Real Estate and Construction Sector Dynamics in the Business Cycle

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Abstract

We investigate the business cycle, property-price and investment dynamics when there is competition between households and firms for real estate. We introduce a construction sector into a RBC framework, which uses land, capital and labour to produce both commercial and residential real estate. This market structure activates a 'real estate substitution channel', where economic disturbances which alter the demand for one type of real estate, by affecting the overall costs of real estate production, endogenously create a substitution with its counterpart. For example, an increase in demand for residential real estate also increases the cost of producing commercial structures, which reduces the quantity demanded by firms. In turn, this crowds out commercial real estate which affects the goods market in a similar way to an adverse aggregate supply shock. 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 primarily driven by technology shocks.

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

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1 Introduction

Real estate is a significant component of the economy's capital stock and households' wealth, which serves as both a crucial input for producers and provider of residence for households. Investment in real estate can be categorised according to its use as either commercial or residential,[1] with commercial real estate (henceforth CRE) typically accounting for around half of business assets (Nelson et al., 2000) and residential real estate (henceforth RRE) constituting one-third of household net worth. Moreover, the construction sector lies in a unique and influential position as a major contributor to the business cycle (Case et al., 2000; Leamer, 2015; Head et al., 2014).

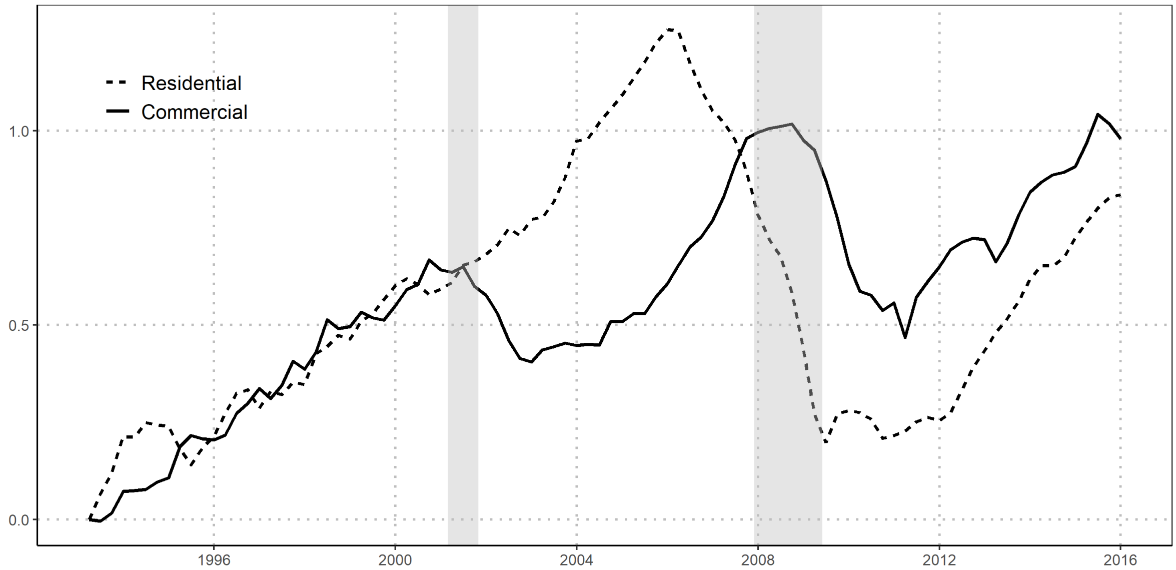
In this paper, we argue that the inclusion of a construction sector as a producer of both commercial and residential real estate is pivotal when evaluating the driving forces behind property prices and economic activity. Firstly, CRE creation is an important indicator of macroeconomic activity since it constitutes a significant factor of production at the firm level. Secondly, the construction sector, as a creator of RRE, responds directly to the demand for residential housing over the business cycle. As a consequence, the competition for inputs that arise in the construction sector, such as land, labour and capital creates direct spillovers between the two types of real estate.

A closer look into the construction sector and the disaggregated construction spending for the US (Figure 1) reveals that despite both commercial and residential spending growing in a similar way until 2001, they behave quite differently following the two recession periods. After the *2001 dot.com* crisis there was a fall in commercial spending, while residential spending continued its upward trend until the onset of the *2007 financial crisis* when it dived sooner and greater than commercial spending. Thus, depending on the source of macroeconomic fluctuation, these two types of real estate can potentially display quite different cyclical behaviours. More recently, the move away from conventional office based work towards home working due to the Covid-19 pandemic has only further emphasised the importance of understanding the properties and mechanisms behind these real estate co-movements.

The level of construction activity is one of the key mechanisms through which changes in real estate prices are transmitted to the wider economy. Since construction spending tracks the overall investment in real estate, i.e. the creation of new structures, investment seems to follows a very similar path. Figure 2 plots the property and land prices, alongside real estate investment. As was the case with construction spending, different types of real estate investment have quite different cyclic behaviours (Wheaton, 1999); this can be particularly evident prior to

[1] Commercial investment consists of new construction and improvements to existing structures in commercial and health care buildings, manufacturing buildings, power and communications structures, and other structures. Residential investment includes new construction of single-family homes and multifamily homes and spending on other residential structures (Lally, 2009) - BEA Briefing

Figure 1 – Construction Spending



Notes: Commercial construction spending (solid line) and residential construction spending (dotted line). Variables are in log units and normalised to the origin of the sample. The shaded bars mark the NBER recession dates. Private construction spending covers the dollar construction work done on new structures or improvements to existing structures. Data estimates include the cost of labour and materials, cost of architectural and engineering work, overhead costs, interest and taxes paid during construction, and contractor's profits. Source: data.gov

the financial crisis. Analogous periods can also be considered, for example, the *2nd energy crisis of 1982*, where the demand for commercial real estate boomed and reached a speculative point in many markets followed by an immediate fall in commercial real estate prices and investment, and the aftermath of the early 1990s recession.

In line with the evidence of Rosen (1979); Roback (1982), and Gyourko (2009), property and land prices appear to comove contemporaneously and have similar time-series patterns. 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 appears to drive both commercial and residential real estate prices (Davis and Heathcote, 2007; Glaeser and Ward, 2009; Gyourko et al., 2013).

We further investigate the dynamics of residential and commercial real estate empirically. We consider the partial derivatives of RRE and CRE investment, and CRE price at various horizons with respect to innovation in the RRE price shock. Figure 3 displays the estimated impulse response of RRE price, RRE investment, CRE investment, and CRE price following a shock to the RRE price series.[2] The impulse responses are estimated in a four-variable Bayesian vector

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

Figure 2 – Real Estate Dynamics

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

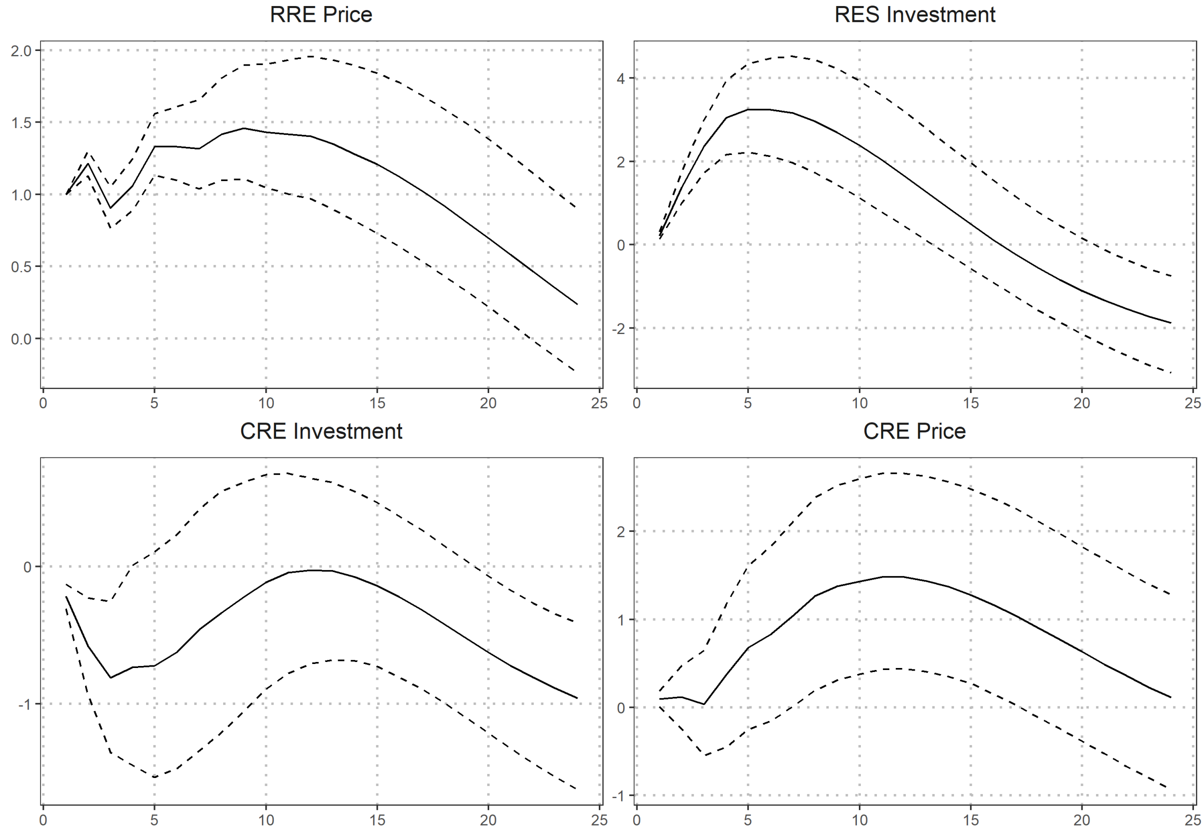
autoregressive (BVAR) model with the Flat Prior. We generate IRFs for an RRE price shock using recursive identification, where we order RRE prices first. Although the identification of the model may appear unguided by theory, it can approximate the effects of a housing demand shock in a DSGE framework that represents an exogenous shift to housing preferences.[3]

A positive shock to the RRE price leads to a positive response of the RRE 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 co-move, the CRE price will increase following a positive shock to RRE 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, and the substitution between residential and commercial investment outlined in Figure 3. 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

[3]Innovations in RRE price may simply reflect information already contained in other variables innovations. To address this possibility, we reorder the variables in the system such that RRE price is orthogonalized with respect to other variables (RRE price is ordered last). We find that, whether or not is first orthogonalized with respect to CRE, the shape of the impulse responses remain identical. For robustness, we perform the same estimation with the Minnesota prior (Doan et al., 1984; Litterman, 1986). Results are available in the Online Appendix.

Figure 3 – RRE Price Shock



Notes: Impulse response to a positive shock to the residential real estate price from a recursive BVAR model with Diffuse Prior. Identification is achieved through Cholesky decomposition with the following ordering {RRE Price, RRE Investment, CRE Investment, CRE Price }, all in real terms. Solid lines represent the median estimated responses and dotted lines the 68% probability bands.

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 whereby 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 analyse 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.

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 their inputs (besides 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 means that the dynamics and level of real estate prices can differ between commercial and residential production.

Our model is able to capture the substitution between commercial and residential investment, which is evident in the BVAR model in Figure 3. We refer to this mechanism as the "real estate 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 is fixed on aggregate, however, real estate investment clearly follows its own law of motion. By introducing a construction sector where investment decisions depend upon not only land but all of the inputs of real estate production, we are able to connect the dynamics of the two series. Our results indicate that in general, the residential/commercial land allocation acts as an anchor for the allocation of its real estate investment counterpart. However, this is by no means always the case and, in particular following recession periods, there is a notable divergence between the movements of land and real estate investment which has non-trivial implications for both real estate dynamics and real economic activity.

The paper proceeds as follows. The next chapter describes the theoretical model. Section 3 reports the calibration and estimation details. Section 4 explains the properties of the model. Section 5 describes the importance of land. 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, while the entrepreneur's utility depends only on consumption goods. Consumption goods production requires labour, capital, and commercial real estate as inputs. Real estate investments require labour, capital, and land as inputs. Furthermore, the entrepreneur in both of these sectors needs external financing for investment spending. Imperfect contract enforcement implies that the entrepreneur's borrowing capacity is constrained by the value of their collateral assets. Because these assets vary depending upon the sector, collateral differs according to the type of production. Borrowing in the consumption good sector is constrained by the value of non-construction capital and the value of the commercial real estate, while the construction 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 in intertemporal preference and labour supply respectively. 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 among sectors. The household allocate labour resources to the productive activities, for $\xi \geq 0$, hours worked are not perfect substitutes between sectors. Specifically, labour in the consumption and real estate sectors in sectors are imperfect substitutes which gives rise to sectoral wage differentials. In contrast, labour can freely move from commercial to residential real estate production and vice versa within the construction sector and they face the same wage.

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

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

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, $L_{hd,t}^{ep}$ is the amount of land that the household is left with after the depreciation of the housing stock where $q_{l,t}$ is the land price. 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

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

where c and h define the respective consumption good and construction good sectors. $C_{i,t}$ denotes the entrepreneur's consumption and γ 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 non-construction 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, $K_{c,t-1}$, $H_{c,t-1}$, $N_{c,t}$, $A_{c,t}$, denote non-construction capital, commercial real estate , labour and labour productivity respectively. The entrepreneur is endowed with $K_{c,t-1}$ units of initial non-construction capital stock and $H_{c,t-1}$ of commercial real estate stock. Production functions in both sectors are subject to an exogenous labour-augmenting productivity shock. The shocks follow

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

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

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

where $q_{hc,t}$ denotes the price of commercial real estate, the variable $\phi_{c,t}$ describes capital adjustment costs and δ_{kc} and δ_{hc} are the depreciation rates of non- construction capital and commercial

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

real estate respectively. The value of land that the entrepreneur is left with after the depreciation of the housing stock is $q_{l,t}L^{ep}_{hc,t}$. Finally, $B_{c,t}$ is the amount of debt used to finance investments in the non-construction sector which is subject to the credit constraint

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

where θ_c can be interpreted as a steady state loan-to-value (LTV) ratio, and ρ_b measures the inertia in the borrowing limit Iacoviello (2015). 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) - (6).

2.4 The Construction Sector

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

$$IH_{c,t} = K^{\alpha_h}_{hc,t-1}L^{\mu_h}_{hc,t-1}\left(A_{hc,t}N_{hc,t}\right)^{1-\alpha_h-\mu_h}, \tag{7}$$

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

$$IH_{d,t} = K^{\alpha_h}_{hd,t-1}L^{\mu_h}_{hd,t-1}\left(A_{hd,t}N_{hd,t}\right)^{1-\alpha_h-\mu_h}, \tag{8}$$

where $IH_{d,t}$ denotes new homes, and $K_{hd,t-1}$, $N_{hd,t}$ and $L_{hd,t-1}$, are the corresponding inputs . $A_{hc,t}$ and $A_{hd,t}$ measure the productivity of commercial and residential construction 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. Construction sector entrepreneurs face the following flow of funds constraint

$$\begin{aligned} C_{h,t} + K_{hc,t} + K_{hd,t} + q_{l,t}\left(L_{hc,t} + L_{hd,t}\right) + w_{h,t}\left(N_{hc,t} + N_{hd,t}\right) + B_{h,t-1} = q_{hc,t}IH_{c,t} \\ + q_{hd,t}IH_{d,t} + (1-\delta_{kh})K_{hc,t-1} + (1-\delta_{kh})K_{hd,t-1} + \frac{B_{h,t}}{R_t} - {\phi_{h,t}}^5, \end{aligned} \tag{9}$$

where $B_{h,t}$ is the debt for financing investments in the construction sector and is subject to the credit constraint

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

The amount the entrepreneur can borrow in the constructions sector is limited by the total value of land and construction 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 (3) subject to (7) - (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 described 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 in 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 new RRE. $H_{c,t}$ evolves according to the law of motion

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

The construction sector 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 real estate. The GDP is the sum of the value added of the consumption good and residential real estate, that is

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

[5] $\phi_{h,t} = \dfrac{\phi_{hc}}{2}\left(\dfrac{k_{hc,t}}{k_{hc,t-1}} - 1\right)^2 k_{hc,t-1} + \dfrac{\phi_{hd}}{2}\left(\dfrac{k_{hd,t}}{k_{hd,t-1}} - 1\right)^2 k_{hd,t-1}$

Available 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

$$\bar{L}_h = L_{hc,t} + L_{hd,t}. \tag{15}$$

We define ex post land, L_{hd}^{ep} and L_{hc}^{ep} as the land which is owned by the respective household and entrepreneur following the depreciation of their housing stock. This is then purchased the construction entrepreneur who uses it as an input. Since all land has a positive value it is always built upon when it becomes available, thus it follows that $L_{hc}^{ep} + L_{hd}^{ep} = \bar{L_h}$ with the following shares applied to each sector

$$L_{hc,t}^{ep} = \frac{\delta_{hc} H_{c,t-1}}{\delta_{hc} H_{c,t-1} + \delta_{hd} H_{d,t-1}} \bar{L}_h \qquad L_{hd,t}^{ep} = \frac{\delta_{hd} H_{d,t-1}}{\delta_{hc} H_{c,t-1} + \delta_{hd} H_{d,t-1}} \bar{L}_h. \tag{16}$$

2.6 Real Estate Substitution

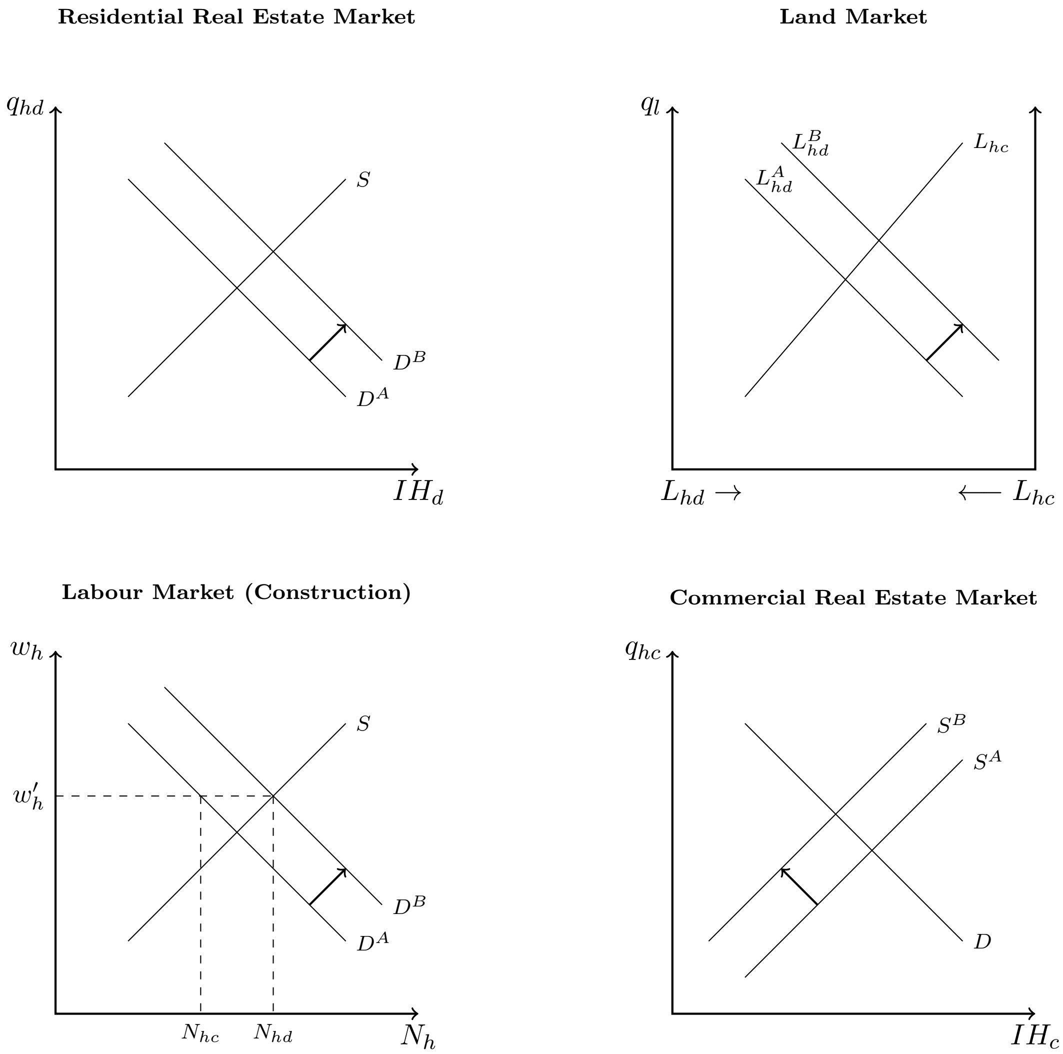
In this section, we use a static model to explain the mechanism of real estate substitution in the presence of a housing demand shock. Figure 4 includes the four markets we consider in our analysis, residential real estate (top left), land market (top right), labour market (bottom left) and commercial real estate (bottom right).

Consider a positive RRE price shock that shifts the demand curve in the RRE market from D_A to D_B. Higher demand for houses will increase RRE prices (q_{hd}) and cause RRE investment to rise. To facilitate this increase in production, demand for construction machinery, labour in the construction sector, and land will also increase. In the land market, the residential land demand curve will shift from L_{hd}^A to L_{hd}^B , increasing competition for the available land, which leads to an increase in land prices and a substitution towards RRE land use. Similarly, the increased demand for labour for residential construction will raise construction sector wages. This hike in construction costs generates a vertical shift in the supply of commercial real estate, displayed by the shift from S^A to S^B, which increase the CRE price, q_{hc} and cause a fall in CRE investment.

Thus "real estate substitution" following a RRE demand shock is driven by cost push pressures which acts to crowd out the CRE market in the same way as an adverse aggregate supply shock.[6] As can be seen in Figure 4, the overall effects of real estate substitution on both real estate prices and investment depend upon the price elasticities of supply and demand in the

[6]There is a strand of literature in urban economics that indicate that the demand for both residential 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.

Figure 4 – Housing Demand Shock



Notes: 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.

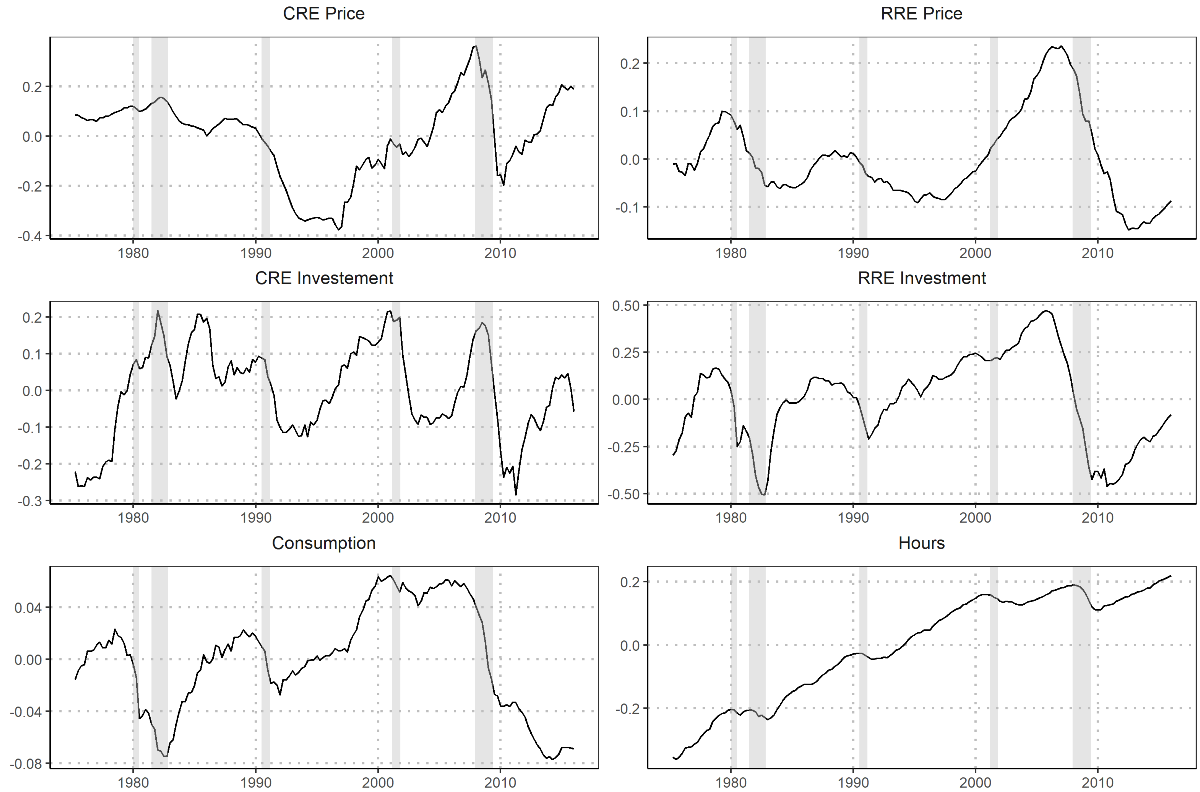
real estate, land and labour markets. To shed further light upon the quantitative and state-contingent behaviour of this channel, we fully estimate the model in the following section.

3 Estimation

We use Bayesian methods to estimate our model. The posterior density is constructed by simulation using the Metropolis-Hastings algorithm (with 200,000 draws) as described in An and Schorfheide (2007).[7] The model due to the innate characteristics of the RBC, can only allow for a

[7] 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 5 – Detrended Data



Notes: Prices, investment and cosumption have been detrended using a quadratic trend and normalized to the beginning of the sample. Hours are demeaned. The model parameters are estimated using data from 1975Q1-2016Q4. Shaded regions indicate the NBER recession periods.

limited number of shocks, which in this case amount to six. Since we can not accommodate more than six shocks in the model we are restricted to six observables: consumption, residential real estate investment, residential real estate price, commercial real estate investment, commercial real estate prices and total hours. All variables are denoted in real terms. All the data have been gathered from freely available sources such as BEA, BLS and FRED. We demean the hours and detrend the logarithm of the rest of the variables independently using a quadratic trend.[8]. The detrended and demeaned data are plotted in Figure 5 The sample covers the period from 1975:Q1 to 2016:Q4.

Due to the low number of observables we are unable to to estimate a wide range of structural parameters, hence we focus our estimation strategy primarily to the shocks' processes.

[8]Appendix A describes further details of the data construction

3.1 Calibrated Parameters

To calibrate, we use data on the US market. Table 1 summarizes our calibration. We set the discount factor for households $\beta_d = 0.9925$, that corresponds to a annual 3% bank prime loan rate. We fix the discount factor for entrepreneurs at $\beta_e = 0.975$, which makes the credit constrain binding in the steady state (Iacoviello, 2005). Since entrepreneurs can use bonds to smooth consumption we assume a higher degree of habit persistence $\gamma_e = 0.65$ than households $\gamma_d = 0.5$. The depreciation rates for residential real estate, non construction capital, commercial real estate, and capital in the construction sector are set to $\delta_{hd} = 0.01$, $\delta_{kc} = 0.025$, $\delta_{hc} = 0.025$ and $\delta_{kh} = 0.04$ (Iacoviello and Neri, 2010). Parameter χ is calibrated to 0.2 to set the steady state of the ratio of residential investment to output.

Real estate also typically accounts for about half of 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). 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, thus the construction factor shares are set to $\alpha_h = 0.20$ for the capital share and $\mu_h = 0.1$ for the land share (Davis and Heathcote, 2005).

Finally, the LTV ratios have to take values less than 0.75, since commercial mortgage-backed securities loans permit maximum LTV of 75%. Grovenstein et al. (2005) measures LTV ratios to be 71.01% in five major commercial real estate property types originating from 10547 loans. Downing et al. (2008) report an average LTV of 67.40% for over 14.000 commercial mortgages between 1996 and 2005. Arsenault et al. (2013) finds a mean of 66% for the period of 1991 to 2011. For our purpose we set consumption good LTV to 70% ($\theta_c = 0.70$), while real estate firms correspond to an aggregate loan-to-value ration to 50% (Gyourko, 2009), thus we set $\theta_h = 0.5$.

Table 2 shows the steady steady ratios of the model. The sum of the consumption share (68%) and the business investment (22%) is the consumption good share, which amounts to

Table 1 – Calibrated Parameter Values

Households			**Entrepreneur**		
β_d	Discount factor	0.9925	β_e	Discount factor	0.975
χ	Housing services	0.2	γ_e	Habit persistence	0.65
γ_d	Habit persistence	0.5	ρ_b	Borrowing inertia	0.8
Entrepreneur: Consumption Good			**Entrepreneur: Construction**		
α_c	Non-construction capital share	0.2	α_h	Construction capital share	0.2
μ_c	Commercial real estate share	0.2	μ_h	Land share	0.1
δ_{kc}	Depreciation of non-construction capital	0.025	δ_{hd}	Depreciation residential real estate	0.01
δ_{hc}	Depreciation of commercial real estate	0.025	δ_{kh}	Depreciation of construction capital	0.04
θ_c	LTV consumption good sector	0.70	θ_h	LTV construction sector	0.5

Table 2 – Steady State Ratios

C/GDP	Consumption share	68%	
IB/GDP	Business investment share	22%	
– IK_c/IB	Software and non-construction equipment share		53%
– IK_h/IB	Construction equipment share		11%
– $q_{hc}IH_c/IB$	Commercial structure share		34%
$q_{hd}IH_d/GDP$	Residential structure share	10%	
$q_{hd}H_d/(4 \times GDP)$	Residential real estate wealth	2.46	
$(q_cH_c + K_c)/(4 \times GDP)$	Consumption good capital	3.1	
$(K_{hc} + K_{hd)}/(4 \times GDP)$	Construction capital	0.16	

90%. The remaining 10% is the residential real estate share. We split the business investment share into three sub-components. The commercial real estate share accounts for 34% of business investment or 7% of GDP. The other two components are software and non-construction capital and construction capital that constitute the largest part of business investment 53% and 11% respectively. To calculate the business capital in the consumption good sector, we sum the capital used in the production of the consumption good and the commercial real estate wealth. The business capital for the construction good is 25% higher than the residential housing wealth, while the business capital of the construction is only 4% of the business capital stock. This means that construction firms possess only a smart part of the total capital.

3.2 Prior & Posterior Distributions

Table 3 summarizes the estimation of the model. We report the estimates of shock and structural parameters at the posterior mean, median and mode, along with the 90% posterior probability intervals. For the shock processes, we use Beta distribution for the persistence with prior mean of 0.8 and a standard deviation of 0.1, and Inverse-Gamma distribution for the standard errors with prior mean 0.001 and standard deviation 0.01. For labour supply elasticity (η) we use a normal distribution centred around 0.5, and we observe a moderate response of labour supply to wages with a median estimate to 0.64. Also, agents exhibit little preference for labour mobility with a median estimate of 0.89.

In the construction sector, we observe that the autoregressive terms are relative high, indicating a persistent and prolonged effect on the construction technology, consistent with Iacoviello and Neri (2010). The standard errors are close 0.03 and 0.031 for commercial and residential, respectively.

Table 3 – Prior and Posterior Distribution

	Prior Distribution			Posterior Distribution				
Parameter	Density	Mean	SD	Mean	2.5%	Median	Mode	97.5%
σ_z	Inv Gamma	0.00	0.00	0.069	0.061	0.069	0.068	0.077
σ_χ	Inv Gamma	0.00	0.00	0.081	0.063	0.08	0.08	0.099
σ_ψ	Inv Gamma	0.00	0.00	0.017	0.016	0.017	0.017	0.019
σ_{Ac}	Inv Gamma	0.00	0.00	0.02	0.017	0.02	0.02	0.023
σ_{Ahc}	Inv Gamma	0.00	0.00	0.03	0.028	0.03	0.03	0.033
σ_{Ahd}	Inv Gamma	0.00	0.00	0.031	0.028	0.031	0.031	0.035
ρ_z	Beta	0.80	0.01	0.78	0.75	0.79	0.79	0.82
ρ_χ	Beta	0.80	0.01	0.95	0.93	0.95	0.95	0.96
ρ_ψ	Beta	0.80	0.01	0.98	0.98	0.98	0.98	0.99
ρ_{Ac}	Beta	0.80	0.01	0.98	0.97	0.98	0.98	0.99
ρ_{Ahc}	Beta	0.80	0.01	0.98	0.97	0.98	0.98	0.99
ρ_{Ahd}	Beta	0.80	0.01	0.96	0.95	0.96	0.96	0.97
ξ	Beta	1	0.1	0.89	0.84	0.89	0.9	0.94
η	Normal	0.5	0.1	0.64	0.41	0.64	0.65	0.88
ϕ_c	Gamma	10.00	6.25	13	10	13	13	17
ϕ_h	Gamma	10.00	6.25	14	8.9	14	10	19

4 Properties of the Model

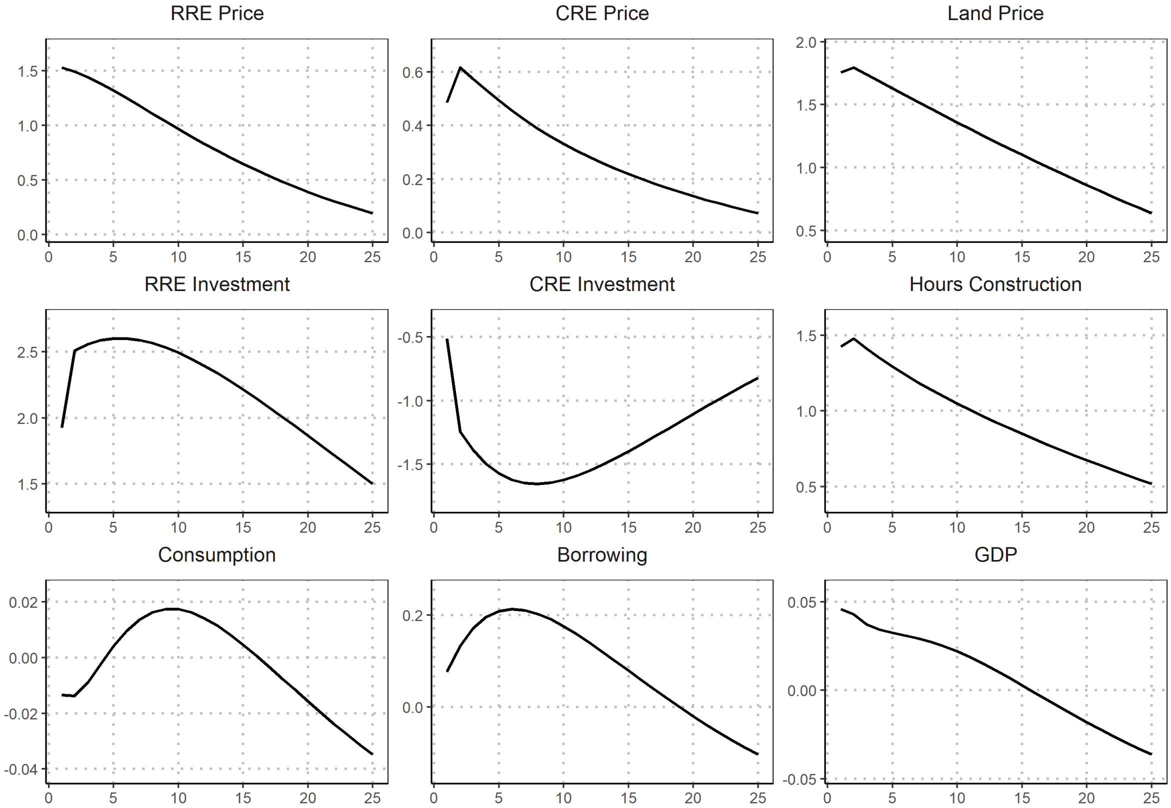
For the central part of the analysis, we focus on two shocks: an RRE preference shock and a technology shock to the consumption good sector. All impulse responses plots correspond to a one standard deviation shock. The *y-axis* measures the deviation from the steady state.

4.1 Estimated IRFs

Figure 6 shows IRFs for the housing preference shock. As explained in section 2.6, the housing preference shock, causes RRE prices and investment to increase.[9] Increases in the production of residential real estate requires more inputs, thus increasing the land prices, wages in the construction sector, and therefore RRE investment itself. However, CRE production also requires these inputs, and it is the rise of these input prices that activate the *real estate substitution* channel and causes a fall in CRE investment.

[9] Alternatively this could be condidered a "housing demand shock" as in Iacoviello and Neri (2010)

Figure 6 – Housing Preference Shock

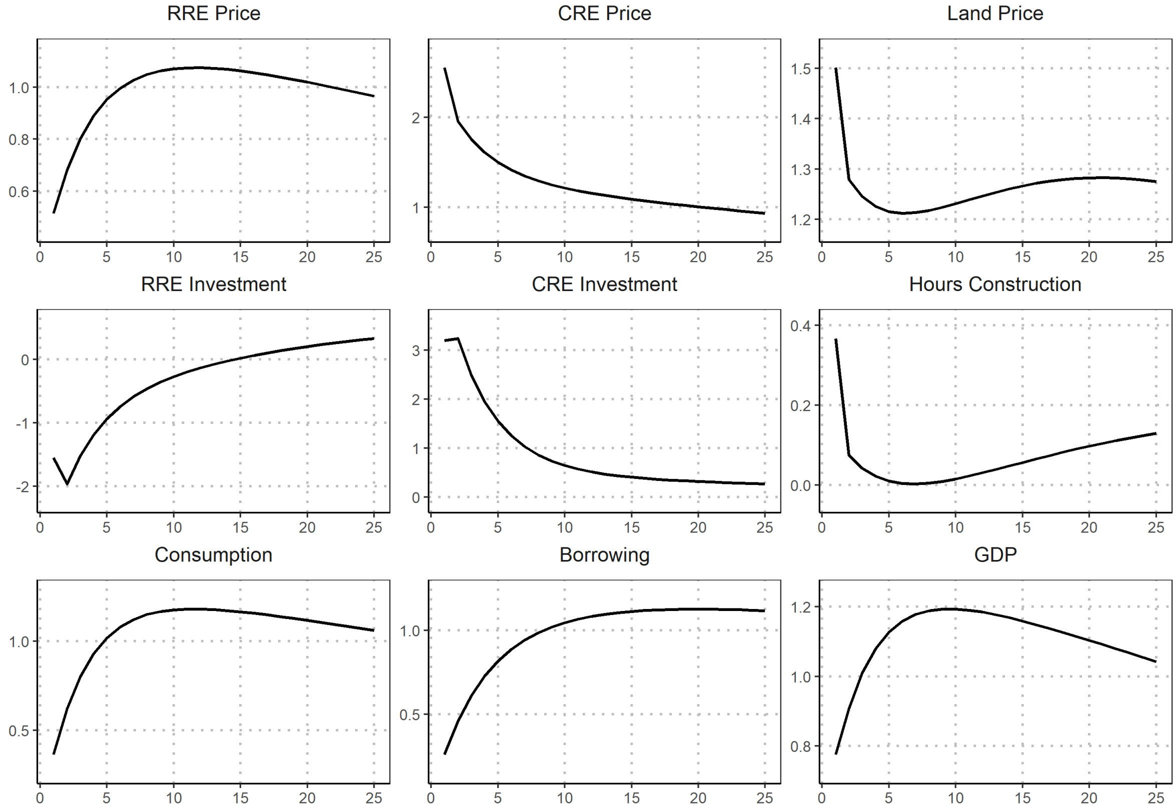


Notes: Impulse responses to a positive (one standard deviation) shock to housing preferences. The y-axis measures percent deviation from the steady state.

In Iacoviello and Neri (2010) a positive housing preference shock creates a rise in capital in the construction sector and a decrease in capital in the consumption sector. This shift in resources between sectors cause a small but negative response to business investment. In our model, CRE investment by definition is included in the business investment; therefore with a reduction in CRE investment, business investment will follow. However, rather than the shift of resources between construction and non-construction capital, the redistribution takes place within the construction sector between the two types of real estate producers.

The increase in land prices also raises the collateral capacity of the entrepreneurs in the construction sector, allowing them to increase borrowing and consumption. On the other hand, the increase in RRE prices and the fall in CRE investment reduces the household consumption and the collateral capacity of entrepreneurs in the consumption good sector, respectively. The behaviour of consumption resembles the case of heterogeneous households (Iacoviello, 2005; Iacoviello and Neri, 2010), where the assumption of constrained-households produces positive co-movement between consumption and house prices. However, in our model, we generate

Figure 7 – Consumption Good Technology Shock



Notes: Impulse responses to a positive (one standard deviation) shock to consumption-good technology. The y-axis measures percent deviation from the steady state.

this co-movement, by utilising the borrowing characteristic of entrepreneurs in the construction sector.

Figure 7 shows the IRF for a technology shock in the consumption good sector. For a technology shock, investment and output go up on impact. However, with the separation of investment, we can observe that it is CRE investment that drives business investment, which in turn increases production and output, while RRE investment declines, by a smaller proportion, and overall output still increases.

Specifically, a positive productivity shock increases the demand and price of the inputs required to produce consumption good, that is consumption good capital, CRE capital and commercial land. In turn, the increase in demand for CRE increase CRE investment, wages in the construction sector and land prices. Higher input prices set up the real estate substitution mechanism, which generates a cost-push increase in residential prices and reduces residential investment. Thus what we initially considered a positive supply shock to the consumption good, instigates the equivalent of a positive demand shock to CRE and, in turn, an adverse supply

Table 4 – Variance Decomposition

Horizon	Discount	Housing Preferences	Labour Supply	Consumption Technology	CRE Tecnology	RRE Technology
	Shocks					
			RRE Prices			
1Q	8.37	62.91	0.26	7.16	7.44	13.87
5Q	12.76	56.94	0.47	16.99	2.17	10.67
10Q	12.34	49.58	0.59	25.54	2.11	9.85
20Q	9.33	38.91	0.76	36.82	2.46	11.73
			CRE Prices			
1Q	7.71	1.71	2.41	46.92	39.55	1.70
5Q	14.48	2.86	1.42	35.34	43.01	2.88
10Q	12.61	2.81	1.15	33.44	47.06	2.93
20Q	9.14	2.39	0.99	33.70	51.21	2.57
			RRE Investment			
1Q	0.40	16.29	1.47	10.57	2.02	69.26
5Q	1.77	21.33	1.50	7.72	0.73	66.94
10Q	1.01	23.25	2.14	4.51	1.34	67.75
20Q	1.12	23.66	2.96	2.65	3.69	65.91
			CRE Investment			
1Q	4.28	1.69	18.77	66.54	7.50	1.22
5Q	11.18	9.21	11.81	36.12	23.51	8.17
10Q	5.97	11.21	8.50	19.18	44.35	10.78
20Q	2.93	10.02	6.34	9.65	60.52	10.55
			Consumption			
1Q	83.12	0.02	2.68	14.15	0.00	0.02
5Q	65.68	0.00	5.12	28.99	0.21	0.01
10Q	44.26	0.01	7.95	46.97	0.80	0.01
20Q	25.06	0.01	10.68	63.07	1.18	0.01

shock to residential property. Borrowing increases stem from the higher value of CRE and the increase in land prices. Consumption follows residential house prices very closely since household utility retains the same relative weights on housing and consumption.

4.2 Relative Importance of the shocks

Table 4 reports variance decomposition 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).

It is clear that the largest variation in RRE prices stems from the housing preference shocks, especially at short horizons. Indeed over longer horizons changes in household income are spread across both the consumption good and house prices which also explains why the two components of household utility are highly correlated. CRE prices react in a similar way, over short horizons most of the variation is attributed to demand (consumption technology shock), while more weight is allocated to supply (CRE technology) as you go in longer horizons. Additionally, discount shocks play a non-trivial role in determining property prices, which further highlights the importance of treating real estate separately to consumption.

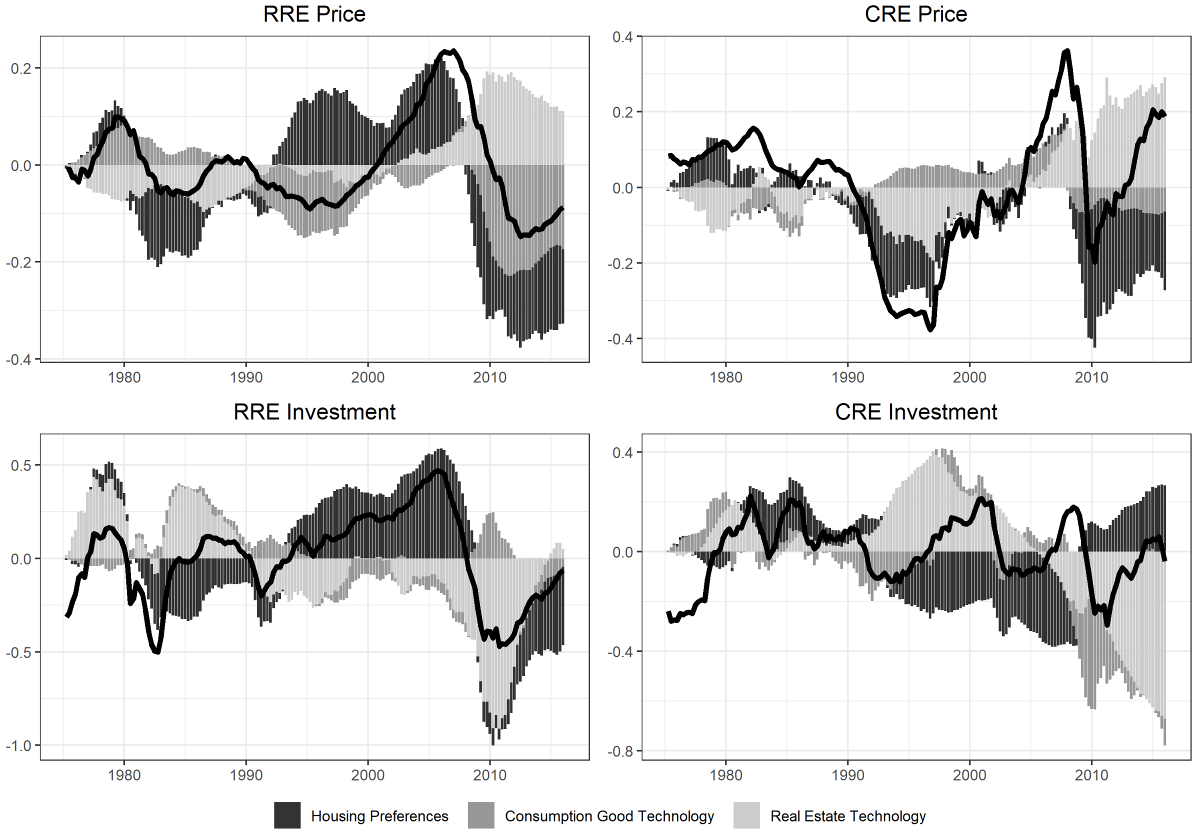
More than half of the RRE investment variation is attributed to the technology shock to the residential construction, and around a quarter of the variation is driven by a housing demand shock. On the other hand CRE investment, on impact is primarily explained by a technology shock to the consumption good, i.e. CRE 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.

Figure 8 displays the historical decomposition of the prices and investment in residential and commercial real estate. The solid lines display the detrended historical data, obtained by applying a quadratic filter on the observed series. The filled regions show the historical contribution of the four shocks under our estimated parameters. In order to observe the technology shock across the whole construction sector, we combine residential and commercial real estate technology as real estate technology.

The sum of these four shocks accounts for most of the variation in the filtered observed series. The *real estate substitution* channel indicates that a positive shock in either the housing preferences or consumption good technology will increase real estate prices, however, the response of each element of investment will be contingent on the source and the dominance of the shock. A positive housing preference shock boosts residential investment and diminishes commercial investment, while consumption good technology works in the opposite way where residential investment drops and commercial investment increases. However, in the bottom two graphs of Figure 8 that display the property quantities (investments) the two shock work against each other, a result that is attributed to the real estate substitution channel. Thus to fully comprehend these investment cycles it is crucial that the demands for the two types of real estate are not considered in isolation, but rather that the relative strength of the disturbances that drive them are considered.

The housing preference shock seems to be the main driver of the 2007 financial crisis, which is evident in all variables besides the CRE prices. Significantly, in the build-up to the financial crises the increase in RRE are not offset by a fall in CRE investment and following the financial crisis both types of investment fall, a result in contrast to the *real estate substitution* channel. In the following section, we detail how the construction sector and its interaction with both land,

Figure 8 – Historical Decomposition of Structural Shocks



Notes: The solid line represents the data. Housing preferences and consumption good technology include only their corresponding shock. Real estate technology shock includes both CRE and RRE technology shocks. All series are in deviation from the estimated trend.

and the two types of real estate, can give rise to both of these investment co-movements.

5 The role of Land

5.1 Land as a unique input

Land, while not *directly* useful as an input for consumption good producers or as a product for households, is a unique factor of production. Competition for land, stems from the fact that not only land is finite[10], but also both households and firms need it *indirectly* through their demands for new RRE and CRE respectively. Liu et al. (2013) were the first to introduce competition for land and the "land reallocation channel" in a DSGE framework. In their novel paper, there was no need for real estate production since land prices are able to capture the largest part

[10] Land can grow at a very small rate if we consider the land zoning restriction lifts, that enable the commercial and residential building to overtake farmlands or previously unzoned territories

of the business cycle fluctuations (Davis and Heathcote, 2007). With the abstraction of real estate production and the construction sector, land prices are identical to property prices, and guarantee that the land reallocation channel will always be present and dominant. However, the price and the quantity of land has very different time-series properties to the price and quantity of land in commercial use (Davis, 2009).

To understand more clearly the relationship between land and real estate in our framework, consider construction sector's demand for land, which for RRE and CRE production is given by

$$q_{l,t} = \beta_e E_t \frac{u_{ch,t+1}}{u_{ch,t}} \left(\mu_h \frac{q_{hc,t} IH_{c,t+1}}{L_{hc,t}} \right) + \lambda_{bh,t}(1-\rho_b)\theta_h q_{l,t+1} \tag{17}$$

and

$$q_{l,t} = \beta_e E_t \frac{u_{ch,t+1}}{u_{ch,t}} \left(\mu_h \frac{q_{hd,t} IH_{d,t+1}}{L_{hd,t}} \right) + \lambda_{bh,t}(1-\rho_b)\theta_h q_{l,t+1} \tag{18}$$

respectively. The term u_{ch} is the marginal utility of consumption and λ_{bh} defines the shadow value of the construction sectors existing loans in consumption units. Like Liu et al. (2013) according to equations (17) and (18) the cost of a unit of land depends upon the marginal utility of land services and the discounted resale value of land. However, the marginal product of land, ($\mu_h \frac{IH_{d,t+1}}{L_{hd,t}}$ and $\mu_h \frac{IH_{c,t+1}}{L_{hc,t}}$) depends upon the real estate demands of the construction sector and not directly on the consumption good producers or households.

At the extreme when $\mu_h \to 1$ in production functions of RRE and CRE ((7) and (8) respectively), the construction of real estate requires only depends land, so that the construction sector becomes redundant. The supply of new structures is constant, and land and real estate are equivalent, so that akin Liu et al. (2013) the change in RRE investment perfectly offsets the change in CRE investment, to equates marginal product of land in each sector.

In our framework, the land reallocation channel is encapsulated through a broader definition of competition in the construction sector, where the competition between households and firms is not for land use but for the two types of real estate. Land reallocation is always present, but in comparison with Liu et al. (2013) it is not always dominant. A critical motivation behind a more flexible version of "real estate substitution" is that the two types of real estate do not always follow an opposing path, so an assumption of complete substitution would be unreasonable. The recent global Covid-19 pandemic has further underscored the importance of this model feature. The restrictions of workers to attend offices and hospitality venues has had severe implications for both the supply of labour, the value of commercial premises, and in-turn commercial real estate investment. On the other hand, the implications for residential real estate investment depend upon changes in both the demand for residential property and *all* of the inputs required for production in the construction sector. To shed further light on this issue we consider a labour supply shock.

Labour supply shocks have been shown to be a significant driver of the fall in labour hours during the Covid-19 pandemic (Brinca et al., 2020).[11] We argue that such a fall in labour supply will unmistakably leads to a fall in CRE investment as the marginal product of CRE falls. However the implications for RRE investment are ambiguous and contingent upon the weight that land has relative to the other inputs required for the construction of real estate. With a construction sector, where the creation of structures is given by equations (7) and (8), we have that land, capital and labour all contribute to the formation of new real estate. As a result, the fall in the supply of labour in Figure 9 with low values of μ_h not only reduces the demand for $IH_{c,t}$ from consumption good producers but also the supply of both labour and capital to the whole of the construction sector. This creates a separation of real estate investment from land use which can be seen by equating (17) and (18) to give

$$IH_{c,t+1} = \frac{L_{hc,t}}{L_{hd,t}} \frac{q_{hd,t}}{q_{hc,t}} IH_{d,t+1} \tag{19}$$

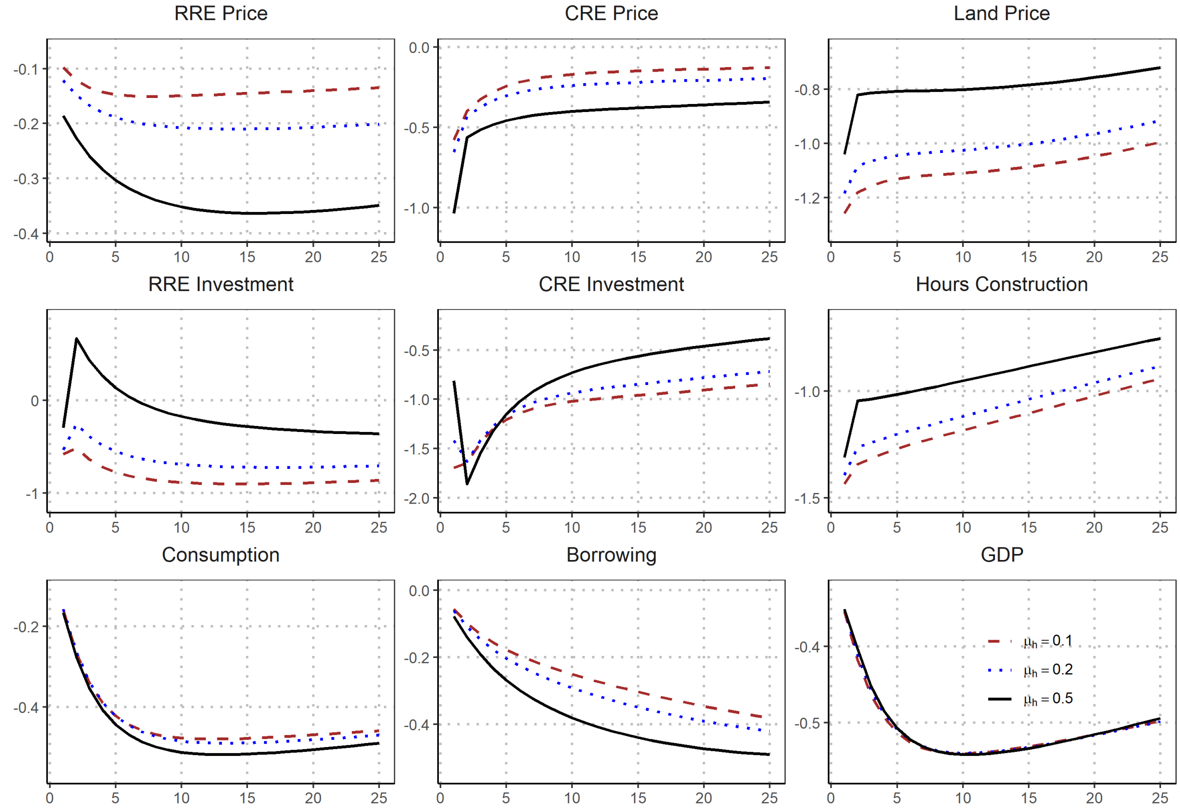
In (19) commercial real estate investment dynamics are not only determined by the ratio of land use, but also by the demands for residential real estate. This separation of $IH_{d,t}$ from $L_{hd,t}$ allows $IH_{c,t}$ to potentially fall which allows for both CRE and RRE investment to co-move such that the aggregate supply of real estate falls. Moreover,as can be seen in equations (17) and (18) and in Figure 9, with lower values of μ_h the falls in the land price has less influence on construction costs and the real estate substitution channel is weakened which suppresses some of the falls RRE and CRE prices. Meanwhile, driven by the reduction in labour hours, spending on both RRE and CRE ($q_{hc,t}IH_{c,t+1}$ and $q_{hd,t}IH_{d,t+1}$ respectively) falls whilst, by assumption, the supply of land is fixed. This reduces the marginal product of land, such that land prices become more volatile. In contrast for higher values of μ_h the real estate substitution channel dominates and the two series take opposing paths.

5.2 Land Shares

To investigate the role of land as input in the construction sector and its implications for the real estate cycle, we examine the simulated path of investment and land share for both residential and commercial real estate. Figure 10 displays the simulated path of RRE investment and residential land in the top panel, and the CRE investment and commercial land in the bottom panel. Land and investment cycles seem to be in synchronisation for most of the sample, however, there are significant divergences, in particular following recession periods.

[11] For tractability we assume that the labour supply shock falls uniformly across our sectors. As argued by Dingel and Neiman (2020), the extent to which work in a sector can be carried out at home would have implications for our model, both for the sectoral response of hours, but also because it creates a separation between labour and CRE in production. In our model this would create a cushioning of the falls in labour supply alongside an amplification of the fall in CRE investment and real estate substitution

Figure 9 – Labour Supply Shock Sensitivity

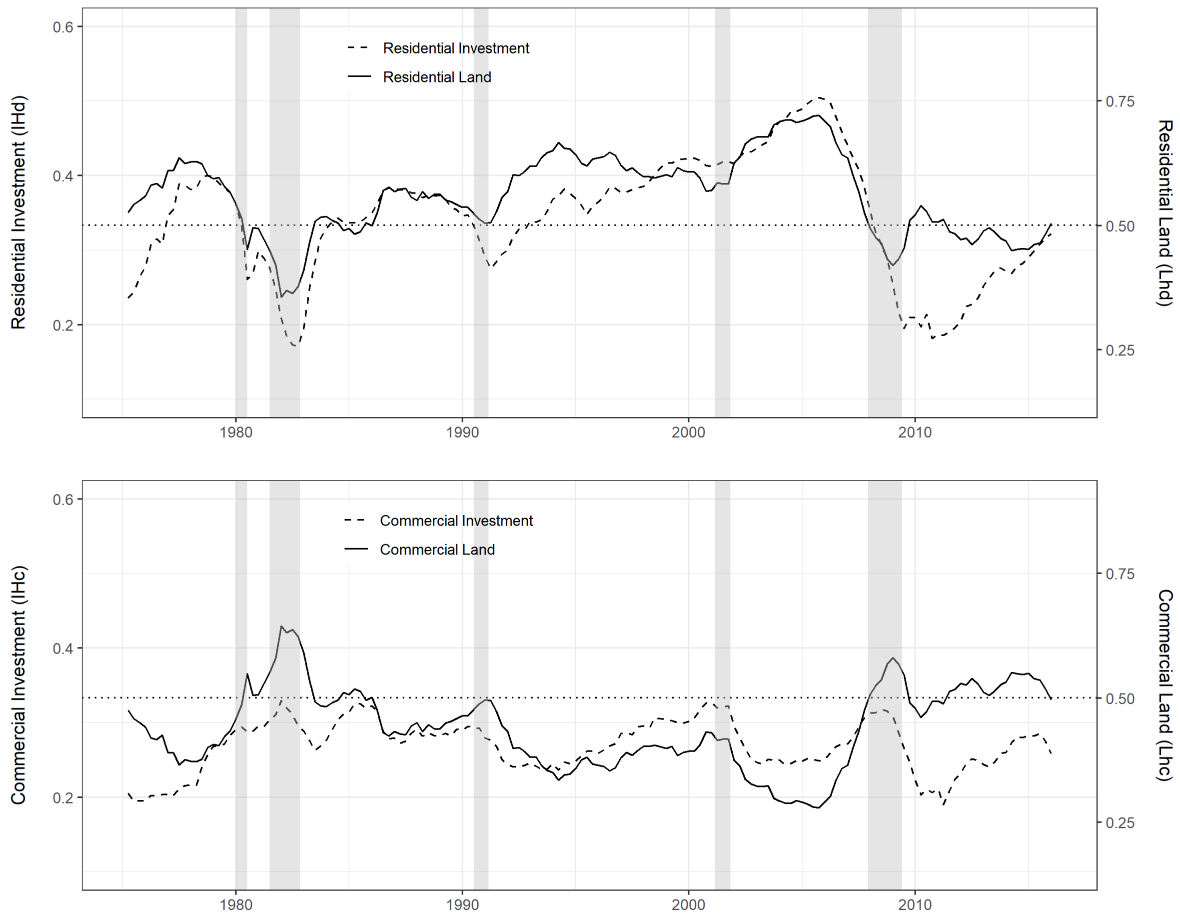


Notes: Impulse responses to a positive (one standard deviation) shock to labour supply. The y-axis measures percent deviation from the steady state.

For example, after the office overbuilding of the 1980s and the consequent collapse, demand for residential land followed a steady upward trend which peaks in 2007. However, post-2007 there is large shift that changes the composition of land share towards the commercial side. Due to the model flexibility, we can observe movements in investment that is not simply equivalent to the supply of land. Moreover, in the post-financial crisis period, we see a significant fall in both RRE and CRE investment that is not attributed to the substitution of land. By ignoring the construction sector, and using land as the only input, the supply land would be significantly overestimated. Eventually, towards the end of the sample where RRE demand begins to recover, residential investment converges towards its land counterpart.

Finally, we compare our estimate of land share with the estimate derived from Davis and Palumbo (2008). Figure 11 plots model estimate of residential land share (dotted line), the aggregate residential land shares (solid line) along with the 68% error bands (dashed lines) that correspond to the bottom 16% and top 84% percentile of the MSA land shares. According to Davis and Heathcote (2007), land values can also be conceptualised as the value of the real estate

Figure 10 – Estimated Path of Variables



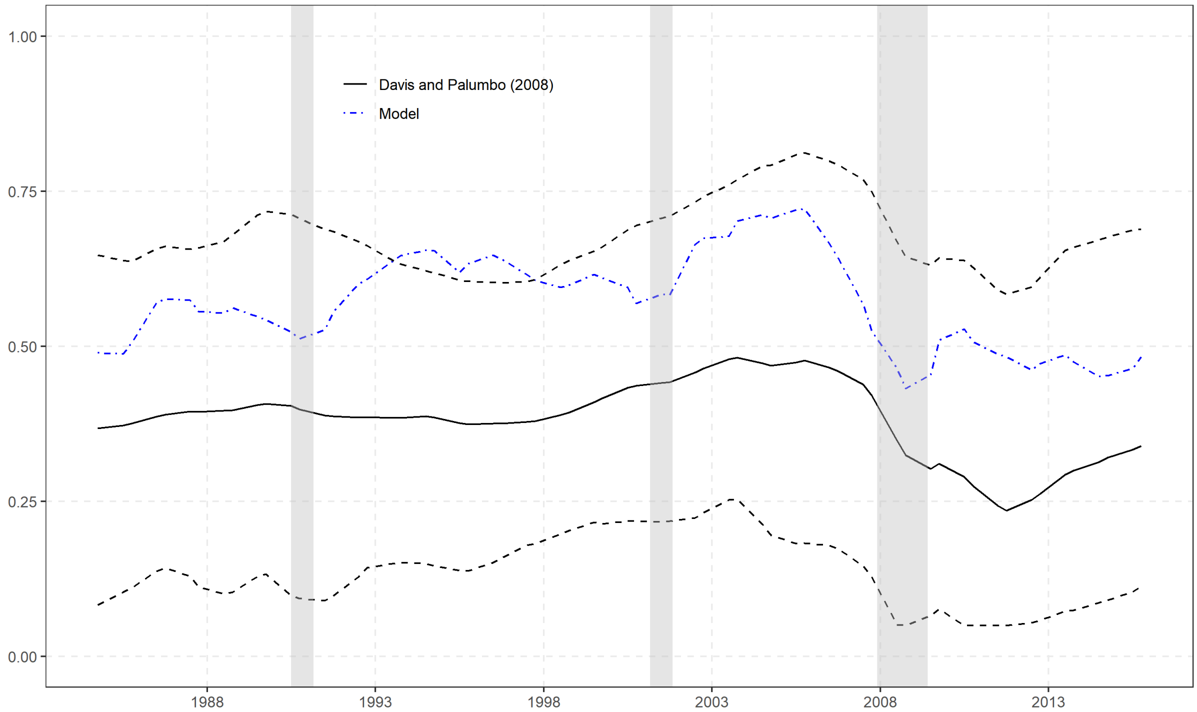
Notes: Top figure display the residential investment (solid line) and the residential land (dashed line). The bottom figure display the the commercial investment (solid line) and the commercial land (dashed line). The sum of land should always be one. Investment is measured on the left axis and land on the right. The shaded bars mark the NBER recession dates.

when you exclude the cost of the structures. Thus the mentioned estimate does not correspond to land measurement, but instead as the ratio of residential real estate value to residential land value. Consistent with Davis and Palumbo (2008), our model estimate shows an upward trend which indicates that residential housing is much more land-intensive than it used to be. Both estimates capture the upward trend and subsequent fall of the land shares after 2007. The crisis in 2007 reverts this trend to 1980s levels.

6 Conclusion

This paper has shown both the existence and potential mechanism behind the real estate substitution channel as well as captured the way it manifests. Notably, the inputs of the con-

Figure 11 – Land Shares



Notes: Empirical land shares are calculated as the ratio of land value over the home value from Davis and Palumbo (2008). The dashed bands indicate the top and bottom decile of the MSA areas land share. The shaded bars mark the NBER recession dates. *Source www.aei.org/housing/land-price-indicators/*

struction 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 and dynamics are not symmetrical, which highlights that even though construction has many 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 merely 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 easily crowd out commercial real estate, which affects the goods market in a similar way to an adverse aggregate supply shock.

The Bayesian estimation of the model reveals that housing preference shocks determine 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 stemmed from a fall in productivity in the consumption good sector. As a result, whilst the co-movements of RRE and CRE prices are somewhat anchored 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

Residential Real Estate 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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