Real Estate and Construction Sector Dynamics over the Business Cycle

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Abstract

This paper explores property prices and investment dynamics over the business cycle when there is competition between households and firms for real estate. We introduce a construction sector into an 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 an increase in demand for residential real estate also increases the cost of producing commercial structures, which crowds out commercial real estate investment. In general, we find that the residential/commercial land allocation acts as an anchor for the allocation of its real estate investment counterpart; however, there are notable separations, particularly following the financial crisis where there was a simultaneous fall in residential and commercial investment. Our results indicate that whilst residential real estate prices were predominately driven by increases in its demand in the buildup to the financial crisis, the fall in demand for commercial real estate played a significant role in generating price falls for both types of real estate in the aftermath. Furthermore, falls in the overall supply of real estate played an important role in reducing real estate investment which put upward pressure on prices throughout the past two decades.

Key Words: Commercial Real Estate; Residential Real Estate; Real Estate Substitution; Land Prices; DSGE Models
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 a provider of residence for households. Real estate investment can be categorised according to its use as either commercial or residential.[1] Commercial real estate (henceforth CRE) typically accounts for around half of the business assets (Nelson et al., 2000) whilst residential real estate (henceforth RRE) constitutes one-third of household net worth. As a result, the construction sector lies in an influential position as a major contributor to the business cycle (Case et al., 2000; Boldrin et al., 2013; Leamer, 2015; Head et al., 2014).

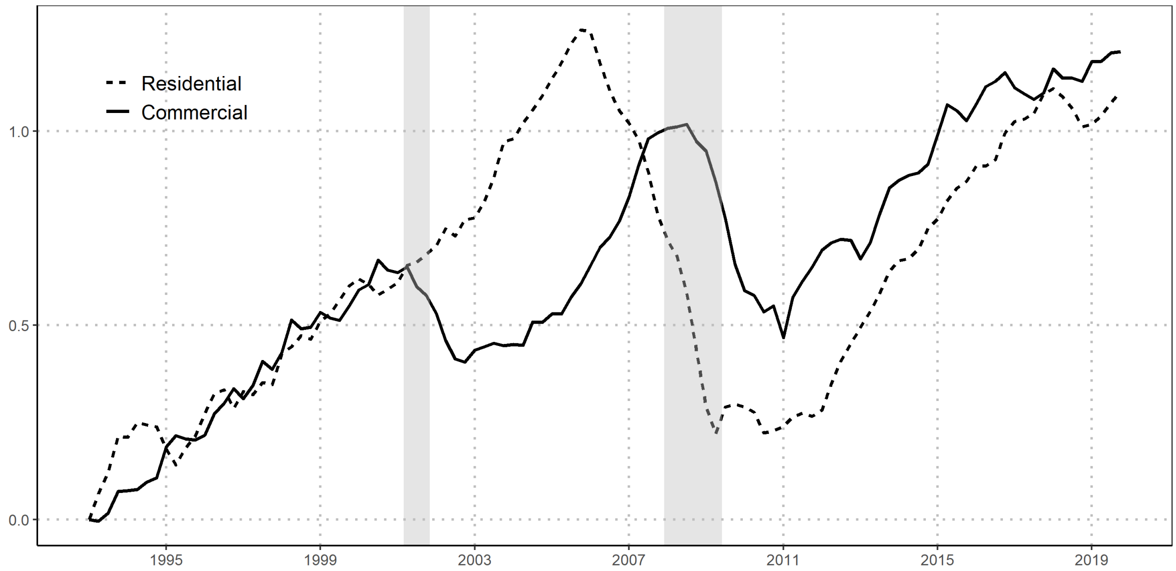
A closer look into the construction sector and the disaggregated construction spending for the US (Figure 1) reveals both commercial and residential spending growing in a similar way until 2001.[2] However, after that period, and particularly following the two recession periods they behave quite differently. After the *2001 dot.com* crisis, there was a fall in commercial spending whilst residential spending continued its upward trend until the onset of the *2007 financial crisis* when it dived sooner and by a greater magnitude. Thus, depending on the source of macroeconomic fluctuation, these two types of real estate can potentially display quite different cyclical behaviours. This relates to the construction sector's unique position as a barometer of macroeconomic activity for both the demand and supply side of the economy. Specifically, CRE is used in production, while RRE responds to housing demand. On the other hand, the competition within the construction sector for inputs such as land, labour, and capital influences the price and investment decisions for the two types of real estate.

This paper builds a quantitative general equilibrium framework to investigate the driving forces behind the price and investment dynamics of the real estate market over the business cycle. We introduce a construction sector into a DSGE model, which undertakes the production of both commercial and residential real estate and gives rise to a *real estate substitution* channel. Following positive housing preference shocks the increase in demand for RRE also increases the cost of producing commercial structures, which increases the CRE price and reduces the quantity demanded by firms. In turn, this crowds out CRE investment which affects the goods market in a similar way to an adverse aggregate supply shock. In contrast, following positive technology shocks this channel works in the opposite direction such that the increased demand for CRE

[1] Commercial real estate refers to the property that is used exclusively for business-related purposes or to provide a workspace rather than as a living space, which would instead constitute residential real estate. 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

[2] In Appendix A there is a detailed description of the data and the transformations used in the paper.

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 carried out 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

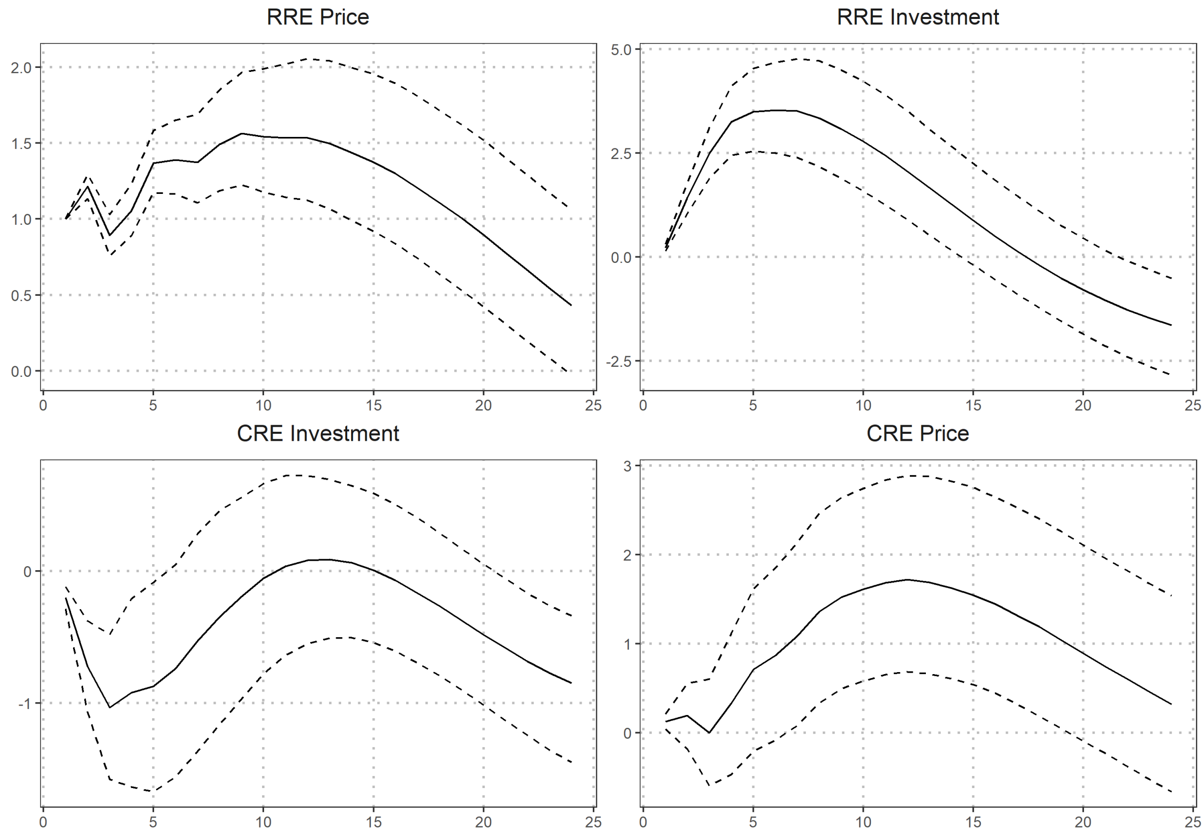
crowds out residential investment. This real estate substitution mechanism also links sectoral investment to broader macroeconomic outcomes. Because commercial real estate (CRE) enters the production function in the consumption-good sector, shifts in land allocation affect not only sectoral investment but also aggregate productivity. These effects arise endogenously through changes in input costs and reallocation pressures, creating a connection between real estate market dynamics and measured total factor productivity (TFP).[3] In Figure 2 we estimate a four-variable Bayesian vector autoregressive (BVAR) model following an RRE demand shock which is consistent with dynamics of real estate substitution in our theoretical model.[4]

Real estate substitution encapsulates the land reallocation channel initially established by Liu et al. (2013). In a recent contribution, Davis et al. (2022) build on this framework by introducing a property sector with imperfect land substitution that drives a dynamic wedge

[3]See (Díaz and Franjo, 2016) for empirical evidence linking real estate and input costs fluctuations to sectoral productivity dynamics

[4]The observables included in the model are RRE prices, RRE investment, CRE investment, and CRE prices. We use a Flat Prior, and generate IRFs for an RRE price shock using recursive identification, where we order RRE prices first. 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 it is first orthogonalized with respect to CRE, the shape of the impulse responses remains identical. For robustness, we perform the same estimation with the Minnesota prior (Doan et al., 1984; Litterman, 1986), where we find similar results. Robustness checks are available in the Online Appendix.

Figure 2 – RRE Price Shock



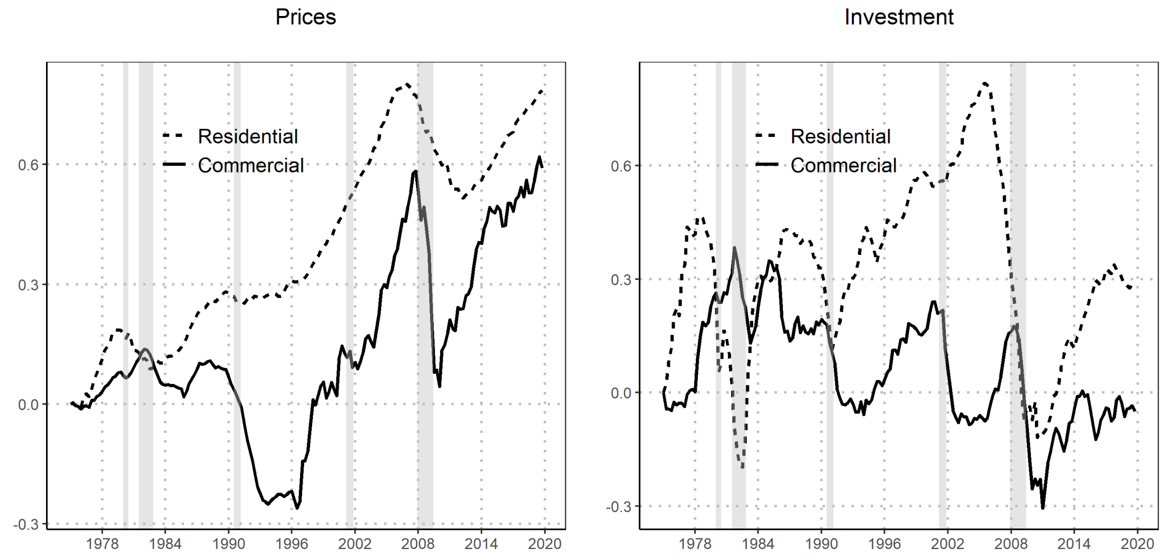
Notes: Impulse response to a positive shock to the residential real estate price from a recursive BVAR model with Diffuse Prior. Identification is achieved through Cholesky decomposition with the following ordering {RRE Price, RRE Investment, CRE Investment, CRE Price}, all in real terms. Solid lines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

between residential and commercial prices.[5] In contrast to these papers, our market structure allows land use and real estate investment to diverge. This separation is crucial to capture the dynamic fluctuations in real estate investment over the business cycle. Land has a unique quality; it is fixed on aggregate, such that a demand-driven increase in land use by one side of the real estate market must be reflected with an equivalent fall in land supply to the other. By introducing a construction sector where investment decisions depend upon not only on land, but all of the inputs of real estate production, we allow for the possibility that the residential and commercial counterparts could co-move. Unlike Liu et al. (2013), who abstract from the structure-production process and therefore cannot explain episodes where both investments boom together, our construction-sector block endogenises that behaviour.

Figure 3 plots property prices alongside real estate investment which shows both the conver-

[5] They show that imperfect substitution, in line with zoning or land use regulation, weakens the collateral channel, whereby an increase in residential land prices leads to an increase in commercial land prices, loosening firm borrowing constraints and increase firm investing.

Figure 3 – Real Estate Dynamics



Notes: Real CRE prices/investment (solid line) and real RRE prices/investment (dashed line). All variables are in log units and normalized to the origin of the sample. The shaded bars mark the NBER recession dates.

gence and divergence of real estate investment. Since construction spending tracks the overall investment in real estate, i.e. the creation of new structures, investment seems to follow a very similar path.[6] As was the case with construction spending, different types of real estate investment have quite different cyclic behaviours (Wheaton, 1999); this is particularly evident prior to the financial crisis where RRE and CRE investment display signs of real estate substitution. Analogous periods can also be considered, for example, during the *2nd energy crisis of 1982* and the aftermath of the early 1990s recession. However, elsewhere there is a positive co-movement between RRE and CRE investment, for example in the build up to the 2001 dot.com crisis and both during and after the 2007-2008 financial crisis. In line with the evidence of Rosen (1979); Roback (1982), and Gyourko (2009), property prices appear to co-move contemporaneously and have similar time-series patterns. In particular, during the financial crisis, both series displayed a sharp fall followed by a more gradual recovery.[7]

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 dynamics. While the long-term implications

[6]The reason we choose to continue our analysis with real estate investment instead of construction spending is twofold: first is due to data unavailability since construction spending starts in 1992 while real estate investment starts in 1970, and secondly, it is more straightforward to map it into our theoretical model.

[7]Land prices have followed a steady upward trend during the whole sample, which appears to be a key driver of both commercial and residential real estate prices (Davis and Heathcote, 2007; Glaeser and Ward, 2009; Gyourko et al., 2013).

for commercial and residential real estate demands are not fully apparent, there is a tendency for many firms to adopt a more flexible home/office work-based model reducing their demand for commercial premises. Moreover, to facilitate these changes, local governments in major global cities such as New York and London have relaxed zoning restrictions to allow empty office space to be more easily converted for residential use.

After experiencing a decline during the pandemic, CRE investment recovered to surpass its pre-pandemic levels by the end of 2022. CRE prices followed a similar path but with a faster recovery, reaching its peak by the end of 2021. However, after the beginning of 2022, the momentum has been reversed as global financial conditions have tightened due to contractionary monetary policy. Tighter financial conditions tend to have a direct impact on commercial property prices thereby lowering investment in the sector. They could also have an indirect impact on the sector by slowing economic activity and reducing demand for commercial property.

According to Davis and Heathcote (2007), fluctuations in real estate values are primarily driven by changes in land prices, and land provides an important collateral value for business investment spending. As a result, we assume that 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 (Chaney et al., 2012; Bahaj et al., 2020). By doing so, there are positive comovements 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.

In order to grasp the significance of land shares and their role in shaping real estate investment dynamics, we analyse the simulated path of investment and land shares for both residential and commercial real estate. Our results indicate that 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 the financial crisis, there was a substantial and persistent fall in both residential and commercial investment and a notable separation between real estate investment and land shares in each sector.

Our historical decomposition sheds light on the driving forces behind movements in the real estate market in particular the comovement of CRE and RRE investment during the financial crisis. Our results indicate that increased demand for RRE drove much of the increase in RRE investment and prices in the build-up to the financial crisis (Iacoviello and Neri, 2010; Liu et al., 2013), which went some way to suppressing CRE investment. However, the fall in demand for CRE played a significant role in generating price falls for both types of real estate in the aftermath of the crisis. Despite this, real estate substitution away from RRE did allow commercial investment to recover more rapidly. Furthermore, falls in the overall supply of real estate played an important role in reducing real estate investment and put upward pressure on real estate prices over the past two decades. This fall in supply was particularly notable in the aftermath of the financial crisis, which helped offset some of the demand-driven fall in prices.

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 unique role 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. Whilst there is a growing literature whereby residential housing production allows households to consume both housing and non-housing 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.[8]. 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 CRE 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 CRE, while the construction sector is constrained by the value of capital and land.

2.1 Households

The representative household seeks to maximize its discounted, time separable lifetime utility. The utility function is given by

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

[8]Our modelling implicitly adopts the conceptual distinction between land and structures, consistent with the approach pioneered by Davis and Heathcote (2007) They highlight that a house can be viewed as a bundle comprising a reproducible structure and a non-reproducible plot of land. By focusing on the production of new structures within our construction sector, and by defining residential investment in terms of these reproducible assets, our model inherently aligns with their methodology of separating the value of structures from the value of land. This ensures that our macroeconomy aggregates, particularly GDP

where $C_{d,t}$ denotes consumption, $H_{d,t}$ denotes the RRE 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 the household discount factor, 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. The parameter χ_t shifts housing preferences away from consumption and leisure towards RRE. The shock processes 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 allocates labour resources to productive activities, where for $\xi \geq 0$, hours worked are not perfect substitutes between sectors. Specifically, labour in the consumption and real estate sectors are imperfect substitutes which give rise to sectoral wage differentials. In contrast, labour can freely move between commercial and residential real estate production within the construction sector where they face the same wage.

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

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

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, we define $L^{ep}_{hd,t}$ as *ex post* residential land, where $q_{l,t}$ is the land price. Specifically, the ex post residential land value enters the household budget constraint since depreciated RRE loses its structure value whilst the land value is retained. 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 entrepreneurs that operate in both the consumption good and the construction sector, where residential and commercial real estate are produced in 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_e is the habit persistence parameter. We ensure that the parameter $\beta_e \in (0,1)$ is smaller than the household's discount factor $\beta_e < \beta_d$, so that the credit constraint is binding in the steady state neighborhood (Iacoviello, 2005). The entrepreneur owns all inputs besides labour, i.e. capital, land and CRE.

2.3 The Consumption Good Sector

The entrepreneur in the consumption good sector produces goods using non-construction capital, non-construction labour, and CRE as inputs. The production function is given by

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

where Y_t denotes output, $K_{c,t-1}$, $H_{c,t-1}$, $N_{c,t}$, $A_{c,t}$, denote non-construction capital, CRE, labour and labour productivity, respectively. The entrepreneur is endowed with $K_{c,t-1}$ units of initial non-construction capital and $H_{c,t-1}$ of CRE. Since CRE is a direct input into production, any shock that raises the CRE user-cost $q_{hc,t}$, for example through land scarcity or competing construction demand, wedges the marginal products of capital and labour and thus generates endogenous fluctuations in measured TFP, even when $A_{c,t}$ itself is held constant. For example, in our baseline calibration following a housing-preference shock, the TFP share of output $\frac{\widehat{\mathrm{TFP}}_t}{\widehat{Y}_t}$ [9] starts above one in the first few quarters—when the TFP wedge precedes the output decline—and converges to approximately 70 percent by quarter 20, indicating that in the medium run the supply-side wedge accounts for the majority of the negative output response [10]. Production functions in both sectors are subject to an exogenous labour-augmenting productivity shock. The shock process follows

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

[9]Measured TFP is the model-simulated Solow residual for the consumption-good sector:

$$\widehat{\mathrm{TFP}}_t = \widehat{Y}_t - \alpha_c \widehat{K}_{c,t-1} - \mu_c \widehat{H}_{c,t-1} - \left(1 - \alpha_c - \mu_c\right) \widehat{N}_{c,t},$$

where "hats" denote log-deviations from steady state. We do not undertake a data-based residual exercise see Díaz and Franjo (2016)); the statistic is quoted solely to convey scale.

[10]See appendix for details

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

$$C_{c,t} + K_{c,t} + q_{hc,t}H_{c,t} + w_{c,t}N_{c,t} + B_{c,t-1} \\ = Y_t + (1-\delta_{kc})K_{c,t-1} + (1-\delta_{hc})q_{hc,t}H_{c,t-1} + \frac{B_{c,t}}{R_t} + q_{l,t}L^{ep}_{hc,t} - \phi_{c,t}{}^{11} \tag{5}$$

where $q_{hc,t}$ denotes the price of CRE, the variable $\phi_{c,t}$ describes capital adjustment costs and δ_{kc} and δ_{hc} are the depreciation rates of non- construction capital and CRE respectively. Analogous to households, the value of land that the entrepreneur is left with after the depreciation of the housing stock is $q_{l,t}L^{ep}_{hc,t}$. Firms pledge the value of CRE to finance investment (Chaney et al., 2012; Liu et al., 2013), where $B_{c,t}$ 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 CRE 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 (DiPasquale and Wheaton, 1994; DiPasquale, 1999; Mayer and Somerville, 2000). Our representation of real estate is similar to Davis and Heathcote (2007) who bundle structures and land to form new real estate. The production function for the CRE 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 CRE. 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; CRE capital, labour and land

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

that is used for CRE, respectively. The production function for RRE is

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

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

$$\begin{aligned} C_{h,t} + K_{hc,t} + K_{hd,t} + q_{l,t}\left(L_{hc,t} + L_{hd,t}\right) + w_{h,t}\left(N_{hc,t} + N_{hd,t}\right) + B_{h,t-1} = q_{hc,t} IH_{c,t} \\ + q_{hd,t} IH_{d,t} + (1-\delta_{kh}) K_{hc,t-1} + (1-\delta_{kh}) K_{hd,t-1} + \frac{B_{h,t}}{R_t} - \phi_{h,t}{}^{12}, \end{aligned} \tag{9}$$

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

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

Note that, unlike in the consumption good sector, the construction entrepreneur cannot pledge structures as collateral because these are under development and cannot yet generate income or serve as valuation benchmarks. Hence, the borrowing constraint (10) is limited to land and capital. [13]. Land serves as a form of collateral for construction loans (Davis and Palumbo, 2008), so 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).

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

[13] This reflects the timing and valuation friction inherent in construction: buildings under development cannot be collateralized until completed. In contrast, the entrepreneur in the consumption good sector can use completed structures as collateral, as shown in equation (6)

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 CRE. The terms $H_{c,t}$ and $H_{d,t}$ evolve according to the

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

and

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

The GDP in our model is defined as the sum of the value added from the consumption good sector Y_t and the value added from the construction of new residential structures ($\bar{q_{hd}} IH_{d,t}$). It is crucial to note that $\bar{q_{hd}}$ represents the price of the reproducible structure component of residential real estate, effectively netting out the non-reproducible land value. [14]

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

Available land does not evolve over time (without loss of generality we can assume land to be fixed at $\bar{L_h} = 1$).[15]. Ex post land, L^{ep}_{hd} and L^{ep}_{hc} is owned by the respective household and entrepreneur following the depreciation of their housing stock. Since all land has a positive value, it is always built upon when it becomes available, thus it follows that $L^{ep}_{hc} + L^{ep}_{hd} = \bar{L_h}$

[14] This approach ensures consistency with National Accounting principles, where land, as a non-produced asset, is excluded from GDP calculations. Our model, therefore, captures the economic activity associated with the creation of new physical capital (structures) rather than changes in the value of existing land.

[15] We also allow land supply to adjust endogenously via a partial-adjustment rule although this does not impact our conclusions. See Appendix B for the full specification, calibration details, and robustness IRFs

with the following shares applied to each sector

$$L^{ep}_{hc,t} = \frac{\delta_{hc} H_{c,t-1}}{\delta_{hc} H_{c,t-1} + \delta_{hd} H_{d,t-1}} \bar{L}_h \qquad L^{ep}_{hd,t} = \frac{\delta_{hd} H_{d,t-1}}{\delta_{hc} H_{c,t-1} + \delta_{hd} H_{d,t-1}} \bar{L}_h. \tag{15}$$

All available land is then purchased by the construction entrepreneur who uses it as an input for the creation of either RRE or CRE. It follows, that the land market clears as in Liu et al. (2013), with the following condition

$$\bar{L}_h = L_{hc,t} + L_{hd,t}. \tag{16}$$

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 markets we consider in our analysis, namely the real estate, land and labour market. [16]

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 (IH_d) to rise. To facilitate this increase in production, demand for construction machinery, labour in the construction sector (N_{hd}), and land (L_{hd}) will also increase. In the land market, the residential land demand curve will shift from D^A_d to D^B_d , increasing competition for the available land, which leads to an increase in land prices (q_l) and a substitution towards RRE land use. Similarly, the increased demand for labour for residential construction will raise construction sector wages (w_h). This hike in construction costs generates a vertical shift in the supply of CRE, displayed by the shift from S^A to S^B in the CRE market, which increase the CRE price (q_{hc}), and causes a fall in CRE investment (IH_c).

Thus real estate substitution following an RRE demand shock instigates cost-push pressures which crowd out the CRE market in the same way as an adverse aggregate supply shock.[17] 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 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.

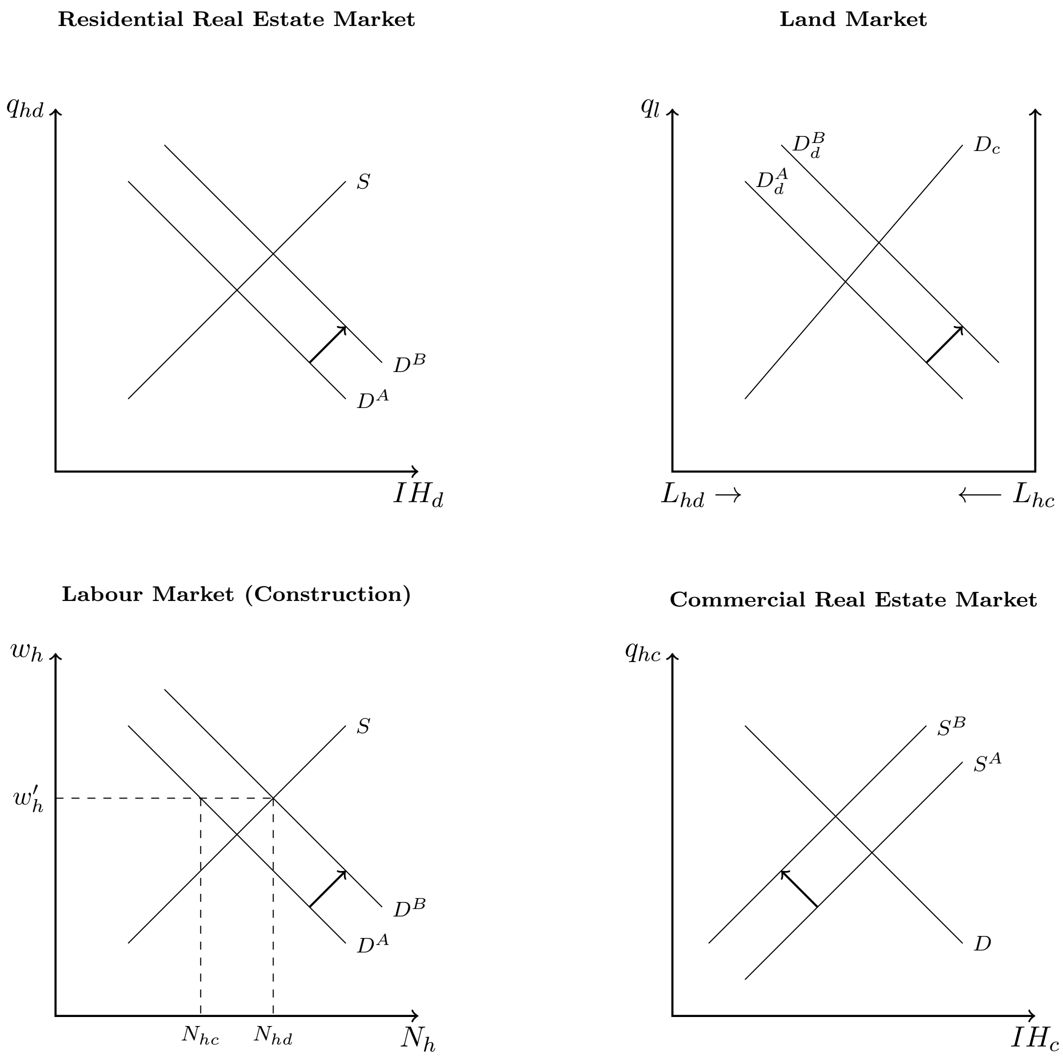
[16] For simplicity and to provide a clearer exposition of our results we don't explicitly refer to the capital market in this section.

[17] There is a strand of literature in urban economics that indicate that demand for both residential and commercial real estate are similar. In this framework introduced by Rosen (1979) and Roback (1982) land prices are 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.

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).[18] The model, due to the characteristics of an RBC model with no growth, can only allow for a limited number of shocks. Thus, since we cannot estimate a wide range of structural parameters, we focus our estimation strategy primarily on the shocks' processes. The model allows for six observables: consumption, RRE investment, RRE price, CRE investment, CRE price and total hours. All variables are denoted in real terms. All the data have been

Figure 4 – Housing Demand Shock



Notes: The figure displays the RRE market (top left), the land market (top right), the labour market (bottom left) and the commercial real estate market (bottom right), following a housing demand shock.

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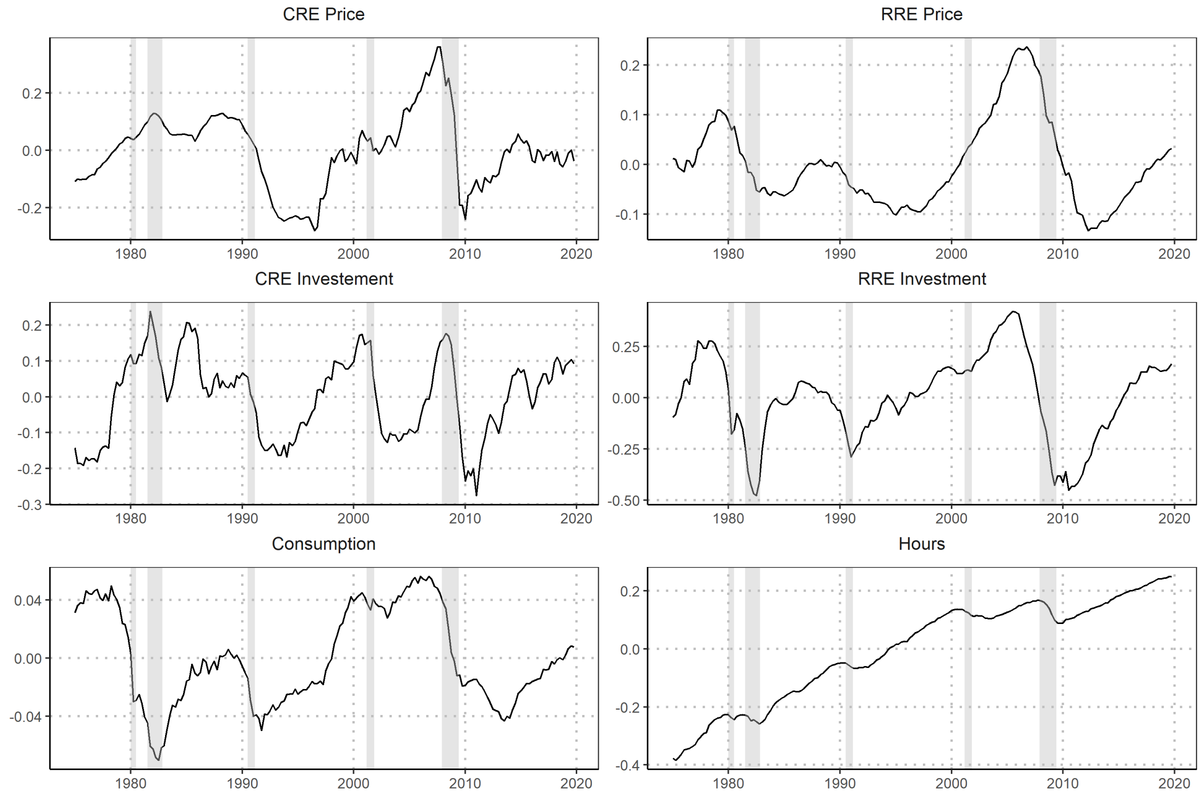
[18] Appendix C plots the prior and posterior densities, details on the estimation strategy and tests of convergence for the stability of the estimated parameters

Figure 5 – Detrended Data



Notes: Prices, investment and consumption have been detrended using a quadratic trend and normalized to the beginning of the sample. Hours are demeaned. The sample period covers data from 1975Q1-2019Q4. Shaded regions indicate the NBER recession periods.

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.[19] The detrended and demeaned data are plotted in Figure 5. The sample covers the period from 1975:Q1 to 2019:Q4.

3.1 Calibrated Parameters

We calibrate the model to US data between 1975-2019. Table 1 summarizes our calibration. We set the discount factor for households $\beta_d = 0.9925$, that corresponds to an annual 3% bank prime loan rate. We fix the discount factor for entrepreneurs at $\beta_e = 0.975$, which makes the credit constraint binding in the steady state (Iacoviello, 2005). We assume a higher degree of habit persistence for entrepreneurs $\gamma_e = 0.65$ than households $\gamma_d = 0.5$ in line with Liu et al. (2013). The depreciation rates for RRE, non construction capital, CRE, 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

[19] Appendix A describes further details of the data transformations.

Table 1 – Calibrated Parameter Values

Households			**Entrepreneur**		
β_d	Discount factor	0.9925	β_e	Discount factor	0.975
γ_d	Habit persistence	0.5	γ_e	Habit persistence	0.65
χ	Housing preference weight	0.2	ρ_b	Borrowing inertia	0.8
ξ	Labour Mobility	0.65			
Entrepreneur: Consumption Good			**Entrepreneur: Construction**		
α_c	Non-construction capital share	0.2	α_h	Construction capital share	0.2
μ_c	CRE 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 CRE	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

Neri, 2010). The parameter χ is pinned to 0.2 in order to target the data-implied steady state ratio of residential investment to output which equals 6%. The parameter for labour mobility ξ has been set to 0.65 according to Iacoviello and Neri (2010).

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, which means that the labour share ought to be larger than the equivalent in 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, we consider the LTV ratios for commercial mortgage-backed securities loans in the consumption-good and the construction sector. If a property is intended to be an investment, usually it requires LTVs lower than 80%. Furthermore, the value of LTV is heavily dependent on the liquidity of the asset that is used as collateral. Thus consumption good LTV is set to 70% ($\theta_c = 0.70$),[20] while real estate firms correspond to an aggregate loan-to-value ratio of 50% ($\theta_h = 0.5$) in line with Gyourko (2009).

Table 2 shows the steady steady ratios of the model, which are in line with the US data over the sample period. The sum of the consumption share (67%) and the business investment share (27%) is the consumption good share, which amounts to 94%. The remaining 6% is the RRE share. We split the business investment share into three sub-components, where CRE accounts for 45%, construction machinery accounts for 10%, while the remaining 45% is software and non-construction capital. To calculate the business capital in the consumption good sector, we sum the capital used in the production of the consumption good and the CRE wealth. The business capital for the construction good is 30% higher than the residential housing wealth, while the business capital of the construction is only 4% of the business capital stock. This

[20] Grovenstein et al. (2005) measures LTV ratios to be 71.01% in five major CRE 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.

Table 2 – Steady State Ratios

Variable	Interpretation	Value	
C/GDP	Consumption share	67%	
IB/GDP	Business investment share	27%	
– IK_c/IB	Software and equipment share		45%
– IK_h/IB	Construction equipment share		10%
– $q_{hc}IH_c/IB$	CRE share		47%
$q_{hd}IH_d/GDP$	RRE share	6%	
$q_{hd}H_d/4 \times GDP$	RRE wealth	1.62	
$(q_cH_c + K_c)/4 \times GDP$	Business capital consumption good	2.38	
$(K_{hc} + K_{hd)})/4 \times GDP$	Business capital in construction	0.16	

Table 3 – Prior and Posterior Distribution

	Prior Distribution			Posterior Distribution				
Parameter	Density	Mean	SD	Mean	5%	Median	Mode	95%
σ_z	Inv Gamma	0.00	0.00	0.047	0.042	0.047	0.046	0.052
σ_χ	Inv Gamma	0.00	0.00	0.059	0.044	0.058	0.057	0.074
σ_ψ	Inv Gamma	0.00	0.00	0.014	0.012	0.014	0.014	0.015
σ_{Ac}	Inv Gamma	0.00	0.00	0.023	0.021	0.023	0.023	0.026
σ_{Ahc}	Inv Gamma	0.00	0.00	0.027	0.025	0.027	0.027	0.029
σ_{Ahd}	Inv Gamma	0.00	0.00	0.03	0.027	0.03	0.03	0.033
ρ_z	Beta	0.80	0.01	0.77	0.74	0.77	0.77	0.8
ρ_χ	Beta	0.80	0.01	0.96	0.95	0.96	0.96	0.98
ρ_ψ	Beta	0.80	0.01	0.99	0.98	0.99	0.99	0.99
ρ_{Ac}	Beta	0.80	0.01	0.97	0.96	0.97	0.97	0.98
ρ_{Ahc}	Beta	0.80	0.01	0.96	0.95	0.96	0.96	0.98
ρ_{Ahd}	Beta	0.80	0.01	0.97	0.96	0.97	0.97	0.98
ϕ_c	Gamma	10.00	6.25	18	14	17	17	21
ϕ_h	Gamma	10.00	6.25	13	8.3	13	13	18

means that construction firms possess only a small proportion of total capital.

3.2 Prior & Posterior Distributions

Table 3 summarizes the estimation of the model. We report the estimates of the 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.

In the construction sector, we observe that the autoregressive terms are relatively high, indicating a persistent and prolonged effect on the construction technology, consistent with Iacoviello and Neri (2010). The standard errors are close at 0.027 and 0.03 for commercial and residential, respectively.

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 in Figure 6 and Figure 7.[21][22]. Impulse responses correspond to the median impulse response of a one standard deviation shock, alongside the 68% credibility intervals. The *y-axis* measures the deviation from the steady state.

4.1 Estimated IRFs

Figure 6 shows IRFs for the housing preference shock, which as explained in section 2.6 causes RRE prices and investment to increase.[23] Increases in the production of RRE requires more inputs, thus increasing the land prices and 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.

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 adjustment is driven by shifts in input demands—particularly land and labour within the construction sector, between residential and commercial real estate producers. In our model, business investment includes CRE investment as well as capital used in construction (e.g., equipment and structures). Following the shock, CRE investment declines due to rising input costs, while investment in construction capital increases as entrepreneurs scale up RRE production. This results in an initial rise in aggregate business investment. However, over time, the contraction in CRE investment dominates, causing business investment to decline below its steady state. Thus, business investment exhibits an initial overshooting response, followed by a reversal, reflecting the underlying real estate substitution dynamics and the reallocation of capital within and across sectors.

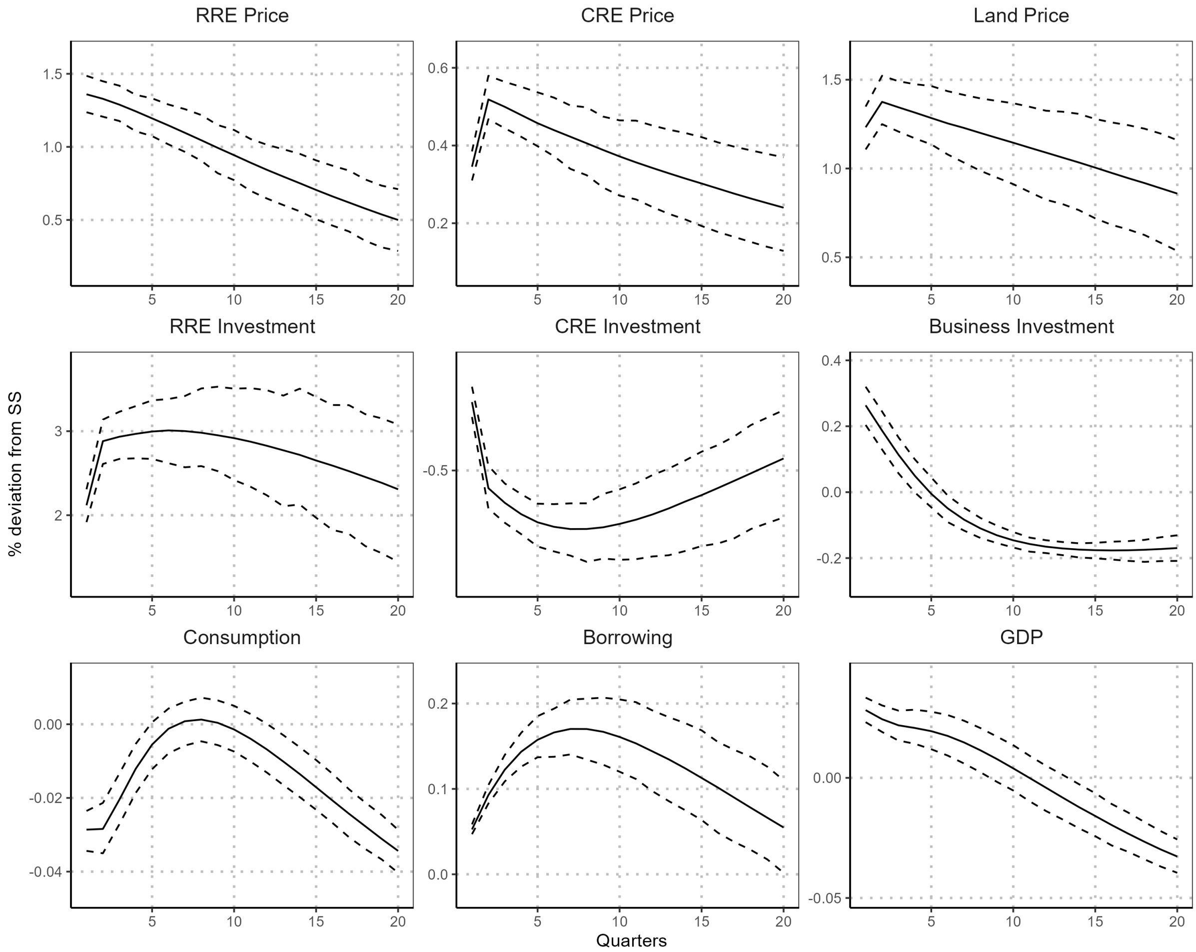
The increase in RRE prices reduces household consumption; however, the rise in land prices raises the entrepreneurs' collateral capacity in the construction sector, allowing them to increase

[21] Appendix C reports impulse–response functions for both the consumption goods productivity shock and the housing preference shock under three zoning elasticities. Zoning alters magnitudes but the real estate substitution mechanism shocks that favour one land using sector crowd out the other remains intact.

[22] For each baseline shock we run two robustness variants: (i) *no adjustment costs*, achieved by closing both labour $\xi = 0$ and investment $\phi_{c,h} = 0$ adjustment costs; (ii) *loose borrowing constraints*, achieved by relaxing both collateral parameters to $\theta_{c,h} = 0.95$. In every case the real-estate-substitution mechanism and the GDP path remain qualitatively unchanged.

[23] Appendix D contrasts the preference shock with a joint easing of entrepreneur collateral constraints—loosening the borrowing limits of construction and final-goods entrepreneurs; households are unconstrained in the baseline.

Figure 6 – Housing Preference Shock



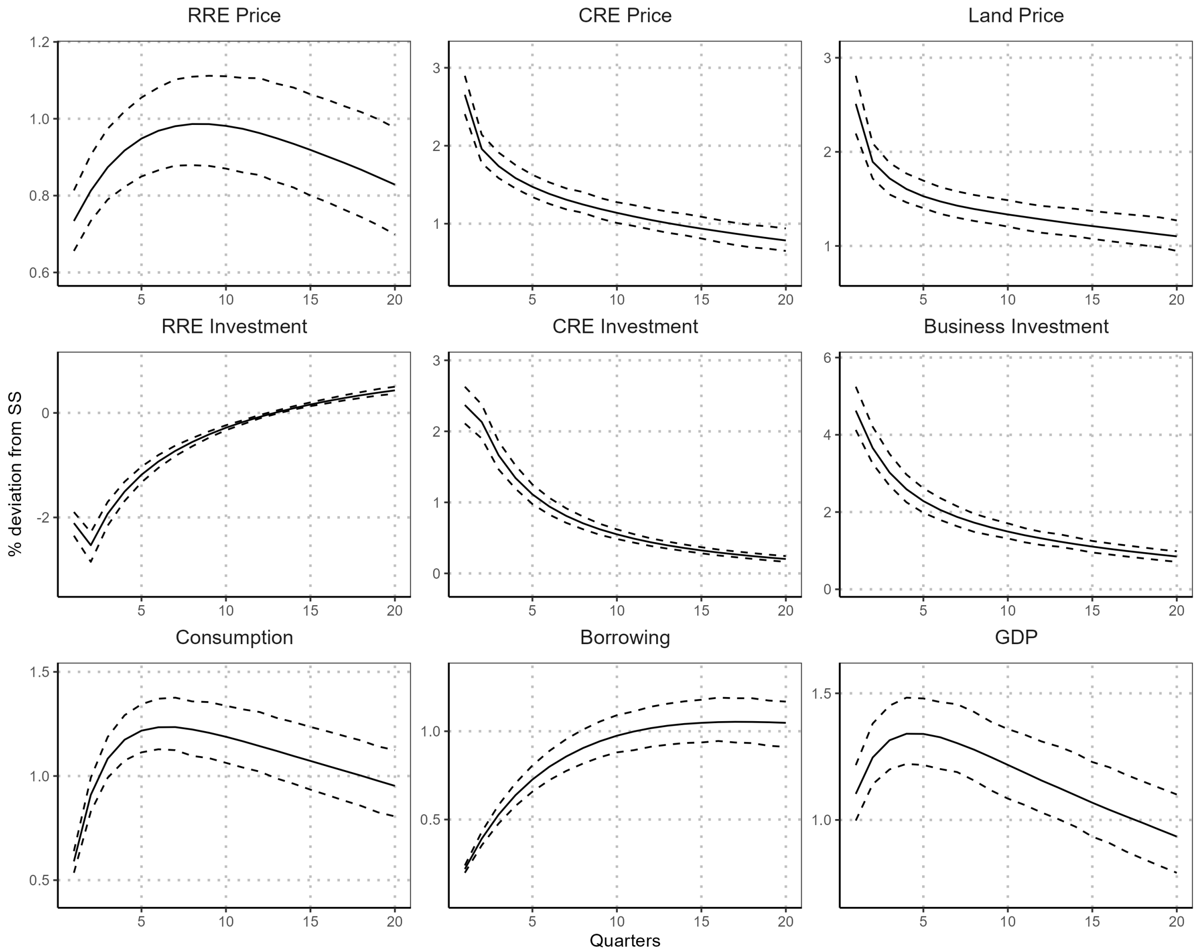
Notes: Impulse responses to a positive (one standard deviation) shock to housing preferences. The y-axis measures percent deviation from the steady state. Solid lines represent the median estimated responses and dashed lines demarcate the 68% credibility bands.

borrowing and consumption. Berger et al. (2018) show that direction of this co-movement depend on factors such as the level and distribution of debt, the size and history of house price shocks, and the level of credit supply and this is also the case in our model. Finally, the presence of habits in entrepreneurs' utility function reinforces the intertemporal smoothing of consumption which creates the hump-shaped response in consumption.

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 goods; namely, consumption good capital, CRE capital and land.

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. Solid lines represent the median estimated responses and dashed lines demarcate the 68% credibility bands.

In turn, the increase in demand for CRE increases CRE investment, wages in the construction sector and land prices. Higher input prices set off the real estate substitution mechanism, which generates a cost-push increase in residential prices and reduces residential investment. Thus, what is initially perceived as a positive supply shock to the consumption good instigates the equivalent of a positive demand shock to CRE and, in turn, an adverse supply shock to residential property. This results in a strong positive response in business investment, led by CRE and construction capital accumulation, while residential investment contracts. The divergence reinforces the negative correlation between business and residential investment in response to this type of shock. 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 Driving Forces of Real Estate Cycles

Table 4 reports variance decomposition for the key variables in the real estate market across the 6 types 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.[24] Over longer horizons changes in household wealth through consumption technology shocks also play a significant role. CRE prices react in an analogous way. Specifically, over shorter horizons, most of the variation is attributed to demand (consumption technology shock), while a greater weight is attached to supply (CRE technology shock) at longer horizons. Additionally, discount shocks play a small but non-trivial role in determining property prices, which further highlights the importance of treating real estate and consumption separately.

More than half of the RRE investment variation is attributed to technology shocks to residential construction, and around a quarter of the variation is driven by housing demand shocks. On the other hand, CRE investment on impact is primarily explained by technology shocks to the consumption good, i.e. CRE demand, and secondarily by technology shocks to commercial construction, i.e. CRE supply. At longer horizons this pattern is reversed with variation in supply, through CRE technology shocks, explaining the majority of the variation in CRE Investment. Regrouping the six shocks into two broad families confirms this pattern: preference shocks account for roughly 60–70 percent of the short-run variation in RRE prices (and 20 percent of CRE prices), while technology shocks explain more than 80 percent of CRE prices and both investment series by the five-year horizon.

To understand how our estimated model interprets specific movements of key variables in the real estate market, 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 housing preference, consumption technology, and the two real estate technology shocks under our estimated parameters. In order to observe the real estate technology shock across the whole construction sector, we combine residential and commercial real estate technology shocks. The sum of these distortions accounts for a substantial variation in the filtered observed series. Furthermore, these four shocks highlight the contribution of changes in demand for each type of real estate (housing preference and consumption technology shocks) and

[24]We do not model an explicit rental market and therefore do not target rent–price ratio dynamics. Our focus is real-side propagation through construction and land allocation. Following Liu, Wang, and Zha (2013), we abstract from credit-supply shocks; the preference shock is used as a reduced-form for housing-demand shifts (see also Iacoviello and Neri, 2010). Extending the model to include rents and lease/vacancy frictions is left for future work.

Table 4 – Variance Decomposition

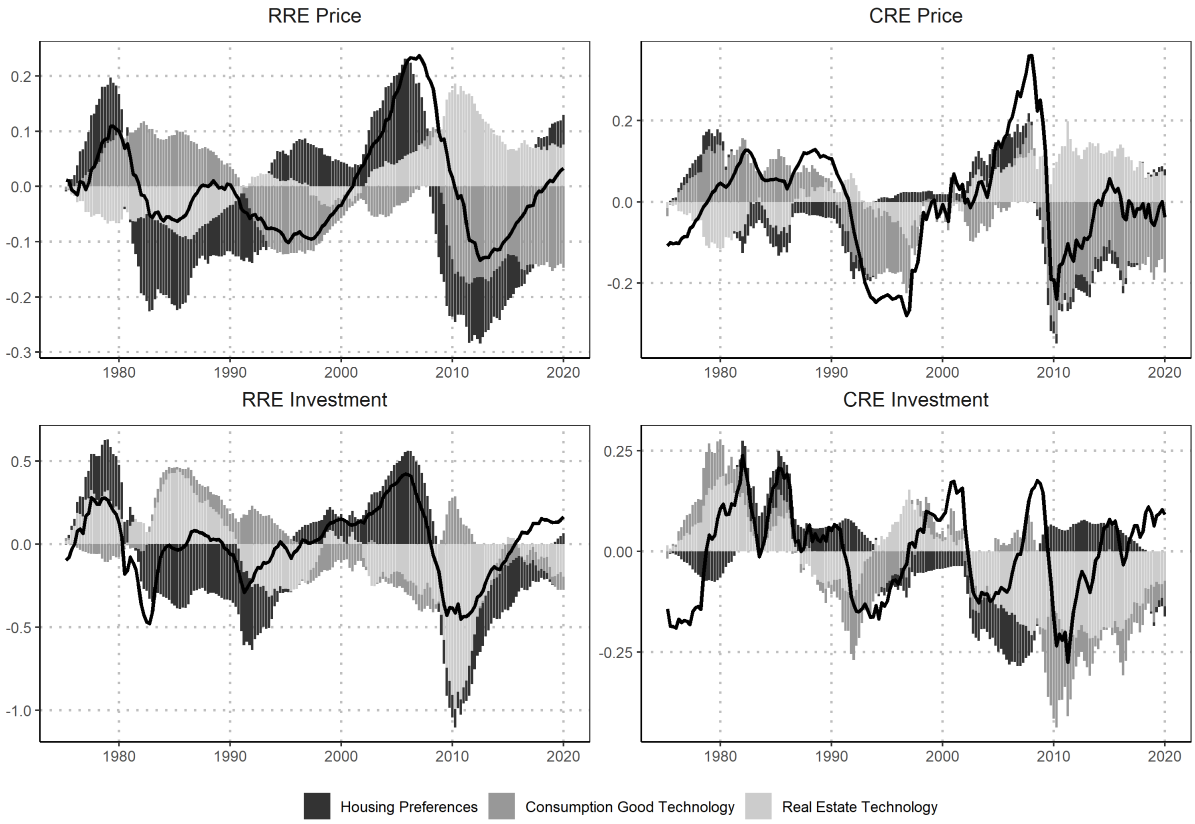
	Discount	Housing	Labour Supply	Cons. Tech	CRE Tech	RRE Tech	Family share (P | T)
				RRE Prices			
1Q	12.44	53.47	0.29	15.97	1.09	16.74	P 65.9% | T 34.1%
5Q	11.48	49.98	0.30	22.70	0.43	15.11	P 61.5% | T 38.5%
10Q	8.54	46.04	0.34	28.61	0.92	15.54	P 54.6% | T 45.4%
20Q	5.79	38.95	0.46	34.73	1.06	19.01	P 44.7% | T 55.3%
				CRE Prices			
1Q	9.94	0.99	1.24	58.67	28.22	0.94	P 10.9% | T 89.1%
5Q	13.21	2.69	0.73	46.38	34.44	2.54	P 15.9% | T 84.1%
10Q	10.23	3.24	0.62	44.56	38.38	2.97	P 13.5% | T 86.5%
20Q	7.58	3.58	0.58	43.51	41.66	3.10	P 11.2% | T 88.8%
				RRE Investment			
1Q	0.64	16.54	0.82	16.55	0.19	65.26	P 17.2% | T 82.8%
5Q	1.57	22.68	0.98	10.54	0.49	63.75	P 24.2% | T 75.8%
10Q	0.92	25.51	1.43	6.10	1.53	64.52	P 26.4% | T 73.6%
20Q	0.94	27.77	2.25	3.67	2.26	63.10	P 28.7% | T 71.3%
				CRE Investment			
1Q	3.59	0.59	12.51	53.73	28.95	0.63	P 4.2% | T 95.8%
5Q	6.95	3.44	10.02	32.31	43.90	3.38	P 10.4% | T 89.6%
10Q	4.18	4.84	9.41	21.11	55.87	4.59	P 9.0% | T 91.0%
20Q	2.65	5.67	9.72	14.20	62.69	5.06	P 8.3% | T 91.7%

Note: Preference (P) adds the Discount and Housing-preference shocks; Technology (T) adds Labour-supply, Consumption-tech, CRE-tech, and RRE-tech shocks.

supply of real estate (real estate technology shocks) for the investment and price dynamics in the sector. Over the full sample (1984 Q1–2019 Q4) the Kalman-smoothed data show virtually no cyclical comovement between the two investment series ($\rho^{data}_{IH_d,IH_c} = 0.039$), a pattern the model replicates ($\rho^{data}_{IH_d,IH_c} = -0.013$)."

During a boom, new RRE demand pushes construction up (DiPasquale and Wheaton, 1994; Topel and Rosen, 1988), but also in our model CRE demand is able to increase construction activity. Thus the increase in real estate demand can either come from the demand side (preferences shock) or the supply side (consumption good technology shock) of the economy. In line with our estimated IRFs because of *real estate substitution*, a positive shock to either housing preferences or consumption good technology will increase both real estate prices. However, the direction of the response of each element of investment will be contingent on the source of the disturbance. Specifically, a positive housing preference shock boosts residential investment and diminishes commercial investment, while consumption good technology works in the opposite direction where residential investment falls and commercial investment increases. This can be seen in the bottom two graphs of Figure 8 where the property quantities (investments) of the two shocks work against each other. Thus to fully comprehend these investment cycles it is crucial that both specific demands and the relative demands of the two types of real estate are

Figure 8 – Historical Decomposition of Structural Shocks



Notes: The solid line represents 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.

considered.

Increases in demand for RRE seem to be the main driver of the increase in RRE investment and prices in the build-up to the 2007 financial crisis. Significantly, there is some suggestion of real estate substitution subduing CRE investment during this period, although the two series are both above their trend at the outbreak of the crisis. This co-movement is in contrast to the *real estate substitution* channel and is also clearly displayed through a large fall in four series in the aftermath of the crisis. Whilst the reduction in residential demand explains some of the fall in residential prices, the fall in commercial demand, by reducing land prices, played a significant role in explaining the price falls for both types of real estate.

Falls in the supply of real estate play a role in inflating real estate prices since 2001 and are the main drivers of the reduction in both types of real estate investment in the aftermath of the crisis which also acts to mitigate some of the collapse in prices. Moreover, in Figure 8 we observe that during this period both the supply for real estate, through negative real estate technology shocks and the demand for real estate, through negative consumption good technology and housing preference shocks, drive down real estate investment. Treated separately, all of these distortions cause both types of real estate investment to fall, with the construction sector responding to falls in GDP but also contributing to the fall in GDP through the lower supply of real estate[25]. However, the relative falls in residential and commercial demand for real estate also matter since unless equal, real estate substitution will take place. Specifically, there is a suggestion that whilst the reversal in the demand for RRE after the crisis prolonged the fall in RRE investment, real estate substitution allowed CRE investment to recover much more quickly. In the following section, we detail the unique role that the construction sector, and its interaction with both land and the two types of real estate, plays in generating both of these investment co-movements.

5 The Role of Land

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 is land finite,[26] 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 a land reallocation channel in a DSGE framework. In their novel paper, they abstract from real estate production and the construction sector since land prices are able to capture the largest part of house price fluctuations (Davis and Heathcote, 2007) and display a clear co-movement with business investment. By omitting real estate production and the construction sector, land prices are identical to property prices, and guarantee that a land reallocation channel will always be present and dominant. However, as shown by Davis (2009) the price and quantity of land in residential use have very different time-series properties than the price and quantity of land in commercial use.

A key message of our paper is that there is a clear distinction between land and real estate. As described by Davis and Heathcote (2007); Davis and Palumbo (2008); Davis et al. (2021) and Nichols et al. (2013), real estate can be viewed as a bundle of structures and land. Since land use is not observed directly and the land measurement is indistinguishable from real estate, land values can also be conceptualised as the value of the real estate when you exclude the cost of the structures. The estimated land value in Davis and Heathcote (2007) is constructed from the RRE value minus the replacement cost of residential structures. In contrast, whilst we do not utilise data on the replacement cost of structures, both residential *and* commercial real estate values and their interaction through the real estate substitution channel contribute to our

[25] Case et al. (2013) and Case and Quigley (2008) show how construction contributes to macroeconomic growth through the wealth and income effect in the USA.

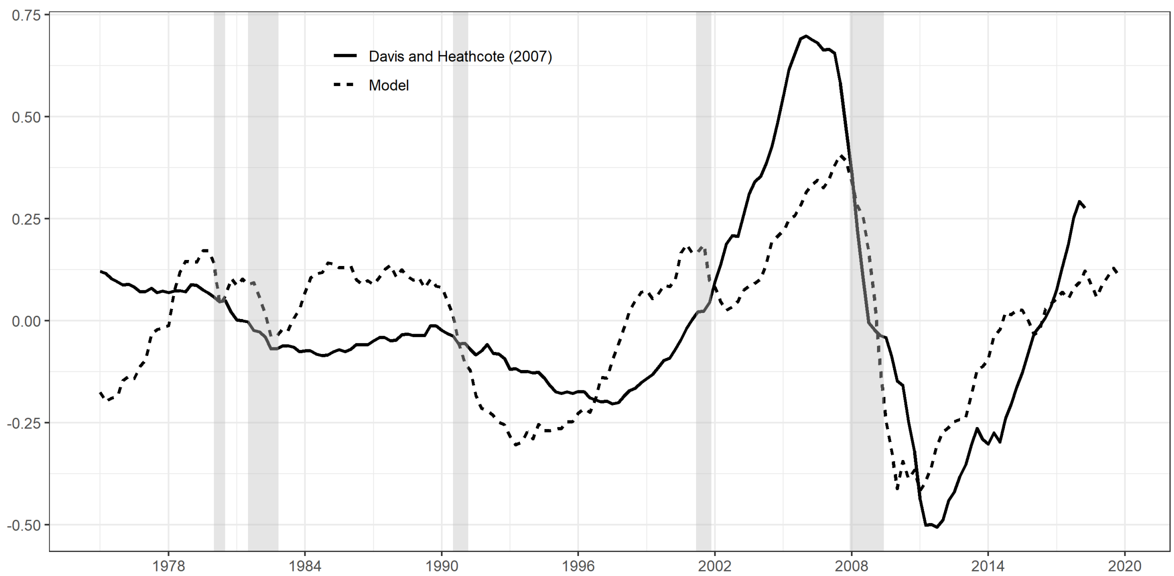
[26] Land can grow at a very small rate if we consider the land zoning restriction lifts, that enable the commercial and residential building to overtake farmlands or previously unzoned territories

measure. In Figure 9 we compare the aggregate land price from our model with the estimated residential land price from Davis and Heathcote (2007). Despite the different approaches both measures capture the persistent upward trend from the late 1990s, the subsequent fall after 2007, and the recent recovery. Moreover, given that changes in RRE prices drove land price movements during this period, one would expect the two series to move more closely together. Nevertheless, the pre-crisis peak land price in our model is significantly lower than that of Davis and Heathcote (2007). As was shown in Figure 8, real estate substitution meant that there was crowding out of CRE investment due to the increased RRE demand. Moreover, by increasing the residential/commercial land shares in the construction sector the relative increase in the supply of RRE offsets some of the land price increase. The contribution of fluctuations in CRE demand to land prices can also be seen through the additional fluctuations before 1990 and a later peak of the price during the start of the financial crisis period.

5.1 Land Shares and Investment

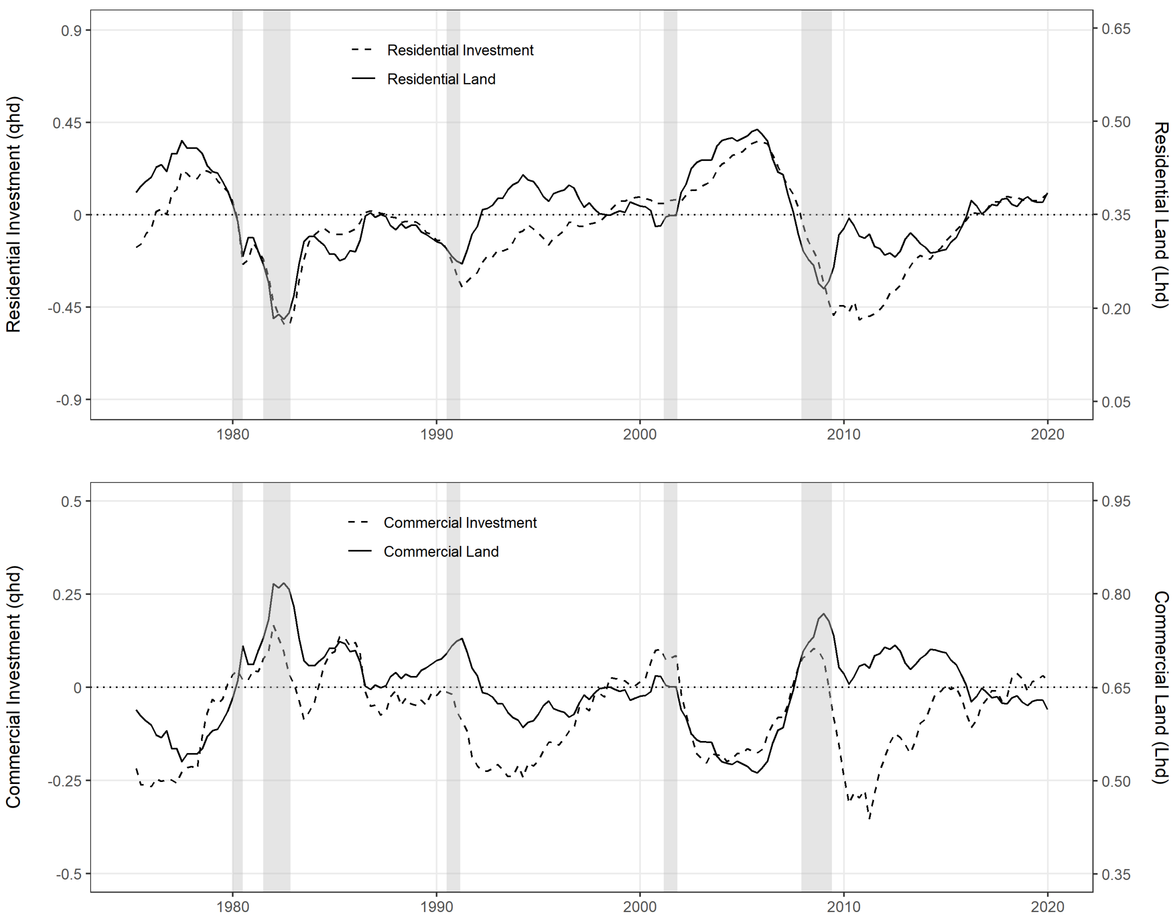
To understand the role of land shares and its relationship with real estate investment we examine the simulated path of investment and land share for both residential and commercial real estate. Figure 10 displays the simulated path of RRE investment and residential land in the top panel, and the CRE investment and commercial land in the bottom panel. Land and

Figure 9 – Land Prices



Note: Real land price represents constant-quality price index for the aggregate stock of residential land in the United States estimated by Davis and Heathcote (2007). Source: *https://www.aei.org/historical-land-price-indicators/*.

Figure 10 – Land Share and Investment



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

investment cycles seem to be in synchronisation for most of the sample, however, there are significant divergences, in particular following recession periods.

For example, following the office overbuilding of the 1980s, there is substitution away from commercial land use towards residential which peaks in 2007. However, post-2007 we observe a large shift that changes the composition of land share towards the commercial side. At the same time, we can observe movements in investment that are not associated with an equivalent reallocation of the supply of land. Specifically, during the post-financial crisis recession, we see a significant and persistent fall in both RRE and CRE investment that is not attributed to the substitution of land. Using land as the only input in the construction sector, the positive co-movements between RRE investment, CRE investment, and GDP would be missing and the supply of real estate would be significantly overestimated.

5.2 Land as a Unique Input

To understand the relationship between land and real estate in our framework more clearly, consider the 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

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

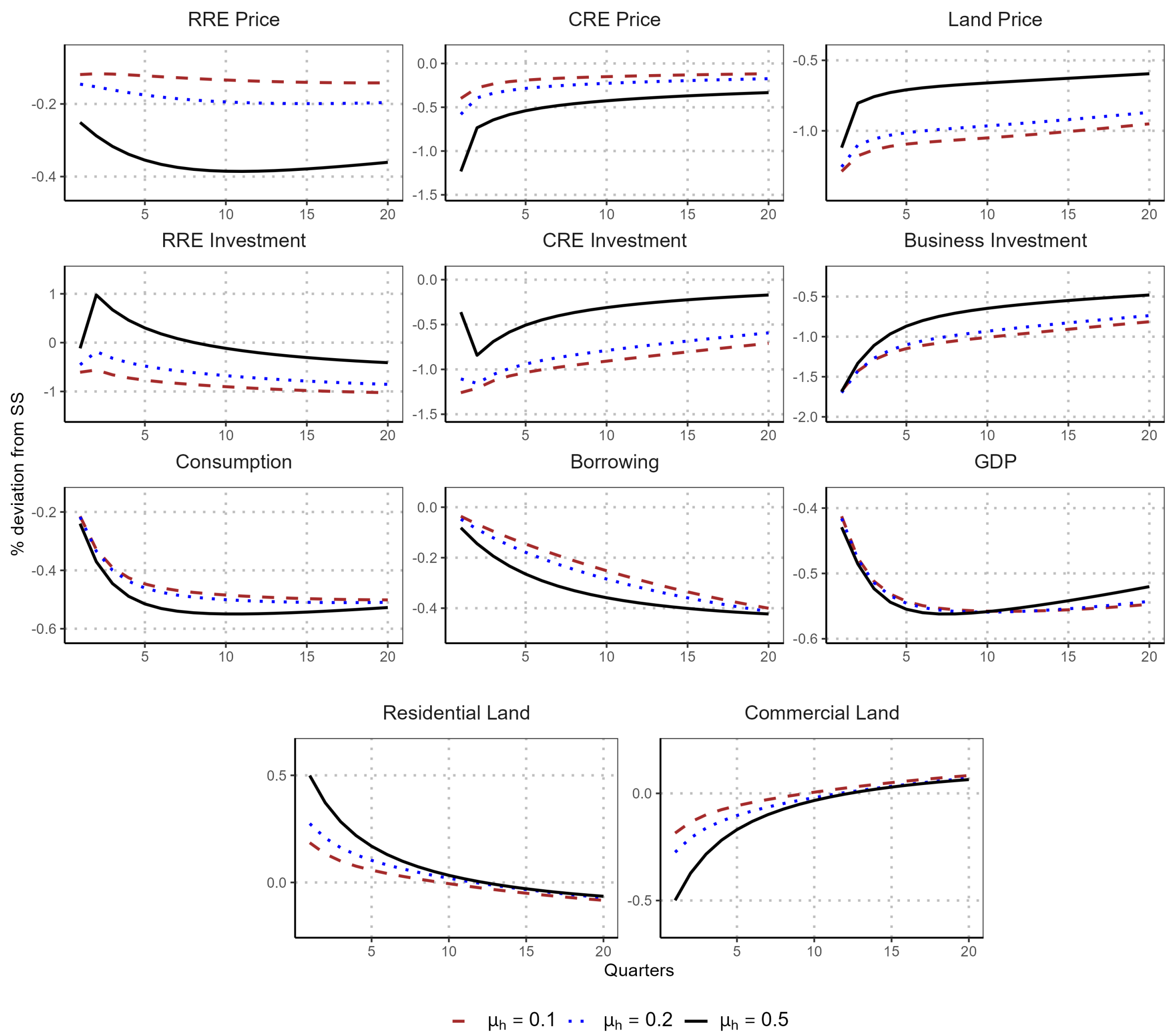
respectively. The term u_{ch} is the marginal utility of consumption and λ_{bh} defines the shadow value of the construction sectors existing loans in consumption units. Like Liu et al. (2013) according to equations (17) and (18) the cost of a unit of land depends upon the marginal utility of land services 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 demands of households or consumption good producers.

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 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 equate the 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, as we have seen in Figure 10, the two types of real estate do not always follow an opposing path. In particular, following the financial crisis, RRE, CRE and GDP saw significant falls so an assumption of complete substitution between the two types of real estate would be unreasonable. The implications for RRE 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.

Our motivation for introducing a labour supply shock is twofold. Firstly, it clearly displays the mechanism behind the real estate investment co-movements in our flexible version of real estate substitution. Secondly, labour supply shocks have been shown to be a significant driver

Figure 11 – Labour Supply Shock and Land Share



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

of the fall in labour hours during the Covid-19 pandemic (Brinca et al., 2020).[27] We argue that such a fall in labour supply will unmistakably lead 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), land, capital, and labour all contribute to the formation of new real

[27]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

estate. For lower values of μ_h, construction is relatively more capital- and labour-intensive, so that a negative labour-supply shock (Figure 11) reduces both the demand for commercial real estate investment and the supply of capital to the construction sector. As a result, residential and commercial real estate investment can decline together, with adjustment occurring through reduced construction activity rather than land reallocation. Specifically, the separation of real estate investment from land use can be seen by equating (17) and (18) to give

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

In (19) RRE investment dynamics are not only determined by the ratio of land, but also by the demand for CRE. This separation of $IH_{c,t}$ from $L_{hc,t}$ allows $IH_{d,t}$ to potentially fall, despite a reallocation of land towards the residential sector ($\frac{L_{hd,t}}{L_{hc,t}}$ increases) 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 11, with lower values of μ_h, falls in the land price have less influence on construction costs and the real estate substitution channel is weakened which suppresses some of the falls RRE and CRE prices. Furthermore, driven by the reduction in labour hours, consumption and GDP, the demands for both CRE and RRE ($q_{hd,t} IH_{d,t+1}$ and $q_{hc,t} IH_{c,t+1}$ respectively) are lower. Whilst, by assumption, the supply of land is fixed, the inputs of labour and capital can fall such that both commercial and residential real estate investment fall. This further reduces the marginal product of land, which causes land prices to become more volatile. In contrast for higher values of μ_h, land reallocation is the main driver of real estate investment such that the real estate substitution channel dominates and the two series take opposing paths.

6 Conclusion

This paper introduces a construction sector into a macroeconomic framework to explain the co-movements of property prices and the substitution of commercial and residential real estate investment that we observe in the data. We refer to this mechanism as "real estate substitution", where the inputs of real estate production and the source of macroeconomic fluctuations play a significant role in determining both the direction and magnitude of construction sector dynamics. Specifically, real estate substitution encapsulates land reallocation, but it does not impose strict substitution between the two types of real estate. This additional degree of flexibility is crucial to explain the large fall in both residential and commercial real estate, which was observed during the financial crisis.

Contrary to the traditional view of the business cycle literature, our sectoral macroeconomic model allows us to identify the interactions within the real estate market and the propagation mechanism. We give a unique interpretation to the housing preference shock, where it does not merely generate a shift in the preference for RRE, instead, it is shown to have a structural connection with CRE and the consumption-good sector. In turn, this relationship explains how demand shocks in RRE can easily crowd out CRE, which affects the goods market in a similar way to an adverse aggregate supply shock.

The past few years have underscored the value of a macro framework that links construction, land allocation, and aggregate dynamics. Looking ahead, a natural extension is to enrich the demand side with an explicit rental market that introduces rents and lease/vacancy frictions so the model can speak directly to rent–price comovement and the distribution of adjustments across tenure types. A second priority is to allow production to make limited use of residential space (e.g., a simple home-production or work-from-home margin), providing a unified way to study persistent changes in space use without committing to any single episode. Together, these extensions would let the same framework speak directly to prices, rents, and space use, providing a clear baseline for future work on real-estate cycles.

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). The CRE price level index is a weighted-average of three appraisal-based commercial property price per square foot series, office property, retail property, and warehouse/industrial property, from NREI. Source: Federal Reserve System

Total Hours: Hours of Wage and Salary Workers on Nonfarm Payrolls: Private (seasonally adjusted, Billions of Hours, Series ID: PRSCQ). Source: FRED

Appendix B: Integrating Endogenous Land Growth

Introduction

This appendix extends the baseline model by endogenising the land supply along the lines of Liu et al. (2013). We add a partial-adjustment rule for the aggregate stock of developed land. Total land allocated to the commercial and residential construction sectors evolves as [28]

$$L_{hc,t} + L_{hd,t} = \lambda_{l,t}\bar{L}, \tag{B1}$$

$$\lambda_{l,t} \;=\; \rho_\ell\, \lambda_{l,t-1} \;+\; (1-\rho_\ell)\, \lambda^{*}_{l,t}, \tag{B2}$$

$$\lambda^{*}_{l,t} \;=\; 1 \;+\; \Phi_\ell \left(\frac{q_{l,t}}{q_l^{\mathrm{ss}}} - 1 \right). \tag{B3}$$

Here $q_{\ell,t}$ is the market price of raw land, q_ℓ^{ss} its steady-state value, and $\bar{L}$ the fixed endowment of land. We set the semi-elasticity $\Phi_\ell = 5$ near the upper end of empirical land-supply elasticity estimates, and $\rho_\ell = 0.8$ for persistence. Roughly 6.4 % of the developed land stock is turned over each year in the baseline calibration (1.6 % per quarter). With $\Phi_\ell = 5$, a 10 % rise in land prices boosts new development by about 50 %, to 9.6% of the stock—consistent with boom-period housing-start surges in more elastic U.S. metros (Glaeser et al., 2008; Saiz, 2010). While the model abstracts from permitting lags and physical construction delays, this elasticity provides a reasonable upper-bound robustness test.

Impulse-response comparison

Figures B1 and B2 plot the responses to (i) a housing-preference shock (χ) and (ii) a consumption goods Technology shock (A_c) under the baseline (solid) and the endogenous land specification (dashed).

Housing-preference shock. Endogenous land supply dampens the land-price spike by roughly 80 %. Lower collateral revaluation means the CRE price and investment fall by less, so the RRE-CRE substitution is smaller but still clearly present. GDP is virtually unchanged.

Consumption good Technology shock. The muted land-price decline cushions the fall in RRE investment. CRE investment increases marginally more with little impact on aggregate variables.

Overall, letting land adjust endogenously marginally alters *levels*, not *directions*: the real

[28] All references to L^{ep}_{hc} and L^{ep}_{hd} use the endogenous land growth framework and no other equations in the model block require manual adjustment

estate substitution mechanism survives intact, echoing the negligible effects reported by Liu et al. (2013).

Figure B1 – Housing Preference Shock with Land Growth

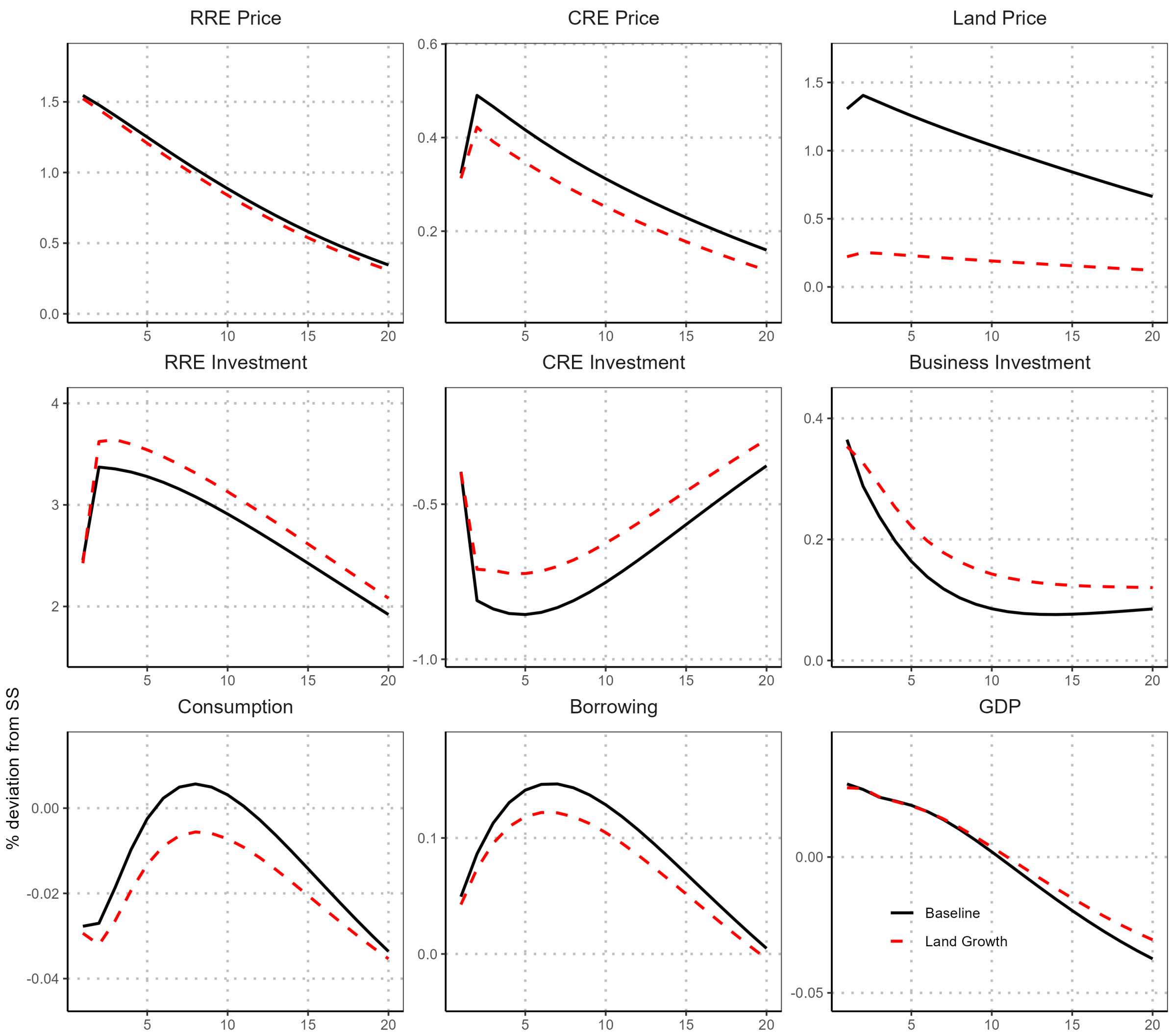
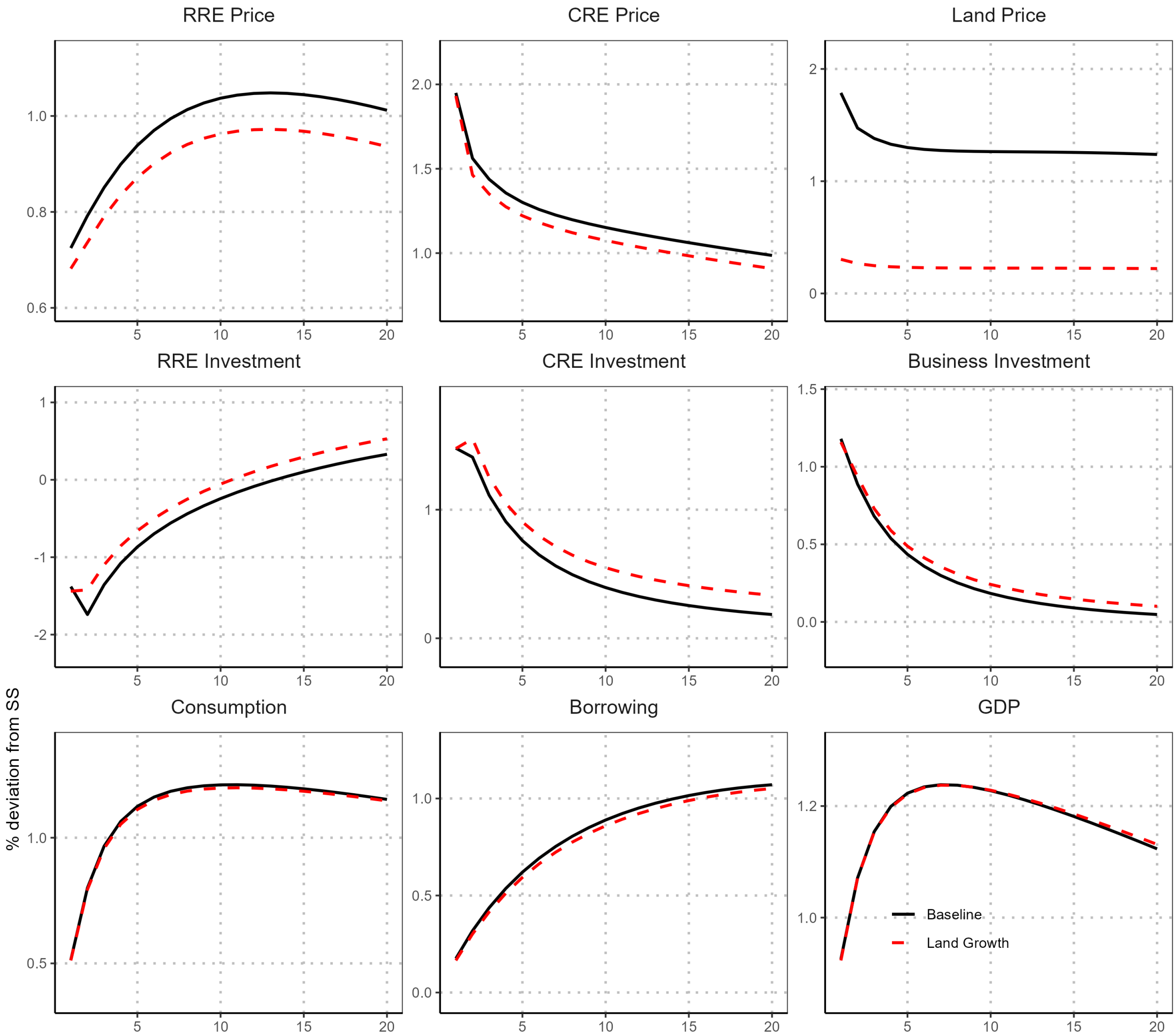


Figure B2 – Consumption Technology Shock with Land Growth



Appendix C: Introducing Imperfect Substitution in Land use

CES Land Aggregator

We capture zoning restrictions with a constant-elasticity-of-substitution (CES) function that combines sector-specific land holdings into a single composite bundle:

$$\tilde{L}_t \;=\; \left[\omega\, L_{hd,t}^{\frac{\sigma-1}{\sigma}} + (1-\omega)\, L_{hc,t}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}. \tag{C1}$$

The elasticity σ is our zoning parameter: high values approximate freer land mobility, while low values represent tight land use regulation that segments residential and commercial markets. This CES specification follows Davis et al. (2022), who estimate land-use substitution elasticities across US metropolitan areas using cross-city land use shares; In line with the estimates of Davis et al. (2020) for land use substitution, we explore $\sigma = 0.16$ (tight zoning restrictions), $\sigma = 0.35$ (average zoning restrictions) to $\sigma = 0.66$ (weak zoning restrictions). A competitive "developer" chooses $(L_{hd,t}, L_{hc,t})$ each period to supply $\tilde{L}_t$ at minimum cost, taking the composite (effective) land price $q_{l,t}$ as the Lagrange multiplier on (C1). The resulting sectoral land prices (the shadow prices for *new* residential and commercial developments) are the CES marginals:

$$q_t^{L,h} = q_{l,t}\,\omega\, S_t^{\frac{1}{\sigma-1}}\, L_{hd,t}^{-\frac{1}{\sigma}}, \tag{C2}$$

$$q_t^{L,c} = q_{l,t}\,(1-\omega)\, S_t^{\frac{1}{\sigma-1}}\, L_{hc,t}^{-\frac{1}{\sigma}}, \tag{C3}$$

where

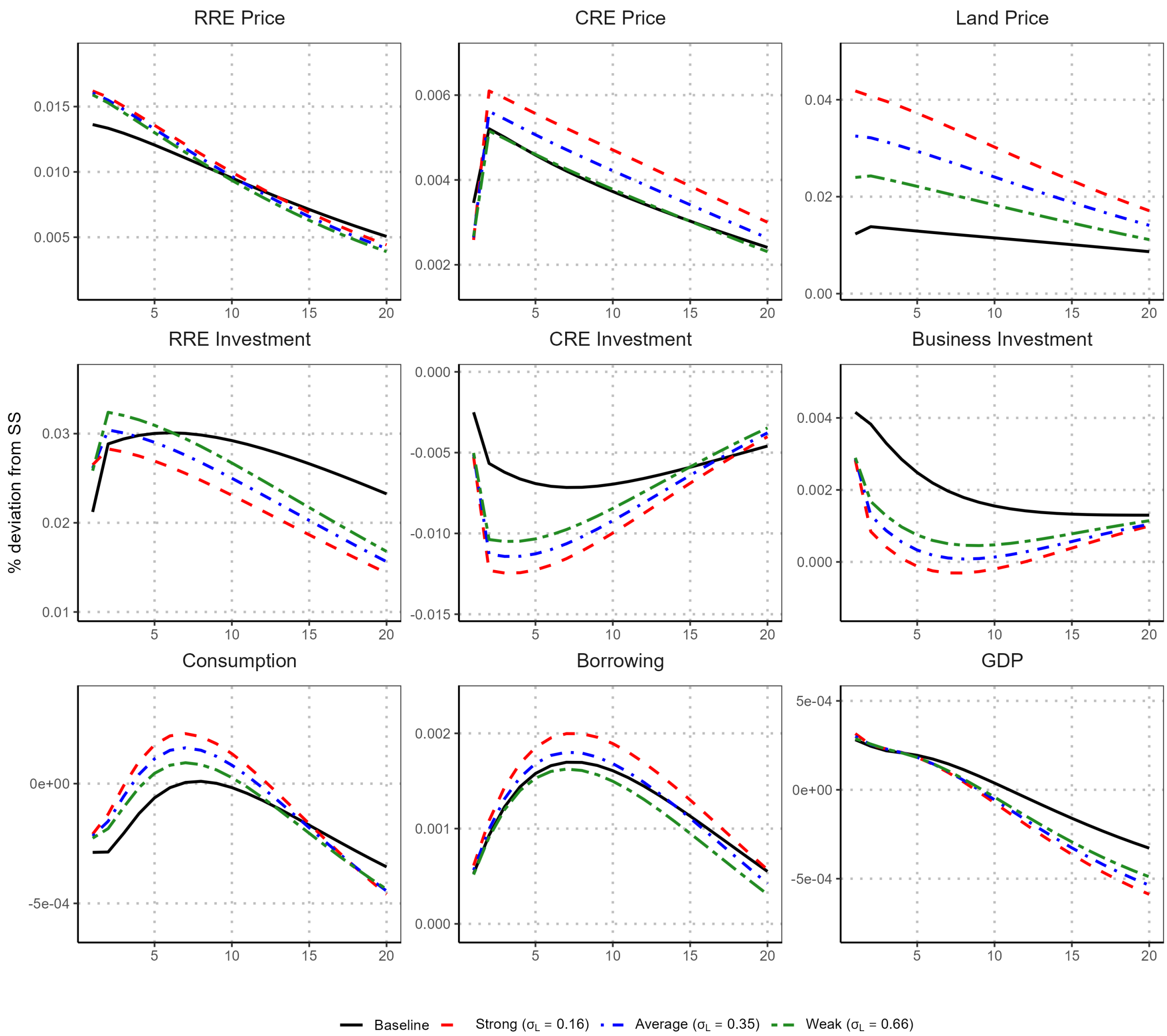
$$S_t \;\equiv\; \omega\, L_{hd,t}^{\frac{\sigma-1}{\sigma}} + (1-\omega)\, L_{hc,t}^{\frac{\sigma-1}{\sigma}} \tag{C4}$$

is the CES index inside (C1). The CES aggregator governs land only. Each sector then nests land with structures capital and other inputs in the production functions laid out in Section 2 of the main text. Zoning therefore hinders the reallocation of land but does not restrict how intensively structures can be placed on a given lot. For every elasticity considered we recalibrate steady-state land shares so that housing and commercial uses each account for half of aggregate land value. All other parameters remain fixed. Shocks are normalised to one baseline-model standard deviation so impulse magnitudes remain comparable across zoning scenarios.

IRFs under Alternative Zoning Regimes

Figure C1 plots the impulse-response functions for a one-standard-deviation increase in the household preference parameter χ. Across all regimes we observe the same qualitative pattern as in the baseline: the composite land price jumps on impact; residential investment rises; commercial investment falls; borrowing and GDP move in the expected directions. What differs

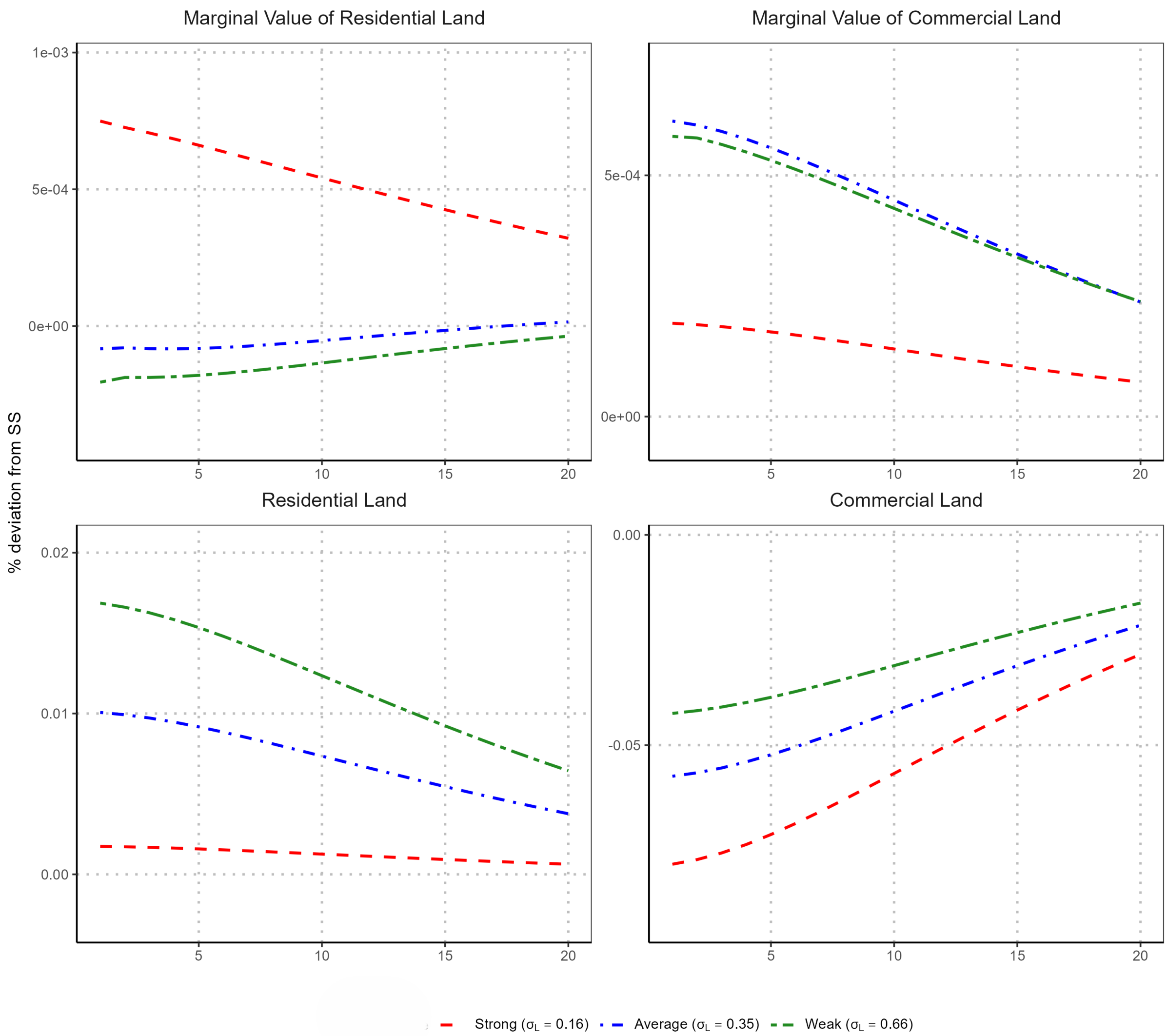
Figure C1 – Housing Preference Shock with Imperfect Land Substitution



with zoning is is the channel of adjustment. With tighter zoning (low σ), the reallocation margin is constrained, so price movements are amplified, RRE investment rises by less, and CRE (and business) investment falls by more relative to the weaker zoning case (high σ).

This pattern is not mechanical. The sectoral decomposition (Figure C2) shows that residential land (L_{hd}) rises while commercial land (L_{hc}) falls after the shock, with the reallocation strongest when zoning is weak (high σ). The marginal values move differently: the residential land shadow value $q_t^{L,h}$ rises *most* under tight zoning (low σ), because quantities cannot shift much, whereas under weak zoning the large expansion of residential land pushes its marginal flat to slightly down. The commercial land marginal $q_t^{L,c}$ increases in all regimes but *least* when zoning is tight where higher land/user costs and the pull of *capital* and *labour* toward RRE production reduce the profitability of new commercial projects. In short, tight zoning chan-

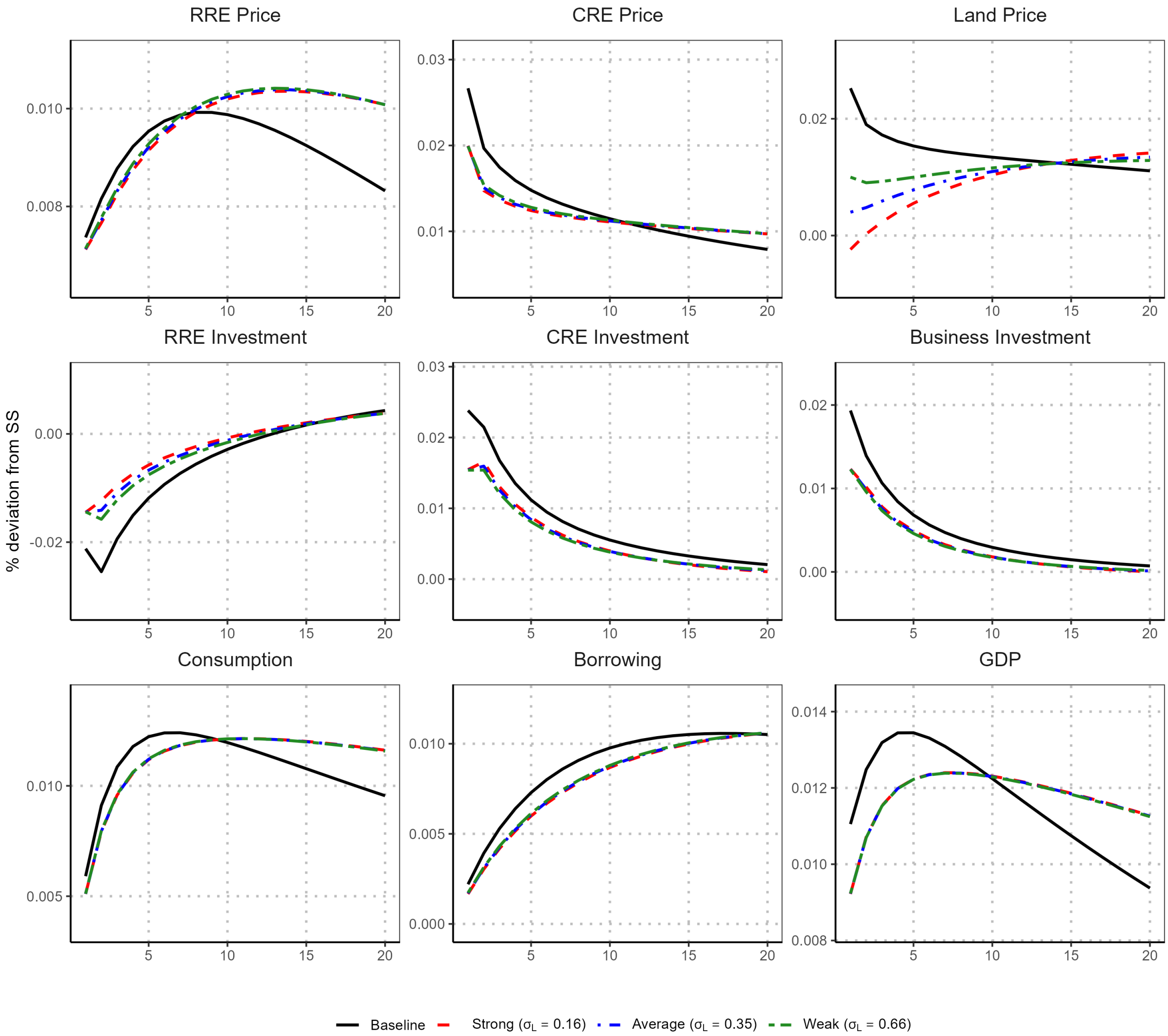
Figure C2 – Housing Preference Shock - Marginal values and land use



nels the housing-preference shock more through prices (marginals) and cuts to commercial land, while weak zoning allows a larger quantity reallocation toward RRE production; the qualitative crowd–out of CRE is preserved, but the price–quantity mix depends on σ.

Figure C3 displays the impulse-response functions for a one-standard-deviation productivity improvement in the consumption-goods (commercial) sector. A one-standard-deviation productivity improvement raises CRE investment and lowers RRE investment; borrowing, consumption and GDP increase modestly. Across zoning elasticities, the CRE asset-price responses are nearly indistinguishable, and macro aggregates move very similarly. Zoning mainly tweaks the adjustment margin: when land is more mobile (high σ), quantity reallocation is a bit larger (bigger rise in CRE investment and deeper fall in RRE investment), whereas tighter zoning (low σ) mutes these quantity movements slightly, with only minor differences in the composite land-price path.

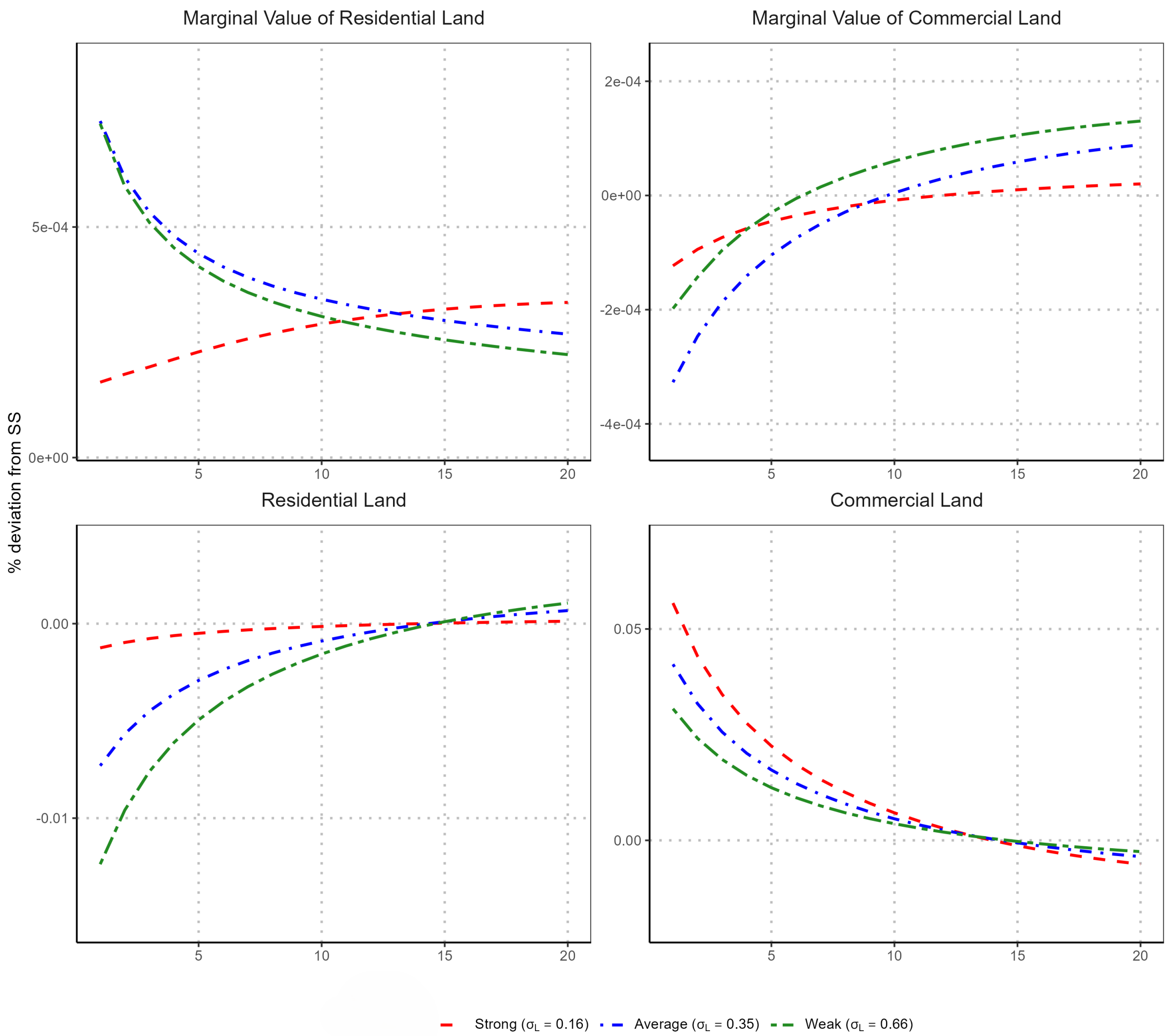
Figure C3 – Consumption Good Technology Shock with Imperfect Land Substitution



Overall, the experiment delivers the same qualitative pattern as in the baseline.

The decomposition in Figure C4 shows how zoning reshapes land quantities and their marginal values after a consumption–goods technology shock. Commercial land (L_{hc}) expands and residential land (L_{hd}) contracts in all regimes; the residential decline is muted under tight zoning (low σ) and largest under weak zoning (high σ). The marginals move differently. The residential land shadow value $q_t^{L,h}$ is highest under weak zoning on impact; under tight zoning it starts low and rises gradually because quantities adjust little. The commercial land marginal $q_t^{L,c}$ *falls on impact in all regimes* as the jump in L_{hc} dilutes its marginal product; the fall is smallest when zoning is tight, since the larger increase in the composite land price $q_{l,t}$ partly offsets this quantity effect. At longer horizons, as reallocation into CRE proceeds under weak zoning, $q_t^{L,c}$ turns positive and is more persistent. Intuitively, the productivity shock raises the

Figure C4 – Consumption Good Technology Shock with - Marginal values and land use



profitability of commercial space and pulls capital and labour toward CRE; whether this shows up more in quantities (weak zoning) or in short-run wedges in shadow values (tight zoning) depends on σ.

Imperfect land substitution preserves the basic mechanism: shocks that favour one land-using sector crowd out the other. Zoning mainly changes *how* adjustment appears, through investment, land shares, or sectoral land values. The balance is not uniform across σ or across shocks reflecting collateral and shadow-value effects rather than pure acreage swaps. Asset-price paths remain similar across regimes; the key differences show up in the allocation of land and investment and in the behaviour of sectoral land marginals.

Appendix D: Collateral easing versus the preference shock

We compare the housing–preference shock (χ) with a *broad easing of entrepreneur credit* that relaxes borrowing limits for (i) construction entrepreneurs and (ii) consumption-goods entrepreneurs. Let $\theta_{h,t}$ and $\theta_{c,t}$ denote their collateral tightness parameters in the borrowing constraints. We introduce a common AR(1) innovation

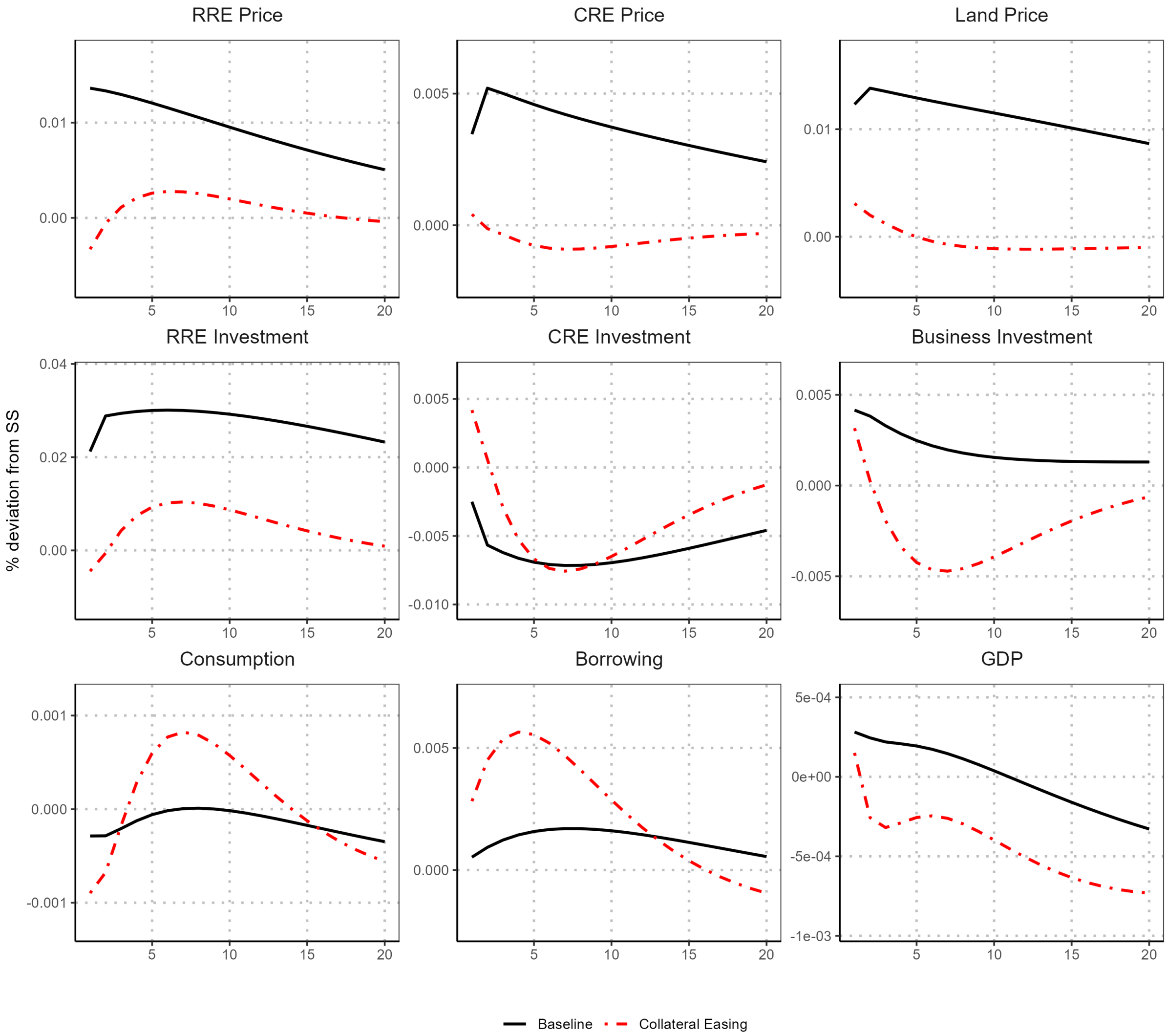
$$\log \theta_{s,t} = (1-\rho_\theta)\log \bar{\theta}_s + \rho_\theta \log \theta_{s,t-1} + \kappa_s\, \varepsilon_t^\theta, \qquad s \in \{h, c\}, \quad \rho_\theta = 0.8,$$

and choose κ_h, κ_c so that the implied loan-to-value ratios for entrepreneurs rise on impact by $\Delta LTV_h = +1\text{pp}$ and $\Delta LTV_c = +1\text{pp}$[29]. We report 20-quarter IRFs as percent log-deviations from steady state in figure D1).

Easing entrepreneur collateral raises entrepreneur borrowing, produces a visible hump in consumption, and it lifts residential investment on impact; however, the effective land price also increases, leaving a small residual reallocation toward housing. As a result, commercial real–estate and non–structure business investment dip initially before recovering. Prices move little compared with χ the RRE price rises only modestly, the CRE price is near flat, and the composite land price shows a small, temporary increase. Quantitatively, these effects are smaller than under χ because the estimated entrepreneur constraints bind only weakly on average and convex adjustment costs smooth construction. The experiment therefore clarifies the contrast: the preference shock produces pronounced substitution (RRE↑, CRE↓), while collateral easing delivers co–movement that is present but limited in magnitude in our estimated environment. Note that, although entrepreneur borrowing rises substantially more under the easing experiment than under the preference shock, the downstream movements in prices and investment are smaller. The reason is threefold: (a) in our estimates the entrepreneur constraints bind only weakly on average, so relaxing them has a low marginal payoff for investment; (b) easing is a financing shock that leaves marginal prices nearly unchanged, unlike the preference shock which directly raises the shadow value of housing services; and (c) easing both entrepreneur constraints simultaneously mutes reallocation and, together with a modest increase in the effective land price, produces only limited sectoral responses while consumption absorbs part of the impulse.

[29] Households are unconstrained in our model; introducing a separate household mortgage constraint would require additional observables/identification and is left for future work.

Figure D1 – Collateral easing (dashed) versus preference shock (solid)



Notes: The collateral shock is a common AR(1) easing of constraints for entrepreneurs in the construction and consumption-goods sectors with $\rho_\theta = 0.8$ and on-impact changes. $\Delta LTV_h = +1$ pp, $\Delta LTV_c = +1$ pp.

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