Commercial Real Estate, Housing and the Business Cycle

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Preliminary and Incomplete

Abstract

The 2007-08 financial crisis exposed the magnitude through which distortions in residential and commercial real estate markets can spillover to the goods markets and the real economy. This paper develops an RBC model with a consumption good and a construction sector, where both commercial and residential real estate forms the construction sector. We investigate the property-price and investment dynamics when there is competition between households and firms for real estate and the implications this market structure has for macroeconomic fluctuations. In doing so we develop a 'real estate substitution channel', where demand shocks, by raising the costs of production create a substitution between the two types of real estate. This gives an alternative interpretation to the housing preference shock, which rather than simply representing a shift in preferences, is also explained as a supply shock to the commercial real estate. The estimated model reveals that housing preference shocks explain the largest part of the variation in property prices and residential investment, while commercial real estate prices are is driven primarily by technology shock.

Key Words: Commercial Real Estate; Land Price; Borrowing Constraints
JEL References: E32; E44; R21; R31

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1 Introduction

Residential and commercial real estate account for a substantial share of both household wealth and capital stock in the US. On average, one-third of household net worth is held in residential real estate, whilst commercial real estate typically accounts for about half the net market(replacement) value of nonfarm, nonfinancial corporate business assets (Case, 2000). Furthermore, fluctuations in land values have been shown to play a significant and unique role in both the amplification and the propagation of the business cycle, especially when combined with financial frictions in the form of collateral constraints. The general mechanism is that when households or firms use real estate as a collateral for borrowing, a decline in land prices will reduce the value of available collateral, and with it the availability of funds for either investment or consumption, thus amplifying the decline in economic activity (Iacoviello, 2005; Iacoviello and Neri, 2010; Liu et al., 2013; Guerrieri and Iacoviello, 2017).

Figure 1 plots the Commercial Real Estate (henceforth CRE) Price, the Residential Real Estate (House) Price and the Land Price for the US[1]. All price variables have been log transformed and normalized to the first observation, in order to observe the relative change over time. In general, property prices appear to comove, in line with evidence of Rosen (1979); Roback (1982) and Gyourko (2009). [2] In particular, during the 2007-2008 financial crisis all three series displayed a sharp fall followed by a more gradual recovery. Finally, land prices have followed a steady upward trend during the whole sample, which appear to drive the increases in both commercial and residential real estate (Davis and Heathcote, 2007; Glaeser and Ward, 2009; Gyourko et al., 2013) and thus suggest a an underlying mechanism in the construction sector.

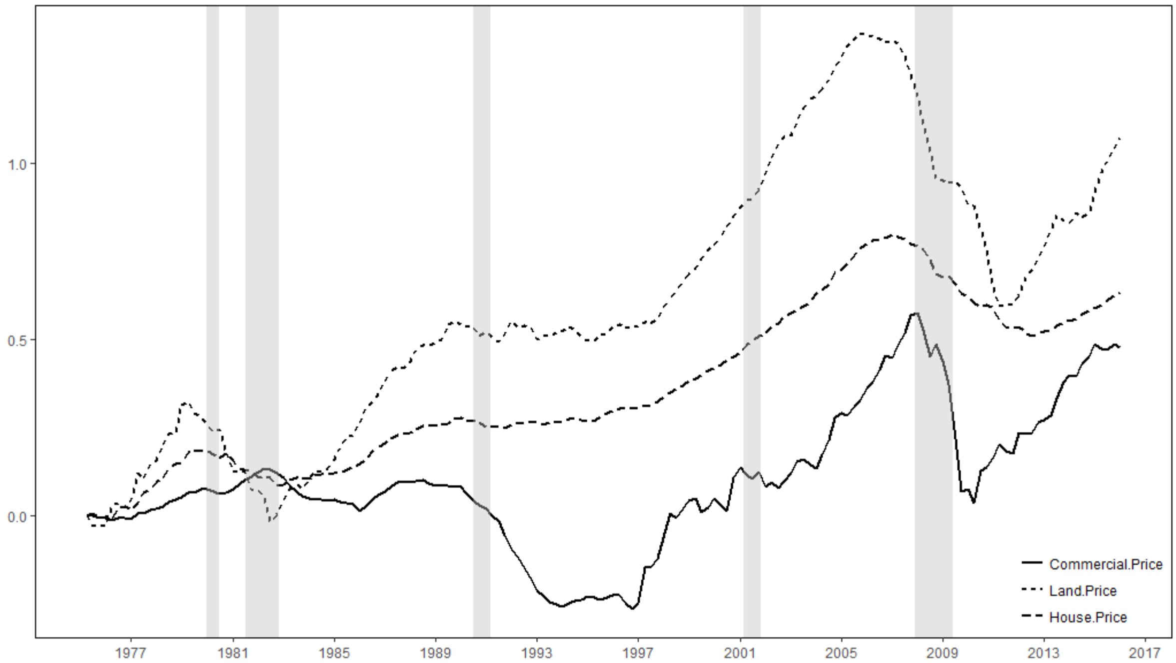
Figure 2 displays the estimated impulse response of House Price, Residential Investment, Commercial structure Investment, Business Investment following a shock to the House price series[3]. The impulse responses are estimated in a four-variable Bayesian vector autoregressive (BVAR) model with the Minnessota Prior (Doan et al., 1984; Litterman, 1986). A positive shock to the house price leads to a positive response of the residential investment. On the other hand, CRE investment has the opposite response, which indicates a substitution between the two real estate sectors i.e. residential and commercial. Since property prices comove, CRE price will

[1]Because, there are no observable data for the land price we use the estimation of residential land price from Davis and Heathcote (2007).

[2]The demand for commercial real estate projects boomed during the early 1980s and reached a speculative pitch in many markets. Real estate financing by commercial banks grew to meet the demand, because deregulation and other factors had created an environment in which commercial real estate lending was lucrative for lenders As a consequence, after 1980 commercial banks dramatically increased the volume of such credits. Evidently, commercial real estate price faced a fall in the 1980s that may be attributed to slump in office construction resulting from overbuilding during the 1980s.

[3] In Appendix 1 there is a comprehensive explanation of the data, and the data-manipulations used in this paper

Figure 1 – PRICES

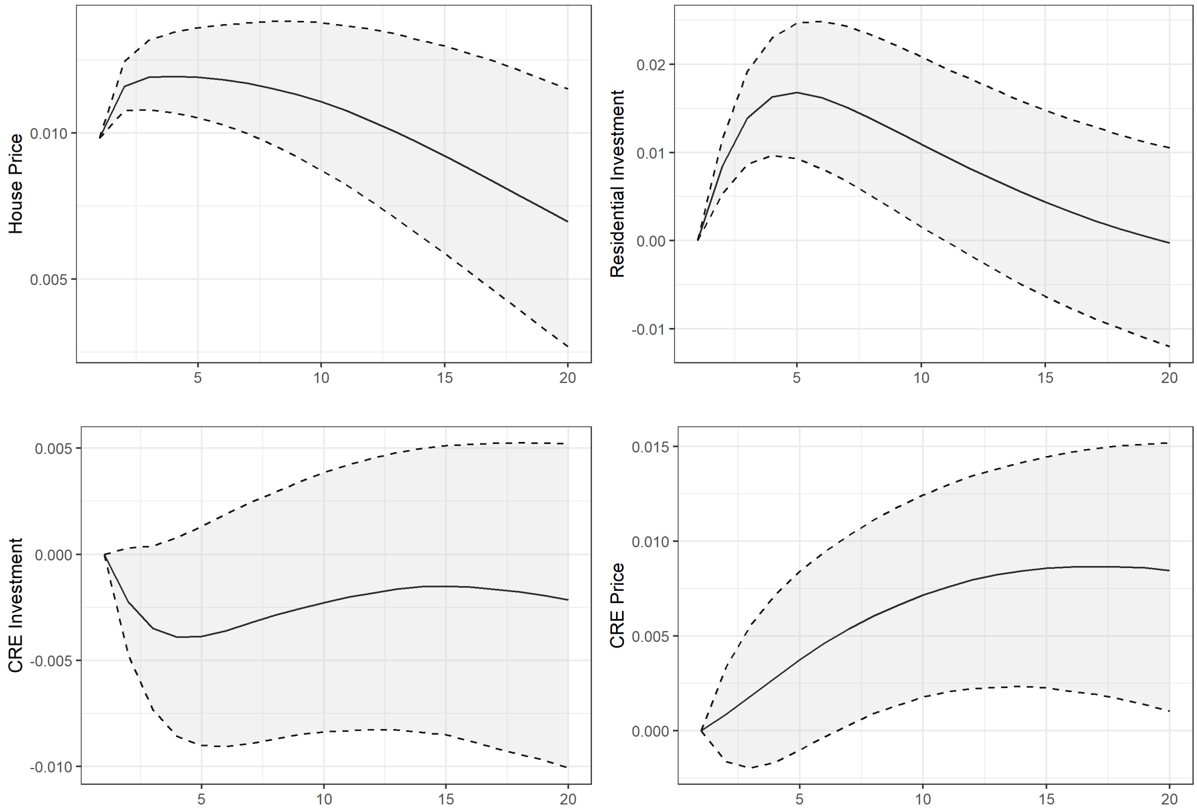


Note: Real commercial property price (solid line), real land price(dotted line) and real house price (dashed line). The variables are in log units and normalized to the origin of the sample. The shaded bars mark the NBER recession dates.

increase following a positive shock to house prices.

The aim of this paper is to shed light on the mechanism behind the relationship between the price of residential and commercial real estate displayed in Figure 1 and the substitution between residential and commercial investment outlined in Figure 2. To do so we introduce a construction sector into a DSGE model, which undertakes the production of both commercial and residential real estate. Specifically, we introduce sectoral heterogeneity as in (Iacoviello and Neri, 2010) by differentiating between two groups of entrepreneurs - consumption good and construction sector. To achieve this multi-sector entrepreneur structure, we disaggregate the capital stock (Davis and Heathcote, 2005) into three components: consumption good, residential and commercial real estate. Whilst there is a growing literature where residential housing production allows households to consume both housing and nonhousing goods (Greenwood and Hercowitz, 1991; Benhabib et al., 1991; Chang, 2000; Davis and Heathcote, 2005; Fisher, 2007), we also allow the construction sector to facilitate the production of new commercial structures. In this way we can analyze the interplay between commercial and residential real estate, when there is both competition for land in the construction sector and competition for real estate between households and consumption good entrepreneurs.

Figure 2 – House Price Shock



Note: Impulse response to a positive shock to the residential real estate price from a recursive BVAR model with Minessota Prior. The ordering is as follows {Residential Real Estate Price, Residential Investment, Commercial structure Investment, Business Investment }, all in real terms. Solid lines represent the mean estimated responses and dotted lines the 68% probability bands

According to Davis and Heathcote (2007) fluctuations in real estate values are primarily driven by changes in land prices, and land provides important collateral value for business investment spending. As a result we assume entrepreneurs in both groups face credit constraints in the spirit of Kiyotaki and Moore (1997), where firms finance investment spending by using the value of the their inputs (beside labour) as collateral. By doing so, there are positive co-movements between land prices and business investment, as in (Liu et al., 2013). However, the additional requirement of commercial and residential investment for construction mean that the dynamics of real estate prices can differ between the commercial and residential sectors, which has non-negligible implications for production and economic activity.

Our model is able to capture the substitution between commercial and residential investment, which is evident in the BVAR model in Figure 2. We name this effect, 'Real Estates Substitution channel'. The channel we address encapsulates the land reallocation channel as was initially established by Liu et al. (2013), however we claim that land does not equate real estate investment. Land has a unique quality, it's fixed on aggregate, however the real estate investment clearly follows a law of motion. We observe that shocks do not have symmetric effects nor the substitution is always warranted. The substitution is present in the event of a demand shock, whether it originates in commercial or residential real estate production. All inputs of production, and not just land contribute to deliver such dynamics, hence producing a clear distinction with previous literature that do not explicitly consider a construction sector.

The paper proceeds as follows. The next chapter describes the theoretical model. Section 3 reports the calibration. Section 4 and 5 explain the properties of the model. Finally, Section 6 concludes.

2 Model

We consider an economy that consists of two types of agents: a representative household and an entrepreneur. The entrepreneur chooses to produce either consumption goods or build new property structures, for residential or commercial purposes. The representative household's utility depends on consumption goods, housing and leisure. Entrepreneur's utility depend only on consumption goods. Consumption goods production requires labour, capital and commercial real estate as inputs. New structures require labour, capital and land as input. The entrepreneur in both sectors needs external financing for investment spending. Imperfect contract enforcement implies that the entrepreneur's borrowing capacity is constrained by the value of collateral assets. Collateral differ depending on the type of the production. Borrowing in the consumption good sector is constrained by the value of non-construction capital and the value of commercial real estate, while on the construction side sector is constrained by the value of capital and land.

2.1 Households

There is a continuum of households indexed by $d \in [0,1]$. The representative household seeks to maximize its discounted, time separable lifetime utility. The utility function is given by

$$E_t \sum_{t=0}^{\infty} \beta_d^t z_t \Big\{ \ln\left(C_{d,t} - \gamma_d C_{d,t-1}\right) + \chi_t \ln\left(H_{d,t}\right) - \frac{\psi_t}{1+\eta}\left(N_{c,t}^{1+\xi} + (N_{hc,t} + N_{hd,t})^{1+\xi}\right)^{\frac{1+\eta}{1+\xi}} \Big\}, \quad (1)$$

where $C_{d,t}$ denotes consumption, $H_{d,t}$ denotes residential housing stock, $N_{c,t}$, $N_{hc,t}$ and $N_{hd,t}$ denote labour hours in consumption good, commercial and residential real estate production, respectively. The parameter $\beta_d \in (0,1)$ is a discount factor, the parameter γ_d measures habits in consumption and parameters ξ and η measure, the labour mobility among the different types of production and the inverse of the Frisch elasticity, respectively. The terms z_t and ψ_t capture shocks intertemporal preference and labour supply. Housing preference shock χ_t shifts preferences away from consumption and leisure towards housing. The shocks follow

$$\ln z_t = \rho_z \ln z_{t-1} + \sigma_z \epsilon_{z,t}, \qquad \ln \psi_t = \rho_\psi \ln \psi_{t-1} + \sigma_\psi \epsilon_{\psi,t},$$
$$\ln \chi_t = (1-\rho_\chi) \ln \bar{\chi} + \rho_\chi \ln \chi_{t-1} + \sigma_\chi \epsilon_{\chi,t},$$

where σ_z, σ_ψ, σ_χ are the standard deviations of the innovation, and $\epsilon_{z,t}$, $\epsilon_{\psi,t}$, $\epsilon_{\chi,t}$ are independent and identically distributed (i.i.d) normal processes.

The disutility of labour, follows Horvath (2000) and Iacoviello and Neri (2010) specification that allows for imperfect labour mobility between sectors. The consumer allocate labour resources to the various productive activities, for $\xi \geq 0$, hours worked are not perfect substitutes for the worker. Having a construction sector means that labour can easily move from commercial to residential real estate and vice versa, facing the same wage. However, sector specificity would mean that moving between sectors would have to face sectoral wage differentials.

The households consume, accumulate houses, work on the consumption good and construction sector, and use bonds to smooth consumption. The flow of funds constraint for the household is given by

$$C_{d,t} + q_{hd,t} H_{d,t} + \frac{S_t}{R_t} \leq q_{hd,t}(1-\delta_{hd}) H_{d,t-1} + w_{c,t} N_{c,t} + w_{h,t} N_{hc,t} + w_{h,t} N_{hd,t} + S_{t-1} + q_{l,t} L^{ex}_{d,t} \quad (2)$$

where $q_{hd,t}$ is the price of residential homes, R_t is the gross real loan rate, and $w_{c,t}$, w_h the real wage of the consumption good and construction sector respectively. S_t is the loanable bond that the household buys in period t which pays off in period $t+1$. Finally, $L^{ex}_{d,t}$ is the amount of land that the household is left with after the depreciation of the housing stock, where $L^{ex}_{d,t} = \delta_{hd} L_{d,t-1}$. The household chooses C_d, H_d, N_c, N_{hc} , N_{hd} and S_t to maximize (1) subject to (2).

2.2 The Entrepreneur

We model the entrepreneurial sector with borrowing constraints *à la.* Iacoviello (2005), where entrepreneurs consume in every period and can raise their net worth by lowering their consumption. To introduce sectoral heterogeneity we consider a representative entrepreneur that operates in two sectors - consumption good and construction sector, where residential and commercial real estate comprise the construction sector. The entrepreneur faces the utility function

$$E_t \sum_{t=0}^{\infty} \beta_e^t \Big(\log(C_{i,t} - \gamma_e C_{i,t-1}) \Big), \quad i = c, h \quad (3)$$

where c and h define the respective consumption good and construction good sectors. $C_{i,t}$ denotes the entrepreneur's consumption and γ_e is the habit persistence parameter. We ensure that the parameter $\beta_e \in (0,1)$ is smaller than the households discount factor $\beta_e < \beta_d$, so that the credit constraint is binding in a neighborhood of the steady state (Iacoviello, 2005). The entrepreneur owns all inputs beside labour, i.e. capital, land and commercial real estate .

2.3 The Consumption Good Sector

The entrepreneur in the consumption good sector produces goods using capital, labour and commercial real estate as inputs. The production function is given

$$Y_t = K_{c,t-1}^{\alpha_c} H_{c,t-1}^{\mu_c} \left(A_{c,t} N_{c,t}\right)^{1-\alpha_c-\mu_c} \tag{4}$$

where Y_t denotes output, $K_{c,t-1}$, $N_{c,t}$, $H_{c,t-1}$ denote non-construction capital, labour, and commercial/industrial real estate respectively. The entrepreneur is endowed with $K_{c,t-1}$ units of initial capital stock and $H_{c,t-1}$ of commercial property. The entrepreneur faces the flow of funds constraint

$$\begin{aligned} C_{c,t} + \frac{K_{c,t}}{A_{kc,t}} + q_{hc,t} H_{c,t} + w_{c,t} N_{c,t} + B_{c,t-1} & \qquad (5) \\ = Y_t + \frac{(1-\delta_{kc})}{A_{kc,t}} K_{c,t-1} + (1-\delta_{hc}) q_{hc,t} H_{c,t-1} + \frac{B_{c,t}}{R_t} + q_{l,t} L_{c,t}^{ex} - \phi_{c,t}{}^{4} & \end{aligned}$$

where $B_{c,t}$ is the amount of debt used to finance investments in the non-construction sector, $q_{hc,t}$ denotes the price of commercial real estate and the variable $\phi_{c,t}$ describes capital adjustment costs. $A_{c,t}$ measure the productivity in the non-construction sector and $A_{kc,t}$ is an investment-specific shock in the consumption good sector. Finally, $q_{l,t} L_{c,t}^{ex}$ is the amount of land that the entreprenuer is left with after the depreciation of the housing stock, where $L_{c,t}^{ex} = \delta_{hd} L_{c,t-1}$. The shocks follow

$$lnA_{c,t} = \rho_{A_c} lnA_{c,t-1} + \sigma_{A_c} \epsilon_{A_c,t}, \qquad lnA_{kc,t} = \rho_{A_{kc}} lnA_{kc,t-1} + \sigma_{A_{kc}} \epsilon_{A_{kc},t},$$

where σ_{Ac} and σ_{Akc} are the standard deviations of the innovation, and $\epsilon_{Ac,t}$ and $\epsilon_{Akc,t}$ are an independent and identically distributed (i.i.d) normal process. The entrepreneur faces the credit constraint

$$B_{c,t} \leq \rho_{bc} B_{c,t-1} + (1-\rho_{bc}) \theta_c E_t \left(q_{hc,t+1} H_{c,t} + \frac{K_{c,t}}{A_{kc,t}} \right), \tag{6}$$

where θ_c can be interpreted as a steady state loan-to-value (LTV) ratio, and ρ_{bc} measures the inertia in the borrowing limit. Following Kiyotaki and Moore (1997) there is a limit on the obligations of entrepreneurs. The amount the creditor can borrow to invest is bounded by a fraction of the value of the collateral assets i.e. the commercial real estate and the non-construction capital. The entrepreneur in the consumption good sector chooses $\{C_{c,t}, K_{c,t}, H_{c,t}, N_{c,t}, B_{c,t}\}$ to maximize (3) subject to (4) through (6).

[4] $\phi_{kc,t} = \frac{\phi_{kc}}{2} \left(\frac{k_{c,t}}{k_{c,t-1}} - 1 \right)^2 k_{c,t-1}$

2.4 The Construction Sector

The entrepreneur in the construction sector produces new commercial and residential structures using capital, labour and land as inputs. The production function for the former is given by

$$IH_{c,t} = K_{hc,t-1}^{\alpha_{hc}} L_{hc,t-1}^{\mu_{hc}} \left(A_{hc,t} N_{hc,t}\right)^{1-\alpha_{hc}-\mu_{hc}}, \tag{7}$$

where $IH_{c,t}$ denotes the commercial real estate, $K_{hc,t-1}$, $N_{hc,t}$, $L_{c,t-1}$, denote the inputs; commercial real estate capital, labour in the housing sector, and land that is used for commercial structures, respectively. The production function for residential structures is

$$IH_{d,t} = K_{hd,t-1}^{\alpha_{hd}} L_{hd,t-1}^{\mu_{hd}} \left(A_{hd,t} N_{hd,t}\right)^{1-\alpha_{hd}-\mu_{hd}}, \tag{8}$$

where $IH_{d,t}$ denotes new homes, and $K_{hd,t-1}$, $N_{hd,t}$ and $L_{d,t-1}$, are the corresponding inputs . $A_{hc,t}$ and $A_{hd,t}$ measure the productivity in the construction sector and follow the processes

$$lnA_{hc,t} = \rho_{A_{hc}} lnA_{hc,t-1} + \sigma_{A_{hc}} \epsilon_{A_{hc},t}$$

$$lnA_{hd,t} = \rho_{hd} lnA_{hd,t-1} + \sigma_{Ahd} \epsilon_{Ahd,t}$$

where $\sigma_{A_{hc}}$ and σ_{Ahd} are the standard deviations of the innovation, and $\epsilon_{A_{hc}}$ and $\epsilon_{Ahd,t}$ are two independent and identically distributed (i.i.d) normal processes. The house producer faces the flow of funds constraint

$$\begin{aligned} C_{h,t} + K_{hc,t} + K_{hd,t} + q_{l,t}\left(L_{hc,t} + L_{hd,t}\right) + w_{h,t}\left(N_{hc,t} + N_{hd,t}\right) + B_{h,t-1} = q_{hc,t} IH_{c,t} \\ + q_{hd,t} IH_{d,t} + (1-\delta_{kh}) K_{hc,t-1} + (1-\delta_{kh}) K_{hd,t-1} + \frac{B_{h,t}}{R_t}, \end{aligned} \tag{9}$$

where $B_{hc,t}$ is the debt for financing investments in the housing sector. The house producer faces the credit constraint

$$B_{h,t} \leq \rho_{bh} B_{h,t-1} + (1-\rho_{bh}) \theta_h E_t \left(q_{l,t+1}\left(L_{hc,t} + L_{hd,t}\right) + K_{hc,t} + K_{hd,t}\right). \tag{10}$$

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The amount the entrepreneur can borrow in the constructions sector is limited by the total value of land and capital in the production of real estate. The entrepreneur in the construction sector chooses $\{C_{h,t}, K_{hc,t}, K_{hd,t}, L_{hc,t}, L_{hd,t}, N_{hc,t}, N_{hd,t}, B_{h,t}\}$ to maximize (4) subject to (7) through (10).

2.5 Market Clearing Conditions and Equilibrium

The goods market produces consumption and business investment. The clearing condition implies that

$$Y_t - \phi_t = C_t + IB_t, \tag{11}$$

where $C_t = C_{d,t} + C_{c,t} + C_{h,t}$ is the aggregate consumption and IB_t is the business investment. Business investment is describe as

$$IB_t = IK_{c,t} + IK_{h,t} + \bar{q_{hc}} IH_{c,t},$$

where $IK_{c,t} = K_{c,t} - (1-\delta_{kc})K_{c,t-1}$ can be described as investment on nonresidential equipment and intellectual property products. The second part of business investment $IK_{h,t} = K_{hc,t} - (1 - \delta_{kh})K_{hc,t-1} + K_{hd,t} - (1 - \delta_{kh})K_{hd,t-1}$ denotes the investment in construction machinery, which is a small part of the total machinery. CRE is used as an intermediate input in the production of consumption good output and built into the capital stock of the sector in the economy, hence the last term $\bar{q_{hc}} IH_{c,t}$ describes the value of the nonresidential structures. $H_{c,t}$ evolves according to the law of motion

$$IH_{c,t} = H_{c,t} - (1 - \delta_{hc})H_{c,t-1}. \tag{12}$$

The housing market produces new homes $IH_{d,t}$

$$IH_{d,t} = H_{d,t} - (1 - \delta_{hd})H_{d,t-1}, \tag{13}$$

where $H_{d,t}$ is the stock of residential housing. The GDP is the sum of the value added of the consumption good and residential housing, that is

$$GDP_t = Y_t + \bar{q_{hd}} IH_{d,t}. \tag{14}$$

Land does not evolve over time (without loss of generality we can assume land to fixed at $\bar{L_h} = 1$). In the spirit of Liu et al. (2013), we assume land market clearing with the following condition

$$\bar{L_h} = L^{\omega}_{hc,t} + L^{\omega}_{hd,t}. \tag{15}$$

Ex post land, L^{ex}_d and L^{ex}_c and is owned by the respective household and entrepreneur following the depreciation of their housing stock. This is then sold to the construction entrepreneur who uses it as an input. It follows that $L^{ex}_c + L^{ex}_d = \bar{L_h}$ with the following shares applied to eah sector

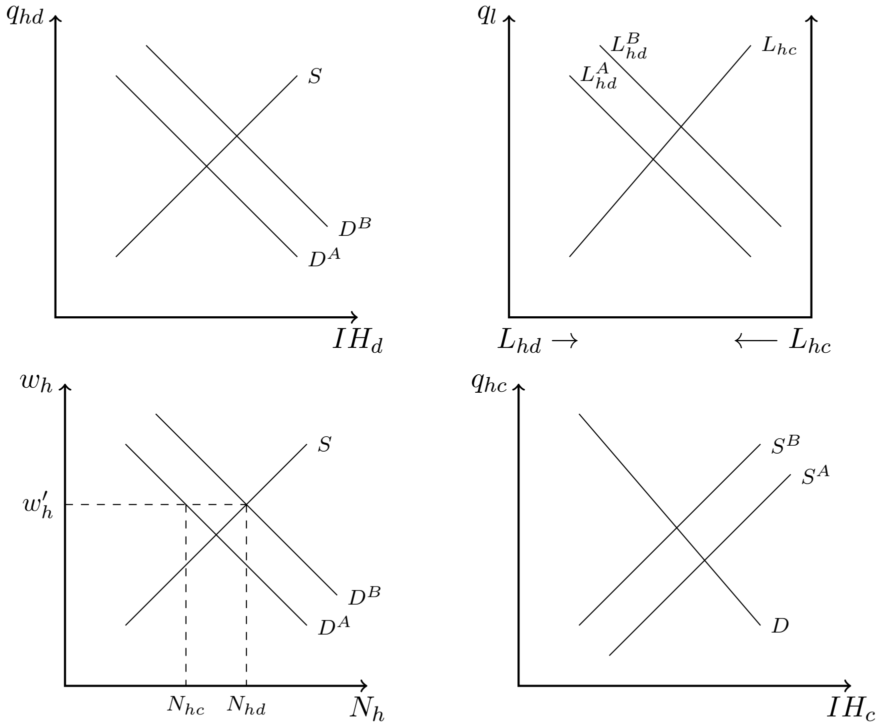
$$L^{ex}_c = \frac{H_{c,t-1}}{H_{c,t-1} + H_{d,t-1}}\bar{L} \qquad L^{ex}_d = \frac{H_{d,t-1}}{H_{c,t-1} + H_{d,t-1}}\bar{L} \tag{16}$$

2.6 Real Estate Substitution

In this section, we explain the mechanism of real estate substitution using a simple demand-supply representation. Figure 3 includes the four markets we take into consideration for this analysis, residential real estate (top left), land market (top right), labour market (bottom left) and commercial real estate (bottom right).

Consider a house price shock (residential real estate demand shock). This shock will increase house prices, shifting the demand curve from D_A to D_B. Higher demand for houses, will be met

Figure 3 – Housing Demand Shock



Note: The figure display the residential real estate market (top left), the land market (top right), tha labour market (bottom left) and the commercial real estate market (bottom right), following a housing demand shock.

by higher production, causing residential investment to rise. The new production increase will require more inputs, thus construction machinery, labour demanded, and demand for residential land will increase. The residential land demand curve will shift from L_{hd}^A to L_{hd}^B leading to higher fraction of land used for residential structures and lower for commercial structures. Since the quantity of total land is finite, the demand for new land will create competition in the land market, resulting to increased land prices. Regarding the labour market of the construction sector, increased demand for labour push wages up, resulting to different equilibrium hours worked for the real estate production. Residential real estate will experience an increase in hours worked, while commercial real estate will face a decrease.

The commercial real estate production now has to face more expensive input prices. As a result they are forced to reduce their production to satisfy their budget constraint. Hence, IH_c will reduce and the supply curve will shift to the left, leading to an increase of commercial real estate price q_{hc}. The "real estate substitution" practically translates a residential real estate demand shock into a commercial real estate supply shock.

There is a strand of literature in urban economics that indicate that the demand for both housing and commercial real estate are similar. In this framework introduced by Rosen (1979) and Roback (1982) land prices is the entry fee that households and firms must pay to access the productivity and the amenities of a labour market area. Because land is substitutable between uses, the price of both residential and commercial property will move together.

Using the same analysis, we can easily explain a shock in commercial real estate side. A demand shock to the commercial real estate originates at the entrepreneurs side, and more specifically in the production function of consumption good sector. A demand shock to the commercial real estate triggers the real estate substitution effect and reproduces the reciprocal effect of the housing demand shock. Thus a demand shock to the commercial real estate is a supply shock to the residential real estate. However, it is not straightforward on what is a commercial real estate demand shock and how can be disentangled from a common supply shock to the consumption good sector.

3 Estimation

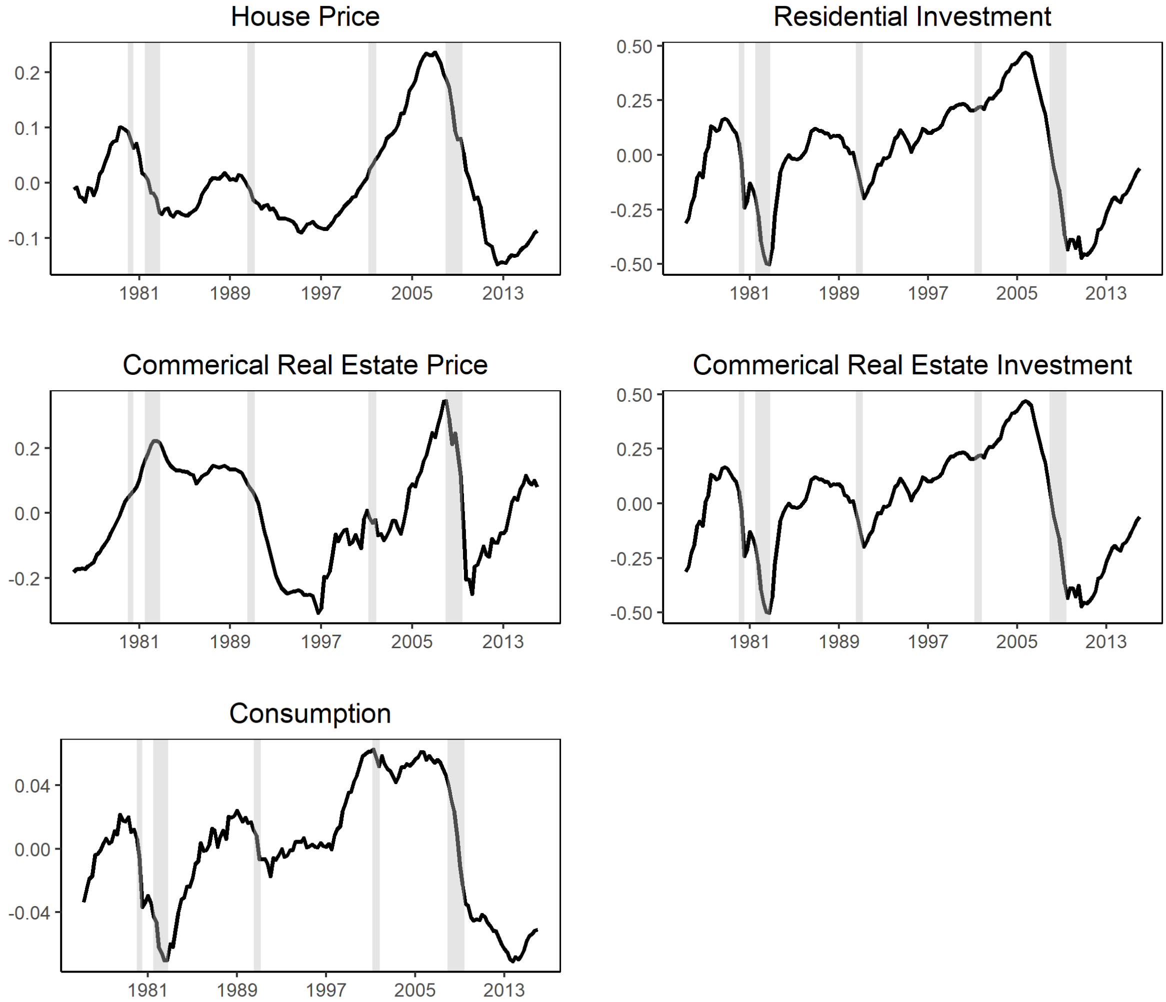
We use Bayesian methods to estimate our model. The posterior density is constructed by simulation using the Metropolis-Hastings algorithm (with 250,000 draws) as described in An and Schorfheide (2007).[5]. The model due to the innate characteristics of the RBC specification can only allow for 6 shocks, 3 technology shocks and 3 demand shocks. Since we can not accommodate more than 6 shocks in the model we we are restricted to less than 6 observables: real consumption, real residential investment, real, commercial real estate investment, house prices, commercial real estate prices. Appendix A describes the data construction. However, due to this impediment we are unable to to estimate a wide range of structural parameters, hence we restrict our estimation to the shocks' processes. All the data have been gathered from freely available sources such as BEA, BLS and FRED. We detrend the logarithm of each variable independently using a quadratic trend. The detrended and demeaned data are plotted in Figure 4

3.1 Calibrated Parameters

Table 1 summarizes our calibration. We set $\beta = 0.9925$, that corresponds to a annual 3% bank prime loan rate. We fix the discount factor at $\beta = 0.965$ in order to make the credit constrain binding in the steady state (Iacoviello, 2005). The depreciation rates for residential real estate, capital in the consumption sector (including commercial real estate), and capital in the construction sector are set to $\delta_{hd} = 0.01$, $\delta_{kc} = \delta_{hc} = 0.025$ and $\delta_{khc} = \delta_{khd} = 0.04$, respectively, to match the steady state values of the data.

[5]Appendix C plots the prior and posterior densities, details on the estimation strategy and tests of convergence for the stability of the estimated parameters

Figure 4 – Detrended Data



Note: The data have been detrended using a quadratic trend and normalized to the beginning of the sample. Shaded regions indicate the NBER recession periods.

Real estate also typically accounts for about half the net market(replacement) value of non-farm, nonfinancial corporate business assets, so we set $\alpha_c = 0.20$ for the capital share and $\mu_c = 0.20$ for the real estate share (Liu et al., 2013). The construction factor shares are set $\alpha_{hd} = \alpha_{hc} = 0.30$ for the capital share and $\mu_{hc} = \mu_{hd} = 0.1$ for the land share (Davis and Heathcote, 2005). It is important to note that the construction sector is more labour-intensive, hence the labour share ought to be larger than the consumption good sector.

Table 2 shows the steady steady ratios of the model. If we sum the consumption share and the business investment share we come up with a consumption good share, of 90%. The residual 10% is the residential housing share. We can split the business investment share into three subcomponents. The commercial structure share accounts for 26% of business investment or 7%

Table 1 – Calibrated Parameter Values

Variable	Value	Description
β_d, β_e	Household's/Entrepreneur's Discount factor	0.9925, 0.975
α_c	Non-housing sector capital share	0.2
α_{hc}, α_{hd}	Commercial/Residential sector capital share	0.2, 0.2
γ_d, γ_e	Household's/Entrepreneur's Habit persistence	0.5, 0.5
η	Inverse of labour elasticity	0.5
μ_c	Housing structure share	0.15
ξ	labour mobility	0.7
μ_{hc}, μ_{hd}	Commercial/Residential land share	0.1, 0.1
χ	Weight on housing services	0.3
θ_c, θ_h	LTV Consumption good/Housing sector	0.7, 0.5
δ_{hc}, δ_{hd}	Depreciation of commercial/residential property	0.025, 0.01
δ_{kc}	Depreciation of non housing capital	0.025
δ_{khc}, δ_{khd}	Depreciation of commercial/residential capital	0.04, 0.04
ϕ_c	Nonhousing capital adjustment cost	10
ϕ_h	Construction capital adjustment cost	9

of GDP. The other two components are software and construction equipment, that constitute the largest part of business investment 64% and 10% respectively. To calculate the business capital in the consumption good sector, we have to sum the capital used in the production of the consumption good and the commercial housing wealth. The business capital in the construction good is 25% higher the residential housing wealth, while the business capital of the construction is only 4% of the business capital stock. That means, that construction firms posses only a smart part of the total capital.

Since both households and entrepreneur are using bonds to smooth their consumption we assume an average habit persistence parameter equal to $\gamma_d = \gamma_e = 0.5$ Downing et al. (2008). The adjustment cost are set to $\phi_c = 10$ for the consumption good sector and $\phi_h = 12$ for the housing sector (Iacoviello and Neri, 2010). Finally, the LTV ratios are set $\theta_c = 0.8$ for the consumption good and $\theta_h = 0.6$ for the construction sector, consistent with Downing et al. (2008) and Gyourko (2009). Our estimation of θ_h equals 0.53, however the calculation does not include the construction machinery, thus we are more conservative by setting it to 0.6.

Table 2 – Steady State Ratios

Parameter	Description	Value	
C/GDP	Consumption Share	67%	
IB/GDP	Business Investment Share	23%	
– IK_c/IB	Software and Equipment share		64%
– IK_h/IB	Construction Equipment share		10%
– $q_{hc}IH_c/IB$	Commercial structure share		26%
$q_{hd}IH_d/GDP$	Residential Housing share	10%	
$q_{hd}H_d/4 \times GDP$	Residential Housing wealth	2.45	
$(q_cH_c + K_c)/4 \times GDP$	Business capital in the consumption good	2.90	
$(K_{hc} + K_{hd)}/4 \times GDP$	Business capital in construction	0.13	

3.2 Prior Distributions

Table 3 summarizes the estimation of the model. We use Beta distribution for the persistence of the shocks with prior mean of 0.8 and a standard deviation of 0.1. We use Inverse-Gamma distribution for the standard errors of the shocks with prior mean 0.001 and standard deviation 0.01.

In the construction sector, we observe that the autoregressive terms are relative high, indicating persistent and prolonged effect on the construction technology, consistent with Iacoviello and Neri (2010). The standard errors, are really close 0.029 and 0.026 for commercial and residential respectively.

The estimated housing demand shocks is very dominant, and has the highest standard error, with a mean close to 0.12.

4 Properties of the Model

We are focused on two shocks for our analysis: a housing preference shock and a technology shock to the consumption good sector. All impulse responses plots correspond to a 1 standard deviation shock. The *y-axis* measures deviation from the steady state.

4.1 Estimated IRFs

Figure 5 shows IRFs for the housing preference shock. The housing preference shock or else as it was established by Iacoviello and Neri (2010) a "housing demand shock", causes house prices and residential investment to rise. New residential investment production requires more

Table 3 – Prior and Posterior Distribution of the shock processes

	Prior Distribution			Posterior Distribution			
Parameter	Density	Mean	SD	Mean	2.5%	Median	97.5%
ρ_z	Beta	0.80	0.01	0.81	0.66	0.85	0.95
ρ_χ	Beta	0.80	0.01	0.92	0.91	0.93	0.93
ρ_ψ	Beta	0.80	0.01	0.8	0.65	0.85	0.96
ρ_{Ac}	Beta	0.80	0.01	0.92	0.9	0.92	0.94
ρ_{Ahc}	Beta	0.80	0.01	0.96	0.94	0.96	0.98
ρ_{Ahd}	Beta	0.80	0.01	0.97	0.95	0.97	0.98
σ_z	Inv Gamma	0.00	0.00	0.04	0.036	0.039	0.043
σ_χ	Inv Gamma	0.00	0.00	0.12	0.1	0.11	0.13
σ_ψ	Inv Gamma	0.00	0.00	0.00061	0.00013	0.00034	0.0012
σ_{Ac}	Inv Gamma	0.00	0.00	0.02	0.018	0.019	0.021
σ_{Ahc}	Inv Gamma	0.00	0.00	0.029	0.027	0.029	0.032
σ_{Ahd}	Inv Gamma	0.00	0.00	0.027	0.024	0.026	0.029

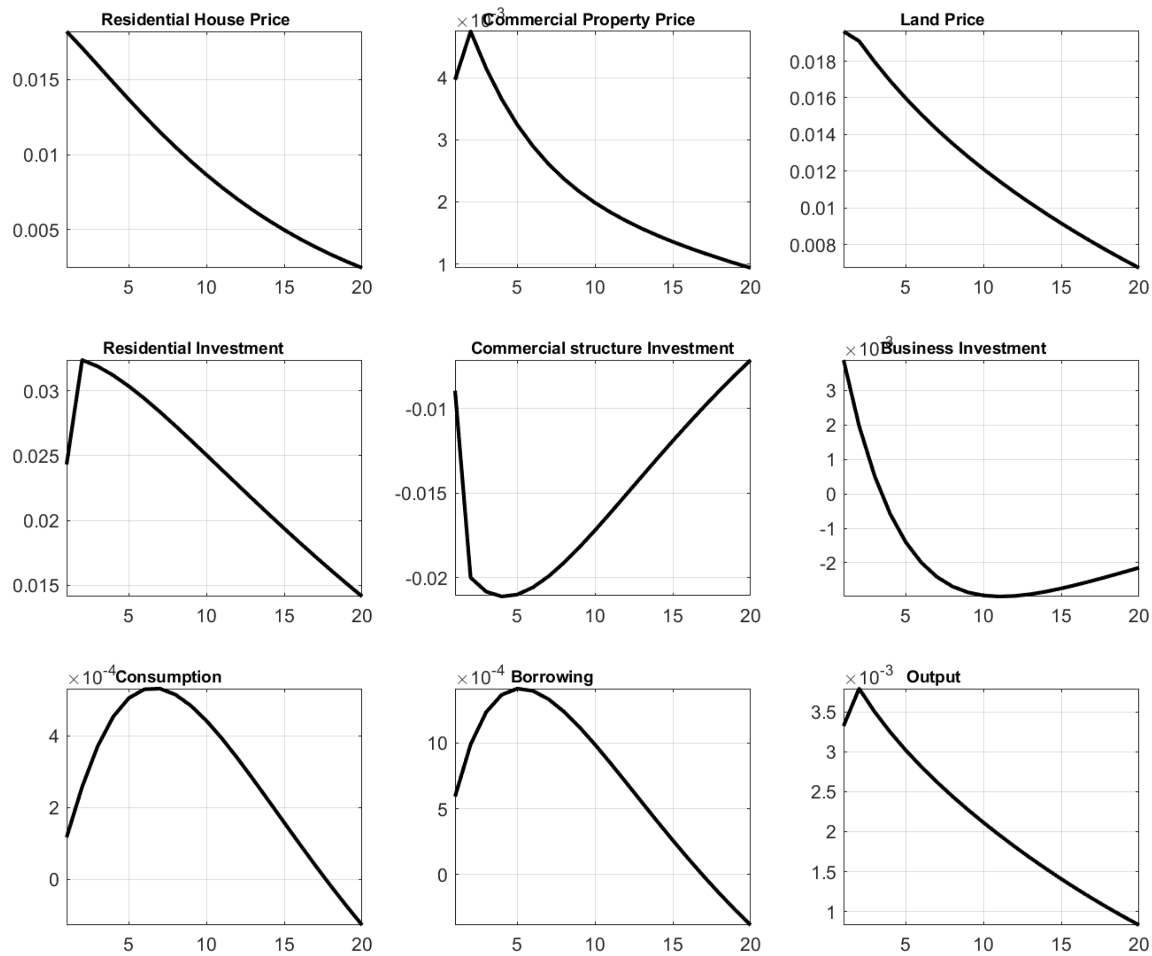
inputs, thus increasing the land prices and wages in the construction sector. The increase of land prices, raises the collateral capacity of the construction entrepreneurs, allowing them to increase borrowing and consumption. On the other hand, the increase of house prices and the fall in CRE, reduces the household consumption and the collateral capacity of entrepreneurs in the consumption good sector, respectively. Since borrowers in the construction sector have higher marginal propensity to consume, the effects of total consumption are positive.

The raise in input prices makes the production of real estate more expensive. Real estate sector comprises of residential and and commercial real estate, residential real estate faces increased demand for production, while CRE meet the old demand, thus causing residential real estate to create downward pressure for commercial real estate. We call this "real estate substitution" channel. The mechanism behind this channel is land and construction sector wages.

The behavior of consumption resembles the case of heterogeneous households (Iacoviello, 2005; Iacoviello and Neri, 2010), where constrained-households produce positive comovement of consumption and house prices. However, in our model we generate this comovement, by utilizing the borrowing characteristic of entrepreneurs in the construction sector.

Technology Shock – Figure 6 shows IRF for the shock in the consumption good sector. The basic trait of a technology shock is that, investment and output go up on impact. However, with the separation of investment we can observe that it is CRE investment that drives business

Figure 5 – Housing Preference Shock

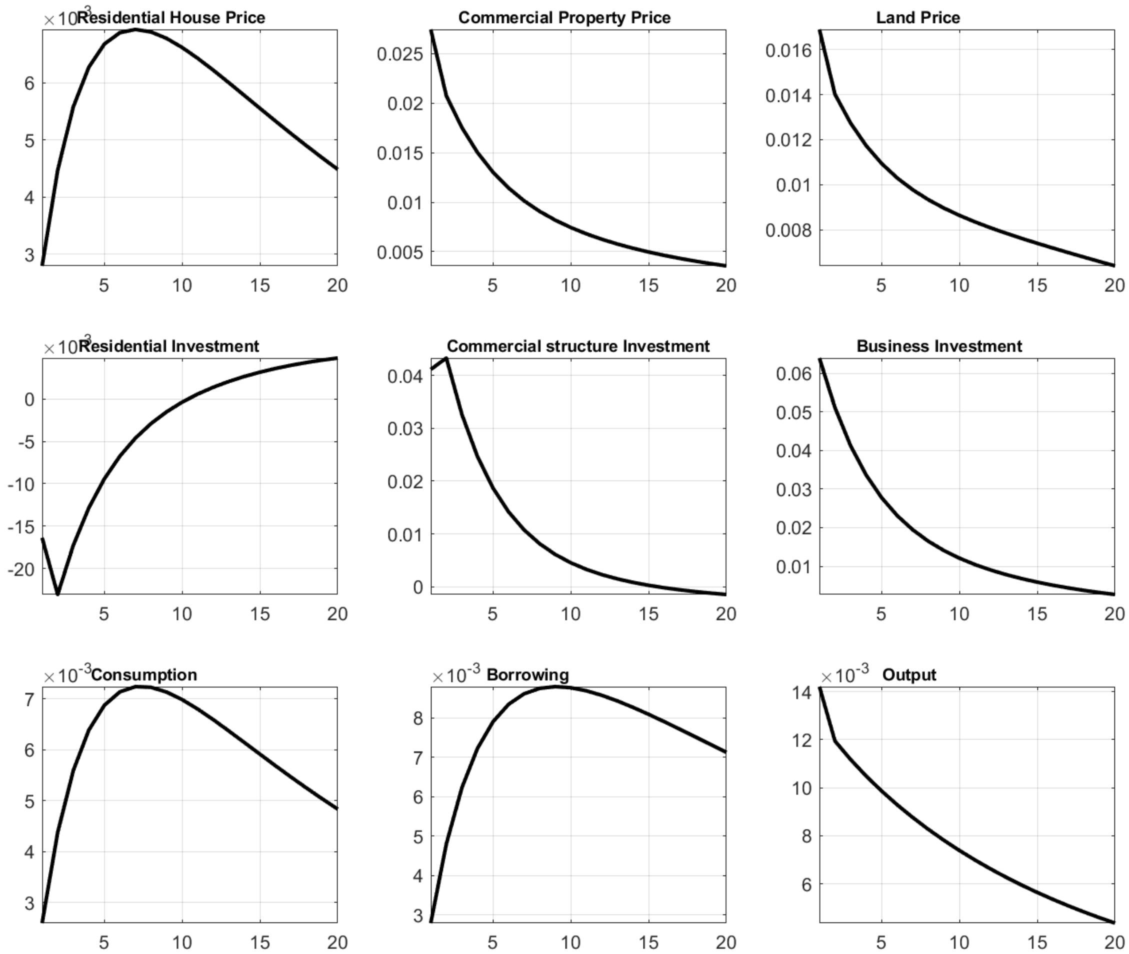


investment, and that in turn, increases output, while residential investment declines, by a smaller proportion, which is not enough to offset the increase in output.

More analytically, a positive productivity shock increase the input required to produce consumption good, that is consumption good capital, CRE capital and commercial land. A demand shock for CRE will increase CRE investment and output. Higher input prices will set up the the real estate substitution mechanism which it will results to increase residential prices and reduces residential investment. We can that what we initially considered a supply shock to the consumption good, can be broke down to a demand shock to CRE and to a supply shock to residential property.

Land price will go up, since increase demand for commercial structures will require more land, thus enabling the competition in the land market. Borrowing, faces a double increase that sources from the increased value of CRE and the increase of land prices. Consumption

Figure 6 – TECHNOLOGY SHOCK



follows very closely the residential house prices, which regardless of the shock they always move together.

4.2 Relative Importance of the shocks

Table 4 reports variance decompositions for the key macroeconomic variables across the 6 type of structural shocks at forecasting horizons between the impact period (1Q) and the five years after the initial shock (20Q).

Since we have an RBC model with no monetary policy it is easier to attribute whether the variance of the variables in our model originates on the demand or the supply side. Now, the distinction of the shocks change i.e. consumption-good technology is not considered only as a supply shock, rather than a demand shock for the commercial sector and a supply shock for the consumption good.

Table 4 – Variance Decomposition of Aggregate Quantities

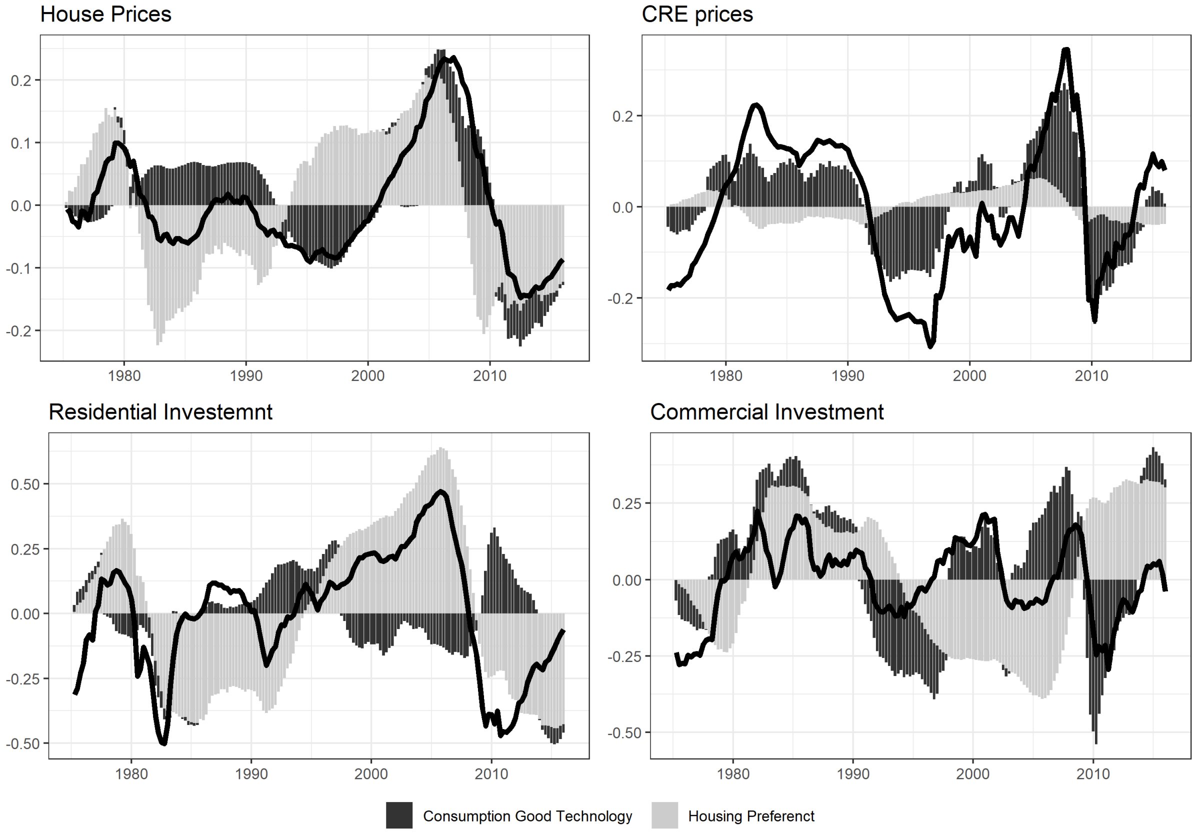
Horizon	Discount	Housing Preferences	Labour Supply	Consumption Tech.	CRE Tech.	Residential Tech.
House Prices						
1Q	11.89	75.56	0.00	1.77	1.64	9.14
5Q	19.31	64.70	0.00	7.19	0.50	8.30
10Q	24.46	54.88	0.00	11.12	0.64	8.90
20Q	27.30	45.04	0.00	14.39	0.68	12.58
CRE Prices						
1Q	4.47	1.49	0.01	71.54	21.14	1.35
5Q	16.53	2.31	0.00	54.98	24.09	2.09
10Q	21.90	2.22	0.00	47.59	25.99	2.30
20Q	23.02	2.09	0.00	42.27	30.06	2.57
Commercial Investment						
1Q	0.17	3.27	0.02	69.13	26.85	0.57
5Q	0.51	11.72	0.01	36.38	46.33	5.06
10Q	0.31	12.12	0.01	20.22	60.24	7.12
20Q	0.37	10.13	0.00	12.22	68.89	8.38
Residential Investment						
1Q	0.06	29.06	0.00	13.20	0.09	57.59
5Q	0.69	32.70	0.00	9.74	2.96	53.90
10Q	0.43	31.59	0.00	5.47	5.60	56.91
20Q	0.81	27.92	0.00	3.62	7.55	60.10

Starting from the House Prices, we can easily say that the biggest part of the variation comes from the housing demand, however the composition changes in longer horizon by allocating more of the weight towards discount shock. Since consumption and house prices are highly correlated, a prolonged shock to the housing demand would mean the households adjust their preferences.

More than half of the residential investment variation is attributed to the technology shock to the residential construction, and a third of the variation is driven by a housing demand shock. On the other hand commercial investment, on impact is primarily explained by a technology shock to the consumption good i.e. commercial real estate demand shock, and secondarily by the technology shock to the commercial construction. However, the effect of the shock in the end changes, and allocates more weight into the supply shock and less to the demand shock.

For the visual representation, Figure 7 shows the historical decomposition of the four key variables namely prices and investment of residential and commercial real estate. The solid lies display the detrended historical data, obtained by applying a quadratic filter on the observed series. The filled regions show the historical contribution of the two shocks under our estimated parameters.

Figure 7 – Historical Decomposition of Structural Shocks



For the top two graphs that display the property prices we observe that the sum two shocks account for most of the variation in the filtered observed series. However, in the bottom two graphs that display the property quantities (investments) the two shock work against each other, a results that stems from the real estate substitution channel. The investment cycles now correspond to the difference of the shocks and not the sum. Housing preference shock boost the residential investment and diminish commercial investment, while consumption good technology works the other way around.

The housing preference shock seems to be the main driver of the 2007 financial crisis, which is evident in all variables beside the CRE prices. CRE prices are primarily driven by technology shocks in the consumption good, which means is more affected from demand shocks, and supply shocks are trivial throughtout the sample period.

5 Concluding Remarks

This paper has shown both the existence and potential mechanism behind the real estate substitution channel as well as captured the way it manifests following demand shocks. Importantly, the inputs of the construction sector play a significant role in explaining the detail and scale of the processes that create this effect. The channel is reciprocal, meaning that it can either originate in residential or the commercial real estate. However, the magnitude is not symmetrical, which highlights that even though construction has a lot of commonalities in the production of the two types of real estate, the specificity of each type is non-trivial.

We give a unique interpretation to the housing preference shock, where it does not simply generate a shift in the preference for housing, instead it is shown to have of a structural connection with commercial real estate. In turn, this relationship explains how demand shocks in the residential real estate can be easily translated as supply shocks to the commercial real estate and vice versa.

The Bayesian estimation of the model reveals that housing preference shocks determines much of the movements in aggregate variables. Moreover, the historical decomposition reveals that whilst movements in housing demand drives all variables, it was the collapse in CRE prices that was particularly dominant in the 2007 crisis, which stemed from a fall in productivity in the consumption good sector. As a result, whilst the co-movement of House prices with CRE prices is close, our results reveal that there are different mechanisms at play which are very important for explaining the short run dynamics in both the construction sector and economy as a whole.

Appendix A: Data and Sources

Aggregate Consumption: Real Personal Consumption Expenditure (seasonally adjusted, chain-type quantity index, base year 2009, table 1.1.3) divided by the Civilian Noninstitutional Population (CNP16OV, source: Bureau of labour Statistics). Source: Bureau of Economic Analysis (BEA)

Business Investment: Real Private Nonresidential Fixed Investment (seasonally adjusted, chain-type quantity index, base year 2009, table 1.1.3) divided by CNP16OV. Source: BEA

Residential Investment Real Private Residential Fixed Investment (seasonally adjusted, chain-type quantity index, base year 2009, table 1.1.3) divided by CNP16OV. Source: BEA

Commercial Real Estate Investment Real Private Nonresidential Structures Fixed Investment (seasonally adjusted, chain-type quantity index, base year 2009, table 1.1.3) divided by CNP16OV. Source: BEA

House Prices : Real House Price Index, United States (NSA) deflated with the implicit price deflator for the nonfarm business sector (table 2 , source: BLS). Source: Census Bureau

Commercial Real Estate Prices : Real Commercial Real Estate Price Index, United States (NSA) deflated with the implicit price deflator for the nonfarm business sector (table 2 , source: BLS). Source: Federal Reserve System

Hours in Consumption Sector: Hours of Wage and Salary Workers on Nonfarm Payrolls: Private(seasonally adjusted, Billions of Hours, Series ID: PRSCQ) less Hours of Wage and Salary Workers on Nonfarm Payrolls: Construction (seasonally adjusted, Billions of Hours, Series ID: CNSTQ). Source: FRED

Hours in Construction Sector: Hours of Wage and Salary Workers on Nonfarm Payrolls: Construction (seasonally adjusted, Billions of Hours, Series ID: CNSTQ). Source: FRED

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