Housing, Credit Market Imperfections, and the Business Cycle

(preliminary and incomplete)

Charles Ka Yui Leung†
Department of Economics
The Chinese University of Hong Kong

Zhixiong Zeng‡
Department of Economics
The Chinese University of Hong Kong

March 2005

Abstract

We study the role of residential housing in financing capital investment in a quantitative dynamic stochastic general equilibrium framework. Residential housing, though nonproductive, is shown to be important in determining the cost of external financing for investment on productive capital. Housing stock serves as collateral in financial contracts for capital investment. We find that when the model is reasonably calibrated, fluctuations in the return to capital investment is not enough to account for the cyclical behavior of the external finance premium. Fluctuations of house prices help generate countercyclical external finance premium by a great deal.

JEL Classification Number: E44, D82, R21, R31

The authors are grateful to the seminar participants of HKEA-WEA Meeting (2005) for comments and discussion, and Chinese University Direct Grant, RGC Earmark Grant, Fulbright Foundation for financial support. The usual disclaimer applies.

†Address: Department of Economics, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong SAR, China. Phone: (852) 2609-8194, Fax: (852) 2603-5805, Email: zzxeng@cuhk.edu.hk.

‡Corresponding Author. Address: Department of Economics, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong SAR, China. Phone: (852) 2609-8183, Fax: (852) 2603-5805, Email: zzxeng@cuhk.edu.hk.
Keywords: Housing, Productive versus nonproductive assets, Credit market imperfections, External finance premium.
1 Introduction

What explains the business cycles? It is a question that has been asked for more than a century. Although a complete answer has yet to come, the pioneer-contribution of Kydland and Prescott (1982), Long and Plosser (1983) point to the direction that technological change is the main driving force for the business cycle fluctuations (so-called “real business cycle” theory, or simply RBC theory). In fact, there are some micro-evidence that technological innovation can explain some of the aggregate fluctuations (for instance, see Jovanovic and Lach (1997)). A common objection to the RBC theory, however, is that the “cycles” are exogenous. Or, to put it another way, it does not provide an internal propagation mechanism. In particular, the standard RBC theory has difficulty to explain two important stylized facts: the positive serial correlation of GNP growth and a hump-shaped impulse-response function to innovations in the temporary component (for instance, see Cogley and Nason (1995)). Interestingly, the endogenous-business-cycle theory, which generates “cycles” based on external effect and is an important alternative of the RBC theory, has an equal difficulty in explaining these facts as well (for instance, see Schmitt-Grohe (1997, 2000)).

This paper follows a third route, which is a combination of the technological explanation (RBC theory) and the imperfect capital market theory. Bernanke, Gertler and Gilchrist (1999) (henceforth BGG), Carlstrom and Fuerst (1997) (henceforth CF), Fisher (1999), Kiyotaki and Moore (1997) (henceforth KM), among others, all belongs to this category. With two theories combined, it should not be surprised that the models of this
class in general generate much richer dynamics than the RBC models. However, this approach is not without drawbacks. For instance, Cordoba and Ripoll (2003) find that with standard assumptions on preference and production technologies, the collateral constraints typically generate small amplification. Gomes, Yaron and Zhang (2003) find that some of these models would imply a procyclical finance premium, which is at odd with the data.

This paper attempts to address the issue by introducing residential housing into a prototype model of this class. Residential housing, though nonproductive, will be important in determining the cost of external financing for investment on productive capital. The intuition is simple. Housing stock does not only provide utility to the owner-occupant, but also serves as collateral in financial contracts for capital investment. In contrast to the previous literature, which do not distinguish the residential capital stock from the business counterpart, the value of the house in practice is independent of the value of the firm run by the entrepreneur-owner-occupant. To take it to the extreme, we assume that all houses are identical and there is no idiosyncrasy associated with the returns to house purchase. The house value is purely driven by aggregate shock. On the contrary, atomless firms are subject to idiosyncratic risk. Thus, houses become “ideal collateral”. This observation has at least two important implications. First, it means that the burden to account for the cyclical behavior of external finance premia and bankruptcy rates is now shared by the fluctuations in capital investment return, as well as the fluctuations in house values. To put it differently, the finance premium no longer needs to be procyclical to generate the business cycles. It turns out that, quantitatively, this effect is important.

Clearly, this paper is related to the emerging literature which relates the housing
market to the macroeconomy. On the empirical front, there are several recent papers which confirm that there exists important linkages between the housing market and the aggregate economy.\(^1\) There are also a number of quantitative theoretical works on housing and the macroeconomy. For instance, KM consider the case where "capital" or "land" are both used as collateral as well as a factor of production. Essentially, KM aggregates the physical capital with household capital. In ex post terms, there is no bankruptcy in their model. Ortalo-Magne and Rady (1999, 2001) distinguishes housing from financial capital in a dynamic exchange economy. They can mimic the observed correlation between housing price and trading volume. Iacoviello (2004) extend KM in several dimensions. First, real estate enters the utility function as well as the production function. Second, monetary shocks are also considered. This paper shares some of these features and differs in other aspects. First, as in Jin and Zeng (2004), housing enter the utility function as a durable consumption goods while physical capital is used exclusively for production. As in KM, housing is also used by the entrepreneurs as a collateral to finance investment. Second, we allow for ex post bankruptcy and generate the external finance premium endogenously. As it will become clear, the bankruptcy rate is closely tied to the aggregate economy. This is important because in the empirical literature, it has been repeatedly documented that the movement of the external finance premium is related the real side of the economy (such as the aggregate output and consumption).\(^2\)


\(^2\)That literature is too large to be reviewed here. See Bernanke and Gertler (1995), De Bondt (2000), among others, for a survey.
2 Baseline Model

Roughly speaking, this model introduces residential housing into a simplified BGG framework. As in Greenwood and Hercowitz (1991) (henceforth GH), residential housing is a consumer durable goods which generates utility to the agents (entrepreneurs and households). And as in KM, residential housing can also be used as collateral by the entrepreneurs to get bank loans and hence the fluctuations of housing price can have important implications to the financing of entrepreneurs (intermediate goods producers). Given these similarities, the description will be brief. Time is discrete and the horizon is infinite. There are two types of agents in this economy, households and entrepreneurs. Households are infinitely lived while the entrepreneurs have only finite lives. When the entrepreneurs “die” (or leave the economy), they would live bequest to their descendants. The number of the descendants is exactly equal to the number of the ancestors and the population of the economy is constant over time. Alternatively, the entrepreneurs can be interpreted as infinite lived with a solvency constraint in each period. The "bequest" are simply the amount of wealth they want to transfer to themselves in the future, provided that they are solvent. There are several types of goods and several market transactions take place in this economy. Therefore, it is instructive to provide a verbal description first before the formal modelling. The exposition will be proceeded in the following order: the entrepreneurs first, then the household sector, and the equilibrium conditions will be reserved to the last.
2.1 Sequence of Events

At the beginning of each period $t$, generation $t - 1$ entrepreneurs possess capital stock $k_t$ and house stock $h_t$ and debt $b_t$. For each entrepreneur, an idiosyncratic shock $\omega_t$ realizes that results in an amount of effective capital $\omega_t k_t$. Entrepreneurs then produce intermediate goods with the formed effective capital using a constant returns-to-scale technology. That is, $m_t = \omega_t k_t$ where $m_t$ is the amount of output produced. All entrepreneurs produce the same type of intermediate goods and sell their product at the competitive intermediate goods market at price $P_t$ (all prices are expressed in units of final consumption goods). They also sell the after-depreciation capital and house to households who are the only type of agents that are endowed with the technology for transforming investment into new capital or house. Such transformation is subject to an adjustment-cost technology where existing capital and house stock may play a nontrivial role. Let $\delta_k$ and $\delta_h$ be the depreciation rates of capital and house respectively, and $\bar{Q}_{kt}$ and $\bar{Q}_{ht}$ be the prices of existing capital and house paid by households to entrepreneurs respectively. An entrepreneur’s total revenue is given by

$$\Omega_t = \omega_t k_t + \bar{Q}_k (1 - \delta_k) \omega_t k_t + \bar{Q}_h (1 - \delta_h) h_t.$$  

Debt repayment then occurs. And an entrepreneur might be solvent or insolvent. A solvent entrepreneur passes the resulting net wealth $w_t$ to her offspring born in period $t$ and then disappear from the scene. For those entrepreneurs who go bankrupt and leave zero net wealth, their offsprings will receive an amount $\varepsilon$ from the government. $\varepsilon$ can be taken to be arbitrarily small so that it is negligible in the aggregate.
Inherited with \(w_t\), a generation \(t\) entrepreneur allocates her wealth to consumption expenditure \(c^e_t\), house expenditure, and net equity \(n_{t+1}\). After negotiating a financial contract with banks, the entrepreneur borrows \(b_{t+1}\), which is then combined with net equity to purchase new capital \(k_{t+1}\) produced by the household sector at price \(Q_{kt}\). The house expenditure is used to purchase new house \(h_{t+1}\) at price \(Q_{ht}\).

The sequence of events pertaining to the entrepreneur sector is summarized in the following table.

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Idiosyncratic shocks realize.</td>
</tr>
<tr>
<td>2.</td>
<td>Produce intermediate goods with capital: (m_t = \omega_t k_t).</td>
</tr>
<tr>
<td>3.</td>
<td>Sell (m_t) at price (P_t), sell ((1 - \delta_k) k_t) at price (\bar{Q}<em>{kt}), sell ((1 - \delta_h) h_t) at price (\bar{Q}</em>{ht}).</td>
</tr>
<tr>
<td>4.</td>
<td>Repay debt (b_t) borrowed at period (t - 1).</td>
</tr>
<tr>
<td>5.</td>
<td>Generation (t - 1) passes wealth (w_t) to generation (t).</td>
</tr>
<tr>
<td>6.</td>
<td>Allocates (w_t) between (c^e_t), (Q_{ht} h_{t+1}), and (n_{t+1}).</td>
</tr>
<tr>
<td>7.</td>
<td>Contract negotiation, borrows (b_{t+1}).</td>
</tr>
<tr>
<td>8.</td>
<td>Purchases (k_{t+1}) at price (Q_{kt}), using (n_{t+1} + b_{t+1}). Purchase (h_{t+1}) at price (Q^b_h).</td>
</tr>
</tbody>
</table>

### 2.2 Entrepreneur’s Wealth Allocation Problem

Entrepreneurs are altruistic and live for two periods. Following Glomm and Ravikumar (1992), Banerjee and Newman (1993), a generation-\(t\) entrepreneur’s utility function is in Cobb-Douglas form, 

\[
U^e(c^e_t, h_{t+1}, \overline{w}_{t+1}) = (c^e_t)^\nu (h_{t+1})^\eta (\overline{w}_{t+1})^{1-\nu-\eta},
\]

where \(c^e_t\) is the consumption of the entrepreneur, \(h_{t+1}\) is the amount of residential housing acquired in period \(t\), \(\overline{w}_{t+1}\) is the expected value of bequest leaving to the offspring.

When the entrepreneur receives bequests \(w_t\) from her ancestor—a generation \(t - 1\)
entrepreneur, she allocates it to consumption expenditure, house expenditure, and net equity to maximize utility. Thus the wealth allocation problem for a typical entrepreneur is

$$\max_{c_t, h_{t+1}, n_{t+1}} U^e(c^e_t, h_{t+1}, w_{t+1})$$

subject to

$$c^e_t + Q_h h_{t+1} + n_{t+1} = w_t$$

and

$$w_{t+1} = w_t (n_{t+1}, h_{t+1}).$$

Here (2) is the entrepreneur’s budget constraint, and (3) is a function according to which the expected value of bequest is generated. Following the entrepreneur’s wealth allocation, the contract negotiation is carried out conditional on the entrepreneur’s choice of $h_{t+1}$ and $n_{t+1}$. It will be shown in next section that the amount of borrowing $b_{t+1}$ agreed upon, and hence the amount of $k_{t+1}$ to be purchased, is a function of $h_{t+1}$ and $n_{t+1}$. Hence $w_{t+1}$ is also a function of $h_{t+1}$ and $n_{t+1}$. Substituting (3) into the utility function and using $\gamma_t$ to denote the Lagrangian multiplier associated with the constraint (2), the first-order conditions with respect to $c^e_t$, $h_{t+1}$, and $n_{t+1}$ are given by

$$\nu (c^e_t)^\nu (h_{t+1})^\eta (w_{t+1})^{1-\nu-\eta} = \gamma_t c^e_t$$

$$\nu (c^e_t)^\nu (h_{t+1})^\eta (w_{t+1})^{1-\nu-\eta} \left[ \eta + (1-\nu-\eta) \frac{h_{t+1}}{w_{t+1}} \frac{\partial w_{t+1}}{\partial h_{t+1}} \right] = \gamma_t Q^h_t h_{t+1}$$

$$\nu (c^e_t)^\nu (h_{t+1})^\eta (w_{t+1})^{1-\nu-\eta} \frac{\partial w_{t+1}}{\partial n_{t+1}} = \gamma_t w_{t+1}$$

respectively. In addition, (2) holds with equality.
2.3 Financial Contract

In this subsection we describe the financial contracting problem between a generation-\( t \) entrepreneur and the bank that finances her capital investment. Taking \( h_{t+1} \) and \( n_{t+1} \) as given, the contract specifies the amount of borrowing \( b_{t+1} = Q_{kt} k_{t+1} - n_{t+1} \) and a state-contingent payment schedule. Define the aggregate (economy-wide) rate of return on capital from period \( t \) to period \( t + 1 \) as

\[
R_{k,t+1} = \frac{P_{t+1} + \tilde{Q}_{k,t+1} (1 - \delta_k)}{Q_{k,t}} \tag{7}
\]

and the pecuniary rate of return on house as

\[
R_{h,t+1} = \frac{\tilde{Q}_{h,t+1} (1 - \delta_h)}{Q_{ht}} \tag{8}
\]

(There is also an implicit rent due to the utility service provided by house.) Then the entrepreneur’s revenue in period \( t + 1 \), \( \Omega_{t+1} \), can be rewritten as

\[
\Omega_{t+1} = \omega_{t+1} R_{k,t+1} Q_{kt} k_{t+1} + R_{h,t+1} Q_{ht} h_{t+1}
\]

The way we introduce credit market imperfections into the model is in line with the costly state verification (CSV) tradition of Townsend (1979). We impose an informational asymmetry between entrepreneurs and banks by assuming that only entrepreneurs can costlessly observe the realizations of the idiosyncratic shock \( \omega \), while banks have to expend a verification cost in order to know the true value. The random variable \( \omega \) is assumed to be unit mean and independent, identically distributed across entrepreneurs, with a common c.d.f. \( \Psi(\omega) \) and p.d.f. \( \psi(\omega) \) on \( (0, \infty) \). Since the informational asymmetry pertains only
to the idiosyncratic risk, it is natural to assume that the verification cost pertains only to
the part of entrepreneurial revenue that is related to \( \omega \), i.e., \( \omega_{t+1} R_{k,t+1} Q_{k,t+1} k_{t+1} \). Following
Carlstrom and Fuerst (1997), the cost is assumed to be proportional to the size (average
value) of this part of revenue, \( R_{k,t+1} Q_{k,t+1} k_{t+1} \), the factor of proportionality being \( \mu \in (0, 1) \).

We follow three steps in analyzing the optimal contract. First, given the amount of
borrowing \( b_{t+1} \), the optimal form of contract is the standard debt contract, as shown by
Gale and Hellwig (1985) and Williamson (1986). The contract can be characterized by a
nondefault interest rate \( z_{t+1} \). When the entrepreneur is solvent, i.e., \( \Omega_{t+1} \geq z_{t+1} b_{t+1} \), she
pays the fixed amount \( z_{t+1} b_{t+1} \) to the bank. No monitoring occurs in this case. Otherwise
the bank monitors and confiscates all the entrepreneur’s revenue and incurs verification
cost \( \mu R_{k,t+1} Q_{k,t+1} k_{t+1} \). Thus, the entrepreneur’s net wealth after debt repayment is

\[
\omega_{t+1} = \begin{cases} 
\Omega_{t+1} - z_{t+1} b_{t+1} & \text{if } \Omega_{t+1} \geq z_{t+1} b_{t+1} \\
0 & \text{if } \Omega_{t+1} < z_{t+1} b_{t+1}
\end{cases}
\]

Given a pair of aggregate rates of return \( (R_{k,t+1}, R_{h,t+1}) \), the cutoff level of revenue \( \Omega_{t+1} = z_{t+1} b_{t+1} \) corresponds to a cutoff value \( \omega_{t+1} \) for the idiosyncratic risk, which satisfies

\[
\omega_{t+1} R_{k,t+1} Q_{k,t+1} + R_{h,t+1} Q_{h,t+1} = \Omega_{t+1}
\]  

Under the debt contract, the expected payment from the entrepreneur to the bank is given
by

\[
\int_{\omega_{t+1}}^{\infty} \Omega_{t+1} d\Psi (\omega) + \int_{0}^{\omega_{t+1}} \Omega_{t+1} d\Psi (\omega) = R_{k,t+1} Q_{k,t+1} k_{t+1} \Gamma (\omega_{t+1}) + R_{h,t+1} Q_{h,t+1} k_{t+1}
\]

where

\[
\Gamma (\omega) \equiv [1 - \Psi (\omega)] \omega + G (\omega)
\]
with

\[ G(\omega) = \int_0^\varpi \omega d\Psi(\omega) \quad (11) \]

Hence the entrepreneur’s expected return is \( R_{k,t+1}Q_{kt}k_{t+1} [1 - \Gamma(\varpi_{t+1})] \), while the bank’s expected return, net of monitoring cost, is given by \( R_{k,t+1}Q_{kt}k_{t+1} * [\Gamma(\varpi_{t+1}) - \mu G(\varpi_{t+1})] + R_{h,t+1}Q_{ht}h_{t+1} \).

Note that the expected returns of the entrepreneur and the bank sum up to

\[ (R_{k,t+1}Q_{kt}k_{t+1} + R_{h,t+1}Q_{ht}h_{t+1}) - \mu G(\varpi_{t+1}) R_{k,t+1}Q_{kt}k_{t+1} \]

where \( \mu G(\varpi_{t+1}) R_{k,t+1}Q_{kt}k_{t+1} \) reflects the deadweight loss, or agency cost, that arises from the information asymmetry.

We now proceed to the second step of analyzing the optimal contract, which follows BGG. Assume that the lending side of the economy is perfectly competitive, then in equilibrium the bank’s expected return must be equal to the opportunity costs of funds lent out. Since the entrepreneurs’ utility depends only on the expected value of period \( t + 1 \) wealth as in (2), the entrepreneurs are risk-neutral with respect to the distribution of wealth, so that they bear all the aggregate risk. Banks get an expected return that is independent of the aggregate shocks. Let \( R_{t+1} \) be the risk-free rate of return from period \( t \) to \( t + 1 \) which is noncontingent on period \( t + 1 \) aggregate shocks. Then the following constraint must hold for every realization of aggregate shocks:

\[ R_{k,t+1}Q_{kt}k_{t+1} [\Gamma(\varpi_{t+1}) - \mu G(\varpi_{t+1})] + R_{h,t+1}Q_{ht}h_{t+1} = R_{t+1} (Q_{kt}k_{t+1} - n_{t+1}) \quad (12) \]

Put differently, (12) must hold for all realizations of the pair \((R_{k,t+1}, R_{h,t+1})\).

It remains to determine the optimal amount of borrowing \( b_{t+1} \), which corresponds to
an optimal value of capital $k_{t+1}$, and the nondefault interest rate $z_{t+1}$. The nondefault interest rate, and hence the cutoff for the idiosyncratic risk $\omega_{t+1}$, will be a function of the aggregate rates of return $(R_{k,t+1}, R_{h,t+1})$.

The optimal competitive contract between the generation-$t$ entrepreneur and the bank solves the following problem:

$$\max_{k_{t+1}, \omega_{t+1}} E_t \{ R_{k,t+1} Q_{kt} k_{t+1} (1 - \Gamma (\omega_{t+1})) \}$$

subject to (12). Let $\lambda_{t+1}$ be the Lagrangian multiplier associated with (12), one for each pair $(R_{k,t+1}, R_{h,t+1})$. Then the first-order conditions with respect to $k_{t+1}$, each $\omega_{t+1}$, and each $\lambda_{t+1}$ are

$$E_t \{ R_{k,t+1} [1 - \Gamma (\omega_{t+1})] + \lambda_{t+1} \{ R_{k,t+1} [\Gamma (\omega_{t+1}) - \mu G (\omega_{t+1})] - R_{t+1} \} \} = 0$$

$$-\Gamma' (\omega_{t+1}) + \lambda_{t+1} [\Gamma' (\omega_{t+1}) - \mu G' (\omega_{t+1})] = 0$$

$$R_{k,t+1} \tilde{k}_{t+1} \{ \Gamma (\omega_{t+1}) - \mu G (\omega_{t+1}) \} + R_{h,t+1} \tilde{h}_{t+1} - R_{t+1} \left( \tilde{k}_{t+1} - \tilde{n}_{t+1} \right) = 0$$

where

$$\tilde{k}_{t+1} \equiv \frac{Q_{kt} k_{t+1}}{w_t}, \quad \tilde{h}_{t+1} \equiv \frac{Q_{ht} h_{t+1}}{w_t}, \quad \tilde{n}_{t+1} \equiv \frac{n_{t+1}}{w_t}$$

are the entrepreneur’s capital expenditure, house expenditure, and net equity relative to her initial wealth.

### 2.4 Partial Equilibrium in the Entrepreneurial Sector

To close the description of the entrepreneurial sector, we investigate how the entrepreneur’s expected return varies with changes in $h_{t+1}$ and $n_{t+1}$. Note that the maximum value for
the constrained problem (13) is precisely $\bar{w}_{t+1}$. By applying the envelope theorem to (13), we find that
\begin{align*}
\frac{\partial \bar{w}_{t+1}}{\partial \bar{h}_{t+1}} &= Q_{h} E_{t} [\lambda_{t+1} R_{h,t+1}] \\
\frac{\partial \bar{w}_{t+1}}{\partial \bar{m}_{t+1}} &= R_{t+1} E_{t} [\lambda_{t+1}]
\end{align*}

(17) (18)

Furthermore, since the optimal solution for $k_{t+1}$ in the problem (13) is proportional to $w_{t}$, and the optimal solution for the $\omega_{t+1}$ schedule is independent of $w_{t}$, one can write $\bar{w}_{t+1} \equiv \zeta_{t+1} w_{t}$ where $\zeta_{t+1}$ is independent of $w_{t}$ and equals $E_{t} \left\{ R_{k,t+1} Q_{kt} \tilde{k}_{t+1} \left[ 1 - \Gamma (\bar{\omega}_{t+1}) \right] \right\}$ evaluated at the optimal $k_{t+1}$ and $\bar{\omega}_{t+1}$ schedule. Substituting (17), (18), and $\bar{w}_{t+1} \equiv \zeta_{t+1} w_{t}$ into the first-order conditions associated with the entrepreneur’s wealth allocation problem, i.e., (4)–(6) and (2), then rearranging, we obtain
\begin{align*}
\frac{\tilde{c}_{t}^{e}}{\tilde{h}_{t+1}} &= \frac{\nu R_{t+1} E_{t} (\lambda_{t+1}) - E_{t} (\lambda_{t+1} R_{h,t+1})}{\eta R_{t+1} E_{t} (\lambda_{t+1})} \\
\frac{\tilde{h}_{t+1}}{\zeta_{t+1}} &= \frac{1}{1 - \nu - \eta R_{t+1} E_{t} (\lambda_{t+1}) - E_{t} (\lambda_{t+1} R_{h,t+1})} \\
\tilde{c}_{t}^{e} + \tilde{h}_{t+1} + \tilde{n}_{t+1} &= 1
\end{align*}

(19) (20) (21)

Finally, the law of motion for aggregate entrepreneurial wealth, denoted by $W_{t}$, is
\begin{equation}
W_{t+1} = W_{t} R_{t+1} \tilde{k}_{t+1} \left[ 1 - \Gamma (\bar{\omega}_{t+1}) \right]
\end{equation}

(22)

To see this, note that for an individual entrepreneur, at a given realization of date $t+1$ state, her wealth is 0 when $\omega_{t+1} < \bar{\omega}_{t+1}$ and equals $\Omega_{t+1} - z_{t+1} b_{t+1}$ when $\omega_{t+1} \geq \bar{\omega}_{t+1}$. Averaging over idiosyncratic shocks, the mean of her period $t+1$ wealth is given by $w_{t} R_{t+1} \tilde{k}_{t+1} \left[ 1 - \Gamma (\bar{\omega}_{t+1}) \right]$. When aggregating across entrepreneurs, the law of large numbers ensures that one can treat each entrepreneur as receiving the mean wealth and adding
them up to obtain the date \( t + 1 \) aggregate wealth, which is given by (22). The period-\( t \) conditional expectation of \( W_{t+1} \) over the distribution of aggregate shocks in period \( t + 1 \) is \( \zeta_{t+1} W_t \). Given \( W_t \), the period \( t \) aggregate entrepreneurial consumption and house demand are simply \( C_t^e = \zeta_t W_t \) and \( H_{t+1}^e = h_{t+1} W_t \), respectively. Note that all entrepreneurs have the same \( \zeta_t \) and \( h_{t+1} \).

To summarize, the partial equilibrium in the entrepreneurial sector can be described by the system consisting of (19)–(21) and (14)–(22). We next turn to the household sector.

3 The Household Sector

There are a continuum of identical households with unit mass. The representative household ranks alternative streams of consumption, house services, and leisure according to the following criterion function

\[
E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^h, H_t^h, L_t) \tag{23}
\]

where \( E_0 \) is the expectation operator conditional on time 0 information. \( C_t^h \) is household consumption in period \( t \). \( L_t \) is hours worked. With time endowment normalized to unity, the household enjoys leisure \( 1 - L_t \). In addition, \( H_t^h \) is the house stock held by the household at the beginning of period \( t \). By letting \( H_t^h \) enters directly the period utility function, we are implicitly assuming that the service stream derived from house is proportional to the beginning-of-period house stock.

While the entrepreneurs are specialized in producing intermediate goods, the households are engaged in combining labor \( L_t \) and intermediate goods \( M_t \) to produce the final
goods $Y_t$, according to the production function

$$Y_t = A_t F(M_t, L_t),$$  \hspace{1cm} (24)$$

where $A_t$ is the period $t$ aggregate productivity shock. The logarithm of $A_t$ follows an $AR(1)$ process:

$$\ln A_t = \rho \ln A_{t-1} + \varepsilon_t$$ \hspace{1cm} (25)$$

where $0 < \rho < 1$ and $\varepsilon_t$ is white noise with normal c.d.f. $N(0, \sigma^2)$.

Moreover, the households are the only type of agents who are endowed with the technology for producing new capital and house. They might allocate the final goods output $Y_t$ to own consumption $C_{th}$, capital investment $I_{kt}$, house investment $I_{ht}$, and goods sold to other agents in the economy. The existing capital and house stock also play a role in the production of new capital and house. To produce new capital goods, households purchase after-depreciation capital $(1 - \delta_k) K_t$ from entrepreneurs at price $\hat{Q}_{kt}$. The gross capital formation is then generated by the function $\Phi^k(I_{kt}, K_t)$ which is strictly increasing, strictly concave, and linearly homogeneous in both arguments.\(^3\) The concavity of $\Phi^k$ in $I_{kt}$ implies that there is a convex capital adjustment cost: capital investment is transformed into newly formed capital at a rate that is declining in the quantity of investment itself. Thus, capital stock evolves according to

$$K_{t+1} = (1 - \delta_k) K_t + \Phi^k(I_{kt}, K_t).$$ \hspace{1cm} (26)$$

Similarly, new house formation is generated by a combination of house investment

\(^3\)Since $\delta_k$ is a constant, it suffices to use $K_t$, instead of $(1 - \delta_k) K_t$, as the second argument of $\Phi^k$.\)
$I_{ht}$ and existing house stock. The household owns $H^h_t$ at the end of period $t - 1$, while entrepreneurs own $H^e_t$. Let $H_t \equiv H^h_t + H^e_t$ be the aggregate house stock at the end of period $t - 1$. The undepreciated part of aggregate house stock in period $t$ is then $(1 - \delta_h) H_t$. Households purchase $(1 - \delta_h) H^e_t$ from entrepreneurs at price $\tilde{Q}_{ht}$. We represent the transformation technology for new house by the function $\Phi^h(I_{ht}, H_t)$ which is strictly increasing, strictly concave, and linearly homogeneous in both arguments. Again, the concavity of $\Phi^h$ in $I_{ht}$ implies that there is convex adjustment cost for house. Hence house stock evolves according to

$$H_{t+1} = (1 - \delta_h) H_t + \Phi^h(I_{ht}, H_t)$$  \hspace{1cm} (27)

Finally, the household faces the following budget constraint:

$$\left( Y_t - C^h_t - I_{kt} - I_{ht} \right) + Q_{kt} K_{t+1} + Q_{ht} H^e_{t+1} + R_t S_t \geq P_t M_t + \tilde{Q}_{ht} (1 - \delta_h) H^e_t + \tilde{Q}_{kt} (1 - \delta_k) K_t + S_{t+1}$$  \hspace{1cm} (28)

On the right-hand side of (28), the term $Y_t - C^h_t - I_{kt} - I_{ht}$ represents the household’s revenues from sales in the final goods market. $Q_{kt} K_{t+1}$ and $Q_{ht} H^e_{t+1}$ are revenues from selling new capital and house stock to entrepreneurs, respectively. $R_t S_t$ is principal plus interest from previous savings, where $S_t$ is savings made by the household and deposited in banks in period $t - 1$, and $R_t$ is the risk-free gross rate of interest from period $t - 1$ to $t$. On the right hand side, $P_t M_t$ is the household’s purchase of intermediate goods from entrepreneurs. $\tilde{Q}_{ht} (1 - \delta_h) H^e_t$ and $\tilde{Q}_{kt} (1 - \delta_k) K_t$ are the household’s purchase of existing house and capital stock from entrepreneurs, respectively. Finally, $S_{t+1}$ is household savings made in period $t$, whose return is to be collected in period $t + 1$. 

15
The household’s problem is to maximize (23) subject to (24), (26), (27), and (28). The associated Bellman equation is

$$ V \left( S_t, H^h_t \right) = \max \left\{ U(C^h_t, H^h_t, L_t) + \beta E_t V \left( S_{t+1}, H^h_{t+1} \right) \right\} $$  \hspace{1cm} (29)$$

subject to the constraints mentioned above. The maximization is over the sequence \( \{Y_t, C^h_t, S_{t+1}, I_{kt}, I_{ht}, K_{t+1}, H^h_{t+1}, H^c_{t+1}, M_t, K_t, H^c_t\}^\infty_{t=0} \). Note that we are abusing notations here. The symbol \( K_t \) refers to the pre-depreciation capital stock that corresponds to the after-depreciation capital stock that the household purchases from entrepreneurs, while \( K_{t+1} \) refers to the new capital stock that the household sell to entrepreneurs. One should not take them to form a single sequence \( \{K_t\}^\infty_{t=0} \). Since the household does not carry capital stock overnight, \( K \) is not a state variable in the Bellman equation. The same thing can be said about \( H^c_t \) and \( H^c_{t+1} \). Since the household holds \( H^h_t \) overnight, it enters the value function of the household’s program together with \( S_t \).

The first-order conditions for the problem (29) are

1. \( U_{Ct} = \beta R_{t+1} E_t U_{C,t+1} \),  \hspace{1cm} (30)
2. \( -\frac{U_{Lt}}{U_{Ct}} = A_t F_{Lt} \),  \hspace{1cm} (31)
3. \( \tilde{Q}_{ht} (1 - \delta_h) = Q_{ht} \left( 1 - \delta_h + \Phi^h_2 t \right) \),  \hspace{1cm} (32)
4. \( Q_{ht} U_{Ct} = \beta E_t \left\{ U_{H,t+1} + Q_{h,t+1} U_{C,t+1} \left( 1 - \delta_h + \Phi^h_{2,t+1} \right) \right\} \),  \hspace{1cm} (33)
5. \( A_t F_{Mt} = P_t \),  \hspace{1cm} (34)
6. \( \tilde{Q}_{kt} (1 - \delta_k) = Q_{kt} \left( 1 - \delta_k + \Phi^k_2 t \right) \),  \hspace{1cm} (35)
\[ Q_{ht} = 1/\Phi_{ht}^{h}, \quad (36) \]
\[ Q_{kt} = 1/\Phi_{kt}^{k}. \quad (37) \]

4 General Equilibrium

Having described the entrepreneurial sector and the household sector, we are ready to define an equilibrium of the model economy. A competitive equilibrium is a sequence of allocations and prices such that

(1) Financial contracts are designed optimally between entrepreneurs and banks. Entrepreneurs solve their wealth allocation problems optimally. Banks earn zero profit.

(2) Given the prices, the allocations solve the household’s problem.

(3) The following market clearing conditions hold:

\[ M_t = K_t \quad (38) \]
\[ Y_t = C_t^h + I_{kt} + I_{ht} + C_t^e + \mu G(\bar{\omega}) R_{kt} \tilde{k}_t W_{t-1} \quad (39) \]
\[ H_{t+1}^{e} = \frac{\tilde{h}_{t+1} W_t}{Q_{ht}} \quad (40) \]
\[ K_{t+1} = \frac{\tilde{k}_{t+1} W_t}{Q_{kt}} \quad (41) \]
\[ S_{t+1} = W_t \left( \tilde{k}_{t+1} - \tilde{n}_{t+1} \right) \quad (42) \]

Equation (38) is the market clearing condition for intermediate goods, the demand for which is \( M_t \) and the supply equals aggregate capital \( K_t \). To see this, note that the production of an entrepreneur is given by \( \omega_t k_t \). Integrating this expression over the distributions of \( \omega \) and \( k \), which are independent of each other, gives the aggregate production of intermediate goods (the mean of \( \omega \) is unity).
The goods market clears when (39) is satisfied. The last term on the right-hand side is the aggregate monitoring cost. To see this, note that in period $t$, the mean monitoring cost for a contracting relationship where the entrepreneur has period $t-1$ wealth $w_{t-1}$, is given by $\mu G(\bar{z}_t) R_{kt} \bar{k}_t w_{t-1}$. Aggregation over all entrepreneurs leads to $\mu G(\bar{z}_t) R_{kt} \bar{k}_t W_{t-1}$. These costs are born by banks and are in the form of final goods.

Equation (40) is the market clearing condition for new house. The left-hand side is the amount of new house supplied by households to entrepreneurs in period $t$. The right-hand side is demand by entrepreneurs. By the definition of $\bar{h}_{t+1}$ we have $h_{t+1} = \bar{h}_{t+1} w_t / Q_{ht}$. Aggregating across all entrepreneurs gives the result. Similarly, equation (41) is the market clearing condition for new capital.

The market clearing condition for loanable funds is given by (42), where $S_{t+1}$ is household savings deposited in banks. The right-hand side is the aggregate demand for funds. Each entrepreneur demands $Q_{kt} k_{t+1} - n_{t+1} = w_t \left( \bar{k}_{t+1} - \bar{n}_{t+1} \right)$. Aggregating across all entrepreneurs gives $W_t \left( \bar{k}_{t+1} - \bar{n}_{t+1} \right)$.

Finally, markets for old capital and house also clear in every period.

Before proceeding to the quantitative assessment of the model, we present a formula for the external finance premium, which is defined as “the difference in cost between funds raised externally and funds generated internally” (see Bernanke and Gertler (1995, p.28)). Here the premium $r_{t+1}$ is simply the nondefault interest rate of the contract $z_{t+1}$ minus the risk-free interest rate $R_{t+1}$. That is $r_{t+1} = z_{t+1} - R_{t+1}$. Since $z_{t+1}$ equals the nondefault payment, $\bar{\Omega}_{t+1} = \bar{\sigma}_{t+1} R_{kt+1} k_{t+1} + R_{ht+1} Q_{ht} h_{t+1}$, divided by the amount of borrowing.
\[ b_{t+1} = Q_{kt}k_{t+1} - n_{t+1}, \]
we have
\[ z_{t+1} = \frac{\bar{z}_{t+1} R_{k,t+1} Q_{kt} k_{t+1} + R_{h,t+1} Q_{ht} h_{t+1}}{Q_{kt} k_{t+1} - n_{t+1}} \]  
(43)

It should be obvious from (43) that *ceteris paribus*, the nondefault interest rate, and therefore the external finance, is positively related to the bankruptcy threshold \( \bar{z}_{t+1} \).

## 5 Quantitative Assessment

### 5.1 Calibration

In this subsection we first describe the parametric specification of the model economy and then discuss our strategy of assigning numeric values to the model’s parameters.

Following BGG, the distribution of entrepreneurs’ idiosyncratic shocks are assumed to be log-normal with \( \ln \omega \sim N\left(-\frac{1}{2}\sigma^2, \sigma^2\right) \), so that the mean of \( \omega \) is unity.

The production function for final goods takes the Cobb-Douglas form:
\[ F(M_t, L_t) = A_t M_t^{1-\alpha} L_t^\alpha. \]  
(44)

Following the literature on capital adjustment cost, the gross capital formation function is represented by
\[ \Phi^k(I_{kt}, K_t) = B_k I_{kt}^{\theta_k} K_t^{1-\theta_k}, \]  
(45)

where \( B_k > 0, \ 0 < \theta_k \leq 1 \). Put differently, the amount of gross capital formation per unit of beginning-of-period capital stock is a power function of the investment-capital stock ratio: \( B_k (I_{kt}/K_t)^{\theta_k} \), which is concave if \( \theta_k < 1 \). The case of no adjustment cost corresponds to \( \theta_k = 1 \). Similarly, the gross house formation function is...
\[ \Phi^h (I_{ht}, H_t) = B_h I_{ht}^{\theta_h} H_t^{1-\theta_h}, \]  \hspace{1cm} (46) 

where \( B_h > 0, 0 < \theta_h \leq 1. \)

In our benchmark specification, the utility function is taken to be log-separable in consumption, housing, and leisure:

\[ U(C_t^h, H_t^h, L_t) = \ln(C_t^h) + \nu_H \ln(H_t) + \nu_L \ln(1 - L_t) \]  \hspace{1cm} (47) 

We shall, however, experiment with other utility functions when performing sensitivity analysis.

We divide the model’s parameters into three groups. The first group pertains to the entrepreneurial sector, which includes \( \nu, \eta, \mu, \sigma. \) The second group concerns household preference and includes \( \beta, \nu_H, \nu_L \) in the benchmark specification. The last group describes technologies in the household sector and consists of \( \alpha, B_k, \theta_k, B_h, \theta_h, \rho \) and \( \sigma. \)

A period in the model corresponds to one quarter in the data.

Table 2. Parameters values—Benchmark specification

<table>
<thead>
<tr>
<th>Entrepreneurial sector:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \mu = 0.2 )</td>
</tr>
<tr>
<td>( \sigma, \nu, \eta ) are such that</td>
</tr>
<tr>
<td>(1) quarterly bankruptcy rate = 0.01 (Fisher 1999)</td>
</tr>
<tr>
<td>(2) annual external finance premium = 187 basis points</td>
</tr>
</tbody>
</table>
(3) liability-asset ratio = 0.49 Rajan and Zingales (1995)

*Household preference:*

\[ \beta = 0.99, \text{ annual real interest rate} = 4\% \]

*Household-sector technologies*

Labor share = 0.64 \\
Depreciation rate (annual): \( K : 0.0648, H : 0.0154 \) \\
Adjustment costs: \( \theta_k = \theta_h = 0.75 \). \\
Productivity shocks: \( \rho = 0.95, \sigma_\varepsilon = 0.007 \)

---

### 5.2 Results

The simulation results are summarized in Table 3 and 4. To partial the effect of house prices, we experiment with a model where house price fluctuations are absent. This is accomplished by setting \( \theta_h \) to 1, which corresponds to a gross capital formation function that is linear in investment. Results pertaining to the model with house price fluctuations with \( \theta_h = 0.75 \) are presented in Table 3, while results for the case without house price fluctuations are shown in Table 4.

As we are particularly interested in how the model economy’s second moments compare to their empirical counterparts, we first describe the cyclical properties of various expenditure components, house price and the external finance premium in the data. These are shown in the column labelled “Data” in the tables. As is well known, consumption and capital investment (or nonresidential investment) are both procyclical with positive
contemporaneous correlations with (real) GDP. Consumption is less volatile than GDP while capital investment is more volatile. The standard deviation of consumption relative to that of GDP is about 0.8, while the relative standard deviation of capital investment is about 2.23.

The cyclical behavior of house (or residential) investment, however, have not received enough attention in the real business cycle literature, with Davis and Heathcote (2004) being an exception. It turns out that house investment is more than twice as volatile as capital investment. Its standard deviation relative to that of GDP is about 5.11. Real house prices, expressed in units of consumption goods, turn out to be slightly more volatile than GDP, with a relative standard deviation of 1.29. In addition, both house investment and house prices are moderately procyclical.

The external finance premium has been regarded as indicative of the presence and significance of credit market imperfections in the actual economy. The countercyclical nature of the external finance premium is well known and we find its contemporaneous correlation with GDP is about \(-0.26\). Surprisingly, researches on the roles of credit market imperfections in the business cycle have largely ignored the actual volatility of this variable. We find its standard deviation to be about 0.39 relative to that of GDP.

In the baseline model we have described thus far, the shock to the final goods production technology is the only source of aggregate shocks that disturb the economy. The results are displayed in the column labelled with “Tech shocks”. The simulation results show that the consumption, capital investment, house investment, and house prices are all strongly procyclical, while the external finance premium is strongly countercyclical.
Capital investment appears to be more volatile compared to that in the data, while house investment is not volatile enough. Concomitantly, the volatility of house prices also appear to be small. The volatility of the external finance premium is slightly more than a half of its empirical counterpart.

Interestingly, when house price fluctuations are absent, the relative volatility of the external finance premium declines to 0.11. Compared to the case with house price fluctuations, this result indicates, roughly, that house price fluctuations account for a half of the total volatility of the external finance premium.

6 House Demand Shocks

The reason for why house investment and house prices display insufficient volatility in the baseline model is related to the nature of the aggregate shocks that hit the economy. There the productivity shock to the final goods production technology is the only source of aggregate shocks. Recall that the two inputs in that production function are labor and intermediate goods respectively, and in equilibrium the amount of intermediate goods equals the amount of capital. Therefore a persistent increase in the aggregate productivity raises the future marginal product of capital, which in turn, raises current capital investment substantially. This effect, however, does not apply to house. For this reason house investment and hence house prices appear to be insufficiently volatile.

In this section, we introduce house demand shocks to the model economy. To do this, we replace \( H_t \) in the household utility function by \( (H_t - \chi_t) \) where \( \chi_t \) is a house demand shock. An increase in \( \chi_t \) raises the marginal utility of house and stimulates house
investment. The results are shown in the columns labelled “HD shocks” in Table 3 and 4.

Suppose that we allow house prices to fluctuate ($\theta_h = 0.75$), then the external finance premium becomes much more volatile, with the relative standard deviation rising to 0.88. Underlying this result is the increased volatility of house investment and house prices. Except for consumption, the contemporaneous correlation between all variables and GDP reverse sign. This is because GDP declines, but only slightly, after a positive house demand shock. To the contrary, capital investment, house investment, and house price all increase, while the external finance premium declines.

When the economy is subject to both technology shocks, the model’s predictions get closer to the data. Most importantly, we are able to generate sufficient volatility of the external finance premium. There is some overshooting of the model’s prediction as compared to the data. The external finance premium remains countercyclical, but less so than in the experiment with technology shocks only. In addition, the volatilities of house investment and house prices are fairly close to the data.

Again, the role played by house price fluctuations can be seen from the comparison between the case with price fluctuations and the case without. For the latter case, the volatility of the external finance premium is quite small. The same is true when the economy is subject to aggregate productivity shock and house demand shock. Therefore when house demand shocks are present, the fluctuations in house prices are responsible for the bulk of the volatility of the external finance premium.
7 Conclusions

In this paper we study the role of residential housing in financing capital investment in a quantitative dynamic stochastic general equilibrium framework. Residential housing, though nonproductive, is shown to be important in determining the cost of external financing for investment on productive capital. Housing stock serves as collateral in financial contracts for capital investment. We find that when the model is reasonably calibrated, fluctuations in the return to capital investment is not enough to account for the cyclical behavior of the external finance premium. Fluctuations of house prices help generate countercyclical external finance premium by a great deal.

Several extensions of the present model are possible. First, we can incorporate monetary shocks into the model to study the effects of money shocks and monetary policy. Second, the model can be incorporated into a setup of multiple production sectors so that the cyclical behavior of residential and nonresidential investment can be matched better.
Table 3. Simulation results with house price fluctuations

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Tech shocks</th>
<th>HD shocks</th>
<th>All shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Relative Volatility: std(x)/std(Y)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$r$</td>
<td>0.39</td>
<td>0.22</td>
<td>0.88</td>
<td>0.56</td>
</tr>
<tr>
<td>$Q_h$</td>
<td>1.29</td>
<td>0.41</td>
<td>3.98</td>
<td>1.34</td>
</tr>
<tr>
<td>$I_h$</td>
<td>5.11</td>
<td>1.64</td>
<td>15.92</td>
<td>5.35</td>
</tr>
<tr>
<td>$I_k$</td>
<td>2.23</td>
<td>4.38</td>
<td>3.22</td>
<td>5.81</td>
</tr>
<tr>
<td>$C$</td>
<td>0.8</td>
<td>0.75</td>
<td>2.37</td>
<td>0.56</td>
</tr>
</tbody>
</table>

**Correlations: corr(x,Y)**

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Tech shocks</th>
<th>HD shock</th>
<th>All shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$</td>
<td>−0.26</td>
<td>−0.979</td>
<td>0.798</td>
<td>−0.825</td>
</tr>
<tr>
<td>$Q_h$</td>
<td>0.53</td>
<td>0.999</td>
<td>−0.999</td>
<td>0.920</td>
</tr>
<tr>
<td>$I_h$</td>
<td>0.47</td>
<td>0.999</td>
<td>−0.999</td>
<td>0.920</td>
</tr>
<tr>
<td>$I_k$</td>
<td>0.75</td>
<td>0.996</td>
<td>−0.999</td>
<td>0.983</td>
</tr>
<tr>
<td>$C$</td>
<td>0.83</td>
<td>0.996</td>
<td>0.999</td>
<td>0.819</td>
</tr>
</tbody>
</table>

Note: $r$: external finance premium, $Q_h$: house prices, $I_k$: capital (or nonresidential) investment, $I_h$: house (or residential) investment, $C$: consumption. $Q_h$, $I_k$, $I_h$, and $C$ are logged. $r$ is in percent per annum. All series are HP-filtered with the smoothing parameter set to 1600.
Table 4. Simulation results without house price fluctuations

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Tech shocks</th>
<th>HD shocks</th>
<th>All shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$</td>
<td>0.39</td>
<td>0.11</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>$Q_h$</td>
<td>1.29</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$I_h$</td>
<td>5.11</td>
<td>11.63</td>
<td>78.87</td>
<td>37.26</td>
</tr>
<tr>
<td>$I_k$</td>
<td>2.23</td>
<td>2.37</td>
<td>2.23</td>
<td>0.80</td>
</tr>
<tr>
<td>$C$</td>
<td>0.8</td>
<td>0.32</td>
<td>1.27</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Correlations: $\text{corr}(x,Y)$

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Model</th>
<th>HD shock</th>
<th>All shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$</td>
<td>−0.26</td>
<td>−0.980</td>
<td>0.337</td>
<td>−0.656</td>
</tr>
<tr>
<td>$Q_h$</td>
<td>0.53</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>$I_h$</td>
<td>0.47</td>
<td>0.946</td>
<td>0.512</td>
<td>0.408</td>
</tr>
<tr>
<td>$I_k$</td>
<td>0.75</td>
<td>0.998</td>
<td>−0.981</td>
<td>0.747</td>
</tr>
<tr>
<td>$C$</td>
<td>0.83</td>
<td>0.978</td>
<td>−0.981</td>
<td>−0.847</td>
</tr>
</tbody>
</table>

Note: $r$: external finance premium, $Q_h$: house prices, $I_k$: capital (or nonresidential) investment, $I_h$: house (or residential) investment, $C$: consumption. $Q_h$, $I_k$, $I_h$, and $C$ are logged. $r$ is in percent per annum. All series are HP-filtered with the smoothing parameter set to 1600.
References


28


[17] Gale and Hellwig


