to the homogeneity of the housing supply curve (14).

The household maximization problem, stated recursively, is:

$$V(w; W, \Gamma, z) = \max_{c^m, c^n, h, a, b} \left\{ \left[E_- \left(c^{1-\theta} h^\theta \right)^{1-\gamma} \right]^{\frac{1-\frac{1}{\sigma}}{1-\gamma}} + \beta \left[E \left(V(w'; W', \Gamma', z')^{1-\gamma} \right)^{\frac{1-\frac{1}{\sigma}}{1-\gamma}} \right]^{\frac{\sigma}{\sigma-1}} \right\} \quad (15)$$

where E_- denotes the expectation at the beginning of period, before the within-period

emergency consumption shock is realized, and where

$$c = \begin{cases} c^n & \text{with prob } 1 - \pi \\ (c^n)^{1-\kappa} (c^m)^\kappa & \text{with prob } \pi \end{cases}$$

subject to

$$c^m + c^n + a + p(W, \Gamma, z) \cdot h - b \leq \Gamma \cdot z + w, \quad (16)$$

$$w' = R_a a + p(W', \Gamma', z') \cdot (1 - \delta) \cdot h - R_b b, \quad (17)$$

$$0 \leq a, b, \quad (18)$$

$$b \leq \psi(p(W, \Gamma, z)) \cdot p(W, \Gamma, Z) \cdot h, \quad (19)$$

$$c^m \leq a. \quad (20)$$

The final two constraints, (19) and (20), represents the two types of liquidity constraints: borrowing constraints and illiquidity. Equations (16) and (17) represent the evolution of household wealth.

4.2.1 Recursive Equilibrium

Definition: A *recursive equilibrium* of the model is a housing price function $p(W, \Gamma, z)$, a value function $V(w; W, \Gamma, z)$, a collection of policy functions $c^m(w; W, \Gamma, z)$, $c^n(w; W, \Gamma, z)$, $a(w; W, \Gamma, z)$, $b(w; W, \Gamma, z)$, and $h(w; W, \Gamma, z)$, and a law of motion for aggregate household wealth $W' = G(W, \Gamma, z, \Gamma', z')$ such that:¹²

a. [Optimality]: Given the housing price function and the law of motion for aggregate household wealth, the value function and the policy functions solve the household maximization problem defined by (15).

b. [Housing market clearing]: The housing market clears at each state:

$$h(W; W, \Gamma, z) = H_0 \cdot p(W, \Gamma, z)^\varepsilon. \quad (21)$$

¹²The law of motion for aggregate household wealth $W' = G(W, \Gamma, z, \Gamma', z')$ depends on the next period states Γ' and z' , because the next period price of the aggregate holding of housing depends on the next period states, which becomes clear in equilibrium condition (22).

c. [**Consistency**]: Given policy functions and the housing price function, $W' = G(W, \Gamma, z, \Gamma', z')$ solves the transition equation of aggregate household wealth:

$$W' = R_a a(W; W, \Gamma, z) - R_b b(W; W, \Gamma, z) + p(W', \Gamma', z')(1 - \delta)h(W; W, \Gamma, Z). \quad (22)$$

The stochastic processes for Γ , z , the housing price function $p(W, \Gamma, z)$, and the law of motion for aggregate household wealth $W' = G(W, \Gamma, z, \Gamma', z')$, collectively determine the joint dynamics of housing prices and household wealth in the equilibrium of the model.

4.2.2 Balanced Growth Path

I choose to define a balance growth path equilibrium as an equilibrium in which the growth rates of the model variables are constant, assuming realizations of the endowment shocks are kept constant. On a balanced growth path with trend endowment growth rate g_t , income y_t , non-housing consumption c_t (both normal consumption c_t^n and emergency consumption c_t^m), and wealth w_t all grow at the rate g_t . The price of housing p_t grows at rate $g_t^{1/(1+\varepsilon)}$. The quantity of housing h_t grows at rate $g_t^{\varepsilon/(1-\varepsilon)}$.

The behavior on the balanced growth path in this model underscores the importance of transition dynamics in my explanation of the Chinese housing boom. The observed faster-than-income growth in housing values is not possible on the balanced growth path of the model, as the value of housing $p_t h_t$ shares the growth rate of income g_t . In other words, the price of housing in the model, absent transition dynamics, cannot grow at the empirical observed rate, given that the quantity of housing also increased substantially in this period. It is possible however, as I show later, if the transition from low initial household wealth is taken into account.

4.2.3 Numerical Solution

I solve for the recursive equilibrium of the model numerically. As with the case for models with trend growth, the recursive equilibrium in this model needs to be normalized before it can be numerically solved;¹³ I detail the normalization procedure in Appendix B. The solution to the model is invariant to the choice of normalization.

¹³See [Aguiar and Gopinath \(2007\)](#) for an example.

The model also belongs to the class of equilibrium models with occasionally binding constraints, which can involve highly non-linear equilibrium functions. Therefore, I solve this model by using globally accurate methods to ensure accuracy with respect to the effects of transition dynamics of aggregate household wealth on the housing market. The numerical procedure is otherwise standard. Starting with a guess for the housing price function and for the law of motion for aggregate household wealth, I use value function iteration to solve the household maximization problem. I then update the guess for the housing price function and for the law of motion for aggregate household wealth, until convergence is achieved.

5 Quantitative Assessment

The model described in the previous section is designed to assess the quantitative plausibility of my explanation for the Chinese housing boom; I base my explanation on the upward transition of Chinese household wealth from a low initial condition, under liquidity constraints. In this section, I perform a quantitative assessment. Specifically, I parameterize versions of the model with (1) a borrowing constraint only, (2) a borrowing constraint plus illiquidity, and (3) no liquidity constraints. I start the model at the empirical value of the initial urban household wealth-to-income ratio, and then calibrate the model to match the increase in the urban household wealth-to-income ratio. Finally, I check the model's fit with respect to the dynamics of housing prices, with respect to the dynamics of aggregate household wealth, and with respect to household portfolio compositions.

5.1 Parameterization

Table 3 presents the values for externally determined parameters.

The model period is chosen to be annual to match the frequency of empirical observations. I choose the endowment growth rate in the high growth state to be 12.5%, which is the sample average real growth rate of urban aggregate income. This growth rate reflects the contribution of migration into urban areas, and therefore is higher than the contemporaneous growth rate of national income. I choose the probability of a slowdown to be 0.05, implying an expected duration of 20 years of high growth conditional on being in the high-growth state. I also choose the endowment growth rate in the low growth rate to be zero, motivated

by the experience of Japan following its high growth period. Finally, I follow [Curtis and Mark \(2010\)](#) and choose parameters for the process for transitory endowment fluctuations to match a standard deviation of 1.7% and a persistence of 0.6.

The housing depreciation rate is set to 1.5% a year, consistent with my construction of housing value and quantities in the city-level panel dataset. I discipline the housing supply elasticity ε by using the empirical ratio of the percentage growth in housing quantity relative to the percentage growth in housing price. The resulting value is 0.67.

My model features an endowment process that is subject to shocks to long-run growth. Following the long-run risk literature, I set the elasticity of intertemporal substitution (EIS) to be 1.5, the value in [Bansal and Yaron \(2004\)](#). The value of the relative risk aversion (RRA) equals 2. This is the preferred value in the portfolio choice model with housing in [Campbell and Cocco \(2015\)](#), and also in the model of liquid asset holding in [Telyukova \(2013\)](#). I set the housing weight in consumption to 0.20, the weight used in the official CPI basket in China.

Real interest rates are set to 0% for bank deposits and 4% for mortgages, the sample average values for the period. The low real interest rate on bank deposits, despite high growth in China, reflects financial repression. The maximum loan-to-value ratio $\bar{\psi}$ is set to be 30%, taking into account regulatory constraints in the Chinese mortgage market, as I discussed in Section 3. Of note, the maximum loan-to-value ratio in the model does not correspond to the maximum loan-to-value ratio for first-time home buyers at origination (70%). The maximum loan-to-value ratio in the model takes into account the additional regulatory restrictions that include age restrictions, payment to income, payment schedule restrictions, and no-borrowing restrictions on investment homes. Not all homes can be borrowed against in mortgages in the China, because many homes constructed before the sample period—especially those built by work units as in-kind benefits—are poor quality and have been improperly maintained. I discipline the evolution of the fraction of collateralizeable homes using an annual survey of home types in Beijing from 2003–2012, and take collateralizeable homes to be commercially constructed homes. The fraction then increases from 1.3% in 2003 to 35% in 2012. I set the functional form of the fraction of collateralizeable homes in the model, $\psi(\cdot)/\bar{\psi}$, to be $\max(0, 1 - \lambda_1/p^{\lambda_2})$, with $\lambda_1 > 0$, $\lambda_2 > 1$, and choose λ_1 , λ_2 to match the empirical fraction in 2003 and 2012 at the empirical level of housing prices.

For the emergency consumption shock, I parameterize it to have a probability of 3% that gives rise to a desired emergency consumption share of 83% ($\pi = 0.03$, $\kappa = 0.83$). To place this number in perspective, 1 percent of urban households in the CFPS 2012 microdata experience medical expenditures that exceeds 83% of total consumption expenditures. The parameters thus assume a 2% chance of other types of emergency consumption needs (e.g. unemployment) that require a substantial holding of financial assets.

Table 3: Parameters determined outside the model

Parameter	Description	Value	Source
$[g_H, g_L]$	Endowment growth	[1.125 1.00]	Growth of urban agg. income
$Pr(g_H g_L)$		0.05	Slow down expected in 20 years
$[z_H, z_L]$	Endowment fluctuations	[0.979 1.021]	$s.e.(z) = 0.017$ in Curtis and Mark (2010)
$Pr(z_H z_L)$		0.2	$\rho(z) = 0.6$ in Curtis and Mark (2010)
δ	Housing depreciation	0.015	Housing land lease up in 70 years
ε	Supply elasticity	0.67	Sample $\% \Delta H / \% \Delta p$
σ	EIS	1.5	Bansal and Yaron (2004)
γ	RRA	2	Campbell and Cocco (2015) , Telyukova (2013)
θ	Housing weight	0.20	CPI basket
(R_a, R_b)	Interest rates	(0%, 4%)	Sample average
$\bar{\psi}$	LTV constraint	30%	Regulatory constraints in Chinese mortgage market
$\psi(\cdot)/\bar{\psi}$	Fraction of collateralizeable homes	1.3% at p_{2003}^{data} 35% at p_{2012}^{data}	Housing survey in Beijing (2003–2012)
π	Prob(emergency cons.)	0.03	1% chance tail medical event plus assumed 2% other events
κ	Emergency cons. weight	0.83	Tail event medical expenditure in CFPS microdata
w_0	Initial W/Y	3.2	Sample initial value

After choosing the externally determined parameters, I calibrate the model with (1) a borrowing constraint only, and (2) a borrowing constraint plus illiquidity (i.e., emergency consumption shocks) to match the observed evolution in Chinese urban households' wealth-to-income ratio.

I start the model in 2003 to reflect institutional developments in the Chinese housing market. In 2003, the State Council announced in Document No. 18 that market provision of housing would be the main form of housing in China, and 2003 marked the first year of a full-fledged housing market in which most households would expect to participate in.¹⁴

I start the model at the empirical initial household wealth-to-income ratio of 3.2 in 2003, and calibrate the discount factor β , which controls the target wealth-to-income ratio (holding other parameters fixed), so as to hit the empirical household wealth-to-income ratio of 5.2 in 2012, assuming income growth g_t and the transitory income state z_t take high realizations during this high growth period in China.

The resulting value of the discount factor β is 0.991 for the model with a borrowing constraint only, and 0.99 for the model with a borrowing constraint plus illiquidity. A large calibrated discount factor implies that Chinese households were relatively patient. This value of the discount factor is not unusual for studies that aim to match patterns in wealth accumulation in China and is lower than the calibrated value in the influential study of [Song et al. \(2011\)](#).

5.2 Main Result

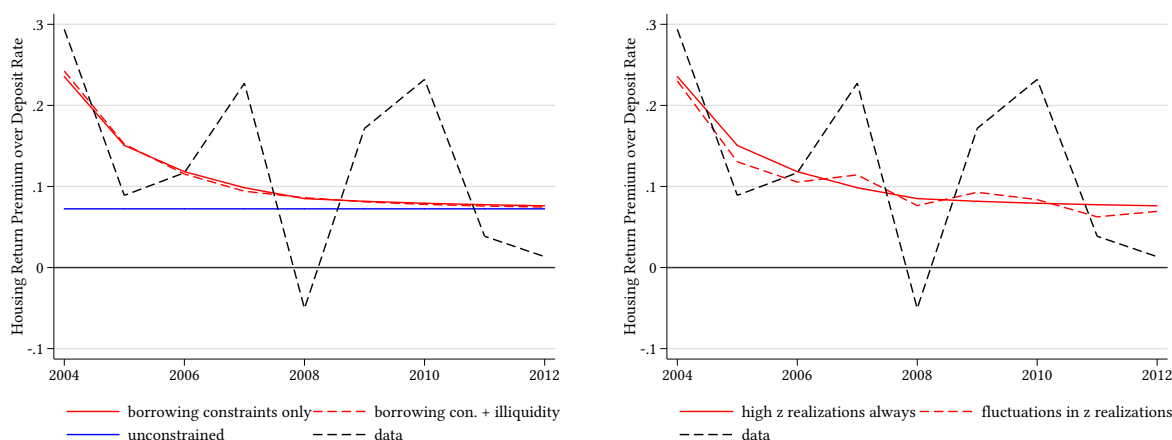
Now, let me turn to my main result. Panel (a) of Figure 7 reports the fit of the model for the housing return premium, the difference between the price return on housing, and the deposit interest rate. Overall, the model quite successfully explains the high level and the declining trend in the housing return premium as well as the large increase in housing prices.

Both the version of the model with a borrowing constraint only and the version of the model with a borrowing constraint plus illiquidity generate an average of an 11.1 percentage points housing return premium from 2003 to 2012, which explains 89% of the empirical average housing return premium of 12.5 percentage points.

The model also generates a declining trend in the housing return premium: the housing return premium is 24 percentage points in 2003-2004, and then gradually declines to 8 percentage points in 2011-2012. The magnitude of this decline is similar to that in the linear

¹⁴Work units provided urban housing as in-kind benefits until the housing benefit was phased out in 1998 and existing homes were essentially transferred to occupants. Between 1998 and 2003, the government stance on housing was that government-supplied “affordable housing” (priced at construction costs with purchase rights allocated through a housing lottery) would be the main supply of housing,

Figure 7: Model versus observed housing return premium
(a) (b)



Note: This figure plots the main results of the model. Panel (a) reports the model's fit in the housing return premium, assuming high realizations in g and z . Versions of the model with liquidity constraints generate time series of the housing return premium that are similar to the data in terms of the level and the trend. Panel (b) reports the extent to which model fluctuations in z can generate the volatility of the housing return premium in the data.

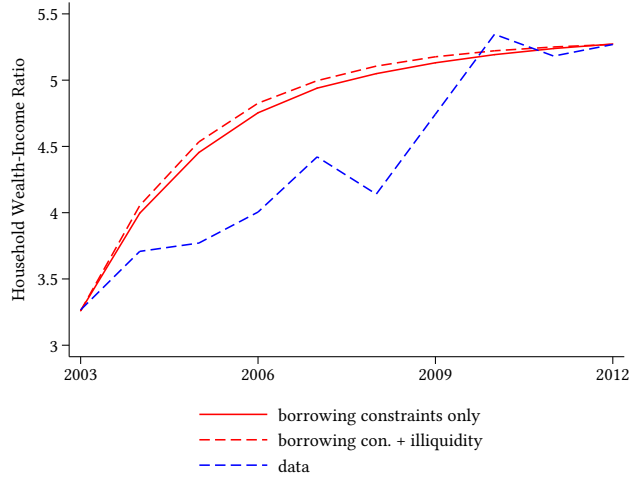
trend of the observed housing return premium, which decreases from 22 percentage points in 2003-2004, to 5 percentage points in 2011-2012.

The borrowing constraint drives virtually all housing price dynamics in the model. The time path of the housing return premium in the version of the model with borrowing constraints only is almost indistinguishable from that in the version of the model with borrowing constraints plus illiquidity.

Both versions of the model generate an increase of 156% in the level of housing prices, which accounts for 92% of the observed increase in the weighted average housing price index from 2003 to 2012.

The model produces a time path of the housing return premium that is much smoother relative to the data in panel (a) of Figure 7. The model calculation assumed that the realization of the transitory aggregate income state z , which is a two-state Markov chain in the model, is always in the high state. In panel (b) of Figure 7, I therefore assess the extent to which transitory fluctuations in aggregate income can generate the volatility of the housing return premium in the data. In the version of the model with a borrowing constraint only, I set the transitory aggregate income state z to be in the high state in years during which the observed housing return premium is above the smoothed trend (2004, 2007, 2009, 2011),

Figure 8: Model versus observed evolution in household wealth-to-income ratio



Note: This figure reports the model's fit with respect to the transition dynamics of the household wealth-to-income ratio. The model is capable of matching the large empirical upward transition in the wealth-to-income ratio, though the model transition in household wealth occurs faster than that in the data.

and in the low state in all remaining years.

The result is the red dashed line in panel (b) of Figure 7. Transitory fluctuations in aggregate income generate a qualitatively similar pattern in the realized housing return premium as that in the data. Quantitatively, transitory fluctuations in aggregate income generate an 1.2% standard deviation in the realized housing return premium relative to trend, which is too low compared to a 9.6% standard deviation relative to trend in the data. Introducing temporary fluctuations in housing supply, which the model currently abstracts from, can potentially increase the volatility of housing prices and housing price return in the model.

I now turn to the model's fit along other dimensions. In Figure 8, I report the model's fit with respect to the transition dynamics of the household wealth-to-income ratio.

The model generates a transition in household wealth that occurs too fast when compared to the data, in that the increase in the wealth-to-income ratio in the model is too concentrated in the first half of the ten-year period of 2003–2012. This occurs because households in the model take great advantage of the high price return on housing in the initial years, saving more and using new savings to buy up housing at the beginning. As they enjoy the benefits of appreciation, the wealth-to-income ratio quickly rises.

The overly fast increase in the wealth-to-income ratio in the model may reflect the ways

in which the model abstracts from indivisibility in housing and heterogeneity in household wealth. If homes have a minimum size, then households with low wealth may not reap the benefit of high housing appreciation in the initial years of the period. Indivisibility also affects households with higher wealth, as they need to accumulate downpayment savings in between purchases of multiple homes. If the indivisibility delays the purchase of homes for a large fraction of households in the initial years of the period, then the increase in the wealth-to-income ratio will be slower, as well as closer to the data.

In Table 4, I report the model's prediction on portfolio moments. Some distance exists between portfolio holdings in the model and in the data. The model generates too much holding of housing relative to wealth. That said, the holding of housing relative to wealth increases over time, both in the model and in the data.

The version of the model with a borrowing constraint only generates no deposit holdings, as expected. The version of the the model with a borrowing constraint and illiquidity generates substantial deposit holdings, despite large differences between the high return on housing and the low return on deposits.

However, the level of deposit holdings in the model does not fully rationalize the data. For example, in 2012, the model generates about a third of the deposit holdings in the data. Boosting relative risk aversion from the baseline value of 2 to a higher value of 5 (the preferred value in the portfolio choice model with housing in [Cocco \(2005\)](#)) increases deposit holdings in 2012 to about a half of the data, as households become more averse to low consumption in emergencies.

In the model, deposit holdings are lower in 2003 relative to later years, because the higher housing return premium in 2003 reduces households' willingness to hold deposits.

Table 4: Model versus observed household portfolio

	Housing/Wealth		Deposits/Wealth	
	2003	2012	2003	2012
Data	0.68	0.86	0.42	0.23
Borrowing constraints only	1.10	1.16	0.00	0.00
Borrowing constraints + Illiquidity	1.05	1.08	0.03	0.07
Borrowing constraints + Illiquidity (RRA = 5)	1.01	1.02	0.07	0.10

Note: This table reports the model's fit on portfolio moments. The model generates too much holding of housing relative to wealth, though the holding of housing relative to wealth increases over time, both in the model and in the data. For 2012, the model generates about a third to a half of the deposit holdings in the data.

The model's abstraction from housing indivisibility could again be one reason for the tension between the model and data with respect to deposit holdings. In terms of indivisibility, households must save sufficiently for the housing downpayment, which might take some time, before they can purchase a first home or additional homes. This might explain the high level of deposits in the data. This might also explain why deposit holdings decrease over time, as more households have accumulated sufficient downpayment savings with the passage of time.

6 Additional Predictions and Discussion

In the previous section, I showed that the model based on the upward transition of aggregate household wealth under liquidity constraints, taking into account key features of the reality in China, is capable of rationalizing the stylized facts on both housing price growth and on the housing return premium in the Chinese housing boom. In this section, I show that although the model is stylized in certain dimensions, the model generates interesting additional

predictions regarding the saving rate of Chinese households, as well as the fate of the Chinese housing market in the event of an economic slowdown. I also use the Singaporean housing market as an example of the applicability of my explanation to other emerging housing markets.

6.1 The Model Predicts a Very High Unconstrained Value of Housing

There is substantial debate in the popular press over whether housing values in China are too high. However, the question is not well-defined in the absence of specified benchmark values of housing against which housing values in the Chinese market can be compared.

The model in this paper provides a framework for thinking about the benchmark value of housing. Specifically, I define two versions of the benchmark value of housing.

The first is the value of housing in the model without liquidity constraints, with household wealth at the 2012 empirical level (to hold fixed income effects of household wealth) and with borrowing interest rates at $R_b = 4\%$. This is the value of housing in the model to a hypothetical unconstrained borrower, whose required rate of return is R_b . In the model, this value is around six times the household income in the high-growth state, and around five times the household income in the low-growth state.

The second versions of the benchmark value of housing differs from the first by setting the both interest rates in the model at $R_a = 0\%$. This is the value of housing in the model to a hypothetical unconstrained deep-pocketed saver, whose required rate of return is R_a . In the model, this value is fifteen times the household income in the high-growth state, and around eight times the household income in the low-growth state.

Both versions of the benchmark value of housing are very high, which points to two key aspects of the reality in China: (1) high expected growth and (2) low financial asset returns as the required rate of return. The intuition follows from the Gordon growth formula $p = d/(r - g)$, which suggests that if a required return r is low and dividend growth g is high, then price will naturally be high.¹⁵ In the deep-pocketed saver's evaluation, especially, the asset of housing is attractive even at a seemingly high price because the alternative is the zero percent saving interest rate.

¹⁵See [Song \(2014\)](#) for a similar discussion.

6.2 The Model Helps Explain the High Household Saving Rate in China

The puzzlingly high saving rate of Chinese households has spurred active research in recent years. Put succinctly, Chinese households save tremendously, even though income growth is very high and the return on financial assets is very low.

The model in this paper generates a high household saving rate. In the model, households save as much as 55 percent of income in 2003. The saving rate gradually declines to 30 percent in 2012.

The housing market boom contributes to this high saving rate through an investment motive: Transition dynamics generates an expected appreciation on housing that is faster than the growth rate of income, especially in 2003. Facing housing returns that exceeds expected income growth, household save in high-return housing and trade off less current consumption for more capital gains and more future consumption.

There is another target savings motive created by liquidity constraints: with constraints on borrowing, households have a target wealth-to-income ratio, and in the face of high income growth, they need to save at a high rate just to maintain the wealth-to-income ratio.

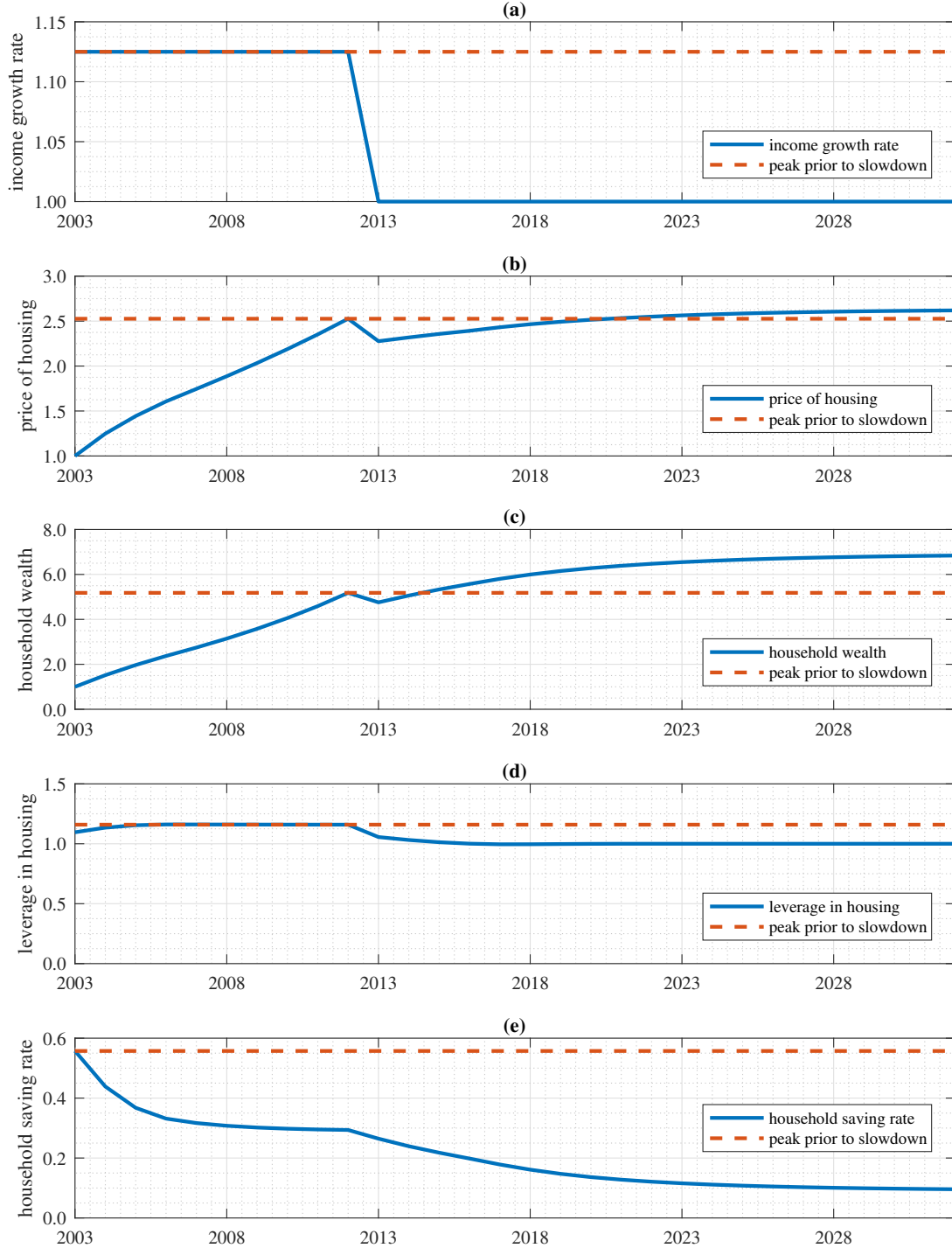
6.3 The Model Predicts A Large Housing Rebound After Income Growth Permanently Ends

Should a permanent growth slowdown impact the Chinese housing market, conventional arguments based on fundamentals conclude that the price of housing will drop permanently.

My model suggests otherwise. In fact, the model as parameterized in the previous section, predicts that the price of housing in China will have only a temporary dip if a permanent growth slowdown occurs and will then rise above the peak level prior to slowdown, even with the extreme assumption that income does not grow at all after the slowdown.

In Figure 9, I report the evolution of the model economy in the hypothetical event of a permanent growth slowdown in the year 2013 (panel (a)), after which there is no income growth (g_t transitions from g_H to g_L , and the growth rate of real income post-slowdown is $g_L = 0$).

Figure 9: Model predictions in the event of a permanent slowdown



Note: This figure reports the predicted evolution of the model economy in the hypothetical event of a permanent growth slowdown in year 2013 (panel (a)), after which there is no income growth (g_t transitions from g_H to g_L , and the growth rate of real income post slowdown is $g_L = 0$).

As shown in panel (b) of Figure 9, the price of housing initially drops by 9.7% upon impact of the permanent slowdown shock, but subsequently rebounds and eventually surpasses the pre-slowdown peak. Again, this assumes the absence of any income growth after the slowdown. What, then, explains this paradoxical rebound and growth in the price of housing after a permanent worsening of fundamentals, absent any further growth in income?

The explanation is that: (1) the liquidity constraints are still binding and affect the price of housing after the slowdown, and (2) households are willing to maintain higher wealth in the low-growth state after the slowdown compared to in the high-growth state. A higher level of household wealth in the low-growth state *increases* the price of housing. In the low-growth state, lower expected income growth, taking as given the same subjective discount rate and the same financial asset returns, generates a higher target wealth-to-income ratio.¹⁶ The target *level* of aggregate household wealth increases, given that the slowdown shock did not change the level of income. The price of housing increases as liquidity constraints tie the movement in the price of housing to the movement in the aggregate household wealth, and the aggregate household wealth increases toward the now higher target, as shown in panel (c) of Figure 9.

The model also predicts leverage on housing will drop permanently in the event of a slowdown, as shown in panel (d) of Figure 9, because return on housing no longer justifies borrowing in the event of a slowdown. However, savers in the model still put any additional savings into housing, absent emergency consumption needs, because the overall return on housing—including the service flow—is still higher than the saving interest rate of zero percent.

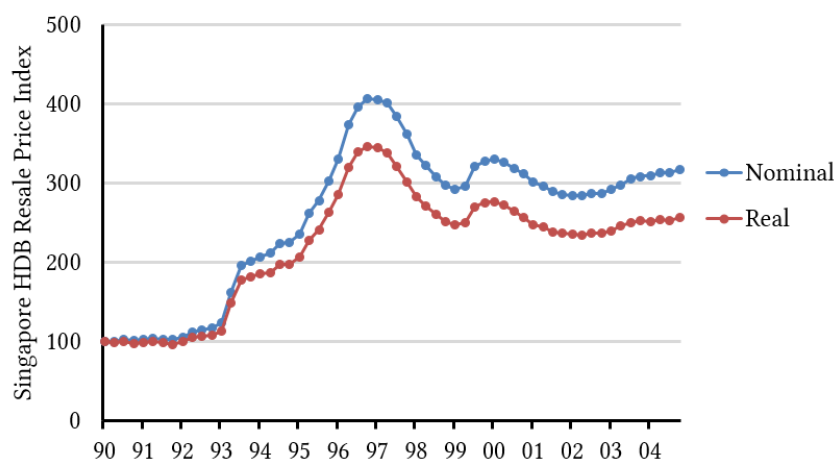
Finally, the model predicts a decline in the household saving rate after the slowdown, as shown in panel (e) of Figure 9. This is mostly because less savings are required to maintain the target wealth-to-income ratio with zero growth in income.

6.4 Beyond China: The Case of Singapore

The Singaporean housing market provides another example that illustrates the relevance of the explanation in this paper.

¹⁶Holding the financial asset returns the same makes sense because interest rates are already low in the high-growth state, a result of financial repression and the underdevelopment of non-bank financial markets.

Figure 10: Singaporean housing market from 1990 to 2004



Note: This figure plots the Singapore HDB Resale Price Index from 1990 to 2004. Following reforms in 1989–1993 that expanded purchase eligibility in Singapore’s HDB resale market, the price of HDB flats rose, and returns on housing were much higher than on other assets. It took about five years for the price of HDB flats to reach the end level.

The Singaporean housing market is dominated by HDB flats: apartments built by the Housing Development Board. There are strong restrictions in the market for HDB flats, such as income ceilings, citizenship requirements, family size restrictions, and financing restrictions. There was a significant reform that removed some of these restrictions in the HDB flat market during 1989-1993.

Before 1989, only citizens who did not own other residential properties in households with a minimum size of two persons, and with household incomes below the HDB-established income ceiling were eligible to purchase new or used HDB flats (Phang (2007)).

In 1989, the income ceiling was removed from the resale market for HDB flats. In addition, permanent residents were allowed to purchase used HDB flats. Beginning in 1991, single citizens above the age of 35 were allowed to purchase used HDB flats. In 1993, household balances in compulsory savings accounts became eligible for mortgage repayments.

In Figure 10, I shows the movements in the Singaporean HDB resale price index following reforms in the resale market of HDB flats. The prices rose, eventually settled at around 240% of its 1990 level. The return on housing was much higher than on other assets. It took about five years for the price of HDB flats to reach its final level.

In my explanation, the large increase in the price of housing in the Singaporean market was

due to prices being initially very low in 1989; the high housing return premium in Singapore persisted for several years because Singaporean citizens and permanent residents required time to build up their wealth and realize the final level of the higher price of housing.

7 Conclusion

Transition dynamics of household wealth from a low initial condition, coupled with liquidity constraints, offer a novel framework for understanding the puzzling housing boom in China. Calibrated to match the empirical transition in household wealth in China, this framework explains the large increase in housing prices, explains the substantial and declining housing return premium relative to interest rates, generates an investment motive in holding housing, helps rationalize the high household saving rate, and offers unique predictions about the effect of a growth slowdown on the Chinese housing market.

This framework can potentially be applied to other emerging housing markets in which households have low wealth and in which there are liquidity constraints (e.g., Japan, beginning in the late 1950s). As more less-developed countries begin similar transition processes, this framework may be useful for understanding similar dynamics in less expected places, such as some of the quickly urbanizing African nations.

This framework offers substantial room for future research. For example, the framework can benefit from introducing additional important frictions in the housing market. Indivisibility is one such friction: Homes are an investment of substantial size, and downpayment savings for large home purchases may rationalize both substantial bank deposit holdings in China and more protracted transitions in household wealth, when compared to the current model.

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Appendix

Appendix A: Data Construction

This appendix section details my construction of a panel dataset of housing values, prices, quantities, household purchasing power, and household wealth for Chinese cities.

I use the panel dataset to construct aggregate housing values and quantities for Chinese cities. This is necessary because data on urban housing in China is scant, even in the aggregate. Further, neither a systematic housing census for housing quantities nor measures of value of housing in flow-of-funds tables exists. I also use the panel dataset to document patterns across Chinese cities. The large number of cities in China provides useful variations in the extent of the housing boom and variations in the covariates of the housing market, which I exploit.

Some of the challenges I encountered in constructing the city panel dataset include scattered data sources, as well as measurement concepts that are sometimes not fully consistent. To make this dataset possible, I therefore make necessary simplifying assumptions.

To construct this city panel dataset, I first describe my measures for housing prices, housing values, and housing quantities. For prices, I use the housing price index in [Fang et al. \(2015\)](#), a constant quality housing price index constructed by comparing prices of comparable new homes in the same development that are sold at different times. The housing price index covers 120 cities from 2003 to 2012. For housing values, I combine information from the housing price index, from the 2005 1% Mini Census microdata,¹⁷ and from local housing administration agencies. To do so, I follow a perpetual inventory approach:

$$\begin{aligned} \text{Value of Urban Housing}_T &= (1 - \delta)^T \cdot \frac{P_T}{P_0} \cdot \text{Value of Urban Housing}_0 \\ &+ \sum_{t=1}^T (1 - \delta)^{T-t} \cdot \frac{P_T}{P_t} \cdot \text{New Urban Housing Sales}_t \end{aligned}$$

where δ is the depreciation rate on housing, and p_t is the housing price index in year t . For the base year of 2003, I make simplifying assumptions. The 2005 1% Mini Census microdata provides building age and square footage of homes occupied at the time of the

¹⁷The 2005 Inter-Census Population Survey, from which I obtain a proprietary 1% random sample, conducted on 1% of the population throughout 2005.

survey, from which I take only homes built in and before 2003. I compute the total square footage of homes built in or before 2003, adjusted for a depreciation rate of 1.5%, and then multiply by the average selling price per square foot of new homes in 2003, information I obtained from local housing administration agencies. I take this product to be the value of urban homes in the base year. For a non-base year, implementation of the perpetual inventory approach is straightforward. I obtain housing values in a non-base year by taking into account appreciation (through the housing price index) and depreciation, and then adding sales of new urban housing, information made from the local housing administration agencies. This particular measure includes homes that are bought in a non-base year and are left vacant; however, unbought inventory is not included in this measure.¹⁸

Next, I construct a measure of household wealth for Chinese cities. The liquidity constraints mechanism predicts that the value of housing is limited by household wealth (up to some leverage). I measure household wealth at the city level by the following:

$$\text{Household Wealth} = \text{Bank Deposits} + \text{Value of Housing} - \text{Mortgage}$$

where I obtain annual city-level observations on household bank deposits and mortgage from local municipal office of finance. This measure takes into account the two largest asset classes held by Chinese urban households in terms of market size: home equity and bank deposits make up 80 to 90% of urban household wealth, according to calculations derived from two national household surveys that became available only around the end of my sample, the Chinese Household Finance Survey (CHFS) and the Chinese Family Panel Studies (CFPS). Data on holdings of other financial assets do not exist for the cities in my sample. Fortunately, non-bank financial markets are underdeveloped in China, and the majority of the household financial assets are in bank deposits. This measure also does not include the value of personal businesses. However, this omission should not matter for checking the liquidity constraint mechanism, because it is hard to borrow against (or cash out of) the value of personal businesses in China.

Finally, I also collect various measures of household purchasing power, including disposable income, retail sales, and population. Because survey-based disposable income measures in

¹⁸Therefore, this measure of housing values is closer to the concept of price times quantity demanded, rather than price times quantity supplied.

China under-samples high income persons, I overcome this data limitation by measuring disposable income as gross city output adjusted by the ratio of household disposable income in the aggregate flow-of-funds data over aggregate gross domestic output. For population, I consider both non-farm hukou population and resident population. Other proxies for the level of economic activities at the city level include electricity use (a key component of the famous Li Keqiang index) and the profits of industrial firms.

Appendix B: Normalization of the Model

This appendix section details the procedure for normalizing the model in Section 4.

Given that a realization of g permanently influences Γ , income is nonstationary with a stochastic trend. To solve the equilibrium of the model, I need to make the model variables stationary. I normalize model variables in a standard way, following [Aguiar and Gopinath \(2007\)](#). For any variable x , I introduce a hat to denote its detrended counterpart:

$$\hat{x}_t \equiv \frac{x_t}{\Gamma_t}$$

with a special treatment of h_t , p_t , and H_t^S to account for the fact that the trend growth of the quantity of housing is slower than the trend growth of income:

$$\hat{h}_t \equiv \frac{h_t}{(\Gamma_t)^{\varepsilon/(1+\varepsilon)}}, \hat{H}_t^S \equiv \frac{H_t}{(\Gamma_t)^{\varepsilon/(1+\varepsilon)}}, \hat{p}_t \equiv \frac{p_t}{(\Gamma_t)^{1/(1+\varepsilon)}}.$$

In normalized form, the household maximization problem can be stated recursively:

$$\hat{V}(\hat{w}; \hat{W}, g, z) = \max_{\{\hat{c}, \hat{a}, \hat{b}, \hat{h}\}} \left\{ \left[E_- (\hat{c}^{1-\theta} \hat{h}^\theta)^{1-\gamma} \right]^{\frac{1-\frac{1}{\sigma}}{1-\gamma}} + \beta \left[E \left(\left((g')^{1-\theta/(1+\varepsilon)} \hat{V}(\hat{w}'; \hat{W}', g', z') \right)^{1-\gamma} \right) \right]^{\frac{1-\frac{1}{\sigma}}{1-\gamma}} \right\} \quad (23)$$

where

$$\hat{c} = \begin{cases} \hat{c}^n & \text{with prob } 1 - \pi \\ (\hat{c}^n)^{1-\kappa} (\hat{c}^m)^\kappa & \text{with prob } \pi \end{cases}$$

subject to

$$\hat{c}^m + \hat{c}^n + \hat{a} + \hat{p}(\hat{W}, g, z)\hat{h} - \hat{b} \leq z + \hat{w}, \quad (24)$$

$$\hat{w}' = \frac{R_a}{g'}\hat{a} - \frac{R_b}{g'}\hat{b} + \frac{\hat{p}(\hat{W}', g', z')}{(g')^{\varepsilon/(1+\varepsilon)}}(1 - \delta)\hat{h}, \quad (25)$$

$$0 \leq \hat{a}, \hat{b}, \quad (26)$$

$$\hat{b} \leq \psi(\hat{p})\hat{p}\hat{h}, \quad (27)$$

$$\hat{c}^m \leq \hat{a}. \quad (28)$$

In normalized form, (24) and (25) represent the evolution of household wealth; (27) and (28) represent the two liquidity constraints in the model: the borrowing constraint and the emergency consumption constraint, respectively. The state vector of the household maximization problem consists of individual household wealth $\hat{w}$, aggregate household wealth $\hat{W}$, trend aggregate income growth rate g , and transitory aggregate income state z .

Recursive Equilibrium (Normalized)

Definition: A *recursive equilibrium* of the model is a housing price function $\hat{p}(\hat{W}, g, z)$, a law of motion for aggregate household wealth $\hat{W}' = \hat{G}(\hat{W}, g, z, g', z')$, a value function $\hat{V}(\hat{w}; \hat{W}, g, z)$, and a collection of policy functions $\hat{c}(\hat{w}; \hat{W}, g, z)$, $\hat{a}(\hat{w}; \hat{W}, g, z)$, $\hat{b}(\hat{w}; \hat{W}, g, z)$, $\hat{h}(\hat{w}; \hat{W}, g, z)$ such that:

a. [Optimality]: Given the housing price function and the law of motion for aggregate household wealth, the value function and the policy functions solve the household maximization problem.

c. [Housing market clearing]: The housing market clears at each state:

$$\hat{h}(\hat{W}; \hat{W}, g, z) = H_0 \cdot \hat{p}(\hat{W}, g, z)^\varepsilon.$$

b. [Consistency]: Given the policy functions and the housing price function, $\hat{G}$ maps current aggregate wealth into next period aggregate wealth.

$$\hat{G}(\hat{W}, g, z, g', z') = \frac{R_a}{g'}\hat{a}(\hat{W}; \hat{W}, g, z) - \frac{R_b}{g'}\hat{b}(\hat{W}; \hat{W}, g, z) + \frac{\hat{p}(\hat{G}(\hat{W}, g, z, g', z'), g', z')}{(g')^{\varepsilon/(1+\varepsilon)}}(1 - \delta)\hat{h}(\hat{W}; \hat{W}, g, z).$$

Table A1: City-level panel regression robustness: More purchasing power controls

	(1)	(2)	(3)	(4)
Dependent Variables	Log(Home Price Index)		Log(Total Value of Housing)	
Household Wealth Measures	Net Worth (Including Housing)	Bank Deposits (Excluding Housing)	Net Worth (Including Housing)	Bank Deposits (Excluding Housing)
Log(Household Wealth)	0.624***	0.516***	1.104***	1.036***
Log(Income)	0.0322	0.296***	0.0508	0.466***
Log(Population)	0.0742	0.207	-0.0278	0.194
Log(RetailSales)	-0.0821	-0.0731	0.00476	-0.0259
Log(ElectricityUse)	-0.0141	0.0349	0.00292	0.0836*
Log(IndustryProfits)	-0.0156*	-0.00447	0.00126	0.0194
Observations	980	980	980	980
Adjusted- R^2	0.94	0.89	0.99	0.99
Number of Cities	98	98	98	98
City FE	YES	YES	YES	YES

Note: This table reports robustness of the city-level panel regression results for regressions (1) and (2) to additional proxies of purchasing power and of levels of economic activity as controls (e.g., retail sales, electricity use, profits of industrial firms). Specifically, this table reports results of the following city panel regressions:

$$\begin{aligned} \log(p_{it}) &= \alpha_i + \beta \log(wealth_{it}) + \gamma_1 \log(income_{it}) + \gamma_2 \log(population_{it}) \\ &\quad + \gamma_3 \log(retailsales_{it}) + \gamma_4 \log(electricityuse_{it}) + \gamma_5 \log(industrialprofits_{it}) + \varepsilon_{it}, \\ \log(p_{it}q_{it}) &= \alpha_i + \beta \log(wealth_{it}) + \gamma_1 \log(income_{it}) + \gamma_2 \log(population_{it}) \\ &\quad + \gamma_3 \log(retailsales_{it}) + \gamma_4 \log(electricityuse_{it}) + \gamma_5 \log(industrialprofits_{it}) + \varepsilon_{it}, \end{aligned}$$

The regressions include city fixed effects. All variables are deflated by the consumer price index at the province level. Two different wealth measures are used: wealth including housing and wealth excluding housing (which is simply household bank savings). Standard errors are clustered at the province level. *** indicates significance at the 1% level. * indicates significance at the 10% level.

Table A2: City-level panel regression robustness: Excluding northeastern provinces

	(1)	(2)	(3)	(4)
Dependent Variables	Log(Home Price Index)		Log(Total Value of Housing)	
Household Wealth Measures	Net Worth (Including Housing)	Bank Deposits (Excluding Housing)	Net Worth (Including Housing)	Bank Deposits (Excluding Housing)
Log(Household Wealth)	0.572***	0.426***	1.080***	0.965***
Log(Income)	-0.0187	0.346***	0.103	0.646***
Log(Population)	0.0588	0.111	-0.0553	0.0249
Observations	880	880	880	880
Adjusted- R^2	0.94	0.90	0.99	0.99
Number of Cities	88	88	88	88
City FE	YES	YES	YES	YES

Note: This table reports robustness of the city-level panel regression results for regressions (1) and (2) to exclusion of cities in the three northeastern provinces (Heilongjiang, Jilin, and Liaoning) that are reputed to be more prone to statistical manipulation. Specifically, this table reports, for the sample excluded cities in the three northeastern provinces, results of the same panel regressions as in (1) and (2):

$$\begin{aligned}\log(p_{it}) &= \alpha_i + \beta \log(wealth_{it}) + \gamma_1 \log(income_{it}) + \gamma_2 \log(population_{it}) + \varepsilon_{it}, \\ \log(p_{it}q_{it}) &= \alpha_i + \beta \log(wealth_{it}) + \gamma_1 \log(income_{it}) + \gamma_2 \log(population_{it}) + \varepsilon_{it},\end{aligned}$$

The regressions include city fixed effects. All variables are deflated by the consumer price index at the province level. Two different wealth measures are used: wealth including housing and wealth excluding housing (which is simply household bank savings). Standard errors are clustered at the province level. *** indicates significance at the 1% level.

Table A3: City-level panel regression robustness: Time and city fixed effects

	(1)	(2)	(3)	(4)
Dependent Variables	Log(Home Price Index)		Log(Total Value of Housing)	
Household Wealth Measures	Net Worth (Including Housing)	Bank Deposits (Excluding Housing)	Net Worth (Including Housing)	Bank Deposits (Excluding Housing)
Log(Household Wealth)	0.582***	0.349***	1.079***	0.771***
Log(Income)	-0.075	-0.004	0.0253	0.140
Log(Population)	0.105	0.144	-0.0284	0.047
Observations	990	990	990	990
Adjusted- R^2	0.95	0.91	0.99	0.99
Number of Cities	99	99	99	99
City FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Note: This table reports robustness of the city-level panel regression results for regressions (1) and (2) to inclusion of time fixed effects in the panel regression, which addresses the concern that coefficients could be picking up common aggregate time trends shared by the housing market and the right-hand-side variables. Specifically, this table reports results of the following panel regressions:

$$\begin{aligned}\log(p_{it}) &= \alpha_i + \delta_t + \beta \log(\text{wealth}_{it}) + \gamma_1 \log(\text{income}_{it}) + \gamma_2 \log(\text{population}_{it}) + \varepsilon_{it}, \\ \log(p_{it}q_{it}) &= \alpha_i + \delta_t + \beta \log(\text{wealth}_{it}) + \gamma_1 \log(\text{income}_{it}) + \gamma_2 \log(\text{population}_{it}) + \varepsilon_{it},\end{aligned}$$

The regressions include city fixed effects and time fixed effects. All variables are deflated by the consumer price index at the province level. Two different wealth measures are used: wealth including housing and wealth excluding housing (which is simply household bank savings). Standard errors are clustered at the province level. *** indicates significance at the 1% level.