Household Borrowing Constraints and Residential Investment Dynamics*

Hashmat Khan†
Carleton University
& Ottawa-Carleton GSE

Jean-François Rouillard‡
Université de Sherbrooke
& GRÉDI

July 25, 2018

Abstract

It is well known that residential investment leads output in the US economy. The main contribution of our paper is to highlight the role of household borrowing constraints in accounting for this fact. We study the role of home-equity loans used to boost consumption as a channel that affects residential investment. We consider a multi-agent model where some home-owning households face borrowing constraints that reflect home-equity loans or refinancing constraints. We show that the severity of the households' borrowing constraints in an economy can generate this stylized fact of US residential investment dynamics. Interestingly, the model correctly predicts coincident residential investment dynamics in countries with less severe borrowing constraints. This prediction is borne out when the model is calibrated to French data.

Key words: Home-Equity Loans, Borrowing Constraints, Residential Investment, Business Cycles
JEL classification: E22, E32, R21, R31

*We thank two anonymous referees, the participants at the Rimini Conference in Economics and Finance 2016, the Annual Conferences of the Société canadienne de sciences économiques 2018, and of Canadian Economics Association 2018, and seminar participants at the Université de Sherbrooke.

†Corresponding Author. Professor in the Department of Economics, D891 Loeb, 1125 Colonel By Drive, Carleton University, Ottawa, Canada. *E-mail:* hashmat.khan@carleton.ca. Tel: +1.613.520.2600 (ext 1561).

‡Assistant Professor in the Department of Economics, Université de Sherbrooke, Sherbrooke, Canada. *E-mail:* j-f.rouillard@usherbrooke.ca.

1 Introduction

Residential investment in the housing sector has long been viewed as important for understanding fluctuations in US economic activity (Burns and Mitchell 1946).[1] Recently, Leamer (2008, 2015) has reemphasized this view by noting that the decline of cumulative residential investment in recessions accounts for about half of the overall decline in US Gross Domestic Product (GDP). He writes '*Of the components of GDP, residential investment offers by far the best early warning sign of an oncoming recession* (Leamer 2008). In this context, a well-known stylized fact is that US residential investment leads output over the business cycle.[2] The main contribution of this paper is to highlight the role of household borrowing constraints in accounting for this fact. In particular, we consider a model where home-equity loans are used to finance consumption and affect residential investment. In this environment, the severity of the borrowing constraint drives the lead of residential investment over output. Interestingly, the model correctly predicts coincident residential investment dynamics in countries with less severe borrowing constraints. This prediction is borne out when the model is calibrated to French data. Household borrowing constraints, therefore, provide an endogenous explanation for understanding residential investment dynamics.[3]

Our focus on borrowing constraints as the underlying force for understanding residential investment dynamics builds on the recent literature that shows that such constraints have both relevant and important business cycle implications. Iacoviello (2005), for example, highlights the importance of collateral for households and firms to amplify the responses to housing price shocks. Iacoviello and Neri (2010) also find that fluctuations in house prices affect the borrowing capacity that can explain aggregate fluctuations. Liu, Wang and Zha (2013) study the importance of land in the firms' collateral constraints and its business cycle effects. Justiniano, Primiceri and Tambalotti (2015) find that the boom in household debt that occur in 2000-2007 was transmitted through

[1] Residential investment refers to investment in residential structures such as new houses, apartment buildings, and other dwellings.

[2] This fact also applies to household investment which includes both residential investment and consumer durables. Fisher (2007) studies a separate stylized fact that household investment leads business investment over the business cycle in the US. In Fisher's model, however, residential investment is coincident with output.

[3] Our main focus is to explain the quantity dimension of residential investment. For asset pricing aspects of housing, we refer the reader to section 18 of Piazzesi and Schneider (2016).

households collateral constraints directly from a change in house prices. Recently, using microdata, Aladangady (2017) finds that the borrowing constraint channel is key to understanding the reaction of consumption to changes in housing wealth.

We explicitly explore the role of home-equity loans to finance consumption. We consider a multi-agent model with homeownership, where some home-owners face borrowing constraints that reflect home equity loans or refinancing constraints. To model this scenario we use the Iacoviello (2005) framework that builds on Kiyotaki and Moore (1997) where homeowners facing borrowing constraints have a smaller discount factor relative to those who do not. In the baseline version of the model, business cycles are assumed to be driven by a standard unanticipated Total Factor Productivity (TFP) shock referred to as the technology shock.

We show that residential investment leads output by one quarter when the fraction of households who face borrowing constraints is matched to US data. The intuition for this result is as follows: there are two incentives that drive the housing investment decision. First is that housing services directly enter the households' utility function. Since the positive TFP shock induces a wealth effect, they decide to spend more on houses. However, this positive wealth effect alone is not sufficient to produce the leading pattern. Second is that a share of households are borrowing-constrained. The accumulation of the housing stock, therefore, allows them to borrow more contemporaneously and in future periods, so that they are also able to consume greater quantities of the non-durable good. The household borrowing constraint and its effect on residential investment are, therefore, important for understanding the lead of residential investment over output.

We find that the severity of the borrowing constraint measured as the share of households facing such a constraint determines whether or not residential investment leads output. In some eurozone countries, residential investment is coincident with output (Kydland, Rupert and Sustek (2016)). Our model is consistent with this fact. In eurozone countries, the share of households facing borrowing constraints is, on average, smaller relative to the US, which according to the model implies that residential investment is coincident with the cycle. One piece of corroborative evidence at the aggregate level is the high household-debt-to-GDP ratio in the US relative to the eurozone. Data from the Bank for International Settlements show that US average household debt over the 1999 to 2015 time-period corresponds to 84.05 percent of annualized GDP, whereas for the

eurozone the same ratio is 56.35 percent.[4] We calibrate the model to French data and show that the model generates coincident residential investment dynamics.

The rest of the paper is organized as follows. Section 2 presents the relation of our paper to the literature. Section 3 presents the model. Section 4 describes the calibration of parameters. Section 5 presents the quantitative results. Section 6 presents sensitivity analysis. Finally, section 7 concludes.

2 Relation to the literature

Previous research that examined the stylized fact mentioned above has considered other mechanisms than ours with limited success.[5] Kydland, Rupert and Sustek (2016) present a model with long-term mortgage loans and multi-period time-to-build in residential construction to account for the lead of residential investment in the US versus coincident movement in eurozone countries. They model the loan structure as 'first mortgage' loans and abstract from the role of collateralized borrowing or refinancing loans against the home for consumption purposes. There are, however, two limitations that remain unaddressed. First is that since the 1980s US households increased their use of home equity loans and mortgage refinancing to cash out previously accumulated equity. As Campbell and Hercowitz (2005) note, the financial reforms of the early 1980s relaxed collateral constraints on household borrowing. Specifically, the federal government abandoned the New Deal regulatory system with the Monetary Control Act of 1980 and the Garn-St.Germain Act of 1982. These developments followed by sharp increases in debt-asset ratios reflecting the emergence of the subprime mortgage lending market, home-equity loans and mortgage refinancing activities. More recently, Gorea and Midrigan (2015) have pointed out that mortgage refinancing accounts for about one-third of the rise and fall in household spending during the 2001-2011 period in the US. Thus, home-equity loans and mortgage refinancing has been a salient feature of US housing market over the past three decades. Our model captures this development in a parsimonious way.

Second is that, for the time period we study relative to Kydland, Rupert and Sustek (2016),

[4] This difference might be due to cultural and institutional factors outside the scope of our model.

[5] The early literature on home production features studies that do not reproduce the lead in residential investment over the business cycle (see, for example, Benhabib, Rogerson and Wright (1991); Gomme, Kydland and Rupert (2001); Greenwood and Hercowitz (1991); McGrattan, Rogerson and Wright (1997)).

both residential investment and housing starts are in fact coincident in some European countries (for example, France and Belgium). This fact makes it difficult to justify the differences in time-to-build between US and eurozone countries.[6]

Our paper is also related to Ren and Yuan (2014) which attempts to explain why residential investment leads the cycle in the US, using a partial equilibrium model with collateral constraints, agent heterogeneity, and TFP news shocks. Their model, however, has the odd implication that agents prefer to purchase houses instead of consumption goods after a positive endowment shock. This is necessarily the case in their model because the mortgage interest rate is lower than the credit card rate, both of which are calibrated parameters. In actual economies, even though the mortgage rate is lower than the credit card rate, the use of credit card for consumer goods purchases is common place. Another aspect that is ignored in the partial equilibrium setting of Ren and Yuan (2014) is that they do not have the labour supply decision in the model. This assumption is not innocuous because TFP news shocks, which are essential to their explanation, can produce wealth effects on labour supply that mitigate business cycle comovements (Jaimovich and Rebelo (2009)). Unlike the model in Ren and Yuan (2014), we consider a general equilibrium framework.

3 The model

The model economy is populated by three categories of agents: impatient and patient households, and entrepreneurs. These agents are denoted by I, P, and E, respectively. The shares of these agents in the economy differ and are denoted as ω_I, ω_P, and ω_E, respectively. Agents are infinitely-lived and maximize a discounted sum of time-separable utilities. We assume that impatient households and entrepreneurs borrow from patient households (the lenders), therefore the discount factors of the two borrowing agents, θ_I and θ_E, are lower than the lenders' discount factor, β. The impatient households' loans are collateralized by the expected value of their stock of housing. Both types of households are employed by firms that produce non-durable goods and houses—a durable good. They derive utility from the consumption of non-durable goods and housing services. We assume that house developers operate in a perfectly competitive environment, and

[6]For the period 1974Q1-2006Q4 studied in Kydland, Rupert and Sustek (2016) housing starts leads the cycle in France. However, for the 1983Q1-2016Q4 period that we study, it is coincident.

that entrepreneurs undertake the production of non-durable goods. They also make non-residential and residential investments and face a collateral constraint. Specifically, their inter-period debt and working capital loans to cover the wage bill cannot exceed a fraction of their capital stock. In the appendix, we present a detailed description of the model.

3.1 Households

All impatient households face the same maximization problem which is the following:

$$\max E_0 \sum_{t=0}^{\infty} \theta_I^t \left(\ln \left(c_{It} - \zeta c_{It-1} \right) + \psi \ln h_{It} + \eta_I \ln \left(1 - \left(n_{Ict}^{1+\epsilon} + n_{Iht}^{1+\epsilon} \right)^{1/(1+\epsilon)} \right) \right) \tag{1}$$

subject to

$$c_{It} + (1+\tau_h) q_{ht} h_{It} - q_{ht}(1-\delta_h) h_{It-1} = b_{Ht} - R_{t-1} b_{Ht-1} + p_{lt} l_{It} + \sum_{i=c,h} w_{it} n_{Iit} - \tau_n \left(\sum_{i=c,h} w_{it} n_{Iit} - \tau_m r_{t-1} b_{Ht-1} \right) + \xi_{It}, \tag{2}$$

$$b_{Ht} \leq m_H E_t q_{ht+1} h_{It}. \tag{3}$$

First, note that variables c_{It}, h_{It}, n_{Ict}, n_{Iht}, b_{Ht}, l_{It}, and ξ_{It} are variables that are expressed per impatient household. Their period utility function is in logarithms and weighs their consumption of the non-durable good, c_{It}, their housing stock, h_{It}, and their hours worked in the production of non-durable goods, n_{Ict}, and houses, n_{Iht}. They have habits in consumption of non-durable goods measured by parameter ζ. We follow Horvath (2000) and Iacoviello and Neri (2010) and allow for an imperfect substitution of labour between sectors that is governed by parameter ϵ. A higher value of ϵ implies a decreased reallocation of hours worked by impatient households from one sector to another in response to wage differentials.

On the right-hand-side of their budget constraint, equation (2), impatient households have different sources of revenues: (i) they earn labour income that is taxed at rate τ_n, so that their total after-tax labour income is $(1-\tau_n) \sum_{i=c,h} w_{it} n_{Iit}$ where wages w_{it} are taken as given, (ii) they borrow b_{Ht} at the interest rate $R_t = 1 + r_t$, so that net borrowing is $b_{Ht} - R_{t-1} b_{Ht-1}$, (iii) they are endowed with one unit of land l_{It} that they sell to house developers at price p_{lt}, and (iii) they receive transfers from the government: ξ_{It}. We also assume that mortgage debt carries a tax advantage

such that a fraction τ_m of interest payments $r_{t-1}b_{Ht-1}$ can be deducted from taxable income. We consider one-period mortgages, as they are renegotiated every period. The left-hand-side consists of expenditures that these households have, (i) for the consumption of non-durable goods, and (ii) the accumulation of housing stock from which a fraction τ_h is taxed. The relative price of housing is q_{ht}, and housing depreciates at rate δ_h.

The second constraint, equation (3), is a collateral constraint. Specifically, the level of debt contracted every period cannot exceed a fraction m_H of the expected value of the households' stock of housing, *i.e.* $E_t q_{ht+1} h_{It}$. Since impatient households have a lower discount factor, this constraint is binding in the steady state. We consider small shocks and a sufficiently low discount factor so that it is also always binding in the neighborhood of the steady state.

The representative patient household's problem departs from the impatient households' problem as their higher discount factor makes it suboptimal for them to carry debt ($\beta > \theta_I$). However, the utility function of patient households takes the same form as is shown by the following equations:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln\left(c_{Pt} - \zeta c_{Pt-1}\right) + \psi \ln h_{Pt} + \eta_P \ln\left(1 - \left(n_{Pct}^{1+\epsilon} + n_{Pht}^{1+\epsilon}\right)^{1/(1+\epsilon)}\right)\right) \tag{4}$$

subject to

$$c_{Pt} + (1+\tau_h) q_{ht} h_{Pt} - q_{ht}(1-\delta_h) h_{Pt-1} = \frac{1}{\omega_P}\left(\omega_I\left(R_{t-1}b_{Ht-1} - b_{Ht}\right) + \omega_E\left(R_{t-1}b_{Kt-1} - b_{Kt}\right)\right) + (1-\tau_n)\sum_{i=c,h} w_{it} n_{Pit} + p_{lt} l_{Pt} + \xi_{Pt}. \tag{5}$$

Note that the variables with subscript P are the counterparts for patient households of variables described above for the impatient households. All variables are expressed per patient household. This category of agents are the savers in the economy as they lend to the impatient households, $\omega_I/\omega_P b_{Ht}$, and entrepreneurs, $\omega_E/\omega_P b_{Kt}$.

3.2 Entrepreneurs

The entrepreneurs maximize the following problem:

$$\max E_0 \sum_{t=0}^{\infty} \theta_E^t \ln\left(c_{Et} - \zeta c_{Et-1}\right) \tag{6}$$

subject to

$$c_{Et} + x_{ct} + x_{bt} + \frac{w_{ct}}{\omega_E} \sum_{j=I,P} \omega_j n_{jct} + \tau_k r_{ct} k_{ct-1} = \frac{y_t}{\omega_E}$$

$$+ b_{Kt} - R_{t-1} b_{Kt-1} + \quad (1-\tau_k) p_{bt} k_{bt} + p_{lt} l_{Et} + \xi_{Et}, \tag{7}$$

$$y_t = z_t \left(\omega_E k_{ct-1}\right)^{\alpha_C} \left(\sum_{j=I,P} \omega_j n_{jct} \right)^{1-\alpha_C}, \tag{8}$$

$$x_{ct} = k_{ct} - (1-\delta_c) k_{ct-1}, \tag{9}$$

$$x_{bt} = k_{bt}, \tag{10}$$

$$b_{Kt} + \frac{w_{ct}}{\omega_E} \sum_{j=I,P} \omega_j n_{jct} \leq m_K k_{ct}. \tag{11}$$

Note that variables c_{Et}, x_{ct}, x_{bt}, b_{Kt}, k_{ct}, l_{Et}, k_{bt}, and ξ_{Et} are variables that are expressed per entrepreneur. Entrepreneurs are borrowing-constrained agents that invest and produce the non-durable goods. Equation (7) shows the production of these goods involves labour provided by impatient and patient households, that are paid at wage w_{ct}, and capital k_{ct}. In addition to the Cobb-Douglas production function, y_t, the exogenous source of fluctuations is ensured by a neutral technology shock z_t. This shock follows an AR(1) process:

$$\ln z_t = \rho_z \ln z_{t-1} + \epsilon_{zt}, \qquad \epsilon_{zt} \sim N(0, \sigma_z^2) \tag{12}$$

where ρ_z corresponds to the persistence parameter and σ_z^2 to the variance of the innovation. Entrepreneurs accumulate capital according to the law of motion that is given by equation (9) where x_{ct} corresponds to the investment in non-durable goods. They also allocate resources for investment in materials used in the construction of houses, x_{bt}. In contrast to capital used in the production of non-durable goods, there is no accumulation of capital in materials k_{bt}, *i.e.* materials used in the construction of new houses in period t cannot be used again in the construction of new houses in future periods. We assume that their imputed rental income of capital $r_{ct} k_{ct}$ is taxed at rate τ_k, where the rental rate r_{ct} corresponds to the marginal product of capital. In similar fashion to the households, they have habits in consumption of non-durable goods c_{Et}. However, for simplicity, we assume that they do not supply labour and do not own houses.

The revenues of the entrepreneurs are shown in the right-hand-side of equation (7). First, a part of the final goods are sold for the consumption of impatient and patient households, and the remaining part is allocated to their own consumption and investments. Second, entrepreneurs sell k_{bt}, to the firms at price p_{bt}. Similar to the imputed rental income of capital, the sale of materials is taxed at rate τ_k. Third, entrepreneurs are endowed with l_t acreage in land every period that they sell to firms at price p_{lt}. Fourth, since they have a lower discount factor, they borrow b_{Kt} at the interest rate R_t, so that their net borrowing is $b_{Kt} - R_{t-1}b_{Kt-1}$. Fifth, they receive governmental transfers ξ_{Et}.

Entrepreneurs have two types of loans: inter-period debt b_{Kt} and working capital loans that are contracted to cover their wage bill. These loans have an intra-period maturity, as they are reimbursed at the end of the period once non-durable goods are sold.[7] As seen in equation (11), the sum of the inter-period debt and working capital loans cannot exceed a fixed fraction m_K of the capital stock.

3.3 House developers

House developers operate in a perfectly competitive market to produce new houses, ih_t. In order to introduce the definition of residential investment, we present their static problem in two stages. In the first stage, a Cobb-Douglas production function aggregates materials and labour to form residential investment, as follows:

$$\max p_{rt}x_{rt} - w_{ht}\sum_{j=I,P}\omega_j n_{jht} - \omega_E p_{bt}k_{bt} \tag{13}$$

subject to

$$x_{rt} = z_t\left(\omega_E k_{bt}\right)^{\alpha_B}\left(\sum_{j=I,P}\omega_j n_{jht}\right)^{1-\alpha_B} \tag{14}$$

$$\tag{15}$$

Every period, the developers pay factors of production for the formation of residential investment, $p_{rt}x_{rt}$. The labour inputs and materials have to be adjusted to account for the difference in

[7] For simplicity, we assume that working capital loans do not incur any interest rates.

population shares of the three categories of agents. The exogenous source of fluctuations in the production of residential investment, z_t, is perfectly correlated with the one in the production of non-durable goods.

The second stage is as follows:

$$\max q_{ht} ih_t - p_{rt} x_{rt} - p_{lt} l_t \tag{16}$$

subject to

$$ih_t = x_{rt}^{\phi} l_t^{1-\phi}, \tag{17}$$

$$l_t = \sum_{j=I,P,E} \omega_j l_{jt}. \tag{18}$$

House developers aggregate residential investment and land to form new houses. The assumption of competitive markets ensures that profit is zero in equilibrium from the sale of houses.

3.4 Government

In this economy, the government does not play any productive role. It levies distortionary taxes on households, and entrepreneurs, and makes lump-sum transfers, so that the total value of transfers corresponds exactly to the amount that these two categories of agents pay in taxes:

$$\xi_{It} = \omega_I \left(\tau_n \sum_{i=c,h} w_{it} n_{Iit} + \tau_h q_{ht} h_{It} - \tau_m \tau_n r_{t-1} b_{Ht-1} \right), \tag{19}$$

$$\xi_{Pt} = \omega_P \left(\tau_n \sum_{i=c,h} w_{it} n_{Pit} + \tau_h q_{ht} h_{Pt} \right), \tag{20}$$

$$\xi_{Et} = \omega_E \tau_k [r_{ct} k_{ct-1} + p_{bt} k_{bt}]. \tag{21}$$

3.5 Market clearing conditions

There is a resource constraint in the economy, so that output corresponds to the sum of consumption, and investment in non-durable goods and in materials:

$$y_t = \sum_{i=I,P,E} \omega_i c_{it} + \omega_E \left(x_{ct} + k_{bt} \right). \tag{22}$$

In accordance with the definition of GDP provided by the NIPA, we measure GDP generated by the model from a value-added approach, so that:

$$GDP_t = y_t + q_{ht} ih_t - \omega_E k_{bt}. \tag{23}$$

Additionally, the law of motion for houses is as follows:

$$ih_t = h_t - (1 - \delta_H) h_{t-1} \tag{24}$$

where $h_t = \omega_I h_{It} + \omega_P h_{Pt}$. We assume that land supply is equal to one for all periods.[8]

4 Calibration

Table 1 shows the calibration of the baseline model. The key parameter is the fraction of impatient households in the economy, which also corresponds in our model to the households' participation rate in mortgage markets. Badarinza, Campbell and Ramadorai (2016) find that this rate is 47 percent for 2010. Consistent with this evidence, we calibrate $\omega_I = 0.47$. In section 5.2, we simulate the baseline model with a lower share of borrowing-constrained households, $\omega_I = 0.2$, to match French and eurozone evidence, as reported by the ECB (2016). As noted above, the evidence from the Bank for International Settlements data that show that US average household debt over the 1999 to 2015 time-period corresponds to 84.05 percent of annualized GDP, whereas for the eurozone the same ratio is 56.35 percent. This 'high' and 'low' pattern for the US and France, respectively, corroborates our calibration choice. It is, therefore, likely that the household debt-to-GDP ratio reflects frictions in contractual enforcements. The exact measure of borrowers subject to collateral constraints is not known and there may also exist unconstrained borrowers in the real world, which are absent in our model. However, the available evidence mentioned above points to a larger share of constrained borrowers in the US relative to France. To address the uncertainty about the exact value of this parameter we conduct a sensitivity analysis and report the results in Figures 3 and 7.

Also from the SCF, Cagetti and De Nardi (2006) report that the percentage of business owners in the population is 9.1 percent, therefore we set $\omega_E = 0.09$. The share of patient households corresponds to the remaining share, $\omega_P = 0.44$.

[8] In similar fashion to Davis and Heathcote (2005), we do not model land dynamics over the business cycle.

TABLE 1: **Calibration of the baseline model**

POPULATION		
ω_I	0.47	fraction of impatient households
ω_P	0.44	fraction of patient households
ω_E	0.09	fraction of entrepreneurs
DISCOUNT FACTORS, PREFERENCES AND LOAN-TO-VALUES		
β	0.9925	discount factor (savers and patient households)
θ_W	0.973	discount factor (impatient households)
θ_E	0.973	discount factor (entrepreneurs)
ζ	0.7	habits in consumption
ψ	0.127	weight on housing
η_I	2.05	weight on leisure (impatient households)
η_P	1.77	weight on leisure (patient households)
ϵ	0.32	sectoral labour mobility
m_H	0.8	impatient households' loan-to-value
m_K	0.5	entrepreneurs' loan-to-value
TAXATION		
τ_n	0.22	labour income tax
τ_k	0.29	capital tax
τ_h	0.00625	property tax
τ_m	1	fraction of deductible mortgage interest payments
DEPRECIATION AND TECHNOLOGY		
δ_m	0.025	depreciation of capital
δ_h	0.004	depreciation of housing
α_C	0.28	elasticity with respect to capital (non-durable goods)
α_B	0.59	elasticity with respect to material inputs (residential investment)
ϕ	0.1	elasticity with respect to land (housing)
ρ_z	0.974	persistence of the technology shock

The value of the patient households and savers' quarterly discount factor is set so that the real interest rate is 3 percent in the steady state. Since impatient households and entrepreneurs are borrowing-constrained, they face a shadow cost of borrowing in addition to interest payments. This cost can be considered as an interest premium. Similar to Bernanke, Gertler and Gilchrist (1999), we choose the impatient households' discount factor to match a two percent interest premium, *i.e.* $\theta_W = \theta_E = 0.973$. For a reasonable size of the TFP shock, this value of the discount factor ensures that the borrowing constraint is always binding. As for the parameterization of habits in consumption, Havranek, Rusnak and Sokolova (2015) conducted a meta-analysis of the estimated values in the literature. Based on 251 studies on the US economy, they report a median value of 0.72 for macro estimates. Therefore, we set ζ to 0.7. In the sensitivity analysis section, we examine how our results change with respect to the value of this parameter.

The weight on housing in the households' utility function is governed by ψ and is set to match the average household market value of real-estate-to-GDP-ratio in the US from 1983 to 2016 which is 4.68. This value is based on the Federal Reserve Board data (Table B.101, line 3). The weights assigned to leisure, η_I and η_P, are picked so that households work 30 percent of their allocated time in the steady state. The parameter that governs the degree of sectoral labour mobility, ϵ, is the only one that is determined outside the steady state. It is set to match the relative volatility of residential investment to GDP. As for the households' loan-to-value parameter, we follow Justiniano, Primiceri and Tambalotti (2015) calibrated value based on the average loan-to-value for purchases and refinancing based on the SCF data of 1992, 1995, and 1998, *i.e.* $m_H = 0.8$. For the entrepreneurs' loan-to-value m_K, we follow Bernanke, Gertler and Gilchrist (1999) and set it to 0.5.

Taxation distorts the decisions of households and entrepreneurs. For labour and capital taxes, τ_n and τ_k, we take the values estimated by Gomme and Rupert (2007) who use Mendoza, Razin and Tesar (1994) methodology to calculate effective average tax rates. We set the property tax rate, $\tau_h = 0.00625$, that is the quarterly value reported for the US in Girouard, Kennedy, Van den Noord and André (2006) based on their survey of housing taxation across OECD countries. Since mortgage interest payments are fully deducted from taxable income in the US, we set $\tau_m = 1$.

The depreciation rate of capital is standard, *i.e.* $\delta_m = 0.025$. We follow Gomme and Rupert

(2007) in computing the housing depreciation rate from BEA data and set $\delta_h = 0.004$. We set the capital share in the production of houses, $\alpha_C = 0.28$ in accordance with the estimations of the same study. We follow Davis and Heathcote (2005) and Iacoviello and Neri (2010) and set the share of land in the production of new houses to $\phi = 0.1$. In the production function of houses, we do not distinguish between capital in structures and intermediate goods. Yet material costs compose a large share of total house production costs. Specifically, in the US input-output tables from 1997 to 2014, this share is 15 percent greater than workers' compensation. We set α_H to match this ratio to which we add a 10 percent share for structures in similar fashion to the two aforementioned studies. Finally, we choose the persistence parameter of the technology shock, $\rho_z = 0.974$. It corresponds to the average between estimates of the persistence of technology shock that affects the housing production and the non-durable goods production as reported by Iacoviello and Neri (2010).

5 Quantitative results

In this section, we first present the main quantitative results for the baseline calibration of the model that matches moments of the US data (values presented in Table 2).

The key finding is that the presence of borrowing constraints is critical to replicate the lead in residential investment and many co-movements and relative volatilities for the US that a standard real business cycle model fails to deliver.

5.1 Results

In Table 2 we report the relative volatilities and co-movements of consumption, residential investment, non-residential investment, housing starts, and housing prices. We have set the degree of sectoral labour mobility measured by ϵ to match the relative standard deviation of residential investment, so we have imposed the model to match this moment. There are, however, no restrictions on the values of all other moments. The model reproduces quite well the relative volatility of non-residential investment. Specifically, the volatility of investment is significantly higher in the housing construction sector both in the data and generated by the model.[9] This success is shared

[9] As stated by equation (23), GDP's definition also includes the value-added of the housing construction sector. However, since that sector accounts for only 1.2 percent of GDP, relative volatilities and co-movements

TABLE 2: **Baseline Model Properties**

Co-movements			Relative volatilities		
STATISTIC	DATA	MODEL	STATISTIC	DATA	MODEL
$\rho(c_t, GDP_t)$	0.87	0.98	σ_c/σ_{GDP}	0.83	0.6
$\rho(p_{rt}x_{rt}, GDP_t)$	0.67	0.86	$\sigma_{prxr}/\sigma_{GDP}$	6.55	6.55
$\rho(x_{ct}, GDP_t)$	0.86	0.97	σ_{xc}/σ_{GDP}	4.22	3.78
$\rho(p_{rt}x_{rt}, x_{ct})$	0.39	0.87	$\sigma_{prxr}/\sigma_{xc}$	1.55	1.74
$\rho(q_{ht}, GDP_t)$	0.51	0.76	σ_{qh}/σ_{GDP}	2.94	0.49

Note—The US data spans from 1983Q1 to 2017Q2. All series are logged and detrended with the HP-filter (with a smoothing parameter λ=1600). Data sources are in the appendix. The variable c_t corresponds to total consumption consistent with NIPA, *i.e.* $c_t = \sum_{i=I,P} \omega_i \left(c_{it} + r_{hit}h_{it}\right) + \omega_E c_{Et}$ where r_{hit} correspond to the imputed rental housing prices ($r_{hit} = u'_{hit}/u'_{cit}$). The variables $p_{rt}x_{rt}$, x_{ct}, ih_t, and q_{ht} are residential investment, non-residential investment, new houses, and housing prices, respectively.

with previous work, *e.g.* Davis and Heathcote (2005), Kydland, Rupert and Sustek (2016), and Fisher (2007), however, a standard multi-sector real business model as in Greenwood and Hercowitz (1991) fails at replicating this relative volatility. The effects of borrowing constraints are not at work here. There are two reasons. First, a lower depreciation rate of houses than capital used in the production of non-durable goods is key to explain the volatility. In fact, the effects of investing in housing production last longer with a lower depreciation rate. Therefore, the response of investment to a TFP shock is greater. Second, contrary to non-residential investment, residential investment is affected twice by the TFP shock. Its supply increases because the TFP shock affects the production of non-durable goods that is used for residential investment, and its demand increases from a greater marginal product of residential investment in the production of new houses. In similar fashion, the house production is very volatile, because the technology shock affects, simultaneously and equally, both sectors.

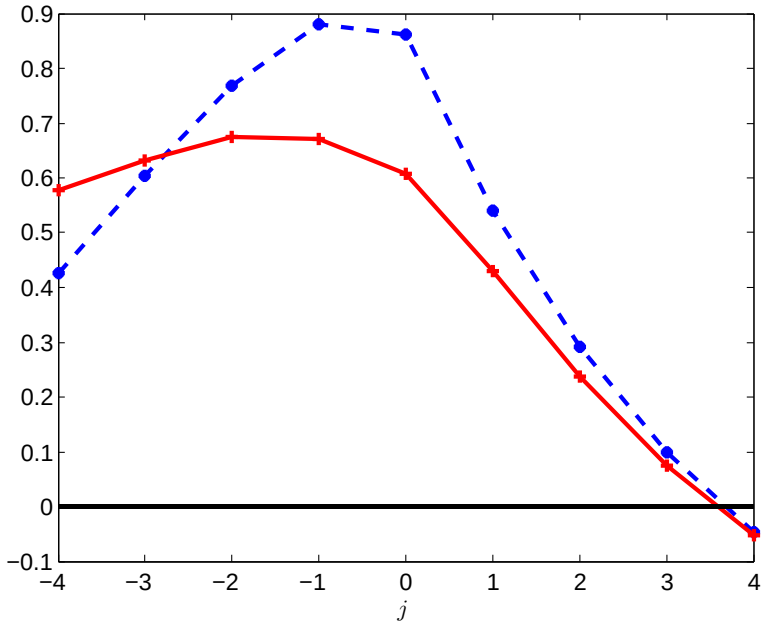
The model is able to replicate the positive co-movements in all aggregate quantity variables as well as in housing prices. Accounting for the high volatility of housing prices in the data, however, remains a challenge for the model.[10] As in the previous literature, it appears that technology shocks

are essentially the same if we remove that sector from GDP's definition.

[10]The price of land is highly volatile, $\sigma_{p_l}/\sigma_{GDP} = 6.55$, and accounts for a large share of the varia-

are not sufficient to explain the radical shifts in housing prices.

Figure 1: **Cross-correlation function between GDP and residential investment conditional on the TFP shock.**



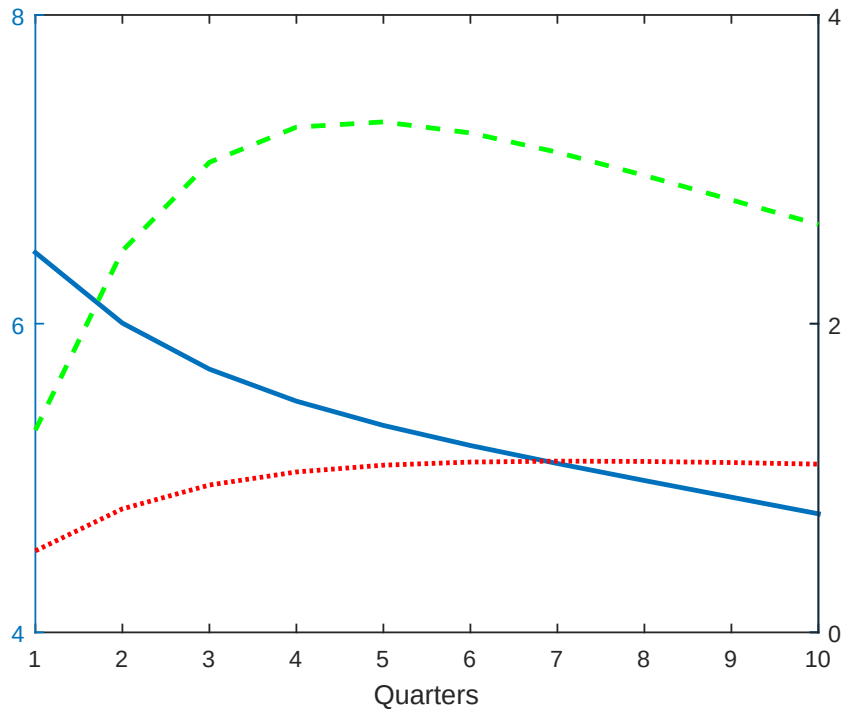
NOTES— Specifically, this function corresponds to the correlation between residential investment at time $t + j$ and output at time t. The blue line corresponds to the correlations generated by the benchmark model and the red line to the correlations estimated from US data between 1983Q1 and 2017Q2 based on calibration in Table 1. All series are logged and detrended with the HP-filter (with a smoothing parameter λ=1600).

In Figure 1, we present the cross-correlation functions between output and residential investment computed from the actual data and those generated by the benchmark model. Residential investment leads output by one quarter. The correlation between residential investment in period $t - 1$ and output in period t has the largest absolute magnitude, reflecting the lead. The cross-correlations in the model between the lags of -2 and 2 are somewhat larger than those in the data, but for the remaining leads and lags, the model predictions are relatively close.

The impulse responses displayed in Figure 2 give evidence of the borrowing constraint mech-

tions in housing price, as it is the case in the data (see, for example, Davis and Heathcote (2005)). The contemporaneous correlation of land prices and GDP generated by the model is also high—0.86.

Figure 2: **Impulse responses to a one percent technology shock.**



NOTES—The solid blue line corresponds to the response of residential investment (left axis), the green dashed line to non-residential investment (right axis), and the dotted red line to GDP (right axis).

anism at play. There are two incentives for purchasing larger quantity of houses. First, housing services directly enter the households' utility function. Since the positive technology shock induces a wealth effect, they decide to spend more on houses. However, this positive wealth effect alone is not sufficient to produce the leading pattern. The key characteristic is that a fraction of these households are borrowing-constrained. Therefore, the accumulation of the housing stock allows them to borrow more contemporaneously and in future periods, so that they are also able to consume greater quantities of the non-durable good.

Habit formation in consumption plays a role in the delayed and hump-shaped response of GDP to technology shocks.[11] Specifically, preferences that feature habits give additional incentives for

[11]This result is shared with Pintus and Wen (2013) who show that habits in consumption coupled with borrowing constraints can create large boom-bust cycles.

TABLE 3: **Housing starts and output**

Correlations between housing starts at time $t+j$ and output at time t									
	$j=-4$	-3	-2	-1	0	1	2	3	4
US data	0.46	0.56	0.62	**0.64**	0.58	0.4	0.22	0.08	-0.05
Baseline calib.	0.43	0.6	0.77	**0.88**	0.87	0.55	0.3	0.11	-0.04
French data	0.36	0.44	0.44	0.44	**0.45**	0.31	0.16	0.02	-0.15
French calib.	0.49	0.67	0.8	0.84	**0.87**	0.59	0.34	0.14	-0.02

Notes—The U.S. data spans from 1983Q1 to 2017Q2 and the French data from 1983Q1 to 2016Q3. All series are logged and detrended with the HP-filter (with a smoothing parameter λ=1600). Data sources are in the appendix. The highest correlations of each row are marked in bold.

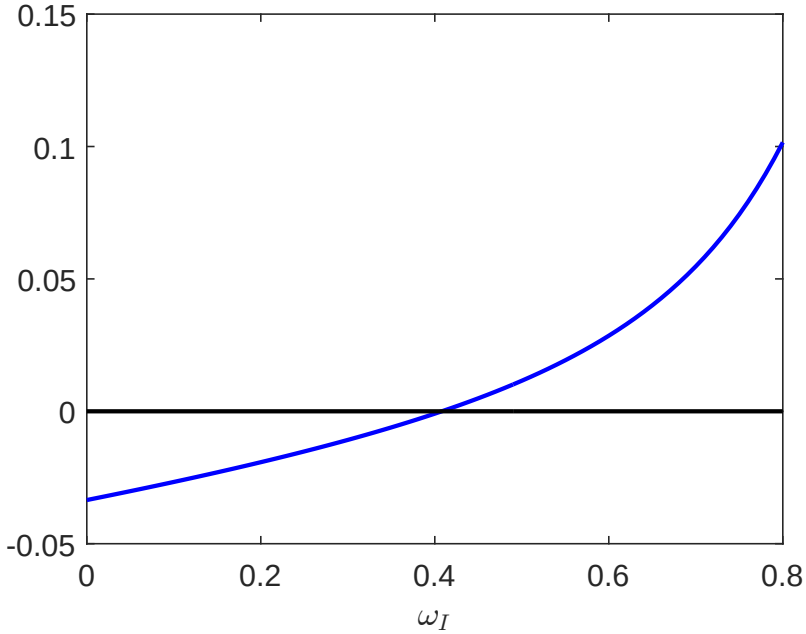
households to demand houses relative to non-durable goods when the shock impacts the economy. However, as will be seen in the next section, for a lower share of impatient households in the economy, habit formation is not sufficient to ensure the lead of residential investment.

Table 3 reports the cross-correlations between housing starts (new houses) and output. Even though the correlations generated by the baseline calibration are larger in magnitude relative to their empirical counterparts in the first two rows, housing starts lead output in the US data and in the model for the baseline calibration. This success of our model is related to the same household borrowing constraint channel described in the previous paragraphs for the lead of residential investment over output.[12]

We now demonstrate a key property of the model. The share of impatient households in the economy drives the lead of residential investment over output. Figure 3 presents the difference between the correlation of residential investment at time $t-1$ and output at time t and the correlation of these two variables at time t for a wide range of the shares of impatient households (ω_I) in the economy. Specifically, when the share of impatient households is increased, the share of patient households is decreased, and vice versa. All the other parameters remain the same as reported in

[12]In order to check the empirical relevance of the model's mechanism to explain the leading behavior of residential investment, we compare the cross-correlation of home-equity loan to GDP between the model and the US data. Home-equity loan to GDP ratio leads GDP both in the model and in the data. The mechanism illustrated through the model is, therefore, consistent with the evidence. A caveat, however, is that the relative volatility in the model is low compared to the data.

Figure 3: **GDP and residential investment (net) cross-correlations conditional on TFP shocks**



NOTES—The figure shows the *difference* between the cross-correlation in output at t and residential investment at time $t-1$ and t, respectively, for a given share of of impatient households (ω_I). All series are logged and detrended with the HP-filter (with a smoothing parameter λ=1600).

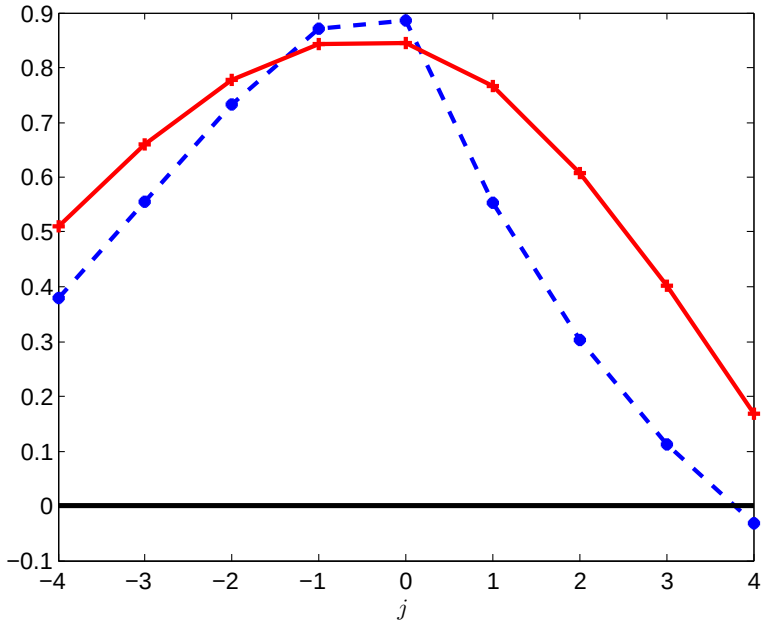
Table 1. A positive gap indicates that the absolute magnitude of the leading correlation is greater than contemporaneous correlation. The gap between the leading and contemporaneous correlations is unambiguously a positive function of the fraction of borrowing-constrained households.

5.2 Alternative calibration for household borrowing

After having stressed the role played by borrowing constraints for the lead of residential investment for the US, we calibrate the financial frictions parameters to match the French data. This is the only parameter that we re-calibrate relative to the benchmark calibration, *i.e.* $\omega_I = 0.2$.

Since the share of households facing the borrowing constraint is relatively small, the additional incentive to acquire housing is significantly reduced. This increases the correlation between aggregate quantity variables. Consequently, the lead in residential investment vanishes as can be seen in

Figure 4: **Cross-correlation between residential investment and GDP conditional on TFP shocks: French calibration**



NOTES—Specifically, this function corresponds to the correlation between residential investment at time $t+j$ and output at time t. The blue line corresponds to the correlations generated by the benchmark model and the red line to the correlations estimated from French data between 1983Q1 and 2016Q4. All series are logged and detrended with the HP-filter (with a smoothing parameter λ=1600).

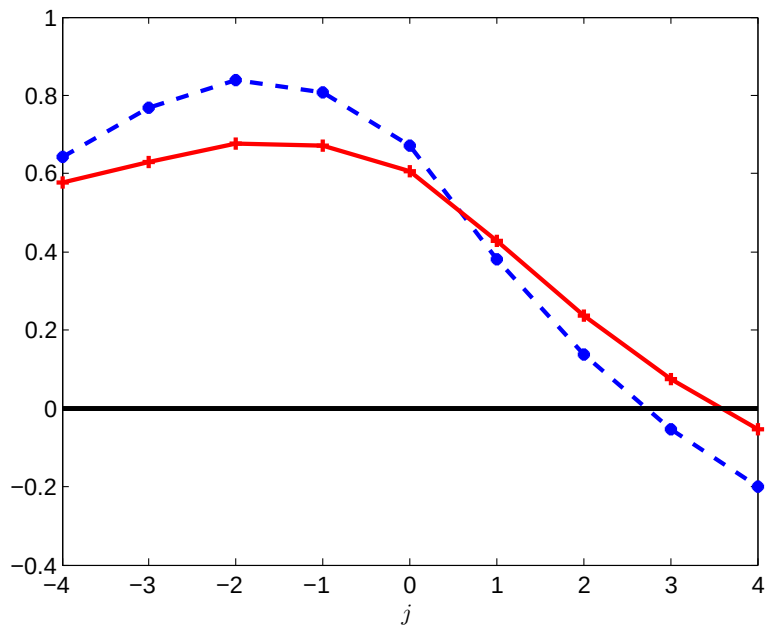
Figure 4. This result is consistent with the cross-correlation pattern for France, indicating a very good fit of the model.[13] Moreover, a lower share of impatient households in the economy make housing starts (new houses) coincident with GDP. This result is consistent with French data as presented by the last two rows of Table 3.[14]

[13]We choose to report the cross-correlation pattern for France for two reasons. First, it is the second-largest economy in the eurozone. Second, its statistical agency reports a long time span of residential investment data. Moreover, from 1983 to 2016, its household-debt-to-GDP ratio is 38.8 percent which is approximately half of the US's ratio.

[14]The ratio of household debt-to-GDP is 50 percent larger in the US than in the eurozone. Our assumption implies that changes in housing wealth generate relatively strong effects through the collateral channel of housing in economies that feature higher rates of participation in the mortgage markets. To support our view that shocks have different effects on homeowners that hold mortgages versus those who do not, we refer to the recent empirical work by Cloyne, Ferreira and Surico (2017). From US and UK micro-data, they find that the size of the responses of consumer spending to monetary policy shocks differ significantly

5.3 Cross-correlations conditional on patience shocks

Figure 5: **Cross-correlation between residential investment and GDP conditional on patience shocks: Baseline calibration**



NOTES— Specifically, this function corresponds to the correlation between residential investment at time $t+j$ and output at time t. The blue line corresponds to the correlations generated by the benchmark model and the red line to the correlations estimated from US data between 1983Q1 and 2017Q2 based on calibration in Table 1. All series are logged and detrended with the HP-filter (with a smoothing parameter λ=1600).

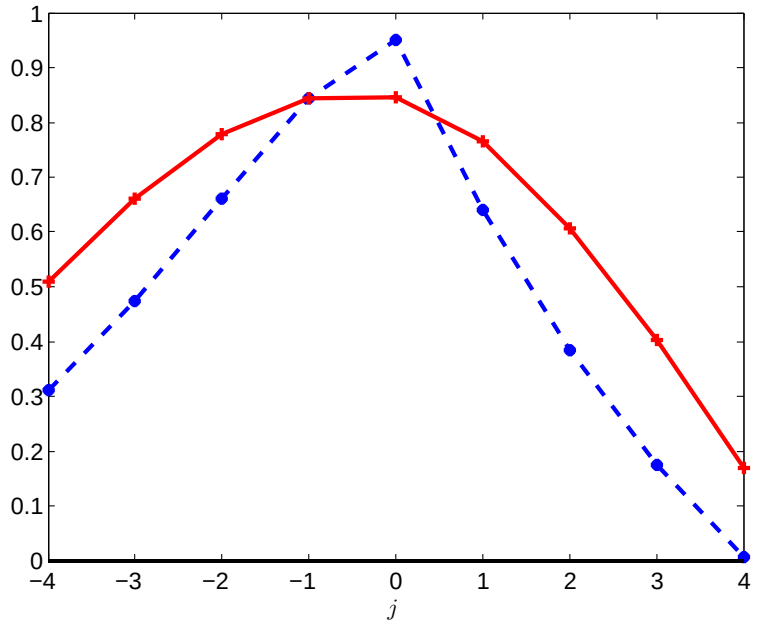
In this section we examine the effects of a shock to the households and entrepreneurs' intertemporal preferences, that we call a patience shock. Specifically, their discount factors are all affected identically, *i. e.* $\theta_I A_t$ for impatient households, βA_t for patient households, and $\theta_E A_t$ for entrepreneurs, where

$$\ln A_t = \rho_A \ln A_{t-1} + \epsilon_{At} \qquad \epsilon_{At} \sim N(0, \sigma_A^2).$$

Following Iacoviello and Neri (2010), we set $\rho_A = 0.97$. In Figures 5 and 6, we present the

between these two types of homeowners. While our explanation is based on a real model without nominal frictions and monetary shocks, the differential response documented in this recent study provides additional corroborative evidence.

Figure 6: **Cross-correlation between residential investment and GDP conditional on patience shocks: French calibration**

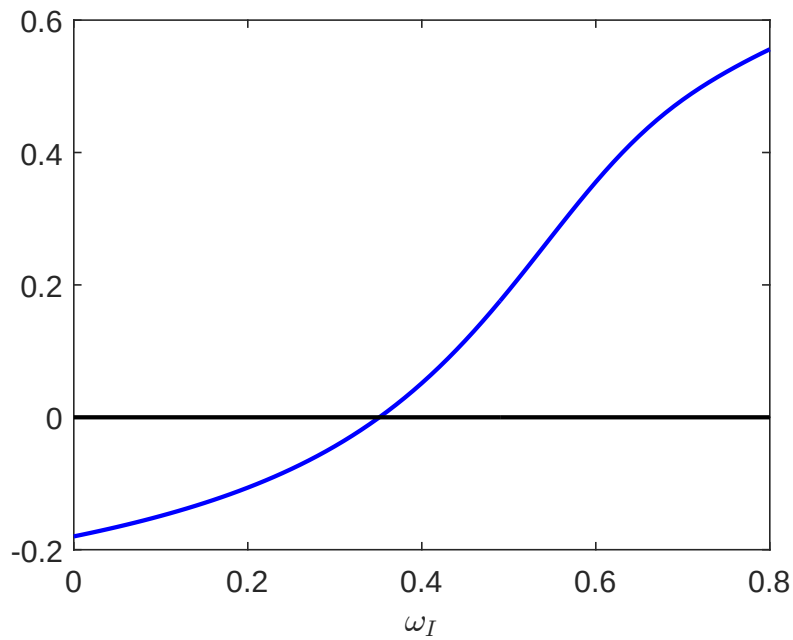


NOTES—Specifically, this function corresponds to the correlation between residential investment at time $t + j$ and output at time t. The blue line corresponds to the correlations generated by the benchmark model and the red line to the correlations estimated from French data between 1983Q1 and 2016Q4. All series are logged and detrended with the HP-filter (with a smoothing parameter λ=1600).

cross-correlation function between residential investment and GDP for the baseline and French calibrations, where preference shocks are the only source of exogenous disturbances. Similar to TFP shocks, lowering the share of impatient households in the economy makes a substantial impact on the cross-correlation function. When 60% of households are impatient, residential investment leads GDP, while the two aggregate variables coincide for 20% share of impatient households.

We consider negative patience shocks, because it is easier to compare their effects to the effects of positive technology shocks. Following negative shocks, all agents become relatively more impatient, and therefore have more pressure to consume housing services and non-durable goods as early as possible. For impatient households, the incentives to accumulate housing stock are even greater because houses are collateral assets that allow them to borrow more. Therefore, a greater share of

Figure 7: **GDP and residential investment (net) cross-correlations conditional on patience shocks**



NOTES—The figure shows the difference between the cross-correlation in output at t and residential investment at time $t-1$ and t, respectively, for different shares of impatient households (ω_I) conditional on patience shocks. All series are logged and detrended with the HP-filter (with a smoothing parameter λ=1600).

borrowing-constrained households in the economy leads to larger positive shifts in the demand for houses relative to non-durable goods for the period when the shock occurs. The larger the share of impatient households the more the increase in the production of non-durable goods is delayed and that contributes to residential investment leading the cycle.

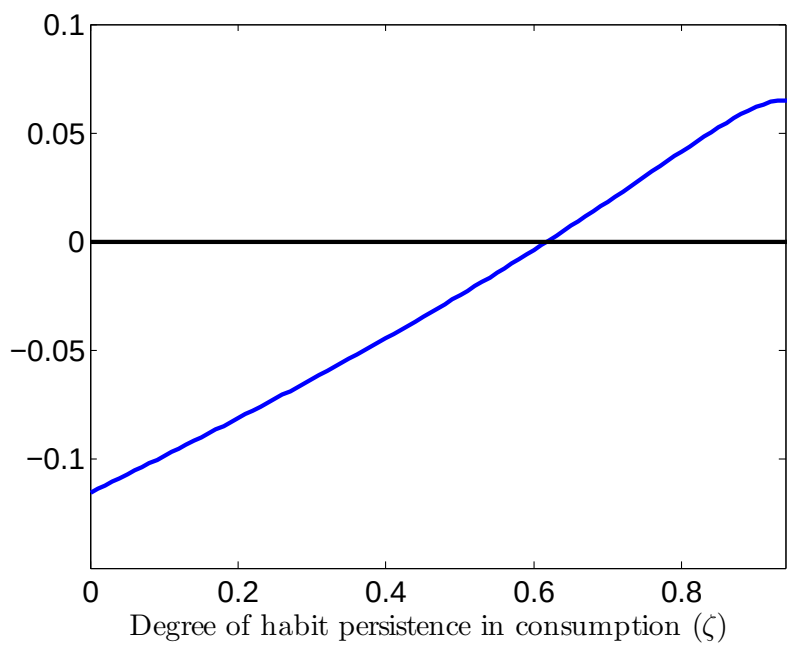
Similar to Figure 3, Figure 7 presents the size of the lead of residential investment conditional on preference shocks for a wide range of the share of impatient households ω_I. For lower values of ω_I, the effects of borrowing constraints are diluted, and residential investment does not lead output.

6 Sensitivity analysis

In this section, we examine the sensitivity of our results in four different ways. First, we evaluate the sensitivity of the cross-correlations to the degree of habit persistence in consumption of non-durable goods. Second, we consider an alternative utility function, that is widely used in the business cycle literature, namely, the Greenwood, Hercowitz and Huffman (1988) (GHH) preferences to mitigate wealth effects on labour supply. Third, we present cross-correlation functions conditional on other types of shocks, in particular, housing preference and LTV shocks. Fourth, we introduce Investment Adjustment Costs (IAC) in the residential and non-residential sectors.

6.1 Habit persistence in consumption

Figure 8: **GDP and residential investment (net) cross-correlations conditional on TFP shocks: sensitivity to the degree of habit persistence in consumption**



NOTES—The figure shows the difference between the cross-correlation in output at t and residential investment at time $t-1$ and t, respectively, for a wide range of values for habit persistence in consumption. All series are logged and detrended with the HP-filter (with a smoothing parameter λ=1600).

In the previous section, we mentioned that habit persistence in consumption of non-durable goods is required to produce hump-shaped responses of consumption and non-residential investment, which are crucial to account for residential investment being a leading indicator of the cycle. As seen in Figure 8, ζ must be greater than 0.55 to obtain this lead.

6.2 Eliminating wealth effects

Since the GHH preferences eliminate the wealth effect on labour supply, the responses of GDP to TFP shocks are typically greater than when log-log preferences are adopted. Here, we are interested to see how shutting down this wealth effect channel affects the cross-correlations. In order to achieve this goal, we simulate the model with modified periodic-utility functions of impatient and patient households, that are the following:

$$u(c_{it}, h_{it}, n_{ict}, n_{iht}) = \ln\left((c_{it} - \zeta c_{it-1})^{1-\psi} h_{it}^{\psi} - \eta_i \frac{\left(n_{ict}^{1+\epsilon} + n_{iht}^{1+\epsilon}\right)^{\frac{1+\chi}{1+\epsilon}}}{1+\chi} \right) \qquad \text{for } i = \{I, P\}. \quad (25)$$

Note that there is an additional parameter, χ, that governs the sensitivity of labour supply to changes in sectoral wages.[15] We set $\chi = 0.5$, which implies a Frisch elasticity of labour supply of 2 in the absence of habits persistence and hours worked in two sectors. We find that the moments obtained from this specification of the utility functions are not significantly different from a log-log specification (see the rows labeled "TFP"). We, therefore, conclude that the mechanism that we emphasize in this paper is robust to eliminating the wealth effects on labour supply via the GHH preferences.

6.3 Housing preference and LTV shocks

We study the effects of two additional shocks on residential investment dynamics—one to housing preferences and the other one to the loan-to-value placed on households' borrowing constraints. Previous work has put these two shocks at the forefront of their analyses, as described below.

From a multi-agent DSGE model estimated using Bayesian methods from US data that spans from 1965Q1 to 2006Q4, Iacoviello and Neri (2010) find that similar housing preference shocks to

[15] Specifically, all else equal, a lower value of χ implies a greater responsiveness of labour supply to variations in sectoral wages.

TABLE 4: **Sensitivity analysis**

	Correlations between residential inv. at time $t+j$ and GDP at time t									$\rho(p_{rt}x_{rt}, x_{ct})$
	$j=-4$	-3	-2	-1	0	1	2	3	4	
United States										
Data	0.58	0.63	**0.68**	0.67	0.61	0.43	0.24	0.07	-0.05	0.36
GHH pref.	0.43	0.57	0.72	**0.83**	0.82	0.45	0.19	0	-0.14	0.96
IAC	0.48	0.67	0.84	**0.95**	0.94	0.74	0.5	0.28	0.08	0.92
Shocks										
TFP	0.43	0.6	0.77	**0.88**	0.86	0.54	0.29	0.1	-0.05	0.87
Patience	0.64	0.77	**0.84**	0.81	0.67	0.38	0.14	-0.05	-0.2	0.76
Housing pref.	**0.71**	0.57	0.35	0.08	-0.38	-0.38	-0.36	-0.33	-0.3	-0.69
LTV	0.5	0.48	0.34	0.03	-0.4	**-0.65**	-0.63	-0.53	-0.42	-0.34
France										
Data	0.51	0.66	0.78	0.84	**0.85**	0.77	0.61	0.4	0.17	0.74
GHH pref.	0.41	0.56	0.71	0.83	**0.84**	0.47	0.21	0.02	-0.12	0.96
IAC	0.45	0.64	0.82	0.94	**0.95**	0.74	0.5	0.28	0.09	0.94
Shocks										
TFP	0.38	0.56	0.73	0.87	**0.89**	0.55	0.3	0.11	-0.03	0.92
Patience	0.31	0.48	0.66	0.84	**0.95**	0.64	0.38	0.17	0	0.9
Housing pref.	0.5	0.67	0.79	0.84	**0.87**	0.58	0.33	0.13	-0.02	-0.68
LTV	0.51	0.45	0.25	-0.11	-0.56	**-0.67**	-0.6	-0.49	-0.38	-0.52

Notes—We present the cross-correlations between residential investment and GDP, and the contemporaneous correlation between the two types of investment for the data and for the model conditional on shocks. We calibrate the variants of the baseline model according to the values reported in Table 1, except for the model with IAC—for which habits persistence are raised to $\zeta = 0.75$. The U.S. data spans from 1983Q1 to 2017Q2 and the French data from 1983Q1 to 2016Q3. All series are logged and detrended with the HP-filter (with a smoothing parameter λ=1600). Data sources are in the appendix. The largest correlations (in absolute value) between residential investment and GDP of each row are marked in bold.

the ones that we simulate explain just above 25% of cyclical variations in residential investment and in housing prices. These shocks are assigned an even larger role in the estimation of a DSGE model by Liu, Wang and Zha (2013). They account for over 90% of fluctuations in land prices and from 30 to 50% in investment (US data, 1975-2010).

As for household LTV shocks, they have received attention in the literature that focuses on the period coinciding with the boom and bust in the housing market during the first decade of 2000s. There is, however, no consensus on the importance of these shocks for explaining investment and house price dynamics. On the one hand, using an overlapping generation model that features heterogeneous homeowners, Favilukis, Ludvigson and Van Nieuwerburgh (2017) argue that they are important. Two features are crucial in their model to get this result: aggregate risk and bequest heterogeneity. On the other hand, Justiniano, Primiceri and Tambalotti (2015) find that changes in collateral requirements cannot explain credit cycle dynamics, and therefore, their role to account for fluctuations in residential investment and housing prices is limited.

In the context of our model, housing preference shocks consist in stochastic disturbances to the parameter ψ that governs the weight of housing in the periodic-utility functions of the impatient and patient households, as featured in equations (1) and (4). They follow an AR(1) process:

$$\psi_t = (1-\rho)\psi + \rho\psi_{t-1} + \epsilon_{\psi t}, \qquad \epsilon_{\psi t} \sim N(0, \sigma_\psi^2). \tag{26}$$

In a similar fashion, we force the loan-to-value parameter m_H of equation (3) to become stochastic, such that it follows an AR(1) process:

$$m_{Ht} = (1-\rho)m_H + \rho m_{Ht-1} + \epsilon_{m_H t}, \qquad \epsilon_{m_H t} \sim N(0, \sigma_{m_H}^2). \tag{27}$$

We set the persistence parameter, $\rho = 0.97$, for both shocks. Since our focus is on correlations, the calibrated values of the innovations' standard deviations do not affect our results.

In Table 4, we compare dynamic correlations of residential investment generated by our baseline model, conditional on different types of shocks, to the same correlations computed from the data. Specifically, we examine the cross-correlation function of residential investment and GDP, and the contemporaneous correlation between the two types of investment, first for a high share of impatient households calibrated to match US evidence, and second for a low share of this category of households calibrated to match French evidence.

With a high share of impatient households ($\omega_I = 0.47$), residential investment leads GDP by four and three quarters, conditional on housing preference shocks, and on household LTV shocks, respectively. However, for both shocks, the contemporaneous correlations of residential investment with GDP and non-residential investment are counter-factually negative. This result arises as too much substitution between types of investment takes place in response to the shocks. With a low share of impatient households ($\omega_I = 0.2$) and conditional on housing preference shocks, residential investment coincides with the cycle, just as it does in the data. In contrast, conditional on household LTV shocks, residential investment is an inverted lagging indicator, since the largest correlation in absolute value is between residential investment at time $t+1$ and GDP at time t. Finally, it appears that the negative correlation between types of investment persists with a lower share borrowing-constrained households.

In short, our mechanism still holds true for the two additional shocks that we examine in this section, even though there are some shortcomings in regards with the contemporaneous correlation between types of investment. Out of the two additional shocks, house preference shocks appear to be more promising to explain residential investment dynamics.

6.4 Investment adjustment costs

We examine the effects of adjustment costs on investment in non-durable goods and in materials. We assume that these costs are quadratic, and that they enter the laws of motion of capital as follows:

$$k_{ct} = (1-\delta_c)k_{ct-1} + x_{ct}\left(1 - \frac{\kappa}{2}\left(\frac{x_{ct}}{x_{ct-1}} - 1\right)^2\right), \tag{28}$$

$$k_{bt} = x_{bt}\left(1 - \frac{\kappa}{2}\left(\frac{x_{bt}}{x_{bt-1}} - 1\right)^2\right). \tag{29}$$

Following Groth and Khan (2010), who find relatively small magnitude of investment adjustment costs at the industry level in the US, we calibrate the adjustment costs parameter $\kappa = 1.1$. The presence of IAC dampens the investment responses to the TFP shock and tends to mitigate the lead of residential investment. As shown in Table 4, the model requires slightly higher degree of consumption habits, $\zeta = 0.75$, to generate the lead of residential investment relative to the

baseline case for the US. For the same calibration of IAC in France, residential investment remains coincidental with output.

7 Conclusion

Residential investment leads the business cycle in the US. The main contribution of this paper is to demonstrate that home-equity loans used for consumption can influence residential investment dynamics in ways that can account for this stylized fact. When the share of constrained borrowers is relatively large, residential investment leads output. When this proportion is relatively small, as in eurozone countries, residential investment becomes coincident with the output and no longer serves as a leading indicator in the economy. Household borrowing constraints, therefore, provide an endogenous explanation to help account for a key feature of residential investment dynamics.

References

Aladangady, A.: 2017, Housing wealth and consumption: Evidence from geographically-linked microdata, *American Economic Review* **107**(11), 3415–46.

Badarinza, C., Campbell, J. Y. and Ramadorai, T.: 2016, International comparative household finance, *Annual Review of Economics* **8**, 111–144.

Benhabib, J., Rogerson, R. and Wright, R.: 1991, Homework in macroeconomics: Household production and aggregate fluctuations, *Journal of Political economy* **99**(6), 1166–1187.

Bernanke, B. S., Gertler, M. and Gilchrist, S.: 1999, The financial accelerator in a quantitative business cycle framework, *Handbook of Macroeconomics* **1**, 1341–1393.

Burns, A. F. and Mitchell, W. C.: 1946, *Measuring Business Cycles*, New York: National Bureau of Economic Research.

Cagetti, M. and De Nardi, M.: 2006, Entrepreneurship, frictions, and wealth, *Journal of Political Economy* **114**(5), 835–870.

Campbell, J. R. and Hercowitz, Z.: 2005, The Role of Collateralized Household Debt in Macroeconomic Stabilization, *NBER Working Papers 11330*, National Bureau of Economic Research.

Cloyne, J., Ferreira, C. and Surico, P.: 2017, Monetary policy when households have debt: New evidence on the transmission mechanism, *Manuscript*, London Business School.

Davis, M. and Heathcote, J.: 2005, Housing and the business cycle, *International Economic Review* **46**, 751–84.

ECB: 2016, The household finance and consumption survey: results from the second wave, *Statistics Paper No 18 - Household Finance and Consumption Network* .

Favilukis, J., Ludvigson, S. C. and Van Nieuwerburgh, S.: 2017, The macroeconomic effects of housing wealth, housing finance, and limited risk sharing in general equilibrium, *Journal of Political Economy* **125**(1), 140–223.

Fisher, J.: 2007, Why does household investment lead business investment over the business cycle, *Journal of Political Economy* **115**(1), 141–68.

Girouard, N., Kennedy, M., Van den Noord, P. and André, C.: 2006, Recent house price developments, *Technical Report 475*, OECD.

Gomme, P., Kydland, F. and Rupert, P.: 2001, Home production meets time to build, *Journal of Political Economy* **109**, 1115–131.

Gomme, P. and Rupert, P.: 2007, Theory, measurement and calibration of macroeconomic models, *Journal of Monetary Economics* **54**(2), 460–497.

Gorea, D. and Midrigan, V.: 2015, Liquidity Constraints in the US Housing Market.

Greenwood, J. and Hercowitz, Z.: 1991, The allocation of capital and time over the business cycle, *Journal of Political Economy* **99**(6), 1188–1214.

Greenwood, J., Hercowitz, Z. and Huffman, G. W.: 1988, Investment, capacity utilization, and the real business cycle, *The American Economic Review* **78**(3), 402–417.

Groth, C. and Khan, H.: 2010, Investment adjustment costs: An empirical assessment, *Journal of Money, Credit and Banking* **42**(8), 1469–1494.

Havranek, T., Rusnak, M. and Sokolova, A.: 2015, Habit formation in consumption: A meta-analysis, *Technical report*, Czech National Bank.

Horvath, M.: 2000, Sectoral shocks and aggregate fluctuations, *Journal of Monetary Economics* **45**(1), 69–106.

Iacoviello, M.: 2005, House prices, borrowing constraints, and monetary policy in a business cycle, *American Economic Review* **46**, 751–84.

Iacoviello, M. and Neri, S.: 2010, Housing Market Spillovers: Evidence from an Estimated DSGE Model, *American Economic Journal: Macroeconomics* **2**(2), 125–64.

Jaimovich, N. and Rebelo, S.: 2009, Can news about the future drive the business cycle?, *American Economic Review* **99**(4), 1097–1118.

Justiniano, A., Primiceri, G. and Tambalotti, A.: 2015, Household leveraging and deleveraging, *Review of Economic Dynamics* **18**(1), 3–20.

Kiyotaki, N. and Moore, J.: 1997, Credit cycles, *Journal of Political Economy* **105**(2), 211–247.

Kydland, F., Rupert, P. and Sustek, R.: 2016, Housing dynamics over the business cycle, *International Economic Review* **57(4)**, 1149–1177.

Leamer, E.: 2008, Housing IS the business cycle, *Housing Finance and Monetary Policy*, Federal Reserve Bank of Kansas City.

Leamer, E.: 2015, Housing really is the business cycle: What survives the lessons of 2008-09?, *Journal of Money, Credit and Banking* **47**(1), 43–50.

Liu, Z., Wang, P. and Zha, T.: 2013, Land-price dynamics and macroeconomic fluctuations, *Econometrica* **81**(3), 1147–1184.

McGrattan, E. R., Rogerson, R. and Wright, R.: 1997, An equilibrium model of the business cycle with household production and fiscal policy, *International Economic Review* **38**(2), 267–290.

Mendoza, E. G., Razin, A. and Tesar, L. L.: 1994, Effective tax rates in macroeconomics: Cross-country estimates of tax rates on factor incomes and consumption, *Journal of Monetary Economics* **34**(3), 297–323.

Piazzesi, M. and Schneider, M.: 2016, Housing and macroeconomics, *Handbook of Macroeconomics*, Vol. 2, pp. 1547–1640.

Pintus, P. A. and Wen, Y.: 2013, Leveraged borrowing and boom–bust cycles, *Review of Economic Dynamics* **16**(4), 617–633.

Ren, Y. and Yuan, Y.: 2014, Why the housing sector leads the economy: The importance of collateral constraints and news shocks, *Journal of Real Estate Finance and Economics* **48**, 323–41.

A Data

A.1 US

The series for output, consumption, residential investment, and non-residential investment are from NIPA, Table 1.1.3. New houses are from the US Bureau of Census, specifically this series "Housing Starts: Total: New Privately Owned Housing Units Started". The housing price index is the S&P/Case-Shiller U.S. National Home Price Index which is divided by the CPI index from the BLS.

A.2 France

The series for output and residential investment are from the Quarterly National Accounts published by the INSEE. Housing starts are from the Main Economic Indicators of the OECD.

B The model equations

B.1 Impatient households

$$\max E_0 \sum_{t=0}^{\infty} \theta_I^t \left(\ln\left(c_{It} - \zeta c_{It-1}\right) + \psi \ln h_{It} + \eta_I \ln\left(1 - \left(n_{Ict}^{1+\epsilon} + n_{Iht}^{1+\epsilon}\right)^{1/(1+\epsilon)}\right)\right) \tag{30}$$

subject to

$$c_{It} + (1+\tau_h) q_{ht} h_{It} - q_{ht}(1-\delta_h) h_{It-1} = \begin{array}{l} b_{Ht} - R_{t-1} b_{Ht-1} + p_{lt} l_{It} + \sum_{i=c,h} w_{it} n_{Iit} \\ -\tau_n \left(\sum_{i=c,h} w_{it} n_{Iit} - \tau_m r_{t-1} b_{Ht-1} \right) + \xi_{It}, \end{array} \tag{31}$$

$$b_{Ht} \leq m_H E_t q_{ht+1} h_{It}, \tag{32}$$

$$n_t = \left(n_{Ict}^{1+\epsilon} + n_{Iht}^{1+\epsilon}\right)^{1/(1+\epsilon)}. \tag{33}$$

First-order conditions

$\mathbf{c_{It}}$:

$$\frac{1}{c_{It} - \zeta c_{It-1}} - E_t \frac{\theta_I \zeta}{c_{It+1} - \zeta c_{It}} = \lambda_{1It} \tag{34}$$

$\mathbf{b_{Ht}}$:

$$\lambda_{1It} - \lambda_{2It} = \theta_I \left(1 + r_t(1 - \tau_n \tau_m)\right) E_t \lambda_{1It+1} \tag{35}$$

$\mathbf{h_{It}}$:

$$q_{ht}\lambda_{1It}(1+\tau_h) - m^H\lambda_{2It}E_t q_{ht+1} = \theta_I(1-\delta_h)E_t\lambda_{1It+1}q_{ht+1} + \frac{\Psi}{h_{It}} \tag{36}$$

$\mathbf{n_{Ijt}}$ $\quad j = c, h$:

$$\lambda_{1It}(1-\tau_n)w_{jt} = \frac{\eta_I}{1-n_{It}}\left(\frac{n_{Ijt}}{n_{It}}\right)^{\epsilon} \tag{37}$$

B.2 Patient households

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln\left(c_{Pt} - \zeta c_{Pt-1}\right) + \psi \ln h_{Pt} + \eta_P \ln\left(1 - \left(n_{Pct}^{1+\epsilon} + n_{Pht}^{1+\epsilon}\right)^{1/(1+\epsilon)}\right)\right) \tag{38}$$

subject to

$$\begin{aligned} c_{Pt} + (1+\tau_h)q_{ht}h_{Pt} - \\ q_{ht}(1-\delta_h)h_{Pt-1} \end{aligned} = \begin{aligned} &\tfrac{1}{\omega_P}\left(\omega_I\left(R_{t-1}b_{Ht-1} - b_{Ht}\right) + \omega_E\left(R_{t-1}b_{Kt-1} - b_{Kt}\right)\right) + \\ &(1-\tau_n)\textstyle\sum_{i=c,h} w_{it}n_{Pit} + p_{lt}l_{Pt} + \xi_{Pt} \end{aligned} \tag{39}$$

$$n_t = \left(n_{Pct}^{1+\epsilon} + n_{Pht}^{1+\epsilon}\right)^{1/(1+\epsilon)}. \tag{40}$$

First-order conditions

$\mathbf{c_{Pt}}$:

$$\frac{1}{c_{Pt} - \zeta c_{Pt-1}} - E_t\frac{\theta_P\zeta}{c_{Pt+1} - \zeta c_{Pt}} = \lambda_{1Pt} \tag{41}$$

$\mathbf{h_{Pt}}$:

$$q_{ht}\lambda_{1Pt}(1+\tau_h) = \beta(1-\delta_h)E_t\lambda_{1Pt+1}q_{ht+1} + \frac{\Psi}{h_{Pt}} \tag{42}$$

$\mathbf{n_{Pjt}}$ $\quad$ j=c,h:

$$\lambda_{1Pt}(1-\tau_n)w_{jt} = \frac{\eta_P}{1-n_{Pt}}\left(\frac{n_{Pjt}}{n_{Pt}}\right)^{\epsilon} \tag{43}$$

$\mathbf{b_{Ht}}$ and $\mathbf{b_{Kt}}$:

$$\lambda_{1Pt} = \beta R_t E_t \lambda_{1Pt+1} \tag{44}$$

B.3 Entrepreneurs

$$\max E_0 \sum_{t=0}^{\infty} \theta_E^t \ln\left(c_{Et} - \zeta c_{Et-1}\right) \tag{45}$$

subject to

$$c_{Et} + x_{ct} + x_{bt} + \frac{w_{ct}}{\omega_E} \sum_{j=I,P} \omega_j n_{jct} + \tau_k r_{ct} k_{ct-1} = \begin{array}{l} \frac{y_t}{\omega_E} + b_{Kt} - R_{t-1} b_{Kt-1} + \\ (1-\tau_k) p_{bt} k_{bt} + p_{lt} l_{Et} + \xi_{Et} \end{array}, \tag{46}$$

$$y_t = z_t \left(\omega_E k_{ct-1}\right)^{\alpha_C} \left(\sum_{j=I,P} \omega_j n_{jct}\right)^{1-\alpha_C}, \tag{47}$$

$$x_{ct} = k_{ct} - (1-\delta_c) k_{ct-1}, \tag{48}$$

$$x_{bt} = k_{bt}, \tag{49}$$

$$b_{Kt} + \frac{w_{ct}}{\omega_E} \sum_{j=I,P} \omega_j n_{jct} \leq m_K k_{ct}. \tag{50}$$

First-order conditions

$\mathbf{c_{Et}}$:

$$\frac{1}{c_{Et} - \zeta c_{Et-1}} - E_t \frac{\theta_E \zeta}{c_{Et+1} - \zeta c_{Et}} = \mu_{1Et} \tag{51}$$

$\mathbf{b_{Kt}}$:

$$\mu_{1t} - \mu_{2t} = \theta_E R_t E_t \mu_{1t+1} \tag{52}$$

$\mathbf{k_{ct}}$:

$$\mu_{1t} - m_K \mu_{2t} = \theta_E E_t \left(\mu_{1t+1}(1 - \delta_c + (1-\tau_k) r_{ct+1})\right) \tag{53}$$

$$\text{where } r_{ct} = \frac{\alpha_c y_t}{k_{ct-1}} \tag{54}$$

$\mathbf{k_{bt}}$:

$$\mu_{1t} = \mu_{1t}(1-\tau_k) p_{bt} \tag{55}$$

$\mathbf{n_{jct}}$:

$$\frac{\mu_{1t}(1-\alpha_C) y_t}{\sum_{j=I,P} \omega_j n_{jct}} = (\mu_{1t} + \mu_{2t}) w_{ct} \tag{56}$$

B.4 House developers

First stage:

$$\max p_{rt}x_{rt} - \omega_E p_{bt}k_{bt} - w_{ht}\sum_{j=I,P}\omega_j n_{jit} \tag{57}$$

subject to

$$ih_t = z_t\left(\omega_E k_{bt}\right)^{\alpha_B}\left(\sum_{j=I,P}\omega_j n_{jht}\right)^{1-\alpha_B}. \tag{58}$$

Second stage:

$$\max q_{ht}ih_t - p_{rt}x_{rt} - p_{lt}l_t \tag{59}$$

subject to

$$ih_t = x_{rt}^{\phi}l_t^{1-\phi}. \tag{60}$$

Land supply:

$$l_t = \sum_{j=I,P,E}\omega_j l_{jt} = 1 \tag{61}$$

Law of motion of houses:

$$ih_t = h_t - (1-\delta_h)h_{t-1} \tag{62}$$

$$h_t = \omega_I h_{It} + \omega_P h_{Pt}. \tag{63}$$

First-order conditions

$\mathbf{n_{jht}}$:

$$w_{ht} = (1-\alpha_B)\frac{p_{rt}x_{rt}}{\sum_{j=I,P}\omega_j n_{jht}} \tag{64}$$

$\mathbf{k_{bt}}$:

$$\omega_E p_{bt} = \alpha_B\frac{p_{rt}x_{rt}}{k_{bt}} \tag{65}$$

$\mathbf{x_{rt}}$:

$$p_{rt} = \phi\frac{q_{ht}ih_t}{x_{rt}} \tag{66}$$

$\mathbf{l_t}$:

$$p_{lt} = (1-\phi)\frac{q_{ht}ih_t}{l_t} \tag{67}$$