Aggregate fluctuations, land dynamics and financial frictions

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Abstract

In this paper, I evaluate the role of commercial land to explain aggregate fluctuations. I estimate the elasticity of substitution between land and a capital/labor ratio composite. The point estimate suggests a value of 0.225 that is significantly below the unitary value implied by a Cobb-Douglas production function. Subsequently, I embed land in a model with financial frictions. In this environment a parameterized elasticity of substitution of 0.25 quadruples the effects of technology shocks on output. These shocks also explain land price dynamics. In contrary, the contribution of financial shocks, defined as stochastic changes in maximum allowable ratio of loans to collateral, to explain real variables fluctuations is negligible.

JEL identification: E32, E44, R33

1 Introduction

The U.S. housing boom and bust that took place in the 2000s and its ties to the subsequent economic activity slowdown have been established extensively (see *e.g.* Bernanke, 2010; Mian and Sufi, 2014; Taylor, 2009). The focus on residential real estate in policy circles seems to have overshadowed the role of commercial real estate in the propagation of business cycles. As can been seen in Figure 1, the increase in the market value of real estate owned by non-financial corporate firms lags the one experienced by the national housing market. However, its peak value corresponds to 94% of the housing market's peak value. The bust was also more severe for firms than households. Swings

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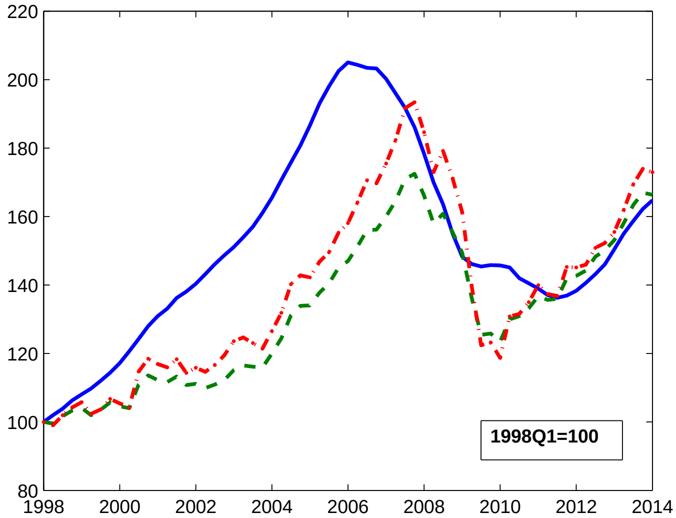

Figure 1: Real estate value indexes (1998Q1=100): the *solid blue* line corresponds to housing, the *dashed green* line to non-financial corporate real estate, and the *dotted-dashed red* line to non-corporate real estate. All series are deflated by the GDP deflator.

in the commercial real estate value coincide with upturns and downturns in economic activity and suggest that linkages between this market and economic activity are bidirectional.

In this paper, I examine the importance of land as collateral for aggregate fluctuations in a dynamic stochastic general equilibrium model that features financial frictions and shocks. Empirical evidence for this channel has been put forward by Chaney, Sraer, and Thesmar (2012) and Gan (2007). Chaney, Sraer, and Thesmar (2012) find a significant increase in investment of six cents in response to each additional dollar in the value of collateral for US firms (1993-2007), whereas Gan (2007) find that a 10% drop in the value of collateral for Japanese firms (1994-1998) causes investment to fall by 0.8%. That should not be surprising considering that the Bank of Japan reports that 70% of loans are backed by land. Moreover, Cvijanovic's (2014) findings emphasize the effects of changes in pledgeable collateral values for firms' financing and payout decisions. Specifically, she finds that an additional one-standard-deviation in predicted value of pledgeable collateral heightens the firm leverage ratio by 3%. Since tangible assets are assets that can be more easily repossessed by banks and since commercial real estate corresponds to 58.13% of non-residential private fixed assets on average in the U.S. (1984-2013), this suggests that investigating land dynamics is fundamental.

Through the lens of a theoretical model, I describe in the following sections the mechanisms at work in the propagation of two types of shocks: TFP and financial shocks. Financial shocks are broadly defined as exogenous stochastic disturbances in borrowing capacity. They resemble collateral shocks, but they are not exactly the same since the enforcement problem is different. Specifically, I augment Jermann and Quadrini's (2012) (hereafter JQ) model with land as a factor of production and collateralized asset. Moreover, I estimate the elasticity of substitution between land and a capital/labor composite. I find a point-estimate of 0.23, that is significantly lower than the unitary elasticity of substitution that is implied by a Cobb-Douglas production. The value of this parameter appears to be crucial for the amplification of TFP shocks. Based on a reasonable parameterization, financial frictions and collateralized land amplify output in response to exogenous TFP shocks in the order of magnitude of over 300%. These frictions also allow important variations in the price of commercial land. The contemporaneous price of land's response is over 14 times larger than the TFP shock. Therefore, my results suggest that TFP shocks are driving forces of business cycles and explain labor market and land dynamics, whereas financial shocks contribute mainly to variations in debt and dividends payout. Although it is an interesting question, studying the interactions between financial shocks and variations in TFP is out of the scope of this paper. Instead I treat both shocks independently.

One main finding of this paper is that financial shocks have negligible effects for aggregate fluctuations. This result is in stark contrast with JQ's findings. In their framework, in response to a reduction in the borrowing capacity, firms cut down their labor demand, because adjusting dividends sharply is costly. Since labor share in output is almost two-thirds, one of their key finding is that output is greatly affected by labor market dynamics. However, my estimation of the parameter that governs dividends adjustment costs suggests that it is null for the baseline model. Therefore, firms disburse more to modify dividends payout and that cancels out the mechanism affecting output described above. Moreover, a greater level of complementarity implies that the marginal product of labor is more affected by changes in hours worked. Therefore, in response to a negative financial shock, firms do not reduce their labor demand as much.

Another effect of a greater level of complementarity is that it leads to amplified output responses to TFP shocks. For this type of shock, the sensitivity of the marginal product of labor is also key to understand the underlying mechanism. Following a positive TFP shock, labor demand increases for a constant level of wages and borrowing constraint tightness. In fact, the level of complementarity multiplies the effects of the TFP shock on the marginal product of labor. Firms wish to increase land as well, but since its supply is fixed, their greater demand is reflected in prices only. They purchase land at a higher price because its greater expected value ensures that their borrowing constraint is relaxed, and also because its marginal product is greater when the elasticity of substitution is lower (greater level of complementarity). Therefore, an increase in the net worth and in the value of collateral also allows firms to have a greater inter-period debt. From that greater debt level, they are able to finance more investments which, in turn, affects positively labor and land demands. So on so forth, there are ripple effects for output, hours worked, land price and investment.

The remainder of this paper is organized as follows. In section 2, I situate my work in the literature on financial frictions and land dynamics. In section 3, I present the baseline model. In section 4, I calibrate that model. In section 5, I analyze the impulse responses and moments generated by the baseline calibration and some of its variations. In section 6, I conclude and propose some extensions.

2 Related literature

This paper contributes to the debate on the quantitative effects of the mechanism proposed by Kiyotaki and Moore (1997) to enhance productivity shocks. In response to these shocks, they find a redistribution of the collateral asset from lower to higher productivity firms as high as $(1-\beta)^{-1}$ where β corresponds to the discount factor. The mechanism at play is completely different from mine. Since my setup precludes redistribution of collateral, labor demand is central to the amplification. Córdoba and Ripoll (2004) and Kocherlakota (2000) present a very skeptical view of the amplification channel put forward by Kiyotaki and Moore (1997). In fact, from an extensive calibration exercise, Córdoba and Ripoll (2004) argue that only the right combination of parameters can lead to a sizable endogenous amplification and that implies making implausible assumptions. Using a Cobb-Douglas production function that aggregates both capital and land inputs, Kocherlakota (2000) also notes the sensitivity of amplification to factor shares. In contrast to these two studies, Mendicino (2012) shows that a lower degree of enforcement (but still sufficiently high) leads to greater amplification effects since the productivity gap between borrowers and lenders is larger. Although significant, the size of output and land price amplification found in her study are much smaller than mine.

Another contribution of my work is to evaluate the role of shocks that emanate from the financial sector for aggregate fluctuations. For example, these financial shocks can be the product of technological innovations in this sector, financial regulatory changes, and waves of pessimism and optimism that affect credit conditions independently of other sources of shocks. As mentioned in the previous section, contrary to my results, JQ find an important contribution of financial shocks to business cycles. They estimate a structural model that comprises seven other shocks and perform a variance decomposition. Their estimates suggest that 46.4% of GDP fluctuations are explained by financial shocks. A significant fraction of output being explained by these shocks is shared with Benk, Gillman, and Kejak (2005) and Nolan and Thoenissen (2009). Specifically, they estimate financial shocks from regulatory changes in the banking sector. A non-exhaustive list of other related work that embed liquidity frictions and shocks and that introduce financial intermediaries is as follows: Del Negro, Eggertsson, Ferrero, and Kiyotaki (2011), Kiyotaki and Moore (2012), and Mendoza and Quadrini (2010). In all of these studies, financial shocks play an important role for aggregate fluctuations.

In the macro real estate literature, most studies have focused on residential real estate and commercial real estate seems to have been left aside.[1] There are some exceptions though. Iacoviello (2005) proposes a hybrid model in which land is in fixed supply and allocated between entrepreneurs, patient and impatient households, so that only patient households are unconstrained by their land holdings. The collateral channel brings about important amplification effects on aggregate demand in response to housing price shocks. In contrast to previous work, Liu, Wang, and Zha (2013) analyze exclusively the role of collateralized commercial real estate in a model that features capital and land aggregated through a Cobb-Douglas production function. In order to match land and output dynamics, they consider different types of shock. In their variance decomposition, around 90% of land prices fluctuations are explained by a housing preference shock at different horizons. For shorter horizons, the contribution of that shock to fluctuations in investment, output and hours worked exceeds that of all other types of shocks. A collateral shock similar to the financial shock embedded in my model has more modest effects since only 6% to 12% of output fluctuations are explained by this shock. Contrary to the mechanism I put forward, Liu, Wang, and Zha (2013) emphasize the reallocation that occurs between residential and commercial sectors so that households' land holdings shrink considerably.

Although real estate does not have productive uses for consumption goods in Iacoviello and Neri's (2010) work, the authors estimate a DSGE model from Bayesian methods that include multiple sources of shocks of which housing demand shocks. These shocks contribute to more than one quarter of housing prices' variance. Technology shocks also explain one quarter of fluctuations in GDP. As it is the case in my framework, I suspect that the assumption of a lower elasticity of substitution would boost the importance of the collateral channel in their study and in Liu, Wang, and Zha's (2013) work. This would probably also lower the size of housing demand shocks.

My paper is also particularly close to the work of Sakuragawa and Sakuragawa (2011) in many ways. From their estimation of elasticities of substitution between land and capital in production for the Japanese economy, they construct a model based on Iacoviello (2005) in which all entrepreneurs face a borrowing constraint. They find that a lower elasticity of substitution coupled with investment adjustment costs leads to greater amplification of TFP shocks. However, the size of output's contemporaneous response is about half of the one I find and its persistence is much lower. Compared with my results and the data, the fluctuations in the price of land generated by their model are also very weak.

My work is also related to studies that focus on the transmission of financial disturbances to the real economy in environments populated with heterogeneous firms. In fact, Buera and

[1] For a survey of the literature, see Davis and Van Nieuwerburgh (2014).

Moll (2012) show that credit crunches, which are similar to the negative financial shocks that I examine, manifest themselves as efficiency wedges in representative-agent representations. In addition to firms' heterogeneity, Khan and Thomas's (2013) framework features partial investment irreversibility. Decreases in borrowing capacity also translate into TFP losses. Shourideh and Zetlin-Jones (2012) examine the effects of a 1% drop in the debt-to-asset ratio in a model where firms are either always borrowing-constrained or unconstrained. They find important reallocation effects as output decreases by 0.5%. It would be interesting to know however how much of this decrease is due to the trade in intermediate inputs between firms that are embedded in their model. These studies also do not consider the specific role of land dynamics.

The ineffectiveness of financial shocks to explain aggregate fluctuations that I find is also shared by work on housing and business cycles. Justiniano, Primiceri, and Tambalotti (2013) find that movements in household debt cannot be attributed to credit liberalization nor to the tightening of mortgage credit conditions. In fact, since financial shocks affect borrowers and lenders in an opposite manner, these effects cancel out in aggregate. This result is in line with Campbell and Hercowitz (2009) and Kiyotaki, Michaelides, and Nikolov (2011) who, nevertheless, stress the importance that changes in loan-to-value ratios have on welfare. Moreover, the first half of the 2000s' credit liberalization cannot account for the surge in housing prices in the framework put forward by Garriga, Manuelli, and Peralta-Alva (2012).

3 The model

There exist various ways to introduce financial frictions in general equilibrium models.[2] Similar to JQ, firms in the following framework will prefer to hold debt over issuing equity, since debt entails tax benefits. The incompleteness of asset markets requires them to hold capital and land as collateral. Moreover, firms have working capital requirements. I depart from JQ's baseline model on one dimension: land dynamics. I assume that firms can use land as a factor of production and a collateral asset. I restrict the usage of land to commercial and industrial activities. This assumption contrasts with the propagation mechanism illustrated in Iacoviello and Neri (2010) and Liu, Wang, and Zha (2013). Specifically, since their models feature land parcels that flows back and forth from the residential to the commercial sector. In the following section, I describe firms and households' optimization problems.

[2]For a survey of approaches adopted in the business cycle literature, see Quadrini (2011). I do not believe that my results would be significantly affected by the use of another approach—*e.g.* heterogeneous discount factors.

3.1 Firms

Firms are atomistic and produce final goods for investment and consumption purposes. Output is given by

$$y_t = f(z_t, k_{t-1}, l_{t-1}, n_t) = \begin{cases} z_t \left(\gamma l_{t-1}^{-\phi} + (1-\gamma) \left(k_{t-1}^{\theta} n_t^{1-\theta} \right)^{-\phi} \right)^{-\frac{1}{\phi}} & \phi \neq 0 \\ z_t l_{t-1}^{\gamma} k_{t-1}^{(1-\gamma)\theta} n_t^{(1-\gamma)(1-\theta)} & \phi = 0 \end{cases}$$

where z_t denotes an exogenous technology (TFP) shock, l_{t-1} denotes land, k_{t-1} denotes capital and n_t is total working hours. Note that I assume a constant-elasticity of substitution (CES) production function for which $\frac{1}{1+\phi}$ corresponds to the elasticity of substitution between land and a capital/labor composite. The parameter γ represents land's weight relative to capital in the production function. I also assume decreasing returns to scale for the aggregation of capital and land, so that $0 < \theta < 1$. In the case of a Cobb-Douglas production function, *i.e.* $\phi = 0$, γ corresponds to the elasticity of output with respect to land, $(1-\gamma)\theta$ the elasticity of output with respect to capital, and $(1-\gamma)(1-\theta)$ to the elasticity of output with respect to labor.

Capital's law of motion is $k_t = (1-\delta)k_{t-1} + x_t$, where δ is the depreciation rate and x_t is investment. Land is a fixed factor of production. However, every period, a fraction of land is separated from firms and is reallocated to households. Land separation could be part of typical search and matching frictions, but for the sake of simplicity, I assume that all land is matched again. Hence, not as common in the literature, land's law of motion corresponds to $l_t = (1-\omega)l_{t-1} + x_{lt}$, where ω is the separation rate and x_{lt} denotes new purchases of land.

As mentioned at the beginning of this section, firms have tax benefits to use debt, specifically *inter-period debt.* They show up in the interest rate at which they borrow $R_t = 1 + r_t(1-\tau)$, where r_t is the interest rate at which households lend and τ corresponds to the tax benefit or subsidy rate.

Firms pay out dividends d_t and the wage bill $w_t n_t$ to households, invest, purchase land at price q_t and incur *inter-period debt* so that their net new borrowing corresponds to $\frac{b_t}{R_t} - b_{t-1}$. However, these expenses are assumed to be incurred earlier in the period, before revenues accrue to the firms. Since firms need working capital, they contract an interest-free *intra-period loan*: $\ell_t = w_t n_t + x_t + q_t x_{lt} + d_t + b_{t-1} - \frac{b_t}{R_t}$ where w_t corresponds to wages and n_t to total hours worked. Their budget constraint is as follows:

$$w_t n_t + x_t + q_t x_{lt} + d_t + b_{t-1} - \frac{b_t}{R_t} = y_t.$$

Total expenses appear on the left-hand side of the equation and coincide with the value of the *intra-period loan*, so that $\ell_t = y_t$.

Since financing itself with debt brings about tax benefits compared to equity funding, firms would like to borrow as much as they want and then give away dividends to households. However, they face an endogenous borrowing constraint. In fact, because debt is not perfectly enforced, firms that borrow may decide not to honor their contract at the end of the period. If that event were to occur, there would be a stochastic probability ξ_t that their collateralized assets would be seized and liquidated in the next period. Variation in this probability corresponds to financial shocks. I refer the reader to Jermann and Quadrini's (2012) for a thorough description of the renegotiation process from which ensues the following borrowing constraint:

$$\xi_t \left(E_t q_{t+1} l_t + k_t - \frac{b_t}{1+r_t} \right) \geq y_t.$$

Furthermore, I embed adjustment costs to dividends payout as JQ show that it plays a crucial role in the short-term propagation of financial shocks. Therefore, firms pay the following dividends to households: $\varphi(d_t) = d_t + \kappa(d_t - \bar{d})^2$ where κ is a parameter that controls a quadratic cost and $\bar{d}$ corresponds to the dividends' steady state value. Note that a decrease in d_t can also represent an increase in equity issuance. These adjustment costs are motivated in part by incentives that managers have to smooth out dividends payout as discussed by Lintner (1956).

Firms are owned by households and their objective function is to maximize the discounted sum of expected dividends payout. I organize their first order conditions and relegate the more complete derivation of their recursive problems in Appendix **??**. By substituting the condition with respect to d_t and b_t with the ones with respect to n_t, k_t and l_t, I can summarize the firms' problem with the following equations:

$$f_n(\Omega_t) = w_t \left(\frac{1}{1 - \mu_t \varphi_d(d_t)} \right), \tag{1}$$

$$E_t m_{t+1} \frac{\varphi_d(d_t)}{\varphi_d(d_{t+1})} \left[-(r_t + \delta) + (1 - \mu_{t+1}\varphi_d(d_{t+1})) f_k(\Omega_{t+1}) \right] + \frac{(1+r_t)}{R_t} = 1, \tag{2}$$

$$E_t m_{t+1} \frac{\varphi_d(d_t)}{\varphi_d(d_{t+1})} \left[-q_{t+1}(r_t + \omega) + (1 - \mu_{t+1}\varphi_d(d_{t+1})) f_l(\Omega_{t+1}) \right] + \frac{E_t q_{t+1}(1+r_t)}{R_t} = q_t \tag{3}$$

where subscripts either express time or correspond to partial derivatives, $\Omega_t = [z_t, k_{t-1}, l_{t-1}, n_t]$ to a vector of the technology shock and the factors of production, μ_t to the Lagrange multiplier attached to the borrowing constraint and m_{t+1} to the stochastic discount factor. Financial frictions add many distortions. From equation (1), the working capital constraint implies that the marginal productivity of labor does not equal wages. Hence, this ensures the presence of a "labor wedge" between the marginal rate of substitution of consumption and leisure and the marginal product of labor, a distortion that would not arise in a complete markets environment. An "investment wedge" also arises as can be seen from equation (2). Firms take into account that capital accumulation allows them to relax their borrowing constraint. In fact, removing debt's tax benefits $\tau = 0$ and the enforcement constraint $\mu_t = 0$, the interest rate would be equal to $r_t = E_t f_k(\Omega_{t+1}) - \delta$. Finally, from equation (3), increases in the expected price of land also lead to a relaxed borrowing constraint.

3.2 Households

Households maximize the discounted sum of their inter-temporal utility function: $E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, n_t)$ where β corresponds to the discount factor. They work and have financial investments as can be seen from the following budget constraint: $s_t(d_t + p_t) + w_t n_t + b_{t-1} - \frac{b_t}{R_t} + q_t x_{lt} = c_t + p_t s_{t+1} + T_t$, where s_t corresponds to equity shares, p_t to the market price of those shares, c_t to consumption, and $T_t = \dfrac{B_t}{1 + r_t(1-\tau)} - \dfrac{B_t}{1 + r_t}$ to lump-sum taxes that allow to subsidize firms' use of debt. Hence, they optimize with respect to their levels of shares, consumption and hours worked. The combination of the two first order conditions leads to

$$p_t u'(c_t) = \beta E_t \left(u'(c_{t+1})(d_{t+1} + p_{t+1}) \right). \tag{4}$$

With the assumption of fixed equity shares, it is possible to show by substituting forward the first order conditions with respect to shares and consumption that the stochastic discount factor is $m_{t+j} = \beta^j E_{t+j} \left(\frac{u'(c_{t+j})}{u'(c_t)} \right)$.

The last two first order conditions give the intra-temporal condition between leisure and consumption, the marginal rate of substitution, as follows:

$$-\frac{u'_{n_t}}{u'_{c_t}} = w_t. \tag{5}$$

3.3 Shocks

There are two types of shocks: TFP and financial shocks that are stochastic, independent from one another and can be expressed as follows:

$$z_t = \rho_z z_{t-1} + \varepsilon_{zt}, \quad \varepsilon_{zt} \sim N(0, \sigma_z) \tag{6}$$

$$\xi_t = \rho_\xi \xi_{t-1} + \varepsilon_{\xi t}, \quad \varepsilon_{\xi t} \sim N(0, \sigma_\xi) \tag{7}$$

where ρ_z and ρ_ξ are persistence parameters of the TFP and financial shocks and σ_z and σ_ξ are the standard deviations of their innovations.

3.4 Market clearing

First, I assume that the quantity of land is fixed. This implies that population and land have the same growth rate. For simplicity, I set the quantity to unity:

$$l_t = 1. \tag{8}$$

This implies that land purchases are also fixed: $x_{lt} = \omega$.

Finally, the resource constraint for the economy as a whole completes the market clearing conditions, so that:

$$y_t = c_t + x_t + \kappa(d_t - \bar{d})^2. \tag{9}$$

Since the quantity of land that is purchased every period corresponds to the quantity of separated matches, land does not show up in the resource constraint.

3.5 Competitive equilibrium

The state of the economy is summarized by $\mathbf{s}_t$ for the definition of the equilibrium and consists of four aggregate variables: the stochastic processes of shocks z_t and ξ_t summarized by equations (6-7), aggregate land L_{t-1} and aggregate capital K_{t-1} and aggregate borrowing B_{t-1}.

Definition 1. *An equilibrium is defined as a set of functions for*

(i) firms' policies $d_t(\boldsymbol{s}_t)$,$n_t(\boldsymbol{s}_t)$,$b_t(\boldsymbol{s}_t)$,$k_t(\boldsymbol{s}_t)$, $l_t(\boldsymbol{s}_t)$;
(ii) households' policies $c_t(\boldsymbol{s}_t)$,$s_t(\boldsymbol{s}_t)$,$n_t(\boldsymbol{s}_t)$
(iii) land prices q_t *and the lending rate* R_t;

(iv) law of motion of the aggregate state $\boldsymbol{s}_{t+1} = \Psi(\boldsymbol{s}_t)$.

Such that:

(i) firms' policies satisfy conditions (1-3);
(ii) households' policies satisfy conditions (4-5);
(iii) interest rates and prices clear the bond and land markets (8);
(iv) the resource constraint (9) is satisfied.

4 Calibration

In this section, I present the calibration strategy. First, I estimate the elasticity of substitution between land a capital/labor composite. Second, I pick preferences, technology and credit parameters so that some of them match steady-state targets. Third, parameters that govern the two shocks and the dividends adjustment cost are estimated by minimizing the distance between empirical standard deviations and their counterparts that are estimated from the model's simulated data.

4.1 Elasticity of substitution between land and a capital/labor composite

Most theoretical work uses a Cobb-Douglas production function to aggregate land, capital and labor thereby assuming a unitary elasticity of substitution. There is no consensus in the empirical literature on the value of this elasticity. For the U.S., point-estimates range from 0.3 to 1.2 (see references within Ahlfeldt and McMillen (2014)). However, most studies focus on cross-sectional or city-based data of the housing market. To my knowledge, no work has focused on estimating this elasticity for the U.S. commercial real estate sector at a national level—yet there is some for Japan. In effect, from Japanese data on non-financial corporations, Sakuragawa and Sakuragawa (2011) find a point-estimate of the elasticity of 1/3. Kiyotaki and West's (2006) estimate, also from Japanese data, is greater than one, but it is based on an indirect inference of VAR impulse responses. I follow Solow (1957) methodology that involves assuming perfect competition on input markets and a production function that exhibits constant returns to scale.[3] The constant elasticity of substitution (CES) production function is given by

$$y_t = f\left(a_t, a_t^L, k_t, l_t, n_t\right) = \left((1-\gamma)\left(a_t k_t^{\theta} n_t^{1-\theta}\right)^{-\phi} + \gamma\left(a_t^L l_t\right)^{-\phi}\right)^{-\frac{1}{\phi}}$$

[3] Hassler, Krusell, and Olovsson (2012) adopt a similar approach to estimate the elasticity of substitution between energy and a capital-labor composite.

where a_t and a_t^L denote capital/labor and land augmenting technology, k_t denotes capital, n_t denotes total labor hours and l_t is land. The corresponding elasticity of substitution between land and the capital/labor composite is $\epsilon = \frac{1}{1+\phi}$ and γ represents land's weight relative to the composite in the production function. I also assume decreasing returns to scale for capital and labor, so that $0 < \theta < 1$. In the case of a Cobb-Douglas production function, *i.e.* $\lim_{\phi \to 0} y_t$, $(1-\gamma)\theta$ corresponds to the elasticity of output with respect to the capital/labor composite and $\gamma\theta$ to the elasticity of output with respect to land. Furthermore, $\lim_{\phi \to -1} y_t$ represents a production function for which land and the capital/labor composite are perfect substitutes and, conversely, if $\lim_{\phi \to \infty} y_t$, then inputs are perfect complements, so that the production function is Leontief. From the assumption of perfect competition in input markets, I derive expressions for the labor share of output and the value of land over output that consist of the following equations:

$$n_t^{SHARE} = \frac{\partial y_t}{\partial n_t}\frac{n_t}{y_t} = (1-\theta)(1-\gamma)\left(\frac{a_t k_t^{\theta} n_t^{1-\theta}}{y_t}\right)^{-\phi}, \tag{10}$$

$$l_t^{RATIO} = \frac{\partial y_t}{\partial l_t}\frac{l_t}{y_t} = \gamma\left(\frac{a_t^L l_t}{y_t}\right)^{-\phi}. \tag{11}$$

Hence, the labor share and land ratio consist in factor prices ($\partial y_t/\partial n_t$ and $\partial y_t/\partial l_t$) multiplied by the ratio of each factor's quantity over output. Since I assume that firms accumulate land, equation (11) cannot be interpreted as a share of output. From equations (10) and (11), the factor augmenting technologies can be isolated as follows:

$$a_t = \left(\frac{y_t}{k_t^{\theta} l_t^{1-\theta}}\right)\left(\frac{n_t^{SHARE}}{(1-\theta)(1-\gamma)}\right)^{-1/\phi}, \tag{12}$$

$$a_t^L = \left(\frac{y_t}{l_t}\right)\left(\frac{l_t^{SHARE}}{\gamma}\right)^{-1/\phi}. \tag{13}$$

I construct a set of new variables that are log-deviations from a linear trend for each variable: $\hat{a}_t$, $\hat{a}_t^L$, $\hat{y}_t$, $\hat{k}_t$, $\hat{n}_t$, $\hat{l}_t$, $\hat{n}_t^{SHARE}$ and $\hat{l}_t^{SHARE}$. For example, $\hat{y}_t = \log(y_t) - \hat{\beta}_0 - \hat{\beta}_1 t$ where β_0 and β_1 are estimated from an OLS regression. Hence, equations (12) and (13) have the following form:

$$\hat{a}_t = \hat{y}_t - \theta\hat{k}_t - (1-\theta)\hat{n}_t - \frac{1}{\phi}\hat{n}_t^{SHARE},$$

$$\hat{a}_t^L = \hat{y}_t - \hat{l}_t - \frac{1}{\phi}\hat{l}_t^{SHARE}.$$

From data on k_t, n_t, l_t, n_t^{SHARE} and l_t^{SHARE} that is described in the appendix, I estimate the following system of equations by maximum likelihood, so that the first difference in technology deviations around trend are minimized:

Table 1: Estimation of the elasticity of substitution

Elasticities					
$\widehat{\epsilon}$	$=$	0.225 (0.0171)	$\widehat{\alpha}$	$=$	0.218 (0.0616)
Covariance matrix					
$\widehat{\Sigma}$	$=$	$10^{-3} \times \begin{pmatrix} 0.0465 & 0.0441 \\ 0.0441 & 0.3336 \end{pmatrix}$			

The standard errors of the estimates are inside parentheses.

$$\Delta Y_t = \alpha \Delta X_t + \frac{1}{\chi} \Delta Z_t + e_t$$

where $Y_t = \begin{pmatrix} \hat{y}_t - \hat{n}_t \\ \hat{y}_t - \hat{l}_t \end{pmatrix}$, $X_t = \begin{pmatrix} \hat{k}_t - \hat{n}_t \\ 0 \end{pmatrix}$, $Z_t = \begin{pmatrix} \hat{n}_t^{SHARE} \\ \hat{l}_t^{SHARE} \end{pmatrix}$ and $u_t = \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix}$. The estimation is conducted in first difference because augmented Dickey-Fuller tests suggest that all series are integrated of order one ($I(1)$). Moreover, the null hypothesis of zero co-integrating vectors cannot be rejected. I refer the reader to Appendix C for the results of these tests.

From U.S. quarterly data that spans from 1964Q1 to 2007Q4, I find an estimate for $\widehat{\left(\frac{1}{\chi}\right)}$. Using the delta method, I compute the estimated elasticity $\widehat{\epsilon} = \left(\frac{1}{1+\widehat{\chi}}\right)$ and the approximation of its standard error $\widehat{\sigma_\epsilon}$ that I report in Table 1 along with the estimated covariance matrix. The results suggest an important level of complementarity between land and the composite of capital/labor, so that the estimated value of the elasticity is significantly below the value implied by a Cobb-Douglas production function. The implications of this low level of elasticity on business cycles will be discussed in the results section.

4.2 Preferences, technology and credit parameters

The calibrated parameters are reported in Table 2. The discount factor β is lower than the standard value, since households are shareholders, its value matches the return on equity in the steady-state. The households' utility function is separable and takes the form: $u(c_t, n_t) = \log(c_t) + \alpha \log(1 - n_t)$. The capital depreciation rate δ is 2.5% on a quarterly basis so that it corresponds to 10% annually. I set the separation rate in land markets ω to match the average annual exit rate of plants as documented by Lee and Mukoyama (2012). From the estimation pursued in the previous section,

Table 2: Calibration

Parameter	Value	Target
Preferences		
β	0.9825	average annual equity return=7.32%
α	1.91	households work 30% of their allocated time
Technology		
δ	0.025	k depreciation rate
ω	0.013475	plant-level average annual exit rate=5.5%
$\epsilon = \frac{1}{1+\phi}$	0.25	elasticity of sub. between land and a capital/labor composite
θ	0.3325	labor share in ouput=0.64
γ	0.037	commercial land market value/output ratio =0.959
Credit		
τ	0.35	tax advantage of debt
$\bar{\xi}$	0.3924	ratio of *inter-period debt* over the value of coll. assets $\bar{b}/\left(\overline{ql}+\bar{k}\right)$=0.75

I set $\epsilon = 0.25$. Firms enjoy a 35% tax benefit when they finance themselves with debt rather than equity that would correspond to a marginal tax rate of the same level.

Another set of parameters α, θ, γ, and $\bar{\xi}$ are jointly chosen to match steady-state targets. The targets are the following ones: households spend n=30% of their time at work, the labor share in output $\overline{wn}/\bar{y}$ corresponds to 64%, the value of land over output $\overline{ql}/\bar{y}$ is 0.959, and the ratio of *inter-period debt* over the value of collateralized assets $\bar{b}/\left(\overline{ql}+\bar{k}\right)$ is 0.75. The first two targets are standard in the literature, whereas the other two are not. The commercial land market value is retrieved from Davis's (2009) decomposition of non-financial real estate into land and structures. The average value over GDP from 1984Q1 to 2007Q4 corresponds to 0.959. *Inter-period debt* over collateralized assets corresponds to a loan-to-value. I follow Liu, Wang, and Zha's (2013) and pick 0.75. From US firms' credit market data and an imputation of land's value in real estate, they find this value. It is also an intermediate value between Sakuragawa and Sakuragawa's (2011) 0.7 who refer to banking practices in Japan and Iacoviello's (2005) 0.89 that is obtained from a structural estimation.

4.3 Estimated parameters

The remaining parameters that need to be picked cannot be set from steady state targets. Hence, I estimate them jointly by simulated method of moments. They control the costs of dividends

Parameters			**Standard deviations** (%)	
ϱ	value		model $\Lambda(\varrho)$	empirical $\tilde{\Lambda}$
κ	0	$\tilde{\sigma}_{ep/y}$	1.62	1.68
ρ_z	0.995	$\tilde{\sigma}_{dr/y}$	2.36	2.21
ρ_ξ	0.72	$\tilde{\sigma}_y$	1.74	1.71
σ_z	0.0031	$\tilde{\sigma}_n$	2.03	1.76
σ_ξ	0.0016	$\tilde{\sigma}_q$	5.72	8.37

Table 3: Estimated parameters and moments' targets (H-P filtered, $\lambda = 1,600$)

payout κ, the persistence of shocks (ρ_z and ρ_ξ) and the standard deviations of their innovations (σ_z and σ_ξ). The five structural parameters are comprised in vector $\varrho = (\kappa, \rho_z, \rho_\xi, \sigma_z, \sigma_\xi)$. The loss function to minimize is a weighted sum of squared distances between empirical standard deviations (1984Q1-2007Q4) and standard deviations generated by the model of dividends payout and debt over real GDP, real GDP, hours worked, and a commercial land price index. The loss function that ϱ minimizes is expressed as follows:

$$\arg\min_{\varrho} \left(\Lambda(\varrho) - \tilde{\Lambda}\right)' W \left(\Lambda(\varrho) - \tilde{\Lambda}\right)$$

where $\Lambda(\varrho)$ corresponds to a vector of standard deviations generated by the model, $\tilde{\Lambda}$ to a vector of empirical standard deviations and W to a diagonal weighting matrix that comprises empirical variances' inverse. I pick the equity payout and debt standard deviations in order to capture the importance of financial frictions in the model. They are defined as follows: $ep_t = d_t$ and $dr_t = b_{t-1} - b_t/(1 + r_t)$. The standard deviations of real GDP and hours worked are typical indicators of business cycle amplitude. Finally, since the price of land plays an important role in the propagation of shocks, matching its standard deviation appears adequate. All variables are logged, except the equity payout and debt repurchase ratios, and are H-P filtered ($\lambda = 1,600$).[4]

Table 3 presents the values of the estimated parameters and the targeted standard deviations. The model hits all targets, except the volatility of land price. Since the estimation suggests that there are no dividends adjustment costs, the propagation channel following *financial* shocks is shut down. Moreover, the TFP shock is highly persistent.

[4]Note that I discard JQ's strategy to estimate the shocks' moments. Their approach consists of constructing shocks as residuals of the production function (TFP shocks) and residuals of the enforcement constraint (financial shocks). However, this approach would be complicated since it would necessitate data on the expected value of land.

Parameters	Baseline $\epsilon = 0.25$	Cobb-Douglas prod. function $\epsilon = 1$	JQ
κ	0	0.22	0.146
ρ_z	0.995	0.995	0.9457
ρ_ξ	0.72	0.61	0.9703
$\rho_{z\xi}$	0	0	-0.0091
$\rho_{\xi z}$	0	0	0.0321
σ_z	0.0031	0.012	0.0045
σ_ξ	0.0016	0.013	0.0098

Table 4: Parameters used by JQ and estimated parameters for elasticities of substitution between land and a capital/labor composite $\epsilon = \{0.25, 1\}$

5 Results

5.1 Impulse responses

In this section, I examine the impulse responses of important variables to TFP and financial shocks. Figures 2 and 3 present the responses to one percent temporary shocks that are derived from the estimation of the baseline model and some of its variants. In order to meet the same calibration targets, some parameters differ when I assume a greater elasticity of substitution between land and a capital/labor composite. I report the estimated parameters for a Cobb-Douglas production function $\epsilon = 1$ in Table 4. Moreover, I report JQ's choice of parameters. There are two additional parameters ($\rho_{z\xi}$ and $\rho_{\xi z}$), since they allow for spill-overs across shocks. Specifically, their shock process is as follows:

$$\begin{pmatrix} z_t \\ \xi_t \end{pmatrix} = \begin{pmatrix} \rho_z & \rho_{z\xi} \\ \rho_{\xi z} & \rho_\xi \end{pmatrix} \begin{pmatrix} z_{t-1} \\ \xi_{t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{zt} \\ \varepsilon_{\xi t} \end{pmatrix}.$$

Since the propagation of shocks is dampened when the production function is Cobb-Douglas, the estimated variance of shocks is heightened in order to match the same moments. Specifically, the financial shock's standard deviation is multiplied by more than eight, yet it is only 30% greater that JQ's. As will be shown in the next section, even for the same variance of shocks, the impulse responses are very sensitive to the elasticity of substitution between land and a capital/labor composite.

5.1.1 TFP shocks

To compare quantitative effects on the same basis, I consider one percent positive TFP shocks in Figure 2. The size of impulse responses when a lower elasticity of substitution is assumed clearly stand out. There are important endogenous amplification effects. From the marginal product of labor that is characterized as follows:

$$f_{nt} = \frac{(1-\gamma)(1-\theta)y_t^{\phi+1}}{n_t^{(1-\theta)\phi+1}k_t^{\theta\phi}}$$

it can be seen that a lower elasticity of substitution (greater ϕ) amplifies the response to TFP shocks. Similarly, the marginal product of land depends negatively on the elasticity of substitution: $f_{lt} = \gamma y_t^{\phi+1}$. As these two marginal products increase following a TFP shock, firms expand their demand for labor and land. A fixed land supply and a greater land demand results in a higher level of land prices. Since the value of their collateral is up, firms borrow more to finance investments in physical capital. As can be seen from the response of the Lagrange multiplier, the borrowing constraint is even relaxed initially that is contrary to the results of an assumed Cobb-Douglas production function and JQ's framework. Capital accumulation leads to increases in labor and land demands, so the effects spiral up. The persistence of output's response is indeed due to capital accumulation and to the persistence of the TFP shock itself. In comparison, the same model with the standard unitary elasticity of substitution (Cobb-Douglas production function) show very small increases in the price of land and there almost is not any endogenous amplification.

5.1.2 Financial shocks

Figure 3 displays the responses of key variables to a one percent positive *financial* shock. Even though firms increase their *inter-period* debt, the effects of this shock on output and the price of land are almost null. This is the consequence of the absence of dividend adjustment costs $\kappa = 0$ which is a parameter that is estimated by matching empirical standard deviations. Most of the increase in borrowing is given back to households in terms of greater dividends payout. The mechanism through which these effects come about in JQ's model also arises from upward shifts in labor demand. However, it is the relaxation of the enforcement constraint that lowers the labor wedge between wages and the marginal product labor, as can be seen in equation (1), that is responsible for the mechanism. As for the model that assumes a Cobb-Douglas production function, its initial output response is less than half of the response generated from JQ's model. Since firms increase their land demand, its price also increases and therefore restricts their investment in physical capital and their labor demand.

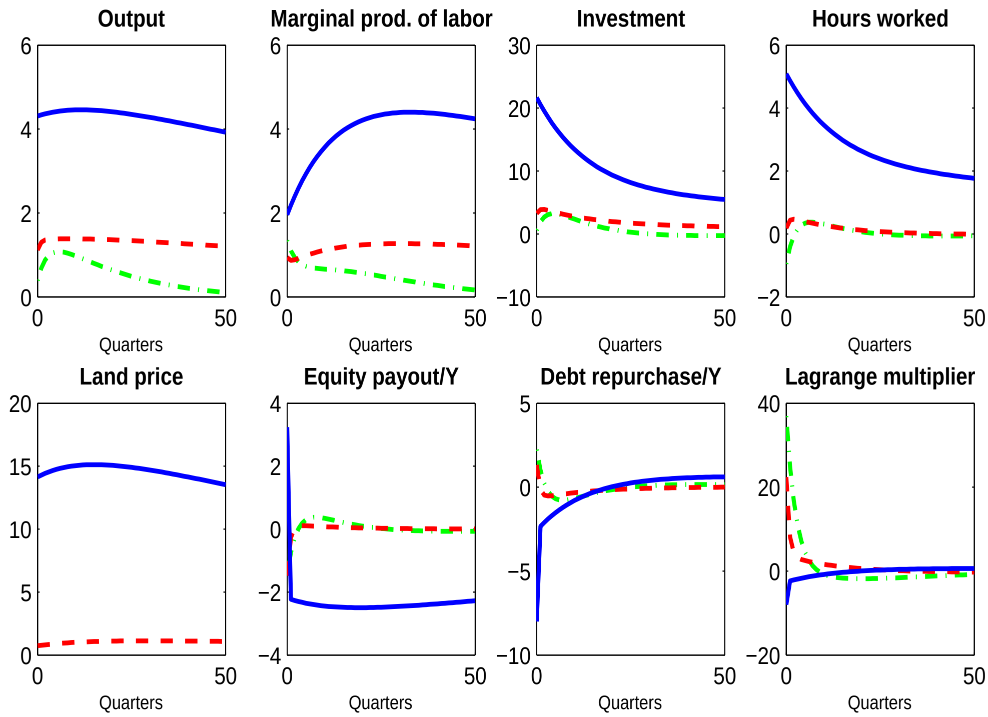

Figure 2: Impulse responses to a one percent positive temporary TFP shock

The *solid* blue lines correspond to the baseline model ($\epsilon = 0.25$), the *dashed* red lines to a Cobb-Douglas production function ($\epsilon = 1$), and the *dash-dotted* green lines to JQ.

5.2 Quantitative analysis

In Table 5, I report various business cycle statistics: standard deviations, co-movements, and a variance decomposition. GDP exhibits more variability for the two models that I estimate than for JQ's model. Variations in output are greater for the baseline model even though the standard deviations of shocks that I use are smaller, as can be seen in Table 4. Moreover, the variabilities of both financial variables, the equity payout and debt repurchase ratios, are all closely matched. The fact that hours worked are more volatile than output is also replicated by the baseline model. As for land dynamics, the standard deviation of land price is smaller than its empirical counterpart, yet it is five times larger than the estimated value for the model where a Cobb-Douglas production function is assumed. The baseline model also replicates the cyclical behavior of the price of land. Hence, these results request a reassessment of TFP shocks' importance for fluctuations in the price of land in the context of estimations of structural models with multiple sources of shocks.

TFP shocks in the baseline model also replicate the counter-cyclical behavior of the debt repurchase-GDP ratio, but fails at matching the cyclical behavior of the equity payout-GDP ratio.

Figure 3: Impulse responses to a one percent positive *financial* shock

The *solid* blue lines correspond to the baseline model ($\epsilon = 0.25$), the *dashed* red lines to a Cobb-Douglas production function ($\epsilon = 1$), and the *dash-dotted* green lines to JQ.

However, this result is sensitive to the definition of equity payout as suggested by Covas and Den Haan (2011). For changes in the book value of equity, they find a negative correlation between equity payout and GDP (positive correlation between equity issuance and GDP). They also find different behavior of largest firms.

The last part of Table 5 displays the fraction of variance that is explained by TFP shocks for real and financial variables in percentage. The remaining is explained by financial shocks, because there are only two shocks. Since the estimated standard deviation of financial shocks is very small, unsurprisingly, almost all variability generated by the baseline model originates from TFP shocks. In the second column, the results suggest that hours worked and financial variables are explained more so by financial shocks for the model for which I assume an unitary elasticity of substitution between land and other factors of production. These findings emerge from the similar mechanism put forward by JQ for which labor dynamics are key to explain output dynamics. However, when their model is augmented with land and some parameters are estimated to match empirical standard deviations, the source of variations in output is no longer financial shocks.

Model:	Baseline $\epsilon = 0.25$	Cobb-Douglas prod. function $\epsilon = 1$	JQ	**Data**
Volatility				
GDP	1.74	2.05	1.02	**1.71**
Equity payout / GDP	1.62	1.45	1.62	**1.68**
Debt repurchase / GDP	2.36	2.65	2.93	**2.21**
Standard deviations relative to GDP				
Investment	4.98	3.33	4.2	**3.93**
Hours worked	1.17	0.71	1.4	**1.03**
Land price	3.29	0.66	-	**6.53**
Co-movement				
Correlations with GDP				
Land price	0.99	0.91	-	**0.52**
Equity payout / GDP	-0.19	0.15	0.75	**0.5**
Debt repurchase / GDP	-0.67	-0.44	-0.80	**-0.75**
Variance decomposition				
GDP	99.99	84.32	29.87	
Equity payout / GDP	92.69	46.1	24.06	
Debt repurchase / GDP	96.57	28.69	19.12	
Investment	99.99	72.37	20.35	
Hours worked	99.99	23.8	15.13	
Land price	99.99	99.99	-	

In the *volatility* section, I report the standard deviations in percentage and relative to GDP's standard deviation for some variables. The first column presents the statistics that are generated from the estimation of the baseline model. The second column presents the statistics that are generated from the estimation of a higher value of the elasticity of substitution between land and a capital/labor composite. The third column corresponds to the results of JQ's model. The last column reports empirical moments estimated from US time series from 1984Q1 to 2014Q1. All series have been logged (except the equity payout and debt repurchase ratios) and H-P filtered with a smoothing parameter of 1,600. In the *variance decomposition* section, the fraction of the variance explained by TFP shocks is displayed for all three models estimated.

Table 5: Business cycle statistics and variance decomposition

5.3 Sensitivity analysis

Results are robust to a different specification of the borrowing constraint, *i.e.* without working capital.

6 Discussion and conclusion

In conclusion, new findings on the role of commercial land in aggregate fluctuations emerge in a framework of endogenous borrowing constraints. First, my findings reinforce the price channel that is central for the endogenous amplification of TFP shocks in Kiyotaki and Moore's (1997) framework. However, in contrast to the reallocation of inputs emphasized by Kiyotaki and Moore (1997), it is labor demand responses that contribute the most to this amplification. It also appears to be conditional on a high level of complementarity between land and a labor/capital composite. Moreover, this level of complementarity allows for greater variations in the price of land. Second, the contribution of TFP shocks to variations in real and financial variables overshadows the contribution of financial shocks, contrary to JQ. This result is partly due to the absence of dividends adjustment costs.

These findings also suggest new directions for the estimation of structural models that focus on financial frictions and land dynamics. In light of my results, Iacoviello and Neri (2010) and Liu, Wang, and Zha (2013) might find completely different results if they also estimate the parameter governing the elasticity of substitution between land and a capital/labor composite. TFP shocks may explain a greater share of aggregate fluctuations and the price of land.

The high level of complementarity between land and a capital/labor composite appears to be crucial to explain the heightened role of TFP shocks. How can the estimation suggest such a high level? One answer might be to look at the dynamics in the construction sector. Activities in this sector are labor-intensive and require land. Despite its small size in aggregate employment and output (around 5%), Boldrin, Garriga, Peralta-Alva, and Sánchez (2013) find that it would account for 52% of the decline in employment and 35% of the decline in GDP during the Great Recession. Therefore, land and labor demands seem to go hand in hand.

extension: interactions with residential sector could be interesting, impact of monetary shocks

References

Ahlfeldt, G. M. and D. P. McMillen (2014): "New Estimates of the Elasticity of Substitution of Land for Capital," Tech. rep., London School of Economics.

Benk, S., M. Gillman, and M. Kejak (2005): "Credit Shocks in the Financial Deregulatory Era: Not the Usual Suspects," *Review of Economic Dynamics*, 8, 668–687.

Bernanke, B. (2010): "Causes of the Recent Financial and Economic Crisis," statement before the Financial Crisis Inquiry Commission.

Boldrin, M., C. Garriga, A. Peralta-Alva, and J. M. Sánchez (2013): "Reconstructing the great recession," Working Papers 2013-006, Federal Reserve Bank of St. Louis.

Buera, F. J. and B. Moll (2012): "Aggregate Implications of a Credit Crunch," NBER Working Papers 17775.

Campbell, J. R. and Z. Hercowitz (2009): "Welfare implications of the transition to high household debt," *Journal of Monetary Economics*, 56, 1–16.

Chaney, T., D. Sraer, and D. Thesmar (2012): "The Collateral Channel: How Real Estate Shocks Affect Corporate Investment," *The American Economic Review*, 102.6, 2381–2409.

Covas, F. and W. J. Den Haan (2011): "The Cyclical Behavior of Debt and Equity Finance," *American Economic Review*, 101, 877–99.

Córdoba, J.-C. and M. Ripoll (2004): "Credit Cycles Redux," *International Economic Review*, 45, 1011–1046.

Cvijanovic, D. (2014): "Real Estate Prices and Firm Capital Structure," *The Review of Financial Studies*, 27, 2690–2735.

Davis, M. A. (2009): "The price and quantity of land by legal form of organization in the United States," *Regional Science and Urban Economics*, 39, 350–359.

Davis, M. A. and S. Van Nieuwerburgh (2014): "Housing, Finance and the Macroeconomy," NBER Working Papers 20287.

Del Negro, M., G. Eggertsson, A. Ferrero, and N. Kiyotaki (2011): "The great escape? A quantitative evaluation of the Feds liquidity facilities," Staff Reports 520, Federal Reserve Bank of New York.

Gan, J. (2007): "Collateral, Debt Capacity, and Corporate Investment: Evidence from a Natural Experiment," *Journal of Financial Economics*, 85.3, 709–734.

Garriga, C., R. E. Manuelli, and A. Peralta-Alva (2012): "A model of price swings in the housing market," Working Papers 2012-022, Federal Reserve Bank of St. Louis.

Hassler, J., P. Krusell, and C. Olovsson (2012): "Energy-Saving Technical Change," NBER Working Papers 18456.

Iacoviello, M. (2005): "House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle," *American Economic Review*, 95, 739–764.

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

Jermann, U. and V. Quadrini (2012): "Macroeconomic Effects of Financial Shocks," *American Economic Review*, 102, 238–271.

Justiniano, A., G. E. Primiceri, and A. Tambalotti (2013): "Household Leveraging and Deleveraging," NBER Working Papers 18941.

Khan, A. and J. K. Thomas (2013): "Credit Shocks and Aggregate Fluctuations in an Economy with Production Heterogeneity," *Journal of Political Economy*, 121, 1055 – 1107.

Kiyotaki, N., A. Michaelides, and K. Nikolov (2011): "Winners and Losers in Housing Markets," *Journal of Money, Credit and Banking, Blackwell Publishing*, 43, 255–296.

Kiyotaki, N. and J. Moore (1997): "Credit Cycles," *Journal of Political Economy*, 105, 211–48.

——— (2012): "Liquidity, Business Cycles, and Monetary Policy," NBER Working Papers 17934.

Kiyotaki, N. and K. D. West (2006): "Land Prices and Business Fixed Investment in Japan," in *Long Run Growth and Short Run Stabilization: Essays in Memory of Albert Ando*, ed. by L. Klein, Cheltenham: Edward Elgar, chap. 12, 303–337.

Kocherlakota, N. R. (2000): "Creating business cycles through credit constraints," *Federal Reserve Bank of Minneapolis Quarterly Review*, 2–10.

Lee, Y. and T. Mukoyama (2012): "Entry, exit and plant-level dynamics over the business cycle," Tech. rep., University of Virginia.

Lintner, J. (1956): "Distribution of Incomes of Corporations Among Dividends, Retained Earnings, and Taxes," *American Economic Review*, 43, 97–113.

Liu, Z., P. Wang, and T. Zha (2013): "Land Price Dynamics and Macroeconomic Fluctuations," *Econometrica, Econometric Society*, 81, 1147–1184.

Mendicino, C. (2012): "On the amplification role of collateral constraints," *Economics Letters*, 117, 429–435.

Mendoza, E. G. and V. Quadrini (2010): "Financial globalization, financial crises and contagion," *Journal of Monetary Economics*, 57, 24–39.

Mian, A. and A. Sufi (2014): *House of Debt: How They (and You) Caused the Great Recession, and How We Can Prevent It from Happening Again*, Chicago University Press.

Nolan, C. and C. Thoenissen (2009): "Financial shocks and the US business cycle," *Journal of Monetary Economics*, 56, 596–604.

Quadrini, V. (2011): "Financial Frictions in Macroeconomic Fluctuations," *Federal Reserve Bank of Richmond Economic Quarterly*, 97.3, 209–254.

Sakuragawa, M. and Y. Sakuragawa (2011): "Quantitative Impacts of the Asset Price Channel in the Credit-Constrained Economy," .

Shourideh, A. and A. Zetlin-Jones (2012): "External Financing and the Role of Financial Frictions over the Business Cycle: Measurement and Theory," Tech. rep., Wharton—University of Pennsylvannia.

Solow, R. M. (1957): "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, 39.3, 312320.

Taylor, J. B. (2009): "The Financial Crisis and the Policy Responses : An Empirical Analysis of What Went Wrong," Tech. rep., NBER Working Paper No. 14631.

A Recursive formulation

A.1 Firms' problem

$$
\begin{aligned}
J(z,k,l,b) = &\max_{d,n,v,k',b',l'} \left\{ d + Em'J(z',k',l',b') \right\} \\
&\text{subject to} \\
&\quad b + wn + x + qx_l = y + \frac{b'}{R} - \varphi(d) \\
&\quad \xi \left(Eq'l' + k' - \frac{b'}{1+r} \right) \geq y \\
&\quad l' = (1-\omega)l + x_l
\end{aligned}
$$

First order conditions

$$\begin{aligned} d: &\quad 1 - \lambda\varphi_d(d) = 0 \\ n: &\quad \lambda f_n - \lambda w - \mu f_n = 0 \\ k': &\quad Em' J'_k - \lambda + \mu\xi = 0 \\ b': &\quad Em' J'_b + \frac{\lambda}{R} - \frac{\mu\xi}{1+r} = 0 \\ l': &\quad Em' J'_l + \mu\xi Eq' - q\lambda = 0 \end{aligned}$$

Envelope conditions

$$\begin{aligned} J_k &= \lambda[1 - \delta_k + f_k] - \mu f_k \\ J_b &= -\lambda \\ J_l &= \lambda f_l + q\lambda(1-\omega) - \mu f_l \end{aligned}$$

A.2 Households' problem

$$\begin{aligned} V(h,s) = \max_{c,n,b',s'} &\left\{ u(c,n) + \beta EV(b',s') \right\} \\ \text{subject to} & \\ wn + qx_l + b + s(d+p_s) &= c + \frac{b'}{1+r} + s'p_s + T \\ 1 &= l \end{aligned}$$

First order conditions

$$\begin{aligned} c: &\quad u_c - \psi = 0 \\ n: &\quad u_n + w\psi = 0 \\ b': &\quad -\frac{\psi}{1+r} + \beta EV'_b = 0 \\ s': &\quad \beta EV'_s - \psi p_s = 0 \end{aligned}$$

Envelope conditions

$$\begin{aligned} V_b &= \psi \\ V_s &= \psi(d+p_s) \end{aligned}$$

A.3 Production function

$$y = c + x + \kappa \left(d - \bar{d}\right)^2$$

B Data sources and construction of variables

B.1 Data sources

Variable name: Price Index for Business Value Added
Source: BEA, NIPA, Table 1.3.4
Definition: Index 2005=100 (seasonally adjusted)

Variable name: Business Value Added ($\mathbf{y_t}$)
Source: BEA, NIPA, Table 1.3.5
Deflator used: Index for business value added (NIPA 1.3.4) (seasonally adjusted)

Variable name: Total private aggregate weekly hours ($\mathbf{n_t}$)
Source: BLS, Current Employment Statistics, national survey

Variable name: Capital expenditures in non-financial businesses
Source: Federal Reserve Statistical Release, Flow of Funds, Table F.101
Deflator used: Index for business value added (NIPA 1.3.4) (seasonally adjusted)

Variables names: Consumption of Fixed Capital in Non-Financial Corporate Business
Consumption of Fixed Capital in Non-Financial Non-Corporate Business
Source: Federal Reserve Statistical Release, Flow of Funds, Table F.8
Definition: Millions of US Dollars (Quarterly)
Deflator used: Index for business value added (NIPA 1.3.4) (seasonally adjusted)

Variable name: Nominal Market Value, Price and Quantity Index of Land
Source: Davis's (2009) database
Definition: 2 categories: non-corporate and corporate non-financial (quarterly)

Variables names: National Income
Compensation of employees
Taxes on production and imports
Source: BEA, NIPA, Table 1.12
Definition: Billions of US Dollars (Quarterly)

B.2 Construction of variables

B.2.1 Construction of the capital stock $\mathbf{k_t}$

In order to have quarterly values, capital stock is constructed recursively in the same way as described in the appendix of JQ. I pick the initial value of $\mathbf{k_t}$ for the last quarter of 1951 such that the capital-output ratio does not exhibit any trend over the period 1952-2010. *Depreciation* corresponds to the sum of *Non-Financial Corporate and Non-Corporate Business Consumption of Fixed Capital* and *Investment* to *Capital Expenditures in Non-Financial Business*.

$$\mathbf{k_{t+1}} = \mathbf{k_t} - \mathit{Depreciation}_t + \mathit{Investment}_t.$$

B.2.2 Construction of labor share in income $\mathbf{n_t^{SHARE}}$

The ratio of $\dfrac{\textit{Compensation of employees}}{\textit{National Income- Taxes on production and imports}}$ corresponds to $\mathbf{n_t^{SHARE}}$.

B.2.3 Construction of land ($\mathbf{l_t}$ and land share in income $\mathbf{l_t^{SHARE}}$

$\mathbf{l_t}$: sum of noncorporate and corporate nonfinancial indexes weighted by their respective share of market land values.

$\mathbf{l_t^{SHARE}}$: $\dfrac{\textit{Sum of noncorporate and corporate nonfinancial market land values}}{\textit{National Income- Taxes on production and imports}}$

C Results of tests

Table 6: Unit root tests (augmented Dickey-Fuller)

Number of lags	$\hat{\mathbf{y}}_\mathbf{t}-\hat{\mathbf{n}}_\mathbf{t}$	$\hat{\mathbf{k}}_\mathbf{t}-\hat{\mathbf{n}}_\mathbf{t}$	$\hat{\mathbf{y}}_\mathbf{t}-\hat{\mathbf{l}}_\mathbf{t}$	$\hat{\mathbf{n}}_\mathbf{t}^{\mathbf{SHARE}}$	$\hat{\mathbf{l}}_\mathbf{t}^{\mathbf{SHARE}}$
0	-1.991	-0.907	-2.36	-1.823	-0.106
1	-2.37	-1.783	-2.052	-1.956	-1.249
2	-2.912^{**}	-2.162	-2.083	-1.889	-1.925

The symbols *, ** and *** correspond respectively to 10, 5 and 1% significance levels.

Table 7: Unit root tests of series in first-differences (augmented Dickey-Fuller)

Number of lags	$\mathbf{\Delta}\left(\hat{\mathbf{y}}_\mathbf{t}-\hat{\mathbf{n}}_\mathbf{t}\right)$	$\mathbf{\Delta}\left(\hat{\mathbf{k}}_\mathbf{t}-\hat{\mathbf{n}}_\mathbf{t}\right)$	$\mathbf{\Delta}\hat{\mathbf{y}}_\mathbf{t}-\alpha\mathbf{\Delta}\hat{\mathbf{l}}_\mathbf{t}$	$\mathbf{\Delta}\hat{\mathbf{n}}_\mathbf{t}^{\mathbf{SHARE}}$	$\mathbf{\Delta}\hat{\mathbf{l}}_\mathbf{t}^{\mathbf{SHARE}}$
0	-13.984^{***}	-8.331^{***}	-17.195^{***}	-11.572^{***}	-6.198^{***}
1	-8.355^{***}	-5.87^{***}	-10.126^{***}	-9.219^{***}	-3.92^{***}
2	-8.424^{***}	-5.028^{***}	-7.145^{***}	-6.397^{***}	-3.385^{***}

The symbols *, ** and *** correspond respectively to 10, 5 and 1% significance levels.

Table 8: Co-integration tests (residual-based augmented Dickey-Fuller)

Number of lags	**Residuals $\hat{\mathbf{u}}_{\mathbf{1t}}$ of equation (??)**	**Residuals $\hat{\mathbf{u}}_{\mathbf{2t}}$ of equation (??)**
1	-1.906	-2.459
2	-2.296	-2.136
3	-2.894	-2.147

The symbols *, ** and *** correspond respectively to 10, 5 and 1% significance levels.