A New Angle on Excess Consumption Volatility in Emerging Countries: Does House Price Matter?*

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Abstract

This paper focuses on house prices in order to explain *excess consumption volatility*, which is one of the stylized facts of the business cycle observed in emerging countries. The relative consumption volatility compared to output volatility is higher in emerging countries than in rich countries. Because house prices in emerging countries are more volatile than in advanced countries, this paper suggests house price fluctuation as a driving source of excess consumption volatility. To begin, I construct a cross-country dataset, and suggest new evidence that house prices are more correlated with consumption in the case of emerging countries compared to rich countries while the correlation between house prices and output are similar between two country groups. Then, I build a business cycle model given exogenous house price and output processes in order to explain excess consumption volatility puzzle. The result of the model suggests that high house price volatility in emerging countries causes their excess consumption volatility and that the mechanisms behind it are a collateral effect and a rental price pass-through. The former is related to the borrowing capacity affected by house price changes, and the latter is related to the link between house prices and housing consumption volatility.

Keywords: House Prices, Emerging Countries, Excess Consumption Volatility, Collateral Constraint, Housing Rental Prices

JEL Classification: C82, E10, E32, F41, F44

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1 Introduction

Emerging economies have attracted considerable interest from researchers who study macroeconomics in terms of both growth and the business cycle. The growth of emerging countries has been a popular research area since these countries are characterized by tremendously high growth rates, which is the main reason why they are called *emerging* economies. At the same time, the business cycle in emerging economies also has distinguishable features from those in advanced countries, which is the basis of this paper. This paper explores a new approach to explaining one of the well-known stylized facts regarding the business cycle — excess consumption volatility — in emerging countries and is therefore an attempt to contribute to the literature on the business cycle in emerging economies.

The motivational facts of this paper are one of the stylized facts documented in Schmitt-Grohé and Uribe (2017) and an empirical finding suggested by Cesa-Bianchi et al. (2015). The former is the fact that the relative consumption volatility compared to output volatility is higher in emerging countries than in developed countries, and the latter is that house prices in emerging economies are more volatile than in advanced countries. Based on the above two empirical facts, we can postulate a hypothesis that the excess consumption volatility in emerging economies is highly related to their greater house price volatility, considering a strong correlation between the aggregate house price and aggregate consumption investigated in the literature (for instance, Campbell and Cocco (2007), Case et al. (2005), among them). However, the papers investigating the relationship between house prices and consumption do not approach it from the perspective of the business cycle, especially for emerging countries. As a result, this paper attempts to answer the question: Can we explain excess volatility of consumption in emerging countries by their relatively high house price volatility?

Several approaches explain excess consumption volatility in emerging countries, which I classify into three groups. The first group highlights non-stationary output shock as in Aguiar and Gopinath (2007) and Garcia-Cicco et al. (2010), and the second group highlights interest rate shock as in Neumeyer and Perri (2005) and Uribe and Yue (2006). The last group involves a more recent paper that argues that volatile durable good consumption is a driving force of excess consumption volatility (Alvarez-

Parra et al. (2013)). With the purpose of contributing to the literature, this paper explores a new approach that focuses on the channel from house prices to consumption. Specifically, the main goal is to explain observed excess consumption volatility in emerging economies using higher house price volatility and determine a possible mechanism behind it.

First, I construct a cross-country dataset containing key macroeconomic variables of interest, including house prices. The main motivational facts — excess consumption volatility and higher house price volatility in emerging countries — are observed in the dataset, and more importantly, there is a higher correlation between house prices and consumption volatility in the case of emerging countries compared to rich countries. This higher correlation implies higher house price volatility observed in emerging countries can be a driving source of their higher relative consumption volatility because the correlations between house prices and output of two country groups are not quite different. In addition, disaggregated consumption for data-available countries show interesting features. First, housing consumption is obviously far more volatile than non-housing consumption in emerging countries, while it is less volatile than non-housing consumption in advanced countries. Finally, despite considering higher housing consumption volatility, there is still excess volatility in non-housing consumption in emerging countries. Based on the above findings, I make a conjecture about the mechanisms behind the relationship between house price volatility and excess consumption volatility in emerging countries. One mechanism is a collateral effect that accounts for excess non-housing consumption volatility, and the other is a rental price pass-through, which explains the link between house prices and total consumption fluctuation through housing consumption.

I then build a business cycle model for an emerging small open economy which incorporates disaggregated consumption of households. Specifically, the model explicitly accommodates a housing rental market by a two-agent setting of homeowners and renters. The housing rental price is endogenously determined by transactions between two agents. The framework also features a housing collateral constraint and an external debt elastic interest rate. To determine the impact of highly volatile house prices, the model assumes that the house price is an exogenously-given stochastic process and that housing supply is perfectly elastic. As a result, homeowners are able to purchase as many houses as possible at a given exogenous house price. These assumptions allow the model to concentrate on the mechanism between the house price and consumption. The approximation result shows that the house price matters considerably compared to endowment shock in explaining excess consumption volatility. The more volatile the house price is, the more volatile total consumption is in the economy. Additionally, I verify the conjecture of the key mechanisms of the positive relationship between house price volatility and relative consumption volatility. First, the collateral effect channel works effectively, and the share of homeowners in the economy matters because owners face collateral constraints. Second, the rental price pass-through also works effectively, which means the relative price of housing consumption strongly responds to house price fluctuation in the same direction. Hence, the model generates high housing consumption volatility and further high total consumption volatility corresponding to high house price volatility.

The rest of this paper is organized as follows. In the next section, I construct the cross-country dataset and document several stylized facts regarding cyclical fluctuations in house prices and consumption in emerging countries. In Section 3, I present the model. Section 4 describes the calibration and presents the results, and Section 5 do counterfactual analysis. Finally, Section 6 concludes.

2 Empirical Facts from Data

2.1 A Cross-Country Dataset for Key Indicators

I construct a cross-country dataset containing key macroeconomic variables of interest, including house prices. First, for the house price data, I aim to gather as long of quarterly data as possible in order to avoid short sample bias.[1] Furthermore, I restrict the house price data source to the BIS property price database[2] to control the issue of multiple source heterogeneity. The other indicators of interest are each country's output and consumption; the source of both of these indicators is the OECD national account database. Since the quarterly national account data in OECD statistics begins from 1950 Q1, the sample period for this paper's dataset depends on the availability of house price data in the BIS database. The resulting dataset is an unbalanced panel of 54 quarterly time series — house price (HP_t), GDP (Y_t), and consumption (C_t) for 18 countries — with varying coverage from 1970 Q1 to 2016 Q3. The minimum coverage is from 1975 Q1 to 2016 Q3 (167 observations) for South Korea. Eighteen countries included in the dataset are categorized as either emerging countries or rich countries according to the classification of Schmitt-Grohé and Uribe (2017)[3]: 4 emerging countries (New Zealand, South Africa, South Korea, and Spain) and 14 rich countries (Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, the United Kingdom, and the United States). It is notable that there are not many emerging countries that have sufficiently long house price data, as Cesa-Bianchi et al. (2015) mentions collecting house price data on emerging economies is difficult given the issue of data availability. I actually initially considered 12 emerging countries, that is, 8 countries other than New Zealand, Spain, South Korea, and South Africa; these were Brazil, Colombia, Greece, Israel, Malaysia, Peru, Portugal, and Thailand.[4] I decided to drop those countries due to the short sample period (the longest series is for Portugal (115 observations) and the shortest series is for Brazil (63 observations)). Nevertheless, the construction of a sufficiently long and credible dataset for house prices across many countries is a contribution of this paper in itself.[5]

The raw data of HP_t, Y_t, and C_t are typically in nominal terms. After deflating each series by a GDP deflator, I implement seasonal adjustment to only house price series

[0]One contribution of Cesa-Bianchi et al. (2015) is the construction of a quarterly house price dataset for a substantial number of countries — 33 emerging countries and 24 advanced countries. However, its sample coverage is from 1990 Q1 to 2012 Q4, thus providing house price time series with a maximum of 92 observations. Even in the case of emerging economies, approximately half of the countries cover less than 68 observations (starting from 1996 Q1), and the minimum coverage is from 2006 Q1 to 2012 Q4 with only 28 observations. This is one weakness of the Cesa-Bianchi et al. (2015) dataset in that it can cause a problem of overestimation of standard deviation.

[1]Cesa-Bianchi et al. (2015) mainly refers the Federal Reserve of Dallas international house price database, OECD house price database, and BIS property price dataset for the sources of their house price dataset. In fact, the Dallas Fed international house price database is not a raw dataset whose house price indices are produced and updated based on its own methodology (Mack and Martinez-Garcia (2011)). OECD house price data are a raw dataset, but I conclude that the BIS dataset is superior to the OECD dataset in terms of the number of countries covered and the length of time series.

[2]Schmitt-Grohé and Uribe (2017) defines the country group with the average PPP converted GDP per capita: poor country (less than \$3,000), emerging countries (between \$3,000 and \$25,000), and rich countries (above \$25,000). Please refer to Chapter 1 in Schmitt-Grohé and Uribe (2017), pp.10-11

[3]The business cycle facts that I show in this paper are robust for the dataset of 14 emerging economies. Additional details are available from the author upon request.

[4]Knoll et al. (2017) is a good example whose main contribution is presenting annual house prices for 14 advanced countries since 1870. Construction of the dataset is demanding, especially in the case of emerging economies, which is why Cesa-Bianchi et al. (2015) assess their own performance highly.

by X-12-ARIMA because HP_t is non-seasonally adjusted data, whereas the raw data of Y_t and C_t are already seasonally adjusted. I then conduct detrending by first log-differencing, which implies that the raw series for house price, GDP and consumption are assumed to be non-stationary. In other words, I eliminated the trend component of each series by inducing stationarity by first differencing the series.[5] Before detrending, in the case of Y_t and C_t, they are divided by population to obtain a per capita measure. The quarterly population is for all ages and both sexes, which is linearly interpolated from annual population data of the UN Population Division. Next, for the purpose of characterizing average business cycle facts for each country group, I compute second moments of interest for each individual country in the sample and then take a population-weighted average (as of 2010) across the countries within each respective group.

2.2 Business Cycle Facts: Emerging vs. Rich Countries

In Table 1, I report the individual sample country's business cycle facts as well as the weighted averages by country group. There are three stylized facts that we can observe in Table 1. First, housing price volatility is much larger in emerging countries than in rich countries, which was suggested by Cesa-Bianchi et al. (2015). Second, output is also more volatile in emerging countries, but its magnitude of volatility is lower than the case of house prices. In the case of output, the emerging country group is 1.3 times as volatile as the rich country group, but, in the case of house prices, the former group is 1.6 times as volatile as the latter. Lastly, emerging countries present higher relative volatility of consumption, or less consumption smoothing. While σ_C/σ_Y for rich countries is 1.01, it is 1.57 in the case of emerging countries. The higher relative consumption volatility — in particular, σ_C/σ_Y substantially greater than one — is known as *excess consumption volatility*, which is declared in several influential papers (Aguiar and Gopinath (2007), Garcia-Cicco et al. (2010), Alvarez-Parra et al. (2013), among them).

Table 1 also presents the correlation between key variables: $\sigma_{C,Y}$, $\sigma_{HP,Y}$, and $\sigma_{HP,C}$.

[5] I check alternative detrending methodologies such as an HP filter and a quadratic filter. Detrending by the HP filter with a constant 1,600 and the quadratic filter shows similar results to what I earn from the first log-differencing, so I can confirm robustness. Additional details are available from the author upon request.

Table 1: Business Cycles in Emerging and Rich Countries

	σ_{HP}	σ_Y	σ_C/σ_Y	$\sigma_{C,Y}$	$\sigma_{HP,Y}$	$\sigma_{HP,C}$
New Zealand	4.22	1.58	2.40	0.22	0.16	0.82
South Africa	2.78	0.93	2.14	0.36	0.38	0.56
South Korea	2.51	1.65	1.21	0.69	0.34	0.37
Spain	2.82	0.79	1.24	0.58	0.38	0.40
Emerging	**2.75**	**1.14**	**1.57**	**0.53**	**0.36**	**0.46**
Australia	2.07	0.92	1.08	0.42	0.32	0.27
Belgium	1.67	0.73	0.92	0.62	0.29	0.14
Canada	2.25	0.81	1.00	0.41	0.27	0.23
Denmark	2.71	1.08	1.61	0.45	0.35	0.26
Finland	2.53	1.46	1.07	0.60	0.38	0.32
France	1.35	0.56	1.24	0.65	0.38	0.30
Germany	0.85	0.98	1.06	0.57	0.29	0.35
Italy	2.00	0.84	1.21	0.53	0.29	0.31
Japan	1.52	1.06	1.02	0.70	0.42	0.34
Netherlands	2.43	1.13	0.97	0.35	0.30	0.40
Sweden	2.25	1.16	1.15	0.40	0.23	0.41
Switzerland	1.80	0.79	0.86	0.64	0.11	0.08
United Kingdom	2.70	0.90	1.19	0.62	0.49	0.51
United States	1.57	0.81	0.86	0.68	0.37	0.41
Rich	**1.68**	**0.87**	**1.01**	**0.62**	**0.36**	**0.37**

[1] The numbers are computed based on quarterly frequency data.
[2] The numbers on the gray-shaded row represent the each country group's population-weighted average (as of 2010).
[3] Sources: BIS property price database, OECD national accounts

Basically, the correlation between consumption and output is weaker in emerging countries compared to rich countries (0.53 for emerging countries, 0.62 for rich countries). More importantly, we can observe the similar correlation between house prices and output between two country groups, while the correlation between house prices and consumption is about 1.3 times higher in emerging country group than in rich country group. Note that the similar $\sigma_{HP,Y}$ between emerging and rich countries can be interpreted as the control of the effect of output on house prices when we compare two country groups' business cycles. Therefore, the evidence of higher $\sigma_{HP,C}$ for emerging countries implies higher house price volatility can be a root of excessive response of consumption for emerging countries. As a result, I declare the above as *Evidence 1.*

Evidence 1 *Consumption is more correlated with house prices in emerging countries than in rich countries, while the correlation between output and house prices for emerging countries is a similar level as for rich countries on average.*

Next, I extend the cross-country dataset to include the disaggregated consumption data series: housing consumption (HC_t) and non-housing consumption (NHC_t). This is because this paper studies the excessive response of household's consumption to house price fluctuation, so we need to look into the consumption related to housing and the consumption less-related to housing. Following Shin (2020)[6], I define housing consumption as expenditures on housing service and housing related utilities. In the view of national accounts, housing consumption is the item of final consumption expenditure on housing, water, electricity, gas and other fuels that are included in the item of expenditures on services. Non-housing consumption is defined as the remaining consumption, which is the sum of durable consumption and non-durable and service consumption other than housing consumption. Due to extremely limited availability for household expenditure data disaggregated by purpose, in particular, in a quarterly frequency, only four countries are available in my eighteen sample countries: two emerging countries (New Zealand and South Korea) and two rich countries (Canada and the United States). Therefore, I take annual frequency data into account for the disaggregated consumption. Nevertheless, the sample size shrinks to nine countries: six rich countries and three emerging countries; Australia, Canada, Denmark, Finland, France, and the United States (rich countries); New Zealand, South Africa, and South Korea

Table 2: Business Cycles with Disaggregated Consumption

	σ_{HP}	σ_Y	σ_C/σ_Y	σ_{HC}/σ_Y	σ_{NHC}/σ_Y
New Zealand	5.83	1.80	1.17	1.85	1.22
South Africa	8.44	2.32	1.25	2.68	1.35
South Korea	7.30	3.67	1.18	1.64	1.25
Emerging	**7.80**	**2.93**	**1.21**	**2.16**	**1.30**
Australia	4.97	1.48	1.07	1.24	1.27
Canada	5.32	2.02	0.75	0.95	0.95
Denmark	7.91	2.06	1.15	1.43	1.48
Finland	8.20	3.21	0.64	0.77	0.88
France	4.77	1.67	0.91	1.03	1.08
United States	5.75	1.99	0.86	0.63	0.94
Rich	**5.59**	**1.94**	**0.87**	**0.92**	**0.98**

[1] The numbers are computed based on annual frequency data. Please refer to the main text for the discussion of consistency between annual frequency observation and quarterly frequency observation.

[2] The numbers on the gray-shaded row represent the each country group's population-weighted average (as of 2010).

[3] Sources: BIS property price database, OECD national accounts, Central banks, National statistics offices

(emerging countries). The sample period for annual data is from 1970 to 2015.[7]

Table 2 presents the key second moments of data-available countries with group average statistics. House prices are more volatile in emerging countries than in rich

[6] Clearly notice that the evidence from disaggregating total consumption is not the original contribution of this paper. Shin (2020) disaggregates total consumption into two parts of housing consumption and non-housing consumption. In the literature, a basic model setup with housing considers two types of consumption goods; one is housing services, and the other is consumption goods. However, there is no existing paper looking into cross-country observations from housing service expenditure data, which is the motivation to collect the disaggregated consumption data across countries. Please refer to Shin (2020) for the detailed discussion.

[7] Finland and New Zealand have different sample periods due to data availability. The time series for Finland starts from 1975, and for New Zealand, it starts from 1987. Additionally, regarding the data source, annual data for South Africa come from the South African Reserve Bank because the OECD national accounts does not contain disaggregated consumption data for South Africa.

countries (1.4 times), and there is excess consumption volatility in emerging countries. It is notable that relative housing consumption volatility is significantly larger than non-housing consumption volatility in emerging countries ($\sigma_{HC}/\sigma_Y = 2.16 > 1.30 = \sigma_{NHC}/\sigma_Y$). In contrast, in rich countries, housing consumption volatility is slightly smaller than non-housing consumption volatility ($\sigma_{HC}/\sigma_Y = 0.92 < 0.98 = \sigma_{NHC}/\sigma_Y$). Another striking feature from Table 2 is that housing consumption volatilities for emerging countries (2.16) are much greater than those for rich countries (0.92). Starting from this finding, I extend the argument that house prices in emerging countries matter for excess consumption volatility. Specifically, higher housing consumption volatility in emerging countries is one of key sources explaining the channel from house prices to consumption volatility. Finally, even if we consider higher housing consumption volatility, there is still excess volatility in the remaining part of consumption for emerging countries. That is, we can observe that the σ_{NHC}/σ_Y values for emerging countries are greater than unity, which requires reasoning beyond higher housing consumption volatility in explaining excess consumption volatility.[8] As a result, I suggest *Evidence 2* and *Evidence 3* as follows.[9]

Evidence 2 *Housing consumption is more volatile than non-housing consumption in emerging countries. In contrast, housing consumption is not more volatile than non-housing consumption in rich countries.*

Evidence 3 *In emerging countries, excess volatility still holds for non-housing con-*

[8]The above observation also holds in quarterly frequency data even though the number of data-available sample countries are only four. House prices are more volatile in New Zealand and South Korea than in the United States and Canada, and there is excess consumption volatility in New Zealand and South Korea, which is the stylized business cycle fact in emerging economies. Relative housing consumption volatility is significantly larger than non-housing consumption volatility in emerging countries ($\sigma_{HC}/\sigma_Y = 1.61 > 1.47 = \sigma_{NHC}/\sigma_Y$ for New Zealand; $\sigma_{HC}/\sigma_Y = 1.65 > 1.37 = \sigma_{NHC}/\sigma_Y$ for South Korea). In contrast, in both the United States and Canada, housing consumption volatility is similar to or smaller than non-housing consumption volatility ($\sigma_{HC}/\sigma_Y = 1.10 < 1.12 = \sigma_{NHC}/\sigma_Y$ for Canada; $\sigma_{HC}/\sigma_Y = 0.86 < 1.03 = \sigma_{NHC}/\sigma_Y$ for the United States). Additionally, housing consumption volatilities for New Zealand and South Korea (1.61 and 1.65, respectively) are much greater than those for Canada and the United States (1.10 and 0.86, respectively). Lastly, there is excess volatility in non-housing consumption for New Zealand and South Korea (1.47 and 1.37, respectively).

[9]Clearly notice that *Evidence 2* and *Evidence 3* are not the original findings of this paper. Shin (2020) compares the volatilities of disaggregated consumption between emerging and rich countries and discusses them rigorously based on the differences in the fundamental related to housing.

Figure 1: House Price Volatility and Rent Volatility

[Figure 1 here]

sumption.

2.3 Intuition: Data to Model

Evidence 1 and *Evidence 2* jointly imply that house price volatility matters for excess consumption volatility in emerging countries through housing consumption rather than non-housing consumption. Since housing consumption expenditure in national account is measured by the sum of rental value of tenant-occupied housing and imputed rental value of owner-occupied housing, the housing rental price emerges as a key factor linking between house price volatility and housing consumption volatility. In fact, a positive correlation between house price volatility and rental price volatility is observed across countries in actual data, as Figure 1 shows.[10] Additionally, the positive relationship is clearer in the case of emerging countries. Hence, I postulate that house prices affect housing consumption through a clear link between house prices and rental prices, which is smoother in emerging countries compared to rich countries, and I refer to it as a rental price pass-through.[11]

Next, according to the *Evidence 1* and *Evidence 3*, we should consider the link between house prices and non-housing consumption in aggregate. Let us first take the

[10] I extracted housing rent indices from CPI for each country. The renal price dataset is an unbalanced panel considering data availability. The sample countries with coverage and sources are as follows: Australia (1973 Q1-2016 Q2, Australian Bureau of Statistics), Canada (1970 Q1-2016 Q2, Statistics Canada), Denmark (2001 Q1-2016 Q2, Statistics Denmark), Finland (2000 Q1-2016 Q2, Statistics Finland), France (1990 Q1-2016 Q2, INSEE), Germany (1991 Q1-2016 Q2, DESTATIS), Italy (1996 Q1-2016 Q2, IStat), Japan (1970 Q1-2016 Q2, Statistics Bureau), New Zealand (1999 Q1-2016 Q2, Statistics New Zealand), South Africa (1970 Q1-2016 Q2, Statistics South Africa), South Korea (1975 Q1-2016 Q2, The Bank of Korea), Spain (2002 Q1-2016 Q2, INE), the United Kingdom (1996 Q1-2016 Q2, Institute for National Statistics), and the United States (1970 Q1-2016 Q2, BLS).

[11] I mute the question of why the effective relationship between rental prices and house prices holds well in emerging countries and why it does not hold well in developed countries. One plausible answer is based on cross-country variation in rental price stickiness. Different institutional environments and subjective factors across countries lead to different magnitudes of rental price rigidity. As a result, rent is relatively flexible in emerging countries, while it is relatively sticky in rich countries, which makes the link between house price volatility and rental price volatility tighter for emerging countries and looser for rich countries.

well-known wealth effect of asset prices on consumption into account. The wealth effect means that a person becomes wealthier when the price of her own asset increases, which makes her consume more than before. But houses are different from other assets for two reasons. First, people usually live in their house and value directly the services that their house provides. Therefore, the benefit of an increase in house prices is directly offset by an increase in the opportunity cost of housing services. Second, houses are not widely traded internationally. Thus, one country's homeowners in aggregate cannot realize their capital gains on houses to increase their consumption. In other words, all homeowners cannot simultaneously move out of homeownership, so the gain to a last-time seller is also a loss to a first-time buyer, who is also the country's consumer. This situation contrasts with capital gains on financial assets. As a result, there is no traditional wealth effect on consumption from house prices. However, there is another explanation in the literature; house prices may have a direct impact on non-housing consumption via the credit market effect, which is the so-called housing collateral effect. Specifically, this channel is rigorously investigated in Iacoviello (2005) and Berger et al. (2018) using the U.S. data. Houses represent collateral for homeowners, and borrowing on a secured basis against housing collateral is generally less expensive than borrowing on an unsecured basis. Thus, an increase in house prices make more collateral available to homeowners, which in turn may encourage them to borrow more (for instance, in the form of mortgage equity withdrawal in the United States) in order to finance consumption. The question that naturally follows is whether or not the collateral channel also works in emerging countries. For emerging countries in my sample, the average of the mortgage-to-GDP ratio, which is widely used as a mortgage depth indicator, is 53.1 percent.[12] This value is compatible with the average for rich countries, which is 58.6 percent. As a result, mortgage also matters in emerging countries, and the collateral effect exists. In next section, I suggest a simple business cycle model that accommodates the above intuitions from the findings: a rental price pass-through and a housing collateral effect.

[12] Badev et al. (2014) gauges the depth of each country's mortgage market by focusing on the total volume. It collects and shows each country's outstanding mortgage debt relative to GDP on average for the period 2006 to 2010. It also presents housing loan penetration indices, which are defined by the percentage of the adult population with an outstanding loan to purchase a home. In terms of both indicators, the mortgage market matters in emerging countries in my sample.

3 The Model

In this section, I build a business cycle model for an emerging small open economy with housing and house prices that can capture the empirical evidence that I suggested in the previous section. This paper borrows the main building blocks from Iacoviello (2005); the model is essentially a business cycle model with a financial friction that takes a form of a collateral constraint. Specifically, Iacoviello (2005) develops a monetary business cycle model with a borrowing constraint to explain a relationship between house prices and an economic fluctuation in a large closed economy such as the United States. This paper has four primary variations. First, I discuss real economic fluctuations in this paper; thus, the model is a real business cycle model but not a nominal model, and it does not include a monetary policy. Second, it is an open economy model; in particular, it considers a small open economy that categorizes most emerging countries. Third, this paper highlights housing consumption whose price measure is the housing rental price. I borrow an idea of rental price determination suggested by Sommer et al. (2013), but my model specification is more intuitive and straightforward because the transaction of homogeneous housing rental service is simply made by the direct interaction between service providers and service demanders.[13] Finally, this paper focuses on the household's consumption responses to exogenous endowment and house price fluctuation, so the model is not a general equilibrium model but a partial equilibrium model without production side, which is described below in detail.

Consider a discrete-time, infinite-horizon endowment economy, where households receive an endowment of goods at every period and there is no endogenous production. The endowment is an exogenous and stochastic process, so it represents one source of uncertainty in the economy. The other source of uncertainty is a house price. It is also assumed to be an exogenously given stochastic process. Given the exogenous house price, an agent can purchase as many houses as she wants. That is, the economy has a demand-determined housing market, and housing supply is assumed to be perfectly elastic. Additionally, two sources of uncertainty are assumed not to affect each other.[14]

[13] Sommer et al. (2013) investigates the dynamics of house prices and rents in the U.S. through a theoretical model framework of housing tenure choice. In Sommer et al. (2013), basically, rents are determined in a rental market where homeowners are rental service providers and tenants are demanders, and I just borrow this idea to model a housing rental market. While Sommer et al. (2013) introduces heterogeneous housing services by size and models endogenous homeownership, I assume the housing is homogeneous goods and homeownership rate is fixed.

Next, the model is a small open economy business cycle model that has an external debt-elastic interest rate following Schmitt-Grohé and Uribe (2003). The agent can access the international financial market, so she can borrow money at given interest rate. In the case of domestic bond market, the borrowing amount by debtors and the lending amount by creditors are exactly the same, which means there is zero-sum domestic debt holding in aggregate. As a result, all debt is international borrowing. Here, I assume that all unsecured lending behavior between lenders and borrowers is captured as domestic financial market transactions. Thus, the model does not consider an unsecured loan market. The only source of borrowing is foreign lenders, and it should be secured lending against housing collateral.[15]

This theoretical world is populated by two types of agents, *homeowners* and *renters*. In every period in the economy, there are ω homeowners and $(1-\omega)$ renters. The parameter ω controls both the share of homeowners and their share in consumption of goods. This parameter cannot change over time. The two agent groups are basically identical except in their ability to purchase houses. Homeowners decide housing investment in each period and access a secured loan against housing collateral from the international financial market, subject to a collateral constraint. In the case of renters, they do not access a financial market because they do not have collateralizable houses. Both agents share the same preference representation, which is non-separable between two goods (i.e., non-housing consumption goods and housing consumption goods). Lastly, the time unit of the model is a quarter.

[14]An independent process is a strong assumption because we generally say a house price is procyclical. In fact, we observe positive correlations between output and house prices in the data. However, the relationship between output and house prices is quite complicated beyond the observed correlation coefficients, so it should be discussed in a general equilibrium model with endogenous house prices. Nevertheless, I should note that I conducted numerical approximation with both independently estimated processes and jointly estimated processes, and I found no significant different numerical results between them.

[15]Imagine commercial banks that finance funding from foreign creditors and domestic savers. Domestic savers are not necessarily homeowners; a domestic saver is either a homeowner or a renter. Banks extend unsecured lending to domestic borrowers, and its source is assumed to be domestic deposits without loss of generality. At the same time, banks extend secured lending against housing collateral, and its source is assumed to be foreign creditors. As a result, the model of this paper is simplified by removing financial intermediaries under the zero-sum domestic lending assumption.

3.1 Homeowners

There are ω infinitely-lived identical homeowners with preferences described by the utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \ln X_t^O \tag{1}$$

where E_t denotes the expectation operator conditional on information available in period t, and X_t^O denotes a consumption aggregate. Note that the superscript "O" represents a homeowner. β is a subjective discount factor, and the periodic utility function takes a form of logarithm. Homeowners consume two goods to increase their utility: non-housing consumption goods, c_t^O, and housing services, s_t^O. The two consumption goods compose a consumption bundle X_t^O, which is a constant elasticity of substitution aggregator

$$X_t^O \equiv \left[\gamma \left(c_t^O\right)^{\frac{\eta-1}{\eta}} + (1-\gamma)\left(s_t^O\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{2}$$

where $\gamma > 0$ is the share of non-housing consumption goods in the consumption aggregator, and $\eta \geq 0$ is the intratemporal elasticity of substitution between non-housing consumption goods and housing services.

The homeowners maximize their lifetime utility subject to the sequence of budget constraints

$$c_t^O + \rho_t s_t^O + q_t[h_t - (1-\delta)h_{t-1}] + d_t = y_t + \frac{d_{t+1}}{1+r_t} + \rho_t h_t \tag{3}$$

where q_t and ρ_t denote a house price and a housing rental price in real terms, respectively. h_t denotes housing stock that the owner is holding at period t, and δ is a quarterly depreciation rate. The homeowner spends funds on purchasing the housing stock at period t given an exogenous house price q_t, and at the same time, she receives as much funds as the current value of housing stock that she holds from the previous period after depreciation. As a result, the terms $h_t - (1-\delta)h_{t-1}$ represents a housing investment that the owner determines at period t. d_t denotes real debts whose maturity is time t, r_t denotes a real interest rate on loans between t and $t+1$, and y_t denotes the endowment the homeowner receives at period t. As seen on the right-hand side of the resource constraint, the funds for homeowners come from three sources: the endowment, international debt, and housing rental income. The last term on the right-hand side of equation (3) is for "gross" housing rental income. Since the linear technology allows the homeowner to produce the exactly same amount of housing services at no cost, the rental price times the amount of housing stock at period t is her rental income. Moving on to the left-hand side of the budget constraint, the uses of funds for homeowners are composed of four components: non-housing consumption given a numeraire price, housing consumption given a rental price, housing investment given a house price, and repayment of debts. In particular, the second term $\rho_t s_t^O$ is for the homeowner's expenditure on owner-occupied housing services. Since homeowners are providers of housing rental services (producing the amount of h_t at time t) and consumers of owner-occupied housing services (consuming the amount of s_t^O at time t), we can define "net" housing rental income as $\rho_t(h_t - s_t^O)$. Another aspect to mention regarding equation (3) is the exogenous variables that the homeowners take as given. One source of uncertainty in the economy is the house price, q_t, and the other source is the endowment, y_t, as I mention above. I assume that the shocks follow the AR(1) process:

$$\ln q_{t+1} = \rho_q \ln q_t + \sigma_q \varepsilon_{q,t+1} \tag{4}$$

$$\ln y_{t+1} = \rho_y \ln y_t + \sigma_y \varepsilon_{y,t+1} \tag{5}$$

where ρ_q and ρ_y are the autoregressive parameters, σ_q and σ_y are the parameters for standard deviation of innovation to corresponding shock, and $\varepsilon_{q,t+1}$ and $\varepsilon_{y,t+1}$ are independently and identically distributed innovation with mean zero and variance one.

As in Iacoviello (2005) and Iacoviello and Neri (2010), I assume that the homeowners face the borrowing limit. Formally,

$$d_{t+1} \leq m q_t h_t \tag{6}$$

where m represents a loan-to-value (LTV) ratio. Equation (6) implies the borrowing amount is limited by the LTV ratio multiplied by the collateral value of housing stock that the owner is holding at period t. As a result, we can interpret the parameter m as the fraction of house value used as a collateral and the term $q_t h_t$ as the market value of collateral based on the current house price (Kaplan et al. (2017), Sommer et al. (2013)).[16] Note that this constraint can be thought of as a down payment constraint for house purchase, but it also applies to any borrowing against home equity, not just to first-lien mortgages. Therefore, the use of d_{t+1} is not constrained. Next, I assume that the borrowing constraint always holds with equality near the steady state.[17] This is because I also assume the agents in the economy are sufficiently impatient. Formally, I assume $\beta(1+r^*) < 1$ where r^* is the steady state level of the interest rate.

Given initial values $\{h_{-1}, d_0\}$, the homeowner chooses $\{c_t^O, s_t^O, h_t, d_{t+1}\}$ to maximize equation (1) subject to equations (3) and (6). The Lagrange multiplier for each constraint is defined as λ_t^O and $\lambda_t^O \mu_t$, respectively. The corresponding first order conditions are as follows:

$$\gamma \left(X_t^O\right)^{\frac{1-\eta}{\eta}} \left(c_t^O\right)^{-\frac{1}{\eta}} = \lambda_t^O \tag{7}$$

$$\frac{1-\gamma}{\gamma} \left(\frac{c_t^O}{s_t^O}\right)^{-\frac{1}{\eta}} = \rho_t \tag{8}$$

$$\lambda_t^O q_t = \lambda_t^O \rho_t + \beta(1-\delta) E_t[\lambda_{t+1}^O q_{t+1}] + m\mu_t \lambda_t^O q_t \tag{9}$$

$$\lambda_t^O \left(\frac{1}{1+r_t} - \mu_t\right) = \beta E_t \lambda_{t+1}^O \tag{10}$$

Equations (7) and (8) are the first order condition with respect to the homeowner's non-housing consumption and housing services, respectively. In particular, equation (8) represents the housing rental service supply condition because homeowners are housing rental service providers. Equation (9) is the first order condition with respect to the homeowner's housing stock, and it equates the marginal utility of non-housing consumption to the shadow value of housing stock. The latter relies on three components: a direct gain from additional rental income, an expected gain from a change in the value of a house realized in the next period, and a marginal utility of relaxing the collateral

[16] Several papers, including Kaplan et al. (2017) and Sommer et al. (2013), suggest that the collateral value in a borrowing constraint is based on the current house price, and I follow their view considering the collateral appraisal procedure using the current house price. At the same time, other papers have presented different views. For example, Iacoviello (2005), Iacoviello and Neri (2010), and Andrés et al. (2017) suggest that agents' maximum borrowing is given by the expected present value of their house times LTV ratio.

[17] We can relax the assumption of binding borrowing constraint by allowing an occasionally binding borrowing constraint. I solve the model with occasionally binding borrowing constraint using the piecewise linear approximation methodology suggested by Guerrieri and Iacoviello (2015), and find the frequency of hitting constraint is 76%. Also, the selected second moment generated are not quite different from the baseline result which will be presented in Table 5. So I confirm the robustness of the result under the assumption of binding collateral constraint.

constraint. Lastly, equation (10) is an Euler equation, but it is not a standard one due to the existence of μ_t. Since I assume that the collateral constraint is always binding, the multiplier $\lambda_t^O \mu_t$ is always positive. If the collateral constraint is slack, μ_t is zero, and we can obtain the standard Euler equation of marginal utilities between periods t and $t+1$.

3.2 Renters

Renters whose proportion in the economy is $(1-\omega)$ maximize their lifetime utility subject to a sequential budget constraint:

$$\max \quad E_0 \sum_{t=0}^{\infty} \beta^t \ln X_t^R \tag{11}$$

$$\text{s.t.} \quad c_t^R + \rho_t s_t^R = y_t \tag{12}$$

where the superscript "R" is for renters, so X_t^R denotes the renter's consumption aggregate, c_t^R denotes her non-housing consumption, and s_t^R denotes her housing services consumed. y_t is the endowment, and it follows the same process as the homeowner's endowment (5) because both agents face the same variation in endowment. The consumption aggregate X_t^R is defined as

$$X_t^R \equiv \left[\gamma \left(c_t^R\right)^{\frac{\eta-1}{\eta}} + (1-\gamma)\left(s_t^R\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{13}$$

Note that there is no intertemporal choice in the renter's problem. The only source of funds the renter has is the endowment that she receives at every period. As a result, the solution to the renter's optimization problem is equal to solve her static utility maximization problem period by period. Additionally, it is worth noting that the parameters such as the discount factor, β, the share parameter, γ, and the elasticity parameter, η do not have superscripts, which implies that homeowners and renters are basically identical households with the exception of homeownership status.

The renter chooses optimal c_t^R and s_t^R at every period to maximize her periodic utility function $\ln X_t^R$ subject to her periodic resource constraint (12). By defining λ_t^R as the Lagrange multiplier for resource constraint, the corresponding first order conditions are followed:

$$\gamma\left(X_t^R\right)^{\frac{1-\eta}{\eta}}\left(c_t^R\right)^{-\frac{1}{\eta}}=\lambda_t^R \tag{14}$$

$$\frac{1-\gamma}{\gamma}\left(\frac{c_t^R}{s_t^R}\right)^{-\frac{1}{\eta}}=\rho_t \tag{15}$$

In equation (14), the renter's marginal utility of non-housing consumption is equated to the shadow value of relaxing budget constraint (12). Equation (15) represents the housing rental service demand condition in the economy, which is because renters are housing rental service demanders in a housing rental market.

3.3 External Debt Elastic Interest Rate

Assume that the interest rate faced by homeowners, r_t, is increasing in the economy's average level of debt, which we denote by $\tilde{d}_{t+1}$ as in Schmitt-Grohé and Uribe (2003). Formally, r_t is given by

$$r_t=r^*+\psi\left(e^{\tilde{d}_{t+1}-\bar{d}}-1\right) \tag{16}$$

where the first term r^* is the steady state level of interest rate and the second term represents the interest rate premium. Note that $\psi>0$ controls interest rate adjustment, and $\bar{d}$ denotes the steady state level of aggregate debt. That is, the interest rate relies on a degree of distance of current debt from the steady state. This is an external debt elastic interest rate (EDEIR) because households take the cross-sectional average level of current debt as exogenously given.[18] Since $\omega d_{t+1}=\tilde{d}_{t+1}$ holds in equilibrium, the above specification (16) is rewritten by

$$r_t=r^*+\psi\left(e^{\omega d_{t+1}-\bar{d}}-1\right) \tag{17}$$

[18] Schmitt-Grohé and Uribe (2017) also introduces the internal debt elastic interest rate (IDEIR) as an alternative way to induce stationarity. While the agents take the interest rate premium as a given in EDEIR specification, the model with an IDEIR assumes that the interest rate in increasing in the individual debt position, and so households internalize the effect that their borrowing choices have on the interest rate they face.

3.4 Equilibrium

The clearing condition of housing rental market is to equate the aggregate amount of rental supply to the aggregate amount of rental demand. Since the economy consists of ω homeowners and $(1-\omega)$ renters, the market clearing condition is

$$\omega s_t^O + (1-\omega) s_t^R = \omega h_t \tag{18}$$

We derived the housing rental service supply condition (8) and demand condition (15) from the respective agent's optimization problem. As a result, we can solve for the rental market equilibrium using the supply and demand condition with the above market clearing condition (18). The equilibrium amount of housing rental service and the equilibrium housing rental prices are

$$s_t^R = \frac{\omega c_t^R}{c_t} h_t \tag{19}$$

$$\rho_t = \frac{1-\gamma}{\gamma} \left(\frac{c_t}{\omega h_t} \right)^{\frac{1}{\eta}} \tag{20}$$

where $c_t = \omega c_t^O + (1-\omega) c_t^R$, which is the total non-housing consumption.

Rigid Adjustment of Rental Prices I introduce rigid adjustment into rental prices in order to avoid extreme response of rental prices and to prevent model from generating extremely volatile housing consumption. In data, housing rents generally less fluctuate than house prices, as Figure 1 presents. Also, several papers, for example, Genesove (2003) and Verbrugge and Gallin (2017) suggest evidence for rental price rigidity. Based on data and literature, the ad-hoc modelling idea of this paper is that rental prices want to stay their steady state level. I introduce adjustment component which does not affect the steady state of the theoretical world. Specifically, I add the adjustment term to the equilibrium rental prices, or Equation (20), so new equilibrium condition for rental prices is

$$\rho_t = \frac{1-\gamma}{\gamma} \left(\frac{c_t}{\omega h_t} \right)^{\frac{1}{\eta}} * \frac{1}{e^{\tau(\rho_t - \bar{\rho})}} \tag{21}$$

where τ is a adjustment parameter and $\bar{\rho}$ is a rigidity anchorage which is the steady state level of rental prices.

Aggregation We can construct the equilibrium process of aggregate variables such as total consumption, TC_t, housing consumption, HC_t, non-housing consumption, NHC_t, housing stock, H_t, international debt holdings, D_{t+1}, and gross income level, Y_t, by

$$HC_t = \rho_t \omega h_t \tag{22}$$

$$NHC_t = c_t \tag{23}$$

$$TC_t = HC_t + NHC_t \tag{24}$$

$$H_t = \omega h_t \tag{25}$$

$$D_{t+1} = \omega d_{t+1} \tag{26}$$

$$Y_t = y_t + \rho_t \omega h_t \tag{27}$$

Note that the last aggregate variable, Y_t, represents GDP measured by the income approach. Since in this theoretical world, income is generated from endowment and housing rental service production, GDP is the summation of the two agents' endowments, $\omega y_t + (1-\omega) y_t$, and homeowners' rental income, $\rho_t \omega h_t$.

As a result, an equilibrium in the model is then a set of processes of 20 endogenous variables $\{c_t^O,\, c_t^R,\, c_t,\, h_t,\, s_t^O,\, s_t^R,\, d_{t+1},\, X_t^O,\, X_t^R,\, \lambda_t^O,\, \lambda_t^R,\, \mu_t,\, \rho_t,\, r_t,\, TC_t,\, HC_t,\, NHC_t,\, H_t,\, D_{t+1},\, Y_t\}_{t=0}^{\infty}$ satisfying (2) to (10), (12) to (15), (17), (18), (19), (21) to (27), given the initial conditions $\{h_{-1},\, d_0\}$ and the processes $\{q_t,\, y_t\}_{t=0}^{\infty}$. Please see the Appendix for a full set of equilibrium conditions and the steady state of the economy.

4 Results

In this section, I solve the basic model numerically through the first order approximation, and I show the results in various ways to learn how the model explains the linkage between the given house price changes and consumption fluctuations. In short, the exogenous house price shock affects the households' total consumption volatility primarily through housing collateral effect, and another source of explanation for the excessive volatility of total consumption — and a novel contribution of this paper — is the housing rental price responses induced by house price changes.

4.1 Calibration

To implement the perturbation method, I calibrate the parameters of the model introduced in the previous section. The target country is basically South Korea, and the time unit is one quarter as in the model.

I set the share of non-housing consumption parameter, $\gamma = 0.19$, to match the average housing consumption share in South Korea over the sample period, from 1975 Q1 to 2016 Q2, which is 15.2%. Together with the other calibrated parameters, it precisely determines the average housing consumption share. For the intratemporal elasticity of substitution between non-housing consumption goods and housing services, Flavin and Nakagawa (2008), Li et al. (2016), and Stokey (2009) estimated the elasticity using household-level data, and they found that it is less than one. That is, non-housing consumption goods and housing services are complements according to the elasticity. Song (2011, 2012) and Davidoff and Yoshida (2013) also estimated an elasticity of less than one from macro-level aggregate consumption data.[19] In this paper, I pick $\eta = 0.35$, which is the estimate that Song (2012) provides. This choice is because the target country is Korea and because Song (2012) estimates the elasticity using aggregate consumption data of Korea. The steady state level of interest rate, r^*, is set to 0.01 to match the average long-run interest rate per annum in Korea, 3.91%, over the sample period, which is from 1981 to 2016 considering data availability. The subjective discount factor is calibrated to $\beta = 0.95$ following Iacoviello (2005). Note that $\beta(1+r^*) < 1$ because households are assumed to be sufficiently impatient, which allows them to bind a borrowing constraint. The quarterly housing depreciation rate, δ, is set to 0.0025 following Iacoviello and Neri (2010). In the case of the key parameter of the collateral constraint, m, the average loan-to-value (LTV) ratio for mortgages in Korea is considered. Due to the limited data availability for the actual LTV ratio in South Korea, I make use of the average over the last five years as a proxy. According to the Bank of Korea, the average LTV ratio from 2012 to 2016 is 40∼60%. Additionally, Korean Financial Supervisory Services reported that the average LTV ratio was 53% as of the end of 2016. Hence, I set $m = 0.5$ for the baseline calibration. In fact, the regulatory

Table 3: Calibration

Parameter		Value
Share of non-housing consumption	γ	0.19
Intratemporal elasticity of substitution	η	0.35
Steady state interest rate	r^*	0.01
Subjective discount factor	β	0.95
Housing depreciation rate	δ	0.0025
Loan-to-value ratio	m	0.5
Homeowner proportion	ω	0.55
Interest rate premium adjustment	ψ	0.000742
Rental price adjustment	τ	245

LTV ratio can be one candidate for m, but there is a substantial gap between regulatory ratio (70% since July 2014) and actual ratio in Korea. The homeowner proportion parameter ω is set to 0.55 to match the average homeownership rate in Korea, 55%. As the statistics for the homeownership rate are available since 1995 in Korea[20], it is also a proxy but it is fine because there is little variation in the homeownership rate over the sample period from 1995 to 2016. Finally, I calibrate the interest rate premium adjustment parameter, $\psi = 0.000742$ following Schmitt-Grohé and Uribe (2003) and the rental price adjustment parameter, $\tau = 245$ matching the ratio of rent volatility to house price volatility in South Korea which is 0.54.

Moving on to the parameters defining the stochastic processes of the exogenous

[19] There is little consensus in the literature on whether the elasticity is less than one or not. In contrast to the papers that I mentioned in the main text, Piazzesi et al. (2007) and Davis and Martin (2009) argue that $\eta > 1$ from the micro-level data estimation. Another branch of the literature ignores non-separable complementarity between non-housing consumption and housing services by using separable preference specification (Iacoviello (2005), Iacoviello and Neri (2010), Calza et al. (2013), Sun and Tsang (2017)), or simply assumes Cobb-Douglas preference, which implies that $\eta = 1$ (Sommer et al. (2013), Li and Yao (2007), Yang (2009), Aoki et al. (2004), Funke and Paetz (2013)).

[20] The homeownership rate in South Korea is a national statistic from two nationwide surveys: a biennial survey conducted by the Ministry of Land, Infrastructure and Transport (2006, 2008, 2010, 2012, 2014, 2016) and a census conducted Statistics Korea every five years (1995, 2000, 2005, 2010, 2015).

Table 4: Estimates for Shock Processes

Parameter		**OLS estimate**
Persistence of house prices	ρ_q	0.6167
Persistence of endowment	ρ_y	0.5479
Standard deviation of innovation to house price shock	σ_q	0.0196
Standard deviation of innovation to endowment shock	σ_y	0.0179

driving forces, there are four parameters according to equations (4) and (5). I conduct OLS estimation for the parameters using GDP and house price data of South Korea from 1970 Q1 to 2016 Q2, and the estimates are presented in Table 4. Both processes are quite persistent, so the shock does not vanish until ten quarters after it occurs. According to the estimates, the volatility of each process is 2.14 for the endowment and 2.49 for the house prices.[21]

4.2 Approximation Results

4.2.1 Selected Second Moments

In the previous section, I constructed several variables to observe the aggregate economy's business cycle feature. Each aggregate variable is defined by the weighted sum-

[21] We can consider an alternative specification for shock processes, which is VAR (1). We can assume that the law of motion of house prices and endowment is given by the following autoregressive process:

$$\begin{bmatrix} \ln q_{t+1} \\ \ln y_{t+1} \end{bmatrix} = A \begin{bmatrix} \ln q_t \\ \ln y_t \end{bmatrix} + \varepsilon_{t+1}$$

where A is 2 by 2 matrix and ε_{t+1} is a white noise of order 2 by 1 distributed $N(\phi, \Sigma_\varepsilon)$. The OLS estimation for the matrix A and Σ_ε results in the followed matrices:

$$A = \begin{bmatrix} 0.60 & 0.06 \\ 0.07 & 0.52 \end{bmatrix}, \qquad \Sigma_\varepsilon = \begin{bmatrix} 0.00039 & 0.00007 \\ 0.00007 & 0.00032 \end{bmatrix}$$

Note that the correlation coefficient parameters are quite small (A_{12}=0.06, A_{21}=0.07), and the innovation of each shock is also lowly correlated ($\Sigma_{\varepsilon,12}$=$\Sigma_{\varepsilon,21}$=0.00007). As a matter of fact, the numerical results from the above VAR(1) specification are not quite different from the baseline case. Therefore, we can confirm that the results from the baseline specification of independent AR(1) shock processes is robust to the alternative one.

mation of corresponding individual variables; in particular, GDP is calculated following the income approach by which GDP includes each group's endowment and homeowners' housing rental income. Then, I compute the unconditional second moments for the aggregate variables to compare them with the business cycle facts observed in the actual data. The variables of primary interest are the relative consumption volatilities, and Table 5 shows the numbers for data and model.

The total consumption volatility relative to GDP volatility for South Korea is 1.21, and the basic model generates 1.37. Notice that the total consumption volatility, σ_C, in the parenthesis next to the relative consumption volatility, is larger for the model compared to the data (2.79 and 2.00, respectively), but the output volatility, σ_Y, for the model is 2.04, which is larger than for the data, 1.65.[22] As a result, the relative consumption volatility, σ_C/σ_Y, in the model successfully matches that observed in the data. Next, the disaggregated consumption volatilities generated in the model also capture the actual data quantitatively well. The key finding from the data is that housing consumption volatility is higher than non-housing consumption volatility in the case of emerging countries, and the model shows large housing consumption volatility compared to non-housing consumption volatility (1.78 and 1.39, respectively).

To see the influence of one shock compared to that of the other shock, I shut down each shock one by one and compute the second moments. The first column of Table 6 is for the baseline case where both the house price and endowment shock are effective. The second and third column are for the case where only one shock is effective. I realized this by assigning zero innovation shocks to the ineffective shock. For example, the second column under the heading of shutdown of endowment shock shows the second moments when the innovation of the endowment process is zero. The last two columns explicitly reveal the dominance of house price shock in the theoretical model. The second moments for the case of shutting down the endowment shock is approximately more than twice as large as the case when the house price shock is shut down. In other words, the endowment shock is not solely able to generate a sufficiently volatile economy. On the other hand, the house price shock solely generates volatilities close to the baseline result. Another point we must focus on is the qualitative comparison.

[22] One rational explanation for the excessive volatilities in consumption and GDP for the model compared to the data regards the assumption of exogenous house prices. Since the model economy cannot adjust future house prices responding to current shocks, other variables such as consumption and GDP become more volatile.

Table 5: Selected Second Moments

	Data[1]		**Model**[2]	
$\frac{\sigma_C}{\sigma_Y}$	1.21	(2.00)[3]	1.37	(2.79)
$\frac{\sigma_{HC}}{\sigma_Y}$	1.65	(2.72)	1.78	(3.62)
$\frac{\sigma_{NHC}}{\sigma_Y}$	1.37	(2.26)	1.39	(2.84)
σ_Y	1.65		2.04	
σ_q	2.51		2.49	
σ_ρ	1.37		1.36	

[1] QoQ growth rate, South Korea, 1970 Q1-2016 Q2
[2] Under baseline calibration (Table 3)
[3] The number in parenthesis represents the volatility of numerator variable. That is, it is the second moment, which is not scaled by GDP volatility.

Regardless of shutdown of one shock, all columns capture the finding of larger housing consumption volatility. Although the only endowment shock is insufficient to generate a result similar to the baseline in terms of size, the third column shows that housing consumption volatility is still larger than non-housing consumption volatility. This result is because the intended channel within the model, which is a rental price pass-through, transmits the house price fluctuation to the price of housing consumption, or the rental prices, effectively.

How important is the house price shock in explaining each aggregate variable? Table 7 presents the predicted contribution of each shock to explaining the volatilities of aggregate total consumption, housing consumption, non-housing consumption, housing stock, debt, GDP, and, housing rental prices. Two main results arise from the variance decomposition. First, the house price shock plays a key role in explaining aggregate fluctuations in the overall perspective, accounting for more than 80 percent of the volatility of all variables except GDP.[23] Second, the variance of housing consumption is relatively less explained by the house price shock. The house price shock accounts for 80 percent of housing consumption volatility, whereas it explains 83 percent and 85

Table 6: Shutdown of Each Shock

	Baseline	Shutdown of	
		Endowment Shock[1]	**House Price Shock**[2]
σ_C	2.79	2.55	1.13
σ_{HC}	3.62	3.25	1.61
σ_{NHC}	2.84	2.62	1.08

[1] The case in which only house price shock is effective.
[2] The case in which only endowment shock is effective.

Table 7: Variance Decomposition

	TC	HC	NHC	H	D	Y	ρ
House Price Shock	0.8347	0.8022	0.8542	0.8190	0.8620	0.055	0.8996
Endowment Shock	0.1653	0.1978	0.1458	0.1810	0.1380	0.9449	0.1004

percent of total consumption and non-housing consumption fluctuation, respectively. We also observe that more than 85 percent of the variances of debt and housing rental price are accounted for by the house price shock. Since homeowners' borrowing amount is directly related to the value of house as collateral, the volatility of D must be mainly explained by the house price shock. In the case of housing rental price, it supports the conjecture regarding a strong relationship between the house price and rental price as discussed in Subsection 2.3.

4.2.2 Impulse Responses

Consider the one standard deviation shock on each exogenous process. According to the estimated parameters of shock processes, the innovations gradually disappear over ten quarters on both processes, and the speed is slightly faster in the case of endowment

[23] According to the definition of aggregate variable Y_t in this simple economy, GDP is composed of endowment and homeowners' rental income. As a result, variance of Y_t is mostly explained by endowment shock rather than house price shock by definition.

Figure 2: Impulse Responses to House Price Shock (Aggregate Level)

[Figure 2 here]

Figure 3: Impulse Responses to House Price Shock (Agent Level)

[Figure 3 here]

process. That is, the house price shock is slightly more persistent, but, overall, a one percent shock on each process hardly causes them to differ.

To begin, I plot the impulse responses of six key aggregate variables — total consumption, housing consumption, non-housing consumption, housing stock, debt holdings, and housing rental price — to the house price shock. Figure 2 indicates that a one standard deviation shock to house price encourages total consumption of the economy when the shock occurs. The increase in total consumption stems from the increase in both housing consumption and non-housing consumption, so I use two approaches to explain the house price driving consumption boom. First, a positive house price shock relaxes homeowners' borrowing constraints through an increase in the value of a collateralizable asset, i.e., the housing stock they hold at the time of the shock. As a result, homeowners have more funding and achieve a higher level of non-housing consumption and housing investment. This is the reason why the non-housing consumption, borrowing amount, and housing stock increase together at the date of shock. Second, the housing rental price responds positively to the house price shock, but it has a hump-shaped response according to Figure 2. Recalling the equilibrium rental price, Equation (20), it relies on two endogenous variables: total non-housing consumption at time t, and housing stock at time t. Although both non-housing consumption and housing stock show a positive response to the house price shock, the magnitude of response and the speed of fall differ from each other, so the rental price presents a hump-shaped response. After the date of the shock, the house price driving consumption boom starts to shrink due to the pressure of debt repayment. Finally, the economy returns to the steady state after twenty quarters. While the shock vanishes after ten quarters, the influence of shock lingers for ten additional quarters.

In fact, the consumption boom after the increase in house prices is mainly led by homeowners. I plot the response of each group's representative agent's consumption aggregator, X_t, the amount of housing service consumed, s_t, and the amount of non-housing consumption, c_t, in Figure 3. A positive house price shock stimulates homeowners to consume both housing services and non-housing consumption goods more than before. This effect is attributed to the improved credit condition by relaxing the financial friction, as the last panel of Figure 3 presents that the debt holding of homeowners soars at the date of the shock. In contrast, a renter shows minimal response to the positive house price shock. Rather, her utility decreases slightly due to the rise in the housing rental price. The renter cannot help adjust her consumption amount in both housing services and non-housing consumption goods in the face of a higher living cost.

Figure 4: Impulse Responses to Endowment Shock (Aggregate Level)

[Figure 4 here]

Figure 5: Impulse Responses to Endowment Shock (Agent Level)

[Figure 5 here]

Next, Figure 4 indicates that a positive endowment shock also leads to a consumption boom; both aggregate housing consumption and non-housing consumption increase, more housing investment and more borrowing take place, and the housing rental price increases. However, they show much smaller effects than the responses to the house price shock. The main reason is that the collateral constraint does not sufficiently relax with only an endowment shock unaccompanied by a change in the house price. Another distinguishable difference from the responses to house price shock is observed in agent-level responses. Figure 5 shows that a renter's responses are larger than a homeowner's responses because the endowment is the unique source of funding for renters.

4.3 House Price and Consumption Volatility

Under the baseline calibration, I compute the theoretical second moments — here, σ_C and σ_Y corresponding to different levels of house price standard deviation shock. Then, I plot the pairs of relative consumption volatility and house price volatility on

Figure 6: House Price and Relative Consumption Volatility

[Figure 6 here]

Figure 7: Cross-Country Observation: σ_{HP} and σ_C/σ_Y

[Figure 7 here]

the same plane, and Figure 6 is the result. According to Figure 6, the more volatile the house price is, the higher the relative consumption volatility is. The threshold of house price volatility for excess consumption volatility is approximately 1.6 in the theoretical world. In other words, if house price volatility is greater than 1.6, the excess consumption volatility is yielded by the model.

The simulation result in Figure 6 is consistent with a cross-country observation of positive correlation between house price volatility and relative consumption volatility. Figure 7 plots the countries in the dataset, which includes 4 emerging countries and 14 rich countries, on a plane which takes σ_{HP} and σ_C/σ_Y as a horizontal and a vertical axis, respectively. That is, a country whose house price volatility is high tends to have higher relative consumption volatility according to the scatter plot. Note that, however, the result of Figure 6 is yielded by the theoretical model for emerging economy and the simulation based on the calibration which targets South Korea. Therefore, this paper compares the baseline result with a counterfactual case of modified model for a rich country.

4.3.1 Key Mechanism 1: Collateral Constraint

Before moving on to the counterfacutal analysis, I describe key mechanisms of the baseline model. First, house price matters for consumption volatility through the collateral effect, which is described in Subsection 2.3 and 4.2.2. To present the importance of the collateral constraint in the model, I compare the performance of a model with a collateral constraint with that of a model without a collateral constraint. As Figure 8 presents, when I exclude a collateral constraint, the relative consumption volatility does not respond to the house price change. The σ_C/σ_Y stays at a low level regardless of a change in house price volatility in the model without a collateral constraint. Likewise, this paper asserts that a financial friction in the form of housing collateral constraint is a

Figure 8: Relative Consumption Volatility without Collateral Constraint

[Figure 8 here]

key in generating excess consumption volatility in emerging countries. As a result, this paper is in line with the literature which highlights a financial friction in explaining the puzzle as in Neumeyer and Perri (2005), Garcia-Cicco et al. (2010), and Alvarez-Parra et al. (2013). While the previous works focus on frictions related to firm investment decision in the form of working capital or domestic interest rate responses, this paper focuses on the household consumption decision related to housing by introducing the collateral constraint.

Since the renter does not access the international financial market and does not face a collateral constraint, the homeowner is a key agent group in generating a positive relationship between house prices and consumption volatility. In particular, the homeownership rate, which is represented by the share parameter of the homeowner group, ω, matters for accounting for excess consumption volatility. Figure 9 shows that the relative consumption volatility is an increasing function with respect to the homeownership rate. Across countries, a positive relationship between relative consumption volatility and the homeownership rate is also observed, as in Figure 10[24], so the model prediction is consistent with actual data.

Figure 9: Homeownership Rate and Consumption Volatility *(Model)*

[Figure 9 here]

Figure 10: Homeownership Rate and Consumption Volatility *(Data)*

[Figure 10 here]

[24] I collect the most recent available homeownership rate statistics to plot Figure 10. The data sources and corresponding years are as follows: Australia (2011, Australian Bureau of Statistics), Belgium (2016, Eurostat), Canada (2014, Statistics Canada), Denmark (2016, Eurostat), Finland (2016, Eurostat), France (2016, Eurostat), Germany (2016, Eurostat), Italy (2016, Eurostat), Japan (2013, Statistics Bureau of Japan), Netherlands (2016, Eurostat), New Zealand (2013, Statistics New Zealand), South Africa (2016, Statistics South Africa), South Korea (2016, Statistics Korea), Spain (2016, Eurostat), Sweden (2016, Eurostat), Switzerland (2016, Eurostat), the United Kingdom (2016, Eurostat), and the United States (2016, United States Census).

Figure 11: House Price and Rent Volatility

[Figure 11 here]

Figure 12: House Price and Disaggregated Consumption Volatilities

[Figure 12 here]

4.3.2 Key Mechanism 2: Rental Price Pass-through

Second, the basic model generates a strictly increasing relationship between house price volatility and rental price volatility, as Figure 11 indicates. This relationship implies that the emerging country whose house price volatility is large tends to have a large rent price volatility compared to the rich country. Even though the magnitude of correlation is larger in the model than in the data, Figure 1 in Subsection 2.3 also explicitly presents a clear relationship across countries. The volatile housing rental price directly affects housing consumption volatility in the economy, which allows the model to replicate two findings observed in the data. First, housing consumption volatility is positively correlated with house price volatility, and second, non-housing consumption volatility also shows a positive correlation with house price volatility, but it is less than housing consumption volatility in the case of emerging countries (Figure 12). This is what I call the rental price pass-through.

Notice that the degree of rental price pass-through is controlled by the rental price adjustment parameter, τ. If there is no adjustment, or $\tau = 0$, which means the rental prices are absolutely floating, the model generates extremely highly volatile rental prices. The simulation result under $\tau = 0$ yields $\sigma_\rho = 4.67$ which is 1.9 times more than house price volatility. More importantly, we can make use of the parameter τ as a source of a difference between emerging countries and rich countries, which is discussed in detail in the next section.

5 Counterfactual Analysis: Emerging Country vs. Rich Country

In this section, I compare the baseline model with the counterfactual one which is designed for an advanced small open economy. Basically, the counterfacutal model environment is not largely varying from the baseline model because both an advanced economy and an emerging economy are a small open economy. Therefore, the main difference emerges in key parameters. First, η, which captures the intratemporal elasticity of substitution between housing consumption goods and non-housing consumption goods, is larger in a rich country, which implies the degree of complementarity between two goods are weaker in a rich country. Second, the rental price adjustment is stronger in rich countries as I discussed in Section 2.3 with Figure 1, which implies higher τ for the counterfactual case. Lastly, the frequency of hitting borrowing constraint would be lower in a rich country when we consider a smaller $\sigma_{HP,C}$ observed in rich countries compared to emerging countries. However, this paper models always-binding borrowing constraint so any parameter is not related to the frequency of hitting the constraint. For the reason, the counterfacutal model for a rich country assumes no collateral constraint.[25]

5.1 Calibration for Counterfactual Economy

Table 8 presents the parameter values for the counterfacutal economy which is Canada. The share of non-housing consumption parameter γ for Canada is 0.53 to match the average housing consumption share over the sample period (23.0%), and the LTV ratio m is set to 0.9 reflecting the average loan-to-value ratio for mortgage in Canada. Homeownership rate parameter ω is also larger for Canada, which is 0.69. More importantly, the key differences in calibrated parameter compared to the baseline calibration for South Korea are on the intratemporal elasticity of substitution parameter η, the subjective discount factor β, and the rental price adjustment parameter τ. As I mentioned above, η for a rich country is larger than that for an emerging country, so I set 0.75. β

[25]The rigorous comparison would be possible if we consider the model with occasionally binding borrowing constraint and high frequency of binding constraint for an emerging economy and low frequency for an advanced economy. However, there are computationally challenging parts to induce the difference in exogenous frequency in the model with occasionally binding borrowing constraint. So this paper leaves it as a room for future research.

Table 8: Calibration for Counterfactual Economy (Canada)

Parameter		Value
Share of non-housing consumption	γ	0.53
Intratemporal elasticity of substitution	η	0.75
Steady state interest rate	r^*	0.01
Subjective discount factor	β	0.99
Housing depreciation rate	δ	0.0025
Loan-to-value ratio	m	0.9
Homeowner proportion	ω	0.69
Interest rate premium adjustment	ψ	0.000742
Rental price adjustment	τ	12,250
Persistence of house prices	ρ_q	0.3033
Persistence of endowment	ρ_y	0.5871
Standard deviation of innovation to house price shock	σ_q	0.0220
Standard deviation of innovation to endowment shock	σ_y	0.0067

is set to 0.99 to satisfy the condition of $\beta(1 + r^*) = 1$ which is necessary for the model without the borrowing constraint. Next, τ is set to match the ratio of rent volatility to house price volatility in Canada, which is 0.39. Finally, the parameters for shock processes are estimated using Canadian data for house prices and GDP.

5.2 Results for Counterfactual Economy

The first two columns of Table 9 come from Table 5 in Section 4.2.1. The first column shows the quarterly business cycle moments in South Korea, and the second one is the moments yielded by the baseline model under the baseline calibration. As we discussed, the baseline model successfully captures the actual data well. In contrast, the model for counterfacutal economy without a collateral constraint (the fourth column under the heading of "CF 1") does not match all moments observed in the Canadian economy

Table 9: Selected Second Moments: Korea vs. Canada

	Korea[1]	**Baseline**[2]	**Canada**[3]	**CF 1**[4]	**CF 2**[5]
$\frac{\sigma_C}{\sigma_Y}$	1.21	1.37	1.00	1.00	0.88
$\frac{\sigma_{HC}}{\sigma_Y}$	1.65	1.78	1.10	4.65	4.52
$\frac{\sigma_{NHC}}{\sigma_Y}$	1.37	1.39	1.12	0.10	1.10
σ_Y	1.65	2.04	0.81	20.85	3.05
σ_q	2.51	2.49	2.25	2.31	2.31
σ_ρ	1.37	1.36	0.87	0.90	63.91

[1] QoQ growth rate, South Korea, 1970 Q1-2016 Q2
[2] Under baseline calibration (Table 3)
[3] QoQ growth rate, Canada, 1970 Q1-2016 Q2
[4] Counterfactual 1: Under counterfactual calibration (Table 8)
[5] Counterfactual 2: Under counterfactual calibration (Table 8) with floating rental prices ($\tau = 0$)

(the third column under the heading of "Canada"). While the approximation of the counterfactual model successfully generates the non-excessive total consumption as we observe in Canadian data (1.00 and 1.00, respectively), there are huge consumption and income fluctuation in the theoretical world, as $\sigma_Y = 20.85$ indicates. Moreover, there is much more enormous volatility in housing consumption, even though the rental price volatility is suppressed by a rent adjustment mechanism. The main reason behind these results is that the housing stock or the amount of housing services is significantly volatile in the economy without a borrowing constraint. Since homeowners can buy and sell housing as much as she wants given exogenous house prices, the volatility of housing stock becomes excessive. Note that the relative non-housing consumption volatility is quite low, $\sigma_{NHC}/\sigma_Y = 0.10$. It is because the rental price or the relative price of non-housing consumption, ρ, is sticky near the steady state value. In fact, if the rental prices are floating (or, the adjustment parameter $\tau = 0$), the relative price of non-housing consumption and housing consumption plays its role; it makes the non-housing consumption volatile and smooths the housing service consumption, as the fifth column of Table 9 under the heading of "CF 2" presents. However, there is still a problem of higher housing stock volatility and the following higher income volatility.

The main takeaway from the counterfacutal analysis is two-fold. First, the collateral constraint and its effect is essential in generating excessiveness in volatility of total consumption given house price volatility. Without the collateral effect, there is no excess consumption volatility even if the house price volatility is sufficiently big as in the case of Canada. Therefore, this paper argues that the effect from the housing collateral constraint should be stronger in emerging economies. Second, the finding of lower housing consumption volatility observed in rich countries is not explained by the simple variation of the baseline model of this paper. As housing consumption is measured by multiplying the amount of housing stock by rental prices, the highly volatile housing stock coming from a model without a borrowing constraint inherently leads to the excessive housing consumption volatility even though the rental prices are sufficiently sticky. Note that, however, the baseline model with a borrowing constraint can yield the lower housing consumption volatility for rich countries with a higher rental adjustment parameter if it sacrifices the non-excessive consumption volatility.[26]

6 Conclusion

With the aim of contributing to the literature explaining excess consumption volatility observed in emerging economies, this paper suggests a new angle regarding house prices. The importance of house prices in understanding a consumption fluctuation in one country should not be neglected because the share of housing service consumption is substantial in household expenditure, and a household's decision-making procedure for housing investment is strongly linked with consumption. Therefore, the stylized fact of higher house price volatility in emerging countries, which this paper suggests, is worth considering as a possible source of explanation for an excess consumption volatility puzzle. As I discussed through the data findings and theoretical model framework, high house price volatility in emerging countries leads to excess volatility in total consumption through both the collateral credit channel and the rental price pass-through.

[26]The baseline model under the counterfacutal calibration for Canada generates 4.28 for σ_C/σ_Y, 4.49 for σ_{HC}/σ_Y, and 4.91 for σ_{NHC}/σ_Y. So, the ratio of σ_{HC}/σ_{NHC} is less than one. However, there is a hugely excessive volatility in total consumption due to a higher LTV ratio, $m = 0.9$, and a higher homeownership rate, $\omega = 0.69$, in Canada.

The housing collateral effect explains why both non-housing consumption and housing service consumption fluctuated in response to changes in house prices through changes in borrowing capacity, which is related to the value of a house as collateral. The rental price pass-through depends on a positive relationship between house price and housing rental price, which explains higher housing consumption volatility in emerging countries. Thus, house price fluctuation affects higher total consumption volatility through higher housing consumption volatility. To conclude, higher house price volatility in emerging countries leads to diverse aspects in these countries even if this paper focuses on its relationship with relative consumption volatility. In particular, the house price would be strongly related to wealth inequality, or wealth redistribution, in emerging countries. The link from house prices to current account is another interesting issue regarding emerging countries with house prices. My hope is that this paper will spark interest in house price volatility in emerging countries.

References

Aguiar, M., Gopinath, G. 2007. Emerging market business cycles: The cycle is the trend. *Journal of Political Economy*, 115 (1), 69–102.

Alvarez-Parra, F., Brandao-Marques, L., Toledo, M. 2013. Durable goods, financial frictions, and business cycles in emerging economies. *Journal of Monetary Economics*, 60, 720–736.

Andrés, J., Arce, Ó., Thomas, C. 2017. Structural reforms in a debt overhang. *Journal of Monetary Economics*, 88, 15–34.

Aoki, K., Proudman, J., Vlieghe, G. 2004. House prices, consumption, and monetary policy: A financial accelerator approach. *Journal of Financial Intermediation*, 13 (4), 414–435, 10.1016/j.jfi.2004.06.003.

Badev, A., Beck, T., Vado, L., Walley, S. 2014. Housing finance across countries: New data and analysis. *World Bank Policy Research Working Paper Series 6756*.

Berger, D., Guerrieri, V., Lorenzoni, G., Vavra, J. 2018. House prices and consumer spending. *The Review of Economic Studies*, 85 (3), 1502–1542.

Calza, A., Monacelli, T., Stracca, L. 2013. Housing finance and monetary policy. *Journal of the European Economic Association*, 11 (S1), 101–122.

Cesa-Bianchi, A., Cespedes, L. F., Rebucci, A. 2015. Global liquidity, house prices, and the macroeconomy: Evidence from advanced and emerging economies. *Journal of Money, Credit and Banking*, 47 (1), 301–335.

Davidoff, T., Yoshida, J. 2013. Estimating consumption substitution between housing and non-housing goods using macro data.

Davis, M. A., Martin, R. F. 2009. Housing, home production, and the equity- and value-premium puzzles. *Journal of Housing Economics*, 18 (2), 81–91, 10.1016/j.jhe.2009.04.006.

Flavin, M., Nakagawa, S. 2008. A model of housing in the presence of adjustment costs: A structural interpretation of habit persistence. *American Economic Review*, 98 (1), 474–495, 10.1257/aer.98.1.474.

Funke, M., Paetz, M. 2013. Housing prices and the business cycle: An empirical application to hong kong. *Journal of Housing Economics*, 22 (1), 62–76, 10.1016/j.jhe.2012.11.001.

Garcia-Cicco, J., Pancrazi, R., Uribe, M. 2010. Real business cycles in emerging countries?. *American Economic Review*, 100, 2510–2531.

Genesove, D. 2003. The nominal rigidity of apartment rents. *Review of Economics and Statistics*, 85 (4), 844–853, 10.1162/003465303772815763.

Guerrieri, L., Iacoviello, M. 2015. Occbin: A toolkit for solving dynamic models with occasionally binding constraints easily. *Journal of Monetary Economics*, 70, 22–38, 10.1016/j.jmoneco.2014.08.005.

Iacoviello, M. 2005. House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review*, 95 (3), 739–764.

Iacoviello, M., Neri, S. 2010. Housing market spillovers: Evidence from an estimated DSGE model. *American Economic Journal: Macroeconomics*, 2 (2), 125–164, 10.1257/mac.2.2.125.

Kaplan, G., Mitman, K., Violante, G. 2017. The housing boom and bust: Model meets evidence. Technical report, 10.3386/w23694.

Knoll, K., Schularick, M., Steger, T. 2017. No price like home: Global house prices, 1870-2012. *American Economic Review*, 197 (2), 331–353.

Li, W., Liu, H., Yang, F., Yao, R. 2016. Housing over time and over the life cycle: A structural estimation. *International Economic Review*, 57 (4), 1237–1260.

Li, W., Yao, R. 2007. The life-cycle effects of house price changes. *Journal of Money, Credit and banking*, 39 (6), 1375–1409.

Mack, A., Martinez-Garcia, E. 2011. A cross-country quarterly database of real house prices: A methodological note. *Federal Reserve Bank of Dallas Globalization and Monetary Policy Institute Working Paper No. 99.*

Neumeyer, P. A., Perri, F. 2005. Business cycles in emerging economies: The role of interest rates. *Journal of Monetary Economics*, 52, 345–380.

Piazzesi, M., Schneider, M., Tuzel, S. 2007. Housing, consumption and asset pricing. *Journal of Financial Economics*, 83 (3), 531–569, 10.1016/j.jfineco.2006.01.006.

Schmitt-Grohé, S., Uribe, M. 2003. Closing small open economy models. *Journal of International Economics*, 61 (1), 163–185, 10.1016/s0022-1996(02)00056-9.

——— , 2017. *Open Economy Macroeconomics*: Princeton University Press, 1-25.

Shin, W. 2020. Housing and consumption volatility.

Sommer, K., Sullivan, P., Verbrugge, R. 2013. The equilibrium effect of fundamentals on house prices and rents. *Journal of Monetary Economics*, 60 (7), 854–870, 10.1016/j.jmoneco.2013.04.017.

Song, I. H. 2011. *Essays on House Prices and Consumption* Ph.D. dissertation, The Ohio State University.

——— , 2012. House prices and monetary policy: Focus on elasticity of intra-temporal substitution between housing and consumption. *KDI Policy Study*, 10.

Stokey, N. L. 2009. Moving costs, nondurable consumption and portfolio choice. *Journal of Economic Theory*, 144 (6), 2419–2439, 10.1016/j.jet.2009.10.008.

Sun, X., Tsang, K. P. 2017. What drives the owner-occupied and rental housing markets? evidence from an estimated dsge model. *Journal of Money, Credit and Banking*, 49 (2-3), 443–468, 10.1111/jmcb.12385.

Uribe, M., Yue, V. Z. 2006. Country spreads and emerging countries: Who drives whom?. *Journal of International Economics*, 69, 6–36.

Verbrugge, R. J., Gallin, J. 2017. A theory of sticky rents: Search and bargaining with incomplete information. , 10.26509/frbc-wp-201705.

Yang, F. 2009. Consumption over the life cycle: How different is housing?. *Review of Economic Dynamics*, 12 (3), 423–443.

A Equilibrium Conditions and the Steady States

An equilibrium in the model is then a set of processes of $\{c_t^O,\, c_t^R,\, c_t,\, h_t,\, s_t^O,\, s_t^R,\, d_{t+1},\, X_t^O$ $,X_t^R,\, \lambda_t^O,\, \lambda_t^R,\, \mu_t,\, \rho_t,\, r_t,\, TC_t,\, HC_t,\, NHC_t,\, H_t,\, D_{t+1},\, Y_t\}_{t=0}^{\infty}$ satisfying (2) to (10), (12) to (15), (17), (18), (19), (21) to (27), given the processes $\{q_t,\, y_t\}_{t=0}^{\infty}$ and the initial condition $\{h_{-1},\, d_0\}$. Therefore, there are 20 endogenous variables, and we need 20 equations to determine equilibrium. Also, we need 2 equations which specify exogenous variable processes.

$$\gamma\left(X_t^O\right)^{\frac{1-\eta}{\eta}}\left(c_t^O\right)^{-\frac{1}{\eta}} = \lambda_t^O \tag{B.1}$$

$$\gamma\left(X_t^R\right)^{\frac{1-\eta}{\eta}}\left(c_t^R\right)^{-\frac{1}{\eta}} = \lambda_t^R \tag{B.2}$$

$$c_t = \omega c_t^O + (1-\omega)c_t^R \tag{B.3}$$

$$\rho_t = \frac{1-\gamma}{\gamma}\left(\frac{c_t}{\omega h_t}\right)^{\frac{1}{\eta}} \tag{B.4}$$

$$s_t^R = \frac{\omega c_t^R}{c_t} h_t \tag{B.5}$$

$$\omega s_t^O + (1-\omega)s_t^R = \omega h_t \tag{B.6}$$

$$\lambda_t^O\left(\frac{1}{1+r_t} - \mu_t\right) = \beta E_t \lambda_{t+1}^O \tag{B.7}$$

$$\lambda_t^O q_t = \lambda_t^O \rho_t + \beta(1-\delta)E_t[\lambda_{t+1}^O q_{t+1}] + m\mu_t\lambda_t^O q_t \tag{B.8}$$

$$X_t^O \equiv \left[\gamma\left(c_t^O\right)^{\frac{\eta-1}{\eta}} + (1-\gamma)\left(s_t^O\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{B.9}$$

$$X_t^R \equiv \left[\gamma\left(c_t^R\right)^{\frac{\eta-1}{\eta}} + (1-\gamma)\left(s_t^R\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{B.10}$$

$$c_t^O + \rho_t s_t^O + q_t[h_t - (1-\delta)h_{t-1}] + d_t = y_t + \frac{d_{t+1}}{1+r_t} + \rho_t h_t \tag{B.11}$$

$$d_{t+1} = mq_t h_t \tag{B.12}$$

$$c_t^R + \rho_t s_t^R = y_t \tag{B.13}$$

$$r_t = r^* + \psi \left(e^{\omega d_{t+1} - \bar{d}} - 1 \right) \tag{B.14}$$

$$HC_t = \rho_t \omega h_t \tag{B.15}$$

$$NHC_t = c_t \tag{B.16}$$

$$TC_t = HC_t + NHC_t = c_t + \rho_t \omega h_t \tag{B.17}$$

$$H_t = \omega h_t \tag{B.18}$$

$$D_{t+1} = \omega d_{t+1} \tag{B.19}$$

$$Y_t = y_t + \rho_t \omega h_t \tag{B.20}$$

$$\ln q_{t+1} = \rho_q \ln q_t + \sigma_q \varepsilon_{q,t+1} \tag{B.21}$$

$$\ln y_{t+1} = \rho_y \ln y_t + \sigma_y \varepsilon_{y,t+1} \tag{B.22}$$

Equation (B.1) and (B.2) are FOCs with respect to each agent's non-housing consumption, equation (B.3) is a definition equation for total non-housing consumption, equation (B.4) is the equilibrium rental price, equation (B.5) is the equilibrium rental service amount, equation (B.6) is the rental market clearing condition, equation (B.7) is the Euler equation earned by differentiating with respect to d_{t+1}, equation (B.8) is FOC with respect to housing purchase decision by homeowner, equation (B.9) and (B.10) are CES aggregators of non-housing consumption and housing service equation for each agent group. Equation (B.11) and (B.12) are a homeowner's resource constraint and a borrowing constraint, respectively. Equation (B.13) is a renter's budget constraint. Equation (B.14) is EDEIR. Equation (B.15) to (B.20) represent the definition of each aggregate variable. Equation (B.21) and (B.22) are exogenous shock processes for house price and endowment, respectively.

The Steady States of the Economy

First of all, r^* is the steady state level of interest rate, by definition.
From (B.21) and (B.22),

$$q^* = 1$$

$$y^* = 1$$

From (B.7),

$$\mu^* = \frac{1}{1+r^*} - \beta$$

Since $\beta(1+r^*) < 1$ is assumed, the shadow price parameter μ^* at the steady state is greater than zero. As we know μ^*, we can earn the steady state level of rental price, ρ^*, from (B.8)

$$\rho^* = 1 - \beta(1-\delta) - m\mu^*$$

Next, from (B.12),

$$d^* = mh^* \tag{B.i}$$

Note that the parameter for the steady state level of aggregate debt, $\bar{d}$ must be equal to ωd^* by (B.14). Moving on to (B.4), we can earn the expression for the term ωh^*

$$\omega h^* = \left(\frac{\gamma}{1-\gamma}\rho^*\right)^{-\eta} c^*$$

Using the above expression, s_R^* can be re-written from (B.5) by

$$s_R^* = \left(\frac{1-\gamma}{\gamma}\right)^{\eta} \rho^{*-\eta} c_R^* \tag{B.ii}$$

By plugging (B.ii) into (B.13), we get the steady state level of renter's non-housing consumption, c_R^*

$$c_R^* = \frac{1}{1 + \left(\frac{1-\gamma}{\gamma}\right)^{\eta} \rho^{*1-\eta}} \tag{B.iii}$$

We earn the expression for c_O^* by rearranging (B.3) using (B.4)

$$c_O^* = \left(\frac{\gamma}{1-\gamma}\right)^\eta \rho^{*\eta} h^* - \frac{1-\omega}{\omega} c_R^* \tag{B.iv}$$

Also, we earn the expression for s_O^* by rearranging (B.6) using (B.ii)

$$s_O^* = h^* - \frac{1-\omega}{\omega}\left(\frac{1-\gamma}{\gamma}\right)^\eta \rho^{*-\eta} c_R^* \tag{B.v}$$

By putting (B.i), (B.iii), (B.iv), and (B.v) into (B.11)

$$h^* = \frac{1}{\omega}\left[\left(\frac{\gamma}{1-\gamma}\right)^\eta \rho^{*\eta} + \delta + \frac{mr^*}{1+r^*}\right]^{-1}$$

Therefore, we can get a set of constant sequences $c_t^O = c_O^* > 0$, $c_t^R = c_R^* > 0$, $c_t = c^* > 0$, $h_{t-1} = h_t = h^* > 0$, $s_t^O = s_O^* > 0$, $s_t^R = s_R^* > 0$, $d_t = d_{t+1} = d^* > 0$, $X_t^O = X_O^* > 0$, $X_t^R = X_R^* > 0$, $\lambda_t^O = \lambda_O^* > 0$, $\lambda_t^R = \lambda_R^* > 0$, $\mu_t = \mu^* > 0$, $\rho_t = \rho^*$, $r_t = r^*$, $TC_t = TC^* > 0$, $HC_t = HC^* > 0$, $NHC_t = NHC^* > 0$, $H_t = H^* > 0$, $D_{t+1} = D^* > 0$, and $Y_t = Y^* > 0$. The multiplier for the collateral constraint should be positive since the constraint is binding at the steady state. House price and endowment are also constant at the steady state, $q_t = q^*$, and $y_t = y^*$.

$$q^* = 1 \quad \text{and} \quad y^* = 1$$

$$d^* = mh^*$$

$$\mu^* = \frac{1}{1+r^*} - \beta \quad > 0$$

$$\rho^* = 1 - \beta(1-\delta) - m\mu^* \quad > 0$$

$$h^* = \frac{1}{\omega}\left[\left(\frac{\gamma}{1-\gamma}\right)^\eta \rho^{*\eta} + \delta + \frac{mr^*}{1+r^*}\right]^{-1}$$

$$c_R^* = \frac{1}{1 + \left(\frac{1-\gamma}{\gamma}\right)^\eta \rho^{*1-\eta}} \quad > 0$$

$$c_O^* = \left(\frac{\gamma}{1-\gamma}\right)^{\eta} \rho^{*\eta} h^* - \frac{1-\omega}{\omega} c_R^* \quad > 0$$

$$c^* = \omega c_O^* + (1-\omega) c_R^*$$

$$s_O^* = h^* - \frac{1-\omega}{\omega} \left(\frac{1-\gamma}{\gamma}\right)^{\eta} \frac{c_R^*}{\rho^{*\eta}} \quad \text{and} \quad s_R^* = \left(\frac{1-\gamma}{\gamma}\right)^{\eta} \frac{c_R^*}{\rho^{*\eta}}$$

$$X_O^* = \left[\gamma (c_O^*)^{\frac{\eta-1}{\eta}} + (1-\gamma) (s_O^*)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \quad \text{and} \quad X_R^* = \left[\gamma (c_R^*)^{\frac{\eta-1}{\eta}} + (1-\gamma) (s_R^*)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$

$$\lambda_O^* = \gamma \left(X_O^*\right)^{\frac{1-\eta}{\eta}} \left(c_O^*\right)^{-\frac{1}{\eta}} \quad \text{and} \quad \lambda_R^* = \gamma \left(X_R^*\right)^{\frac{1-\eta}{\eta}} \left(c_R^*\right)^{-\frac{1}{\eta}}$$

$$HC^* = \rho^* \omega h^* \qquad NHC^* = c^* \qquad TC^* = c^* + \rho^* \omega h^*$$

$$H^* = \omega h^* \qquad D^* = \omega d^* \qquad Y^* = 1 + \rho^* \omega h^*$$

Figure 1: House Price Volatility and Rent Volatility

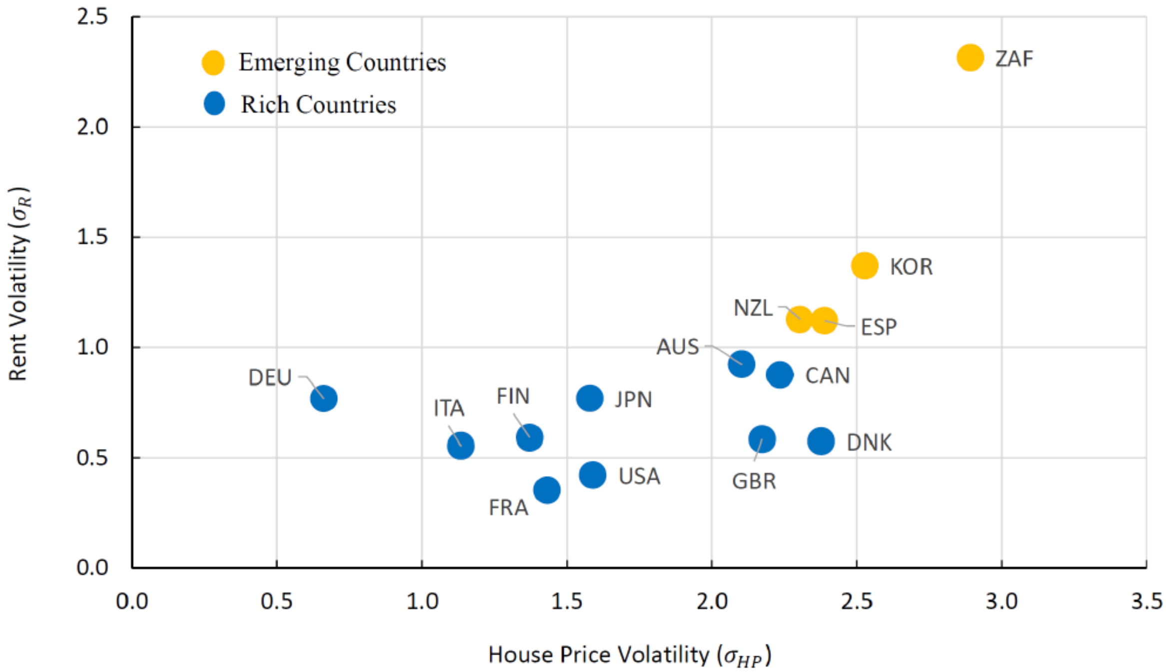

Figure 2: Impulse Responses to House Price Shock (Aggregate Level)

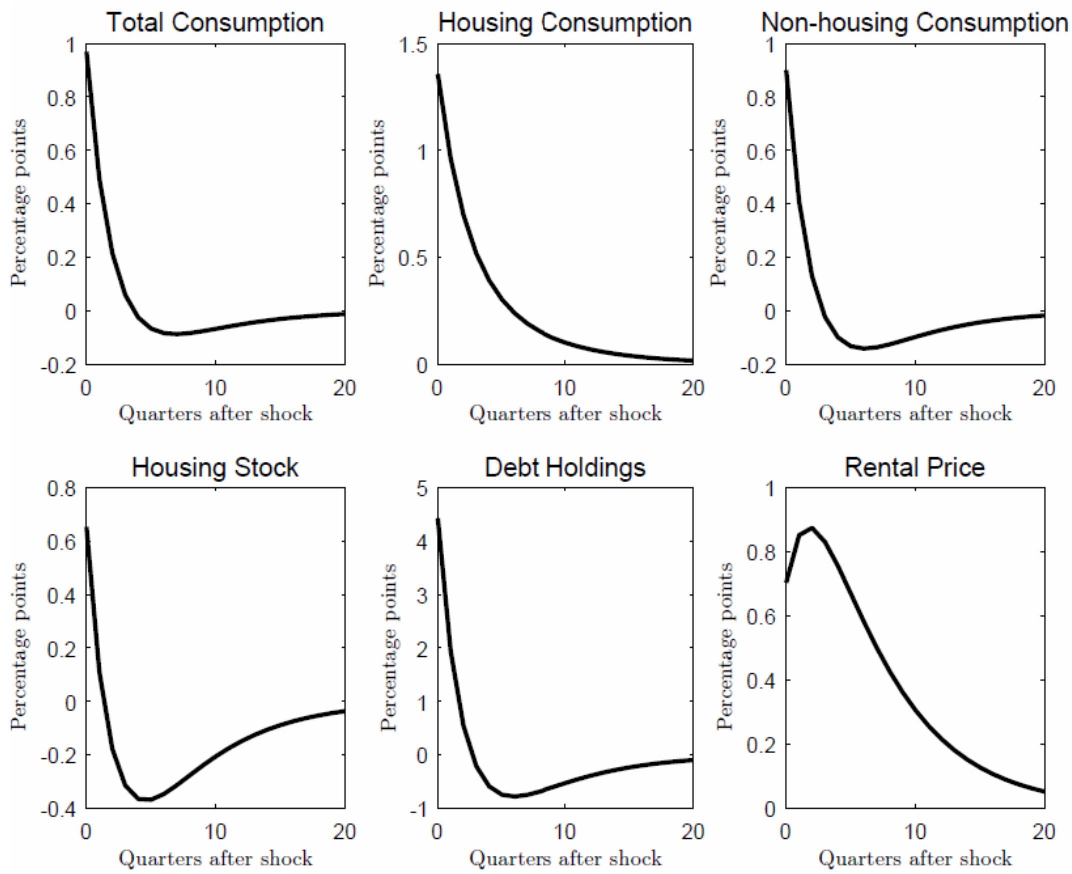

Figure 3: Impulse Responses to House Price Shock (Agent Level)

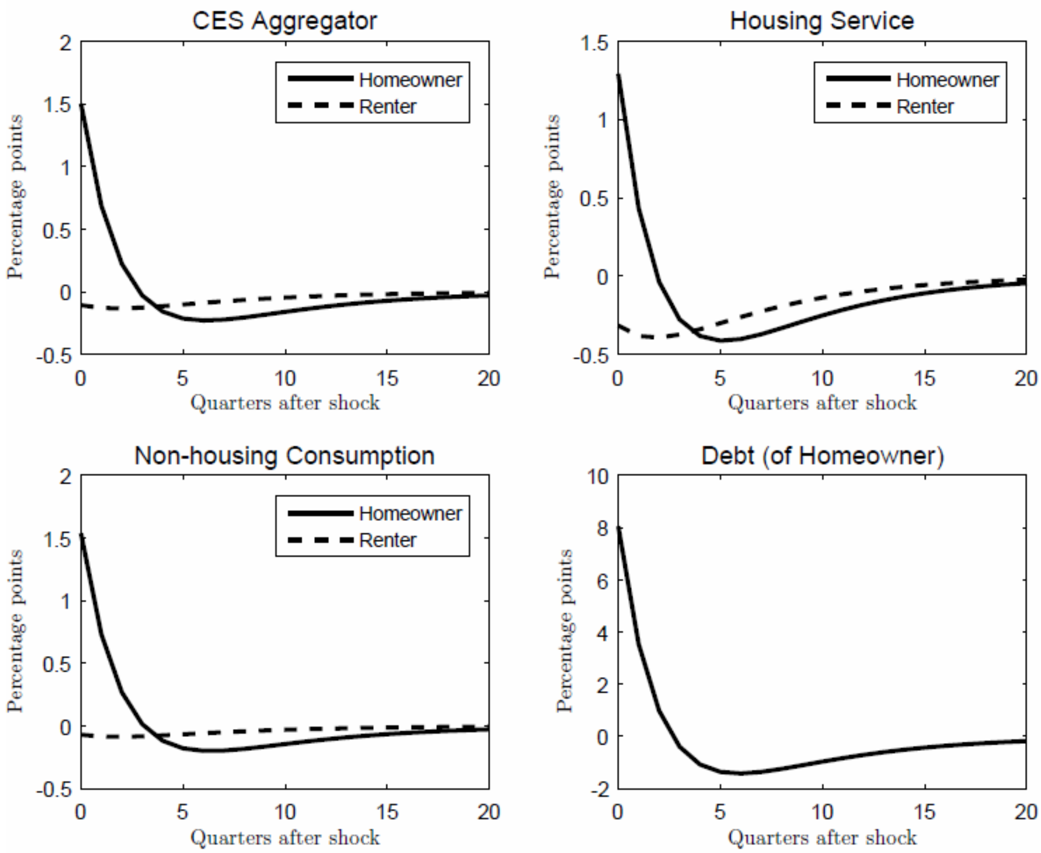

Figure 4: Impulse Responses to Endowment Shock (Aggregate Level)

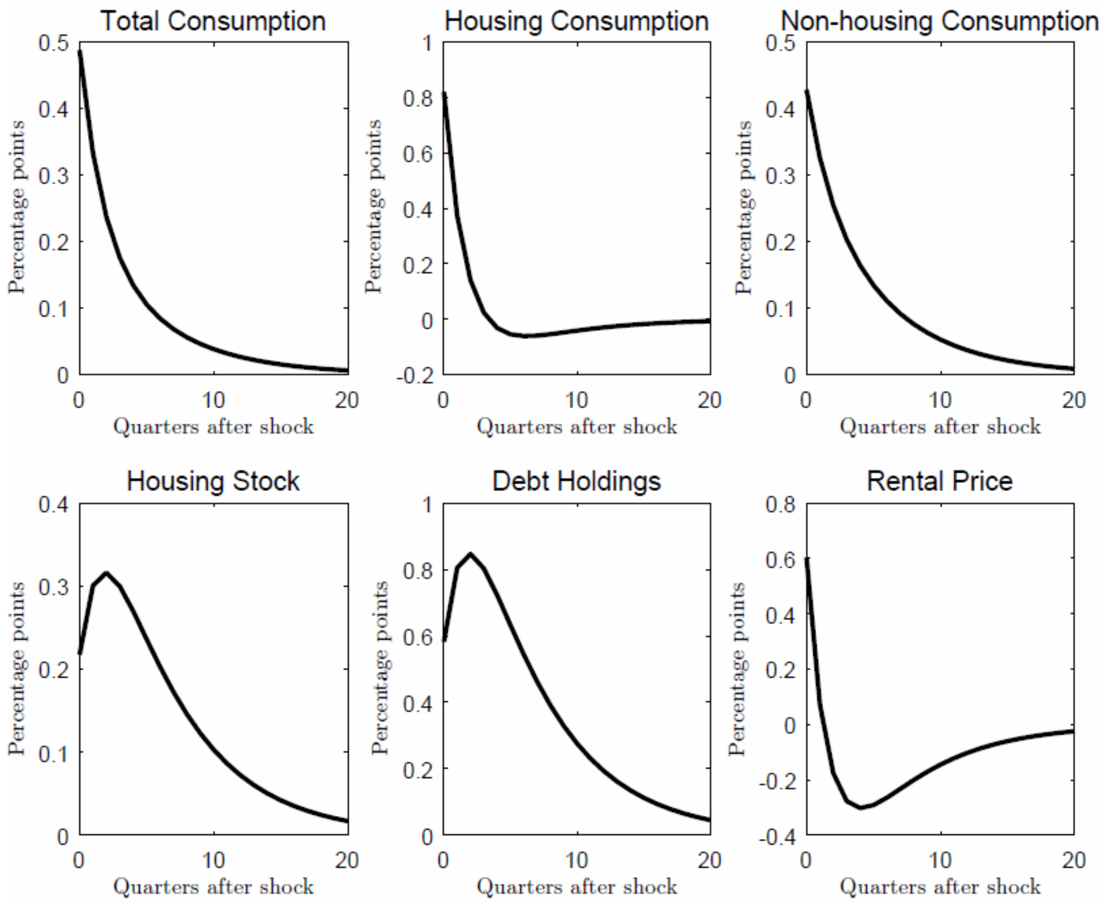

Figure 5: Impulse Responses to Endowment Shock (Agent Level)

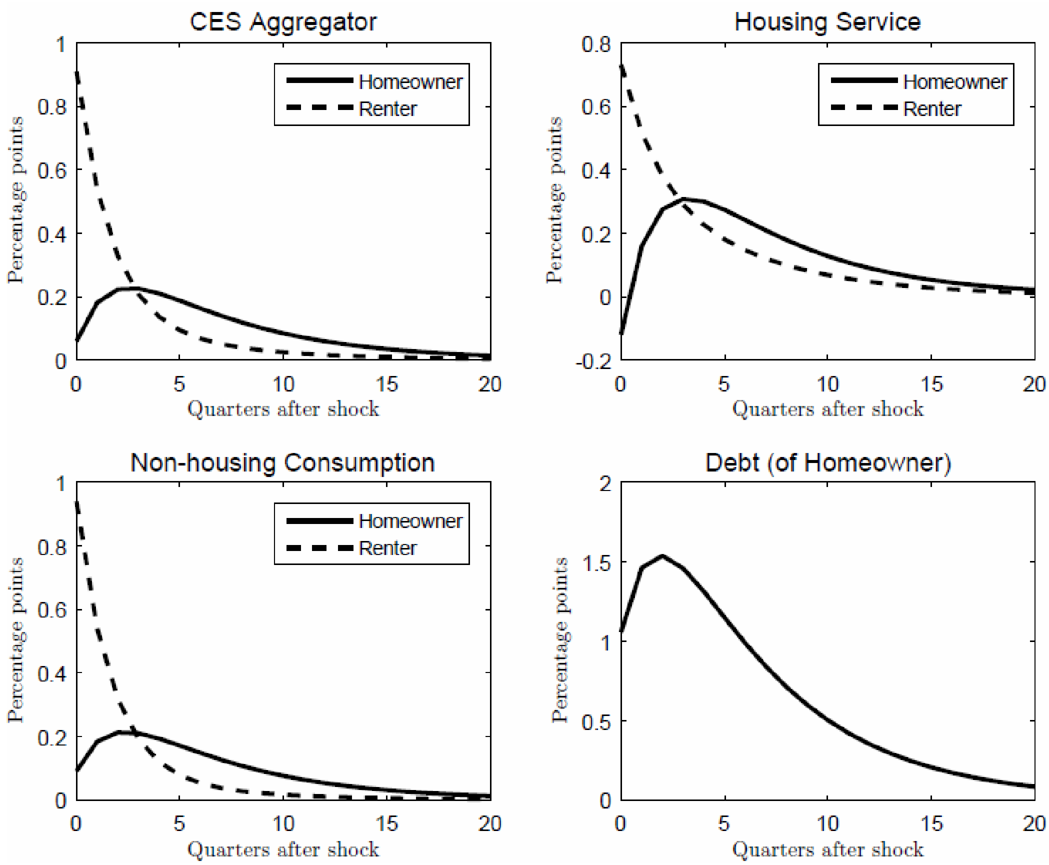

Figure 6: House Price and Relative Consumption Volatility

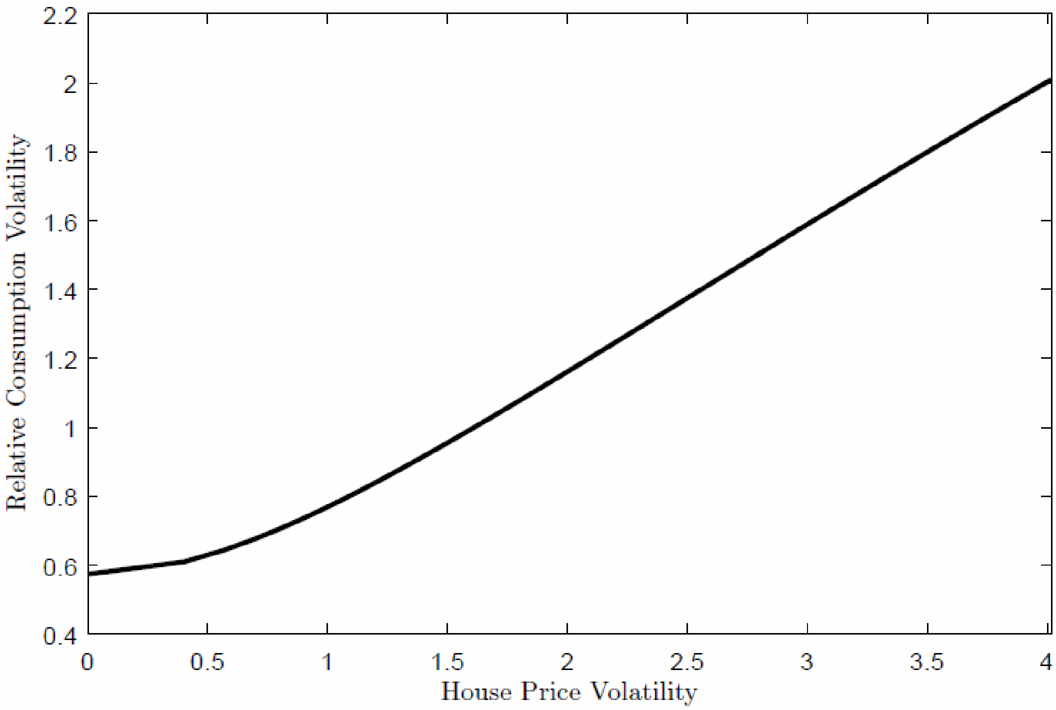

Figure 7: Cross-Country Observation: σ_{HP} and σ_C/σ_Y

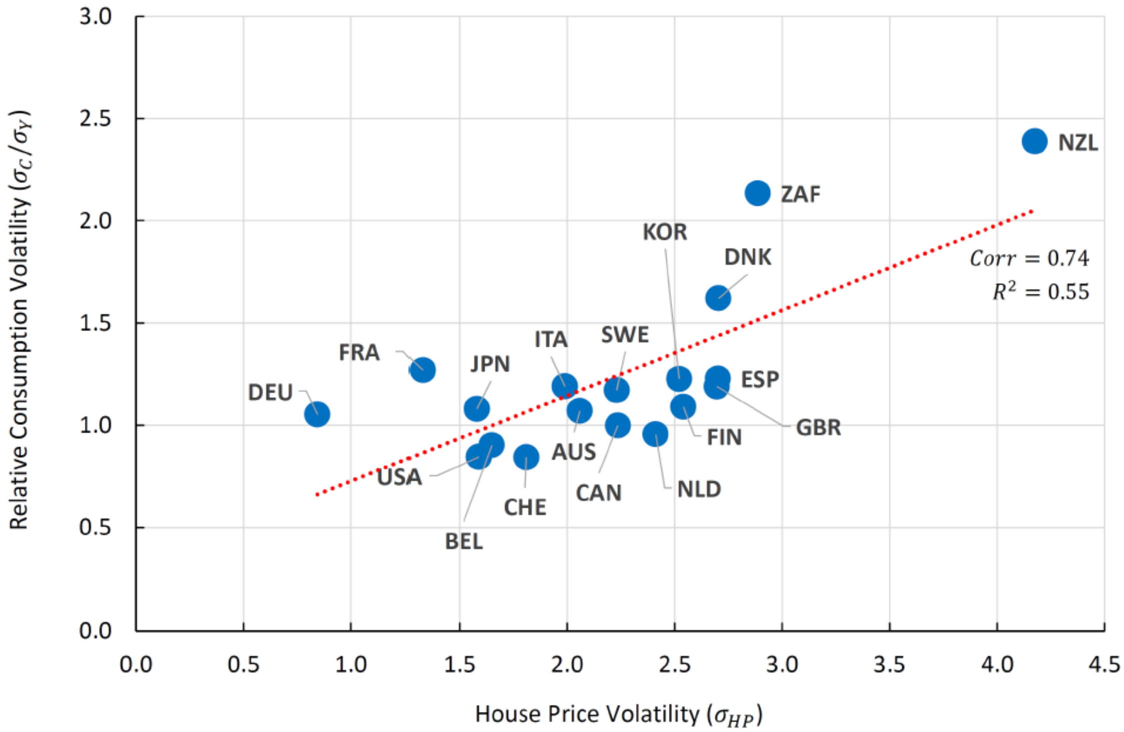

Figure 8: Relative Consumption Volatility without Collateral Constraint

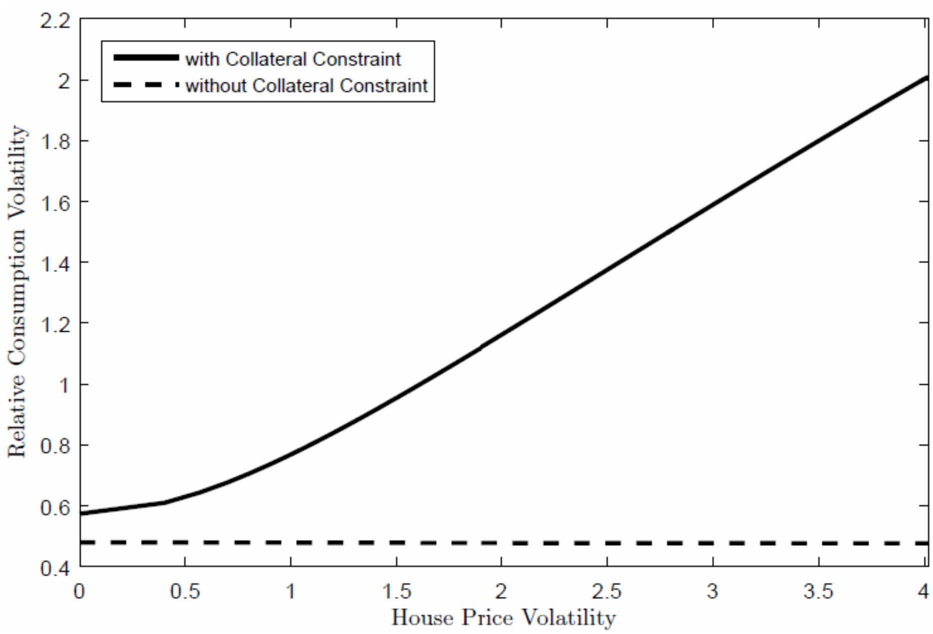

Figure 9: Homeownership Rate and Consumption Volatility *(Model)*

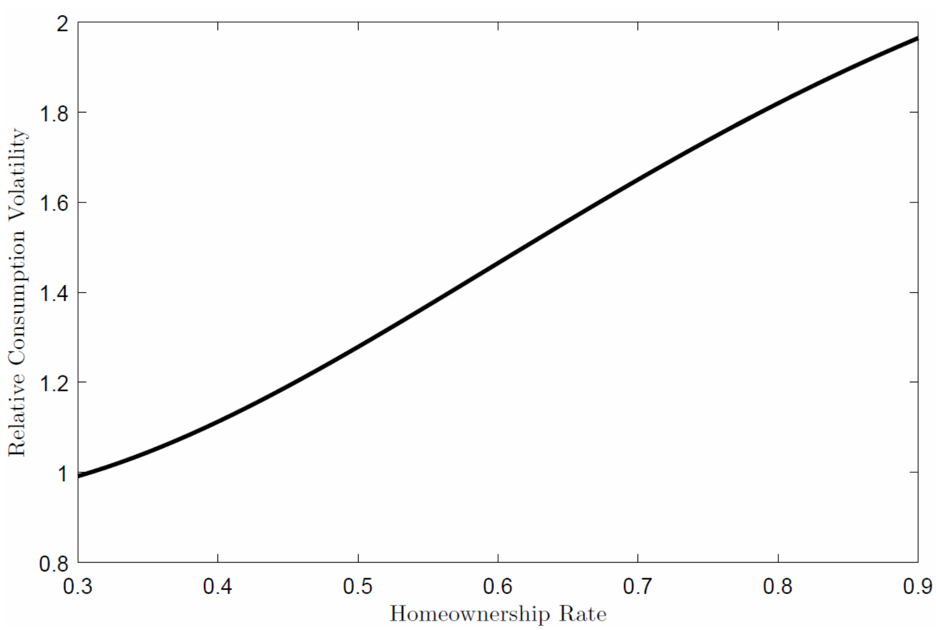

Figure 10: Homeownership Rate and Consumption Volatility *(Data)*

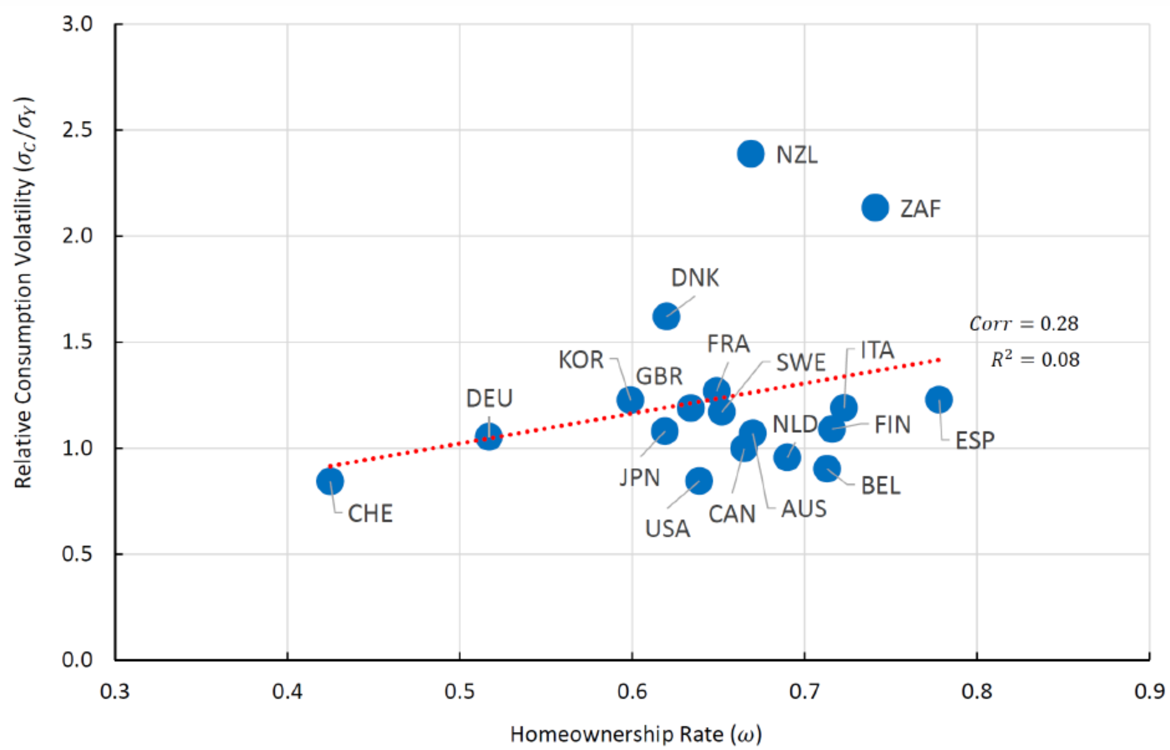

Figure 11: House Price and Rent Volatility

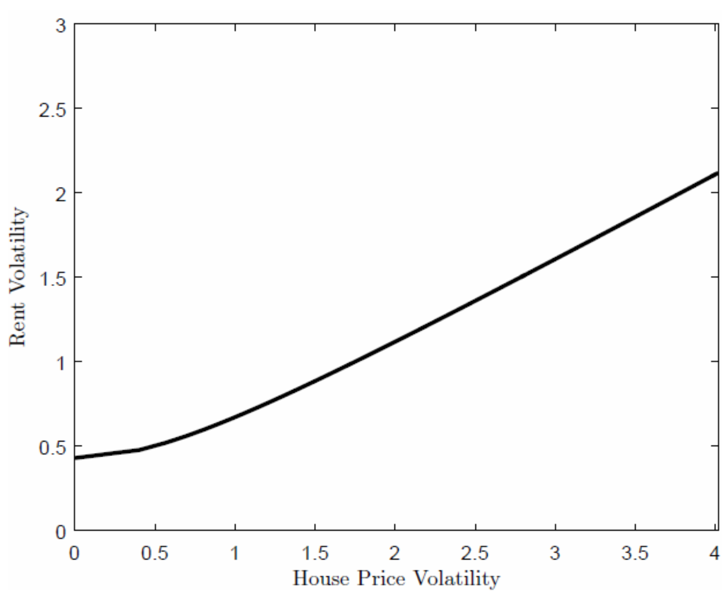

Figure 12: House Price and Disaggregated Consumption Volatilities