Business Cycles, Land Dynamics and Financial Shocks

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Abstract

I reexamine the amplification mechanism of Kiyotaki and Moore (1997) and find that the endogenous propagation of productivity shocks is muted if the collateral asset, land, is elastically supplied. However, exogenous maximum allowable ratio of loans to collateral, *financial shocks*, lead to a considerable reallocation of the asset from patient to impatient agents. I show that this type of shock is an important source of business cycle fluctuations. Moreover, the estimate of the elasticity of substitution between land and capital from an aggregate CES production function is 0.25. Hence, for a reasonable choice of parameters, if the standard assumption of a unitary elasticity of substitution is cut by quarter, I find additional amplification effects.

JEL identification: E32, E44, R33

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"*But though credit is never anything more than a transfer from hand to hand, it is generally, and naturally, a transfer to hands more competent to employ the capital efficiently in production.*"(John Stuart Mill, 1848)

1 Introduction

From credit crunch to downturn in economic activity, the Great Recession has indisputably shed light on the linkages between financial markets and business cycle fluctuations. The recent episode of coincident business and credit cycles is, however, far from being unique. Based on a sample that covering a large number of advanced and emerging economies over a long period of time (1960:Q1-2007:Q4), Claessens, Kose, and Terrones (2011) have documented the cyclical behavior of credit and asset prices during the booms and busts phases of cycles.[1] They also find that house prices busts tend to be associated with prolonged recessions. These findings suggest that the framework of analysis should depart from a complete markets environment and should lead researchers to investigate which mechanisms are important for the transmission of financial flows to the real economy.

In a synthesis of recent developments in the macro-finance literature, Quadrini (2011) classifies propagation channels into two broad categories: amplification and financial shocks. Financial frictions can play a role in amplifying and propagating shocks that do not emanate from the financial sector, whereas financial shocks can also have direct effects on real economic activity. The scope of this paper is essentially to compare the effectiveness of these two channels in a framework in which land and real estate dynamics play a prominent role.

Financial frictions are characterized by an endogenous borrowing constraint that arises from a limited enforcement problem. The approach that I favor is to introduce heterogenous economic agents who discount the future at different rates, so that borrowers are impatient and lenders are patient. Liquidation costs related to asset redeployment also induce lenders to accept contracts for which loans are a fraction of the value of borrowers' assets. The model that I develop is based on Kiyotaki and Moore's (1997) type of collateral constraint. In their framework, a positive productivity shock leads to a rise in the value of a collateralized asset available in fixed supply, such as land, thereby allowing the borrowing constraint to be relaxed. Therefore, more assets are allocated to borrowers that have a higher marginal productivity and output movements are amplified.

[1]From US micro-data, Covas and Den Haan (2011) find that the two financing means of firms: debt and equity are cyclical. Moreover, Reinhart and Rogoff (2009), in their historical survey of crisis periods, highlight the role that financial variables have played.

I also introduce the idea of working capital as an additional financial friction. It is important to note that my results are robust to different borrowing constraint characterizations, but this particular one has the advantage of being derived from a micro-founded debt renegotiation problem. Since factors of production need to be paid before revenues are recouped, firms contract both *inter-period debt* and interest-free *intra-period loans* and use productive assets as collateral. This introduces a distortion between the marginal product of labor and the wage. Embedding this characterization, I compare the explanatory power of land dynamics to the main source of business cycles according to Jermann and Quadrini (2012): labor demand fluctuations.[2]

The type of financial shocks that are examined in this paper are similar to those considered by Jermann and Quadrini (2012) and Perri and Quadrini (2011). These shocks alter the fraction of the collateralized asset that can be repossessed by lenders. Many factors such as waves of optimism and pessimism, regulations and financial innovations are contributors to these shocks emanating from the financial sector. For Jermann and Quadrini (2009) the nature of these shocks is very broad: "something changing the ability of borrowers to raise funds". In this paper, I do not explore the causes of movements in financial shocks or "financial market freezes", see *e.g.* Acharya, Gale, and Yorulmazer (2011) and Chiu and Koeppl (2011) for micro-founded approaches of sudden financial market disruptions.[3]

Even though borrowing constraints and financial shocks are similar to Jermann and Quadrini (2012) and Perri and Quadrini (2011) in this paper I place a greater emphasis on the role of commercial real estate and its interactions with capital rather than labor demand fluctuations. Following Davis and Heathcote (2007), real estate can be decomposed into land and structures components, so that commercial land and capital have different properties. As highlighted by Shleifer and Vishny (1992) in their analysis of Williamson's (1988) concept of asset redeployment, commercial land has a higher liquidation value than capital since it has more alternative uses.

Housing markets also have received much attention during the recent financial crisis that has shadowed the importance of land as a collateral asset for firms' investment decisions. The 1990's Japanese land market collapse is often used as an example to study the importance of commercial real estate in business cycles. Gan (2007) finds evidence of a significant collateral channel, so

[2]Working capital requirements have been used extensively in the monetary economics literature, but have also been embedded in non-monetary models, see Neumeyer and Perri (2005). The approaches put forward by Mendoza (2010), Jermann and Quadrini (2012) and Perri and Quadrini (2011) aim at reconciling working capital with other financial frictions.

[3]Many advances have been realized on the ground of identification. From a borrowing constraint that is always binding, Jermann and Quadrini (2012) retrieve a financial shock analogously to the Solow residual from a production function. The shock identified by Benk, Gillman, and Kejak (2005) involves policy regulatory changes in the banking sector. From a structural FAVAR model, Gilchrist, Yankov, and Zakrajsek (2009) find that shocks originating from the corporate bond market are important contributors to downturns in economic activity. The importance of contractions in credit supply is reassessed with the construction of a credit spread index in Gilchrist and Zakrajsek (2011).

that a 10% decrease in land value led to a drop in the investment rate of 0.8%. That should not be surprising considering that the Bank of Japan reports that 70% of loans are backed by land. For the U.S. booming commercial real estate market (1993-2007), Chaney, Sraer, and Thesmar's (2012) findings point to the fact that U.S. corporate firms increase their investment by $0.06 for every additional $1 increase in the value of their collateral. Contrary to Japan, it is not possible to obtain a ratio of loans to the value of land for the U.S. corporate sector. However, Berger and Udell (1990) find that collateral is pledged for over 70% of commercial and industrial loans. Since tangible assets are assets that can be more easily repossessed by banks and since commercial real estate corresponds to 58% of tangible assets,[4] this suggest that investigating land dynamics is fundamental.

In this paper, I adapt the framework of Kiyotaki and Moore (1997) in order to match more closely key characteristics of the real estate market. I relax the assumption of inelastic land supply and introduce land developers that react to changes in land prices. I present empirical evidence in the next section that point to elastic land supply even at business cycle frequencies. In the theoretical exercise that I pursue, I find that allowing for elastic land supply partially shuts down the price channel that is central to the amplification mechanism. Therefore, in this environment there does not seem to be any value-added to use a model that encompasses borrowing-constrained agents. In contrast, financial shocks lead to smoother responses of land prices or in some cases cause land prices to drop, so that the lending rate does not appreciate as much. Hence, more borrowing occurs due to an increase in the quantity of land owned by borrowers rather than a price appreciation of this asset.

An additional finding is that financial shocks lead to considerable reallocation of land from lenders to borrowers and generate more endogenous fluctuations in output than productivity shocks. Augmenting the benchmark model with reproducible capital, I also find that the elasticity of substitution between land and capital can greatly affect the size of output responses to financial shocks. Hence, for a reasonable choice of parameters, if the standard assumption of a unitary elasticity of substitution is cut by half, I find an additional amplification of over 50%. In comparison, labor market dynamics that are central to Jermann and Quadrini's (2012) results do not seem to affect output fluctuations as much.

This paper contributes to the debate on the quantitative effects of the mechanism proposed by Kiyotaki and Moore (1997) to enhance productivity shocks. Córdoba and Ripoll (2004) and Kocherlakota (2000) present a very skeptical view of the amplification channel, but yet they still find small effects. My results are much starker as they point to lower amplification effects than for a representative-agent framework following a productivity shock. In fact, from an extensive calibration exercise, Córdoba and Ripoll (2004) argue that only the right combination of parameters can

[4] This ratio is compiled by Liu, Wang, and Zha (2011) from Flow-of-Funds tables made available by the Federal Reserve Board.

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 Córdoba and Ripoll (2004), Mendicino (2011) 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. I find, however, that these effects vanish once an elastic land supply is assumed. In fact, the stock of non-farm land varies across business cycles due to zoning regulations for example.

In the macro real estate literature, most studies have focused on residential real estate and commercial real estate seems to have been left aside. 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 (2011) 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. 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 model.

Finally, my paper is particularly close to the work of Sakuragawa and Sakuragawa's (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. In contrast to my model, reallocation of land occurs between residential and commercial sectors so that households' land holdings shrink considerably. In a framework that features elastic land supply and reallocation of land across firms, I find that productivity shocks have negligible effects.

The remainder of this paper is organized as follows. In section 2, I present some stylized facts on land dynamics. Section 3 lays out the baseline model in which the production side of the economy is collateralized. In section 4, I calibrate the model along the lines of Mendicino's (2011) in order to have a better understanding of the role of elastic land supply. In section 5, results of the baseline model's estimation are analyzed and a sensitivity analysis with regards to factor shares is performed. In section 6, I conclude and propose some extensions.

2 Commercial land stylized facts

2.1 Elasticity of land supply

Use of land changes throughout time as farmland can be substituted by urban land for residential or commercial uses. Around the years of the U.S. housing boom, Shiller (2007) argued that

> "there is reason to expect that as existing urban land becomes very expensive to structures, there will be efforts to substitute away from that land [...]."

This implies that zoning is endogenous. [5] A demand shock that puts upward pressure on land prices may lead local authorities to change zoning from farmland to urban, since the city or municipality would benefit from higher property tax revenues. Glaeser, Gyourko, and Saks (2005) find evidence that rights to build and other regulatory constraints significantly affect housing prices. Glaeser and Gyourko (2008) also argue that the rapid population growth experienced by cities in Sun Belt states during the recent housing boom is due to quick changes in zoning of farmland to urban land. Moreover, cities across the country compete to attract firms to relocate or start up their productive activities. Cheaper developable land for which zoning has recently been changed can be a good selling point. This extensive margin can be important for land supply fluctuations at business cycle frequency.

2.2 Elasticity of substitution between land and capital

Most theoretical work uses a Cobb-Douglas production function to aggregate land, capital and labor thereby assuming a unitary elasticity of substitution. However, there is some empirical evidence that points out to the existence of greater levels of complementarity. From Japanese data on non-financial corporations, the estimates of Sakuragawa and Sakuragawa (2011) suggest an elasticity of 1/3. For the United States residential sector, Albouy and Ehrlich (2012) obtain a point estimate of 0.49 for metropolitan areas, although they cannot reject unity. 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. To my knowledge, no work has focused on estimating this elasticity for the U.S. commercial real estate sector at a national level. I follow Solow's (1957) methodology that

[5] See McMillen and McDonald, 1991 for implications of endogenous zoning on urban land value functions.

involves assuming perfect competition on input markets and a production function that exhibits constant returns to scale. [6]

The constant elasticity of substitution (CES) production function is given by

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

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 ψ represents land's weight relative to capital in the production function. I also assume decreasing returns to scale for the aggregation of capital and labor, so that $0 < \alpha < 1$. In the case of a Cobb-Douglas production function, *i.e.* $\lim_{\phi\to 0} y_t$, $(1-\psi)\alpha$ corresponds to the elasticity of output with respect to the capital/labor composite and $\psi\alpha$ 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 land and labor shares of output that consist of the following equations:

$$n_t^{SHARE} = \frac{\partial y_t}{\partial n_t}\frac{n_t}{y_t} = (1-\alpha)(1-\psi)\left(\frac{a_t k_t^{\alpha} n_t^{1-\alpha}}{y_t}\right)^{-\phi}, \quad (1)$$

$$l_t^{SHARE} = \frac{\partial y_t}{\partial l_t}\frac{l_t}{y_t} = \psi\left(\frac{a_t^L l_t}{y_t}\right)^{-\phi}. \quad (2)$$

Hence, factor shares 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. From equations (1) and (2), the factor augmenting technologies can be isolated as follows:

$$a_t = \left(\frac{y_t}{k_t^{\alpha} l_t^{1-\alpha}}\right)\left(\frac{n_t^{SHARE}}{(1-\alpha)(1-\psi)}\right)^{-1/\phi}, \quad (3)$$

$$a_t^L = \left(\frac{y_t}{l_t}\right)\left(\frac{l_t^{SHARE}}{\psi}\right)^{-1/\phi}. \quad (4)$$

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

Table 1: 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 2: Unit root tests of series in first-differences (augmented Dickey-Fuller)

Number of lags	$\mathbf{\Delta}(\hat{\mathbf{y}}_\mathbf{t} - \hat{\mathbf{n}}_\mathbf{t})$	$\mathbf{\Delta}\left(\hat{\mathbf{k}}_\mathbf{t} - \hat{\mathbf{n}}_\mathbf{t}\right)$	$\mathbf{\Delta}\hat{\mathbf{y}}_\mathbf{t} - \alpha\mathbf{\Delta}\hat{\mathbf{l}}_\mathbf{t}$	$\mathbf{\Delta}\hat{\mathbf{n}}_\mathbf{t}^\mathbf{SHARE}$	$\mathbf{\Delta}\hat{\mathbf{l}}_\mathbf{t}^\mathbf{SHARE}$
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.

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 (3) and (4) have the following form:

$$\begin{aligned}
\hat{a}_t &= \hat{y}_t - \alpha\hat{k}_t - (1-\alpha)\hat{n}_t - \frac{1}{\phi}\hat{n}_t^{SHARE}, \\
\hat{a}_t^L &= \hat{y}_t - \hat{l}_t - \frac{1}{\phi}\hat{l}_t^{SHARE}.
\end{aligned}$$

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 technology deviations around trend $\hat{a}_t$ and $\hat{a}_t^L$ are minimized:

$$Y_t = \alpha X_t + \frac{1}{\phi} Z_t + u_t \tag{5}$$

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 $u_t = \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix}$.

However, before proceeding with the estimation, I test the stationarity of time series that are

Table 3: Co-integration tests (residual-based augmented Dickey-Fuller)

Number of lags	**Residuals $\hat{\mathbf{u}}_{\mathbf{1t}}$ of equation (5)**	**Residuals $\hat{\mathbf{u}}_{\mathbf{2t}}$ of equation (5)**
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.

Table 4: Estimation of the elasticity of substitution

Elasticities

$$\widehat{\epsilon} = \underset{(0.0249)}{0.235} \qquad \widehat{\alpha} = \underset{(0.0727)}{0.237}$$

Covariance matrix

$$\widehat{\Sigma} = 10^{-3} \times \begin{pmatrix} 0.0625 & 0.0717 \\ 0.0717 & 0.4401 \end{pmatrix}$$

The standard errors of the estimates are inside parentheses.

comprised in Y_t, X_t and Z_t. The results of the augmented Dickey-Fuller tests reported in Tables 1 and 2 indicate that all series are integrated of order one ($I(1)$). Moreover, I estimate equation (5) by OLS and test the stationarity of residuals. The results of the residual-based augmented Dickey-Fuller tests are reported in Table 3. They suggest that the null hypothesis of zero co-integrating vectors cannot be rejected. Hence, I estimate the system of equations in first differences as follows:

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

where $\Delta Y_t \equiv Y_t - Y_{t-1}$, $\Delta X_t \equiv X_t - X_{t-1}$, $\Delta Z_t \equiv Z_t - Z_{t-1}$ and $e_t \equiv u_t - u_{t-1}$.

From U.S. quarterly data that spans from 1960Q1 to 2007Q4, I find an estimate for $\widehat{\left(\frac{1}{\phi}\right)}$. Using the delta method, I compute the estimated elasticity $\widehat{\epsilon} = \left(\frac{1}{1+\widehat{\phi}}\right)$ and the approximation of its standard error $\widehat{\sigma_\epsilon}$ that I report in Table 4 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 below.

3 The model

The model is based on Kiyotaki and Moore (1997) in which firms face endogenous borrowing constraints. I assume an additional factor of production and collateral asset to land that is capital. Moreover, there are two types of agents with different discount factors, so that firms are either owned by patient or impatient agents.

All firms are atomistic and the only difference between them is the way their investors discount the future: they can either be patient ($i = 1$) or impatient ($i = 2$). Hence, discount factors are ordered in the following way: $1 > \beta_1 > \beta_2$, so that firms owned by patient investors have a higher discount factor than those owned by impatient investors. In equilibrium, patient investors are lenders and impatient investors are borrowers. The parameter $\omega \in (0, 1)$ corresponds to the fraction of patient investors. Population grows at constant rate η and all variables of the model are expressed in per-capita terms. It should be noted that the version of the model described below is the most general one and the interpretation of special cases is discussed in the results section.

3.1 Firms

Output is given by

$$f(z_t, k_{it-1}, l_{it-1}, n_{it}) = \begin{cases} z_t \left(\psi \frac{l_{it-1}}{1+\eta}^{-\phi} + (1-\psi) \left(\frac{k_{it-1}}{1+\eta}^{\alpha} n_{it}^{1-\alpha} \right)^{-\phi} \right)^{-\frac{1}{\phi}} & \phi \neq 0 \\ z_t (1+\eta)^{-\alpha} l_{it-1}^{\psi} k_{it-1}^{(1-\psi)\alpha} n_{it}^{(1-\psi)(1-\alpha)} & \phi = 0 \end{cases} \tag{6}$$

where z_t denotes an exogenous productivity shock common to both types of investors, l_{it-1} denotes land, k_{it-1} denotes capital and n_{it} is total labor 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 capital and ψ 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 $0 < \alpha < 1$. In the case of a Cobb-Douglas production function, *i.e.* $\phi = 0$, $\psi\alpha$ corresponds to the elasticity of output with respect to land and $(1 - \psi)\alpha$ the elasticity of output with respect to capital.

Firms' capital accumulation is subject to depreciation and to an adjustment cost similar to that described in ? that is the following:

$$k_{it} = (1-\delta)\frac{k_{it-1}}{1+\eta} + \left(\left(\frac{g_{1k}}{1-\phi_k}\right)\left(\frac{x_{it}(1+\eta)}{k_{it-1}}\right)^{1-\phi_k} + g_{2k}\right)\frac{k_{it-1}}{1+\eta} \tag{7}$$

where x_{it} corresponds to investment, δ to the depreciation rate, and $1/\phi_k$ to the elasticity of investment with respect to Tobin's q that is denoted as Q_{kit}. The other parameters, g_{1k} and g_{2k}, are set so that Tobin's q is equal to 1 in the steady state.

Land is purchased from land developers and is also subject to installation costs. The equation of land accumulation is as follows:

$$l_{it} = \frac{l_{it-1}}{1+\eta} + \left(\left(\frac{g_{1l}}{1-\phi_l}\right)\left(\frac{x_{lit}(1+\eta)}{l_{it-1}}\right)^{1-\phi_l} + g_{2l}\right)\frac{l_{it-1}}{1+\eta} \tag{8}$$

where x_{lit} corresponds to firm-specific investment in land. that is $1/\phi_l$ corresponds to the elasticity of investment in land with respect to Tobin's q that is denoted as Q_{lit}. The roles of the other parameters, g_{1k} and g_{2k}, are similar to the ones of capital adjustment costs and are set so that Tobin's q is equal to 1 in the steady state. Hence, outside the model's steady state, movements in the price of land originate from two sources: the price set by land developers q_t and Tobin's q Q_{lit}.

At the end of each period, firms recover revenues from the sales of their production that can be used by both firms and investors as consumption or investment goods. Their budget constraint is as follows:

$$d_{it} + w_{it}n_{it} + x_{it} + q_t x_{lit} + \frac{b_{it-1}}{1+\eta} = f(z_t, k_{it-1}, l_{it-1}) + \frac{b_{it}}{R_t}. \tag{9}$$

Firms pay out dividends d_{it} and the wage bill $w_{it}n_{it}$ to households, invest x_{it}, buy or sell land at price q_t and incur new debt at interest rate R_t so that their net new borrowing corresponds to $\frac{b_{it}}{R_t} - \frac{b_{it-1}}{1+\eta}$. 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*:

$$\ell_{it} = d_{it} + w_{it}n_{it} + x_{it} + q_t x_{lit} + \frac{b_{it-1}}{1+\eta} - \frac{b_{it}}{R_t} \tag{10}$$

from investors that do not own or work for the firm, so that $\ell_{it} = f(z_t, k_{it-1}, l_{it-1}, n_{it})$. In equilibrium, firms that are owned by impatient investors will borrow from the ones that are owned by patient investors. Since debt is not perfectly enforced, firms that borrow may decide not to honor their contract at the end of the period. In that event, a stochastic fraction ξ_t of their collateralized assets would be seized and liquidated in the next period. Variation in this fraction corresponds to the financial shocks.

I also assume that lending firms must go through a liquidation process and cannot directly use the repossessed assets to produce. The value of liquidated assets would be $\xi_t(q_{t+1}l_{it} + \vartheta k_{it})$ where ϑ controls capital degree's of liquidity relative to that of real estate. I refer the reader to Perri and Quadrini's (2011) appendix that shows that a Pareto-optimal allocation can be reached in the event of no default so that firms have the following borrowing constraint:

$$b_{it} + f(z_t, l_{it-1}, k_{it-1}) \leq \xi_t \left(E_t \left(q_{t+1}l_{it}\right) + \vartheta k_{it}\right). \tag{11}$$

On the left-hand side of equation (11), overall borrowing that corresponds to the sum of *inter-period debt* and *intra-period loans* cannot exceed a fraction of land and capital expected values. Since firms face working capital requirements, an increase in current production tightens their inter-period borrowing. Lending and borrowing firms are both rational and have the same information and expected price of next period's land at the end of the period when borrowing firms can default. I assume that borrowing firms have all the bargaining power. I formulate the optimization problem recursively as follows:

$$V(\mathbf{s}; n_i, k_i, l_i, b_i) = \max_{d_i, n_i, k_i', x_i, l_i', x_{li}, b_i'} \left\{d_i + E_i m_i' V(\mathbf{s}'; n_i', k_i', l_i', b_i')\right\} \tag{12}$$

subject to:

$$b_i + w_i n_i + d_i + x_i + q x_{li} = f(z, k_i, l_i, n_i) + \frac{b_i'(1+\eta)}{R},$$

$$\xi(E_i q' l_i' + \vartheta k_i') \geq \frac{b_i'}{R} + f(z, k_i, l_i, n_i),$$

$$(1+\eta)k_i' = (1-\delta)k_i + \left(\left(\frac{g_{1k}}{1-\phi_k}\right)\left(\frac{x_i}{k_i}\right)^{1-\phi_k} + g_{2k}\right) k_i,$$

$$(1+\eta)l_i' = l_i + \left(\left(\frac{g_{1l}}{1-\phi_l}\right)\left(\frac{x_{li}}{l_i}\right)^{1-\phi_l} + g_{2l}\right) l_i.$$

The value of the firm $V(\mathbf{s}; n_i, k_i, l_i, b_i)$ is characterized by the aggregate state variable $\mathbf{s}$, labor n_i, capital k_i, land l_i and inter-period debt b_i. In any given period, it is defined as the sum of its current dividends and the expected continuation value that is discounted at stochastic factor m_i. The investors' optimization problem determines the value of this factor. Firms face budget, borrowing and capital accumulation constraints with corresponding Lagrange multipliers θ_i, λ_i and Q_i. In order to simplify the equations, I substitute the first order condition for d_i, $\theta_i = 1$ into the remaining ones for b_i', n_i, x_i, k_i', l_i' and obtain:

$$
\begin{aligned}
1 &= REm'_i + \lambda_i, && (13) \\
w_i &= f_{n_i}(1-\lambda_i), && (14) \\
Q_{ki} &= g_{1k}\left(\frac{k_i}{(1+\eta)x_i}\right)^{\phi_k}, && (15) \\
Q_{li} &= g_{1k}\left(\frac{l_i}{(1+\eta)x_{li}}\right)^{\phi_l}, && (16)
\end{aligned}
$$

$$
Q'_{ki}\left[1-\delta+g_{2k}+g_{1k}\left(\frac{\phi_k}{1-\phi_k}\right)\left(\frac{x_i}{k_i}\right)^{1-\phi_k}\right]+\lambda_i\vartheta\xi-\lambda'_i f_{k'_i}, \quad (17)
$$

$$
\begin{aligned}
Q'_{li}q &= Em'_i\left(f_{l'_i}+Q'_{li}q'\right)+\lambda_i\xi Eq'-\lambda'_i f_{l'_i}, && (18) \\
\lambda_i &\geq 0, && (19) \\
0 &= \left(b'_i+f(z,k_i,l_i)-\xi\left(Eq'l_i+\vartheta k_i\right)\right)\lambda_i && (20)
\end{aligned}
$$

The last two equations (18-19) are Kuhn-Tucker conditions. In the case of firms owned by patient investors, the borrowing constraint is never binding so that λ_1 is equal to zero. I assume that the distance between the discount factors β_1 and β_2 is large enough and shocks sufficiently small to ensure that the borrowing constraint of firms owned by impatient investors is always binding ($\lambda_2 > 0$).[7] That implies from equation (13) that their discount rate is always greater than the interest rate.

Financial frictions add a distortion to the optimization problem of the borrowing firms. From equation (14), the working capital constraint implies that the marginal labor productivity of borrowing firms does not equal the wage. Hence, this ensures the presence of a "labor wedge" between the marginal rate of substitution of consumption and leisure and marginal product of labor, a distortion that would not arise in a complete markets environment.

3.2 Households

The owners of the firms, households, receive dividends d_{it} every period and maximize the utility function: $E_{i0}\sum_{t=0}^{\infty}\beta_i^t u(c_{it}, n_{it})$. They face the following budget constraint: $s_{it}(d_{it}+p_{it})+w_{it}n_{it} = c_{it}+p_{it}s_{it+1}$, where s_{it} corresponds to equity shares and p_{it} to the market price of those shares. They optimize with respect to their levels of shares, consumption and hours worked.

[7] The estimation of the model by the parameterized expectations approach allows me to confirm that the assumption of a binding constraint is reasonable for the calibrated values of the parameters that I describe in the next section.

The combination of the two first order conditions leads to

$$p_{it}u'(c_{it}) = \beta_i E_{it}\left(u'(c_{it+1})(d_{it+1} + p_{it+1})\right), \tag{21}$$

so that, by forward substitution, the market price of shares is equal to the discounted sum of expected dividends: $p_{it} = E_{it}\sum_{j=1}^{\infty}\left(\beta_i\left(\frac{u'(c_{it+1})}{u'(c_{it})}\right)\right)$. Since the price of the shares coincide with the value of the firm, the stochastic discount factor is $m_{it+j} = \beta_i E_{it+j}\left(\frac{u'(c_{it+j})}{u'(c_{it})}\right)$.

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

$$-\frac{u'_{n_{it}}}{u'_{c_{it}}} = w_{it} \tag{22}$$

3.3 Land developers

I depart from Córdoba and Ripoll (2004) and Mendicino's (2011) models in relaxing the assumption that total land supply for use in production is fixed. Hence, since land supply is not completely inelastic, I assume there exists a different category of firms, called developers, that clears land or buys it from the agricultural sector and sells it to producers at price q_t.[8] This market is competitive, so that, in equilibrium, a zero-profit condition applies. I assume myopic land developers that optimize with respect to total commercial land supply $\bar{l}_t$ and developments in land holdings $\bar{x}_{lt}$, so that their maximization problem is as follows:

$$\max_{\bar{l}_t, \bar{x}_{lt}} \Pi_t = q_t\left(\bar{l}_t - \frac{\bar{l}_{t-1}}{1+\eta}\right) - \bar{x}_{lt}$$

subject to:

$$\bar{l}_t = \frac{\bar{l}_{t-1}}{1+\eta} + \bar{x}_{lt}\left(\frac{\bar{l}_{t-1}}{1+\eta}\right)^{-\zeta} \tag{23}$$

The constraint describes the accumulation process for land and allows investment costs. The cost of one additional unit of land faced by land developers corresponds to $\frac{\bar{x}_{lt}}{\bar{l}_t - \frac{\bar{l}_{t-1}}{1+\eta}} = \frac{l_{t-1}}{1+\eta}^{\zeta}$. If $\zeta = 0$, land accumulates in a similar fashion to capital with no depreciation. At the other extreme, if $\zeta \to \infty$, land supply is fixed. From the land developers' problem, the implied inverse land supply function is given by:

$$q_t = \left(\frac{\bar{l}_{t-1}}{1+\eta}\right)^{\zeta} \tag{24}$$

[8] Alternatively, I could assume that land developers buy land permits from the government.

where ζ corresponds to the inverse of land supply elasticity, so that it controls how much land prices react to developments in land supply. Since firms face adjustment costs, the measured aggregate price of land $\overline{q}_t$ also comprises Tobin q's of both types of firms, so that

$$\overline{q}_t = q_t \frac{\sum_{i=1}^{2} Q_{lit} l_{it}}{\overline{l}_t}.$$

3.4 Shocks

Shocks are stochastic, so that Γ corresponds to a 2×2 persistence matrix, and A_t consists of a matrix of productivity and financial shocks as described by the following equation:

$$A_t = \Gamma A_{t-1} + \varepsilon_t, \varepsilon_t \sim N(0, \Sigma) \tag{25}$$

where $A_t = [z_t, m_t]'$ and $\varepsilon_t = [\varepsilon_{z_t}, \varepsilon_{\xi_t}]'$ that is the innovations matrix. Elements off the diagonal of matrix Γ are defined as spill-overs. The variance-covariance matrix is given by $E_t(\varepsilon_t \varepsilon_t') = \Sigma$.

3.5 Market Clearing

The land market clears since land developers sell all new parcels of commercial land to firms, as summarized by the following equation:

$$\omega l_{1t} + (1 - \omega) l_{2t} = \overline{l}_t. \tag{26}$$

Moreover, the bond market clearing condition is:

$$\omega b_{1t} + (1 - \omega) b_{2t} = 0. \tag{27}$$

Since firms and investors have the same effective discount factor, all dividends are consumed:

$$d_{it} = c_{it} \qquad \text{for } i = 1, 2. \tag{28}$$

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

$$Y_t = \omega f_{1t} + (1 - \omega) f_{2t} = \omega(c_{1t} + x_{1t} + q_t x_{l1t}) + (1 - \omega)(c_{2t} + x_{2t} + q_t x_{l2t}). \tag{29}$$

where Y_t corresponds to total output for the economy.

3.6 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 shocks A_t summarized by (25), aggregate land $\overline{L}_{t-1}$ 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 $d_{it}(\boldsymbol{s}_t)$,$n_{it}(\boldsymbol{s}_t)$,$b_{it}(\boldsymbol{s}_t)$,$k_{it}(\boldsymbol{s}_t)$, $l_{it}(\boldsymbol{s}_t)$;
(ii) investors' policies $c_{it}(\boldsymbol{s}_t)$,$s_{it}(\boldsymbol{s}_t)$,$n_{it}(\boldsymbol{s}_t)$
(iii) real estate developers' policies $\overline{l}_t(\boldsymbol{s}_t)$, $\overline{x}_{lt}(\boldsymbol{s}_t)$;
(iv) land prices q_t *and the lending rate* R_t;
(v) law of motion of the aggregate state $\boldsymbol{s}_{t+1} = \Psi(\boldsymbol{s}_t)$.

Such that:

(i) firms' policies satisfy conditions (13-19);
(ii) households' policies satisfy conditions (21-22);
(iii) land developers' policies satisfy conditions (24);
(iv) interest rates and prices clear the bond and land markets (26-27);
(v) the resource constraint (29) is satisfied.

4 Econometric methodology

Parameters are subdivided in two categories and their values are chosen in order to match U.S. quarterly data. The first category consists of parameters that are calibrated, either determined outside the model or chosen to match steady-state ratios. While the second category includes parameters that are estimated by minimizing the distance between empirical impulse responses and moments and their counterparts that are estimated from the model's simulated data.

4.1 Preferences and technology parameters

The calibrated parameters are reported in Table 5. Population growth η is set to match the average quarterly population growth in the United States from 1960 to 2008. The fraction of investors that are borrowing-constrained is set to 0.5, a level that is consistent with Campbell and Mankiw's (1990) estimates of households that face credit constraints. The households' utility function is

Table 5: Calibration

Symbol	Value	Definition
Population		
η	0.365%	population growth
ω	0.5	fraction of lenders
Preferences		
χ_1	1.98	hours worked of the patient investor ($n_1 = 0.3$)
χ_2	2	hours worked of the impatient investor ($n_2 = 0.3$)
β_1	0.99	patient investor discount factor
β_2	0.97	impatient investor discount factor
Technology		
δ_k	0.025	k depreciation rate
ζ	1	inverse land supply elasticity
ς=1/(1+ϕ)	0.25	elasticity of sub. between land and capital
α	0.26	elasticity of capital with respect to the capital/labor composite
ψ	0.12	elasticity of land with respect to output
Credit		
$\bar{\xi}$	0.8	enforcement parameter in s.s.
ϑ	0.68	fraction of capital collateralized relative to land in s.s.

separable and takes the form: $u(c_{it}, l_{it}) = \log(c_{it}) + \xi_i \log(1 - n_{it})$ where ξ_i is chosen so that households spend 30% of their time at work. The patient households' discount factor β_1 is chosen to imply a 4% annual risk-free interest rate. Since impatient households face a shadow price of borrowing, I follow Bernanke, Gertler, and Gilchrist (1999) and set the impatient household discount factor β_2 so that the interest premium ($\frac{\lambda_2}{\beta_2}$) is two percent. The capital depreciation rate δ is 2.5% on a quarterly basis so that it corresponds to 10% annually.

As for the parameter that controls the inverse commercial land supply elasticity ζ, to my knowledge no estimation has been performed for the United States' commercial land sector. However, Saiz (2010) estimates local housing supply elasticity and, from his sample of metropolitan statistical areas, finds a mean value of 1.17 and a median value of 0.9. At a national level, Topel and Rosen's (1988) estimates suggest a short-run (one-quarter) housing supply elasticity of 1.0. Hence, I set $\zeta = 1$ and consider the sensitivity of my results to alternative values for this parameter. One key parameter for which the United States commercial land literature is silent is the one that controls the elasticity of substitution between land and capital ς. From the estimation pursued in section 2.2, I set $\varsigma = 0.25$.

Another set of parameters are jointly chosen to match steady-state ratios that are the

The enforcement parameter is set to 0.7 in line with Sakuragawa and Sakuragawa (2011) who refer to banking practices in Japan. This value is also at midpoint of the loan-to-value parameters estimated by Iacoviello's (2005) that are 0.89 for entrepreneurs and 0.55 for impatient households.

The parameter that controls the share of land in the production function, ψ, is set to match the ratio of commercial land over capital of non-financial businesses $\frac{q\bar{l}}{k_1 + k_2}$. I make use of Davis's (2009) decomposition of the market value of non-financial real estate into market values of structures and land in order to retrieve a ratio of one over the other for a time period that spans from 1952Q1 to 2007Q4. The land-capital ratio is adjusted in two ways. First, since the price index of capital in structures has increased more than the CPI and, in my model, capital and consumption take the same price, the denominator is deflated. Second, I use Gomme and Rupert's (2007) estimates of the weight of capital in structures in total non-residential capital. The ratio's average from these two adjustments corresponds to 0.12 for the time-period that I study. I calibrate ψ to match it in the steady-state.[9]

Moreover, I assume that capital cannot be liquidated as easily as commercial land, so that $\vartheta < 1$. I refer to Williamson's (1988) concept of assets' redeployment. In the event of a default to repay their debt, the firm that repossess the assets can use commercial land for different uses, whereas capital can be industry-specific or firm-specific. The steady-state target that ϑ is chosen to match is the ratio of inter-period debt over output for non-financial businesses. I use financial data from the Flow of Funds Account of the Federal Reserve Board for non-financial corporate and non-corporate credit market instruments (Table B.102, line 22 and Table B.103, line 25) and for non-financial businesses income before taxes (Table F.101, line 1) from 1952Q1 to 2007Q4 and find a ratio of 3.65.

For calibrated values of the persistence and volatility of shocks, since I present impulse responses only I do not proceed to any estimation. I follow a common practice in the real business cycle literature for productivity shocks and assume that they follow a $AR(1)$ process for which persistence parameters are 0.95. Thus far, there is no interaction between both types of shocks. Hence, elements off the diagonal matrices Γ and Σ are equal to zero. Note that the Solow residual typically estimated does not correspond to the exogenous productivity shock considered here, since capital and land reallocation lead to endogenous total factor productivity disturbances. Total factor productivity is instead computed as follows:

$$TFP_t = \frac{f(z_t, k_{1t-1}, l_{1t-1}, n_{1t}) + f(z_t, k_{2t-1}, l_{2t-1}, n_{2t})}{f(1, k_{1t-1} + k_{2t-1}, l_{1t-1} + l_{2t-1}, n_{1t} + n_{2t})}$$

[9]Since the market value of land is retrieved as a residual, Davis (2009) makes the implicit assumption that the real estate production function is Cobb-Douglas. Hence, for the parameters that are calibrated in steady-state, I assume a unitary elasticity of substitution ($\varsigma = 1$).

where the numerator corresponds to total production of the borrowing and lending firms and the denominator to the measure of production of a representative firm that aggregates all inputs with productivity shock $z_t = 1$ at the steady state. Since in this framework a fraction of firms are borrowing-constrained, the reallocation of inputs to firms that have the greatest marginal productivity leads to an endogenous increase in TFP that is not captured by movements in the technology shock z_t.

5 Results

Since I augment Kiyotaki and Moore's (1997) work along several dimensions, I present the baseline model first and compare the second-period responses of productivity shocks and financial shocks for different specifications for which labor supply is inelastic. I present my results this way in order to disentangle the effects of land and labor market dynamics. Second, I show the contribution of land dynamics to output amplification in a framework for which land is the sole factor of production and collateral asset. Finally, I assess the role of labor dynamics for output fluctuations, and I consider two types of preferences: (i) partially non-separable, and (ii) non-separable GHH. In a similar fashion to Mendicino (2011), my results are displayed in order to isolate the sensitivity of results to different levels of the enforcement parameter.

5.1 Model with labor inelastically supplied

5.1.1 Baseline model with land and capital

I examine two key features of land separately: (i) the level of land supply elasticity, and (ii) the value of the elasticity of substitution between land and capital. Figure 1 presents the amplification effects of productivity shocks and financial shocks and also compares two versions of the model: one for which commercial land is supplied inelastically and another one for which the total quantity of commercial land varies as a result of land developers' decisions. In order to assess the importance of the elasticity of commercial land supply, I assume a unitary elasticity of substitution between land and capital ($\varsigma = 1$). I investigate the second-period responses of output, land price, and borrowers' land and capital holdings as seen in Figure 1. Contemporaneous effects are not as interesting, since inputs take one period to enter the production function. Figure 2 presents the sensitivity of responses to values of the elasticity of substitution between land and capital ς that range between 1/3 and 1.

First, I analyze the amplification effects of a productivity shock. For output impulse responses,

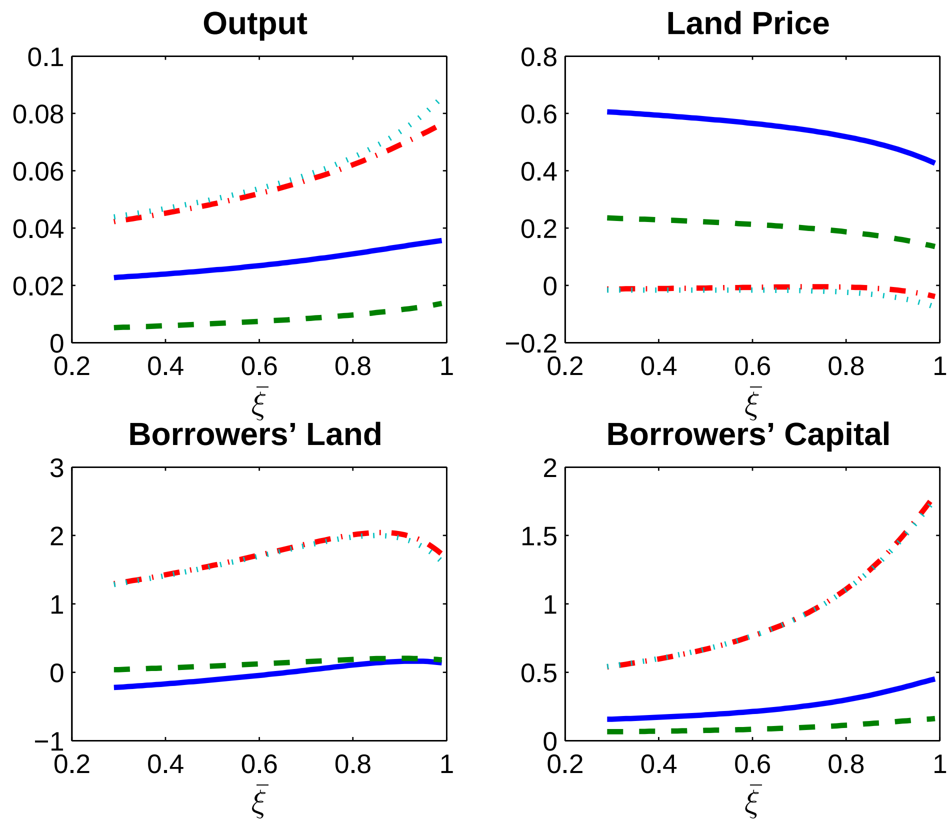

Figure 1: Amplification effects of the baseline model in response to 1% temporary shocks to productivity for which the *solid* line corresponds to an *inelastic* land supply and the *dashed* line to an *elastic* land supply, and 1% temporary financial shocks for which the *dash-dotted* line corresponds to an *inelastic* land supply and the *dotted cyan* line to an *elastic* land supply. Responses are all measured in percentage deviations from their steady state, except for the response of output to a productivity shock that singles out the exogenous amplification, so that results that are depicted correspond to $\frac{Y_2 - 0.01\Gamma(1,1) - \bar{Y}}{\bar{Y}} \cdot 100$.

I only consider the *endogenous amplification effects*, so that I remove the direct effects on output caused by the exogenous technology shock. Hence, for a 1% technology shock and a persistence parameter that corresponds to 0.95, I subtract 0.95% from the original output impulse responses. It is important to note that a similar representative-agent model that shares all characteristics with the baseline model besides the heterogeneity in discount factors also generates endogenous amplification effects that takes place from capital and land (if it is elastic) accumulation. Reallocation of assets from lending firms to borrowing-constrained firms leads to additional amplification effects, since the productivity gap between the two types of firms effectively shrinks.

For lower levels of the enforcement parameter ($\bar{\xi} < 0.7$) and an inelastic land supply, land is reallocated from borrowing to lending firms in the opposite direction than expected. Following a positive shock, lenders also cut down their inter-temporal lending. Since capital depreciates over time, land that they purchase initially will be sold later in order to cover capital expenses. For greater levels of the enforcement parameter ($\bar{\xi} > 0.7$), the flows of land are reversed for reasons that will be made clearer in the model for which land is the only asset. The enforcement parameter's threshold ($\bar{\xi} = 0.7$) also corresponds to the level for which output impulse responses are greater than the representative-agent model ones (0.025). Hence, reallocation of assets to borrowing-constrained firms is key for amplification.

For the elastic land supply version of the baseline model, land accrues to borrowers, but output impulse responses are much smaller than for the inelastic land supply case. Smaller growth in capital holdings explains the difference between output responses of the two models. Borrowing firms accumulate land in order to sell it back to land developers in the future. However, the proceeds of land sales are not redistributed from lenders to borrowers or vice-versa, as land developers collect these. Therefore, resources that could be allocated for capital holdings are curtailed by land developers. Smaller amplification is nevertheless compensated by greater persistence of output. As in Córdoba and Ripoll (2004), the addition of reproducible capital does not contribute to enhance output responses significantly whether land supply is elastic or inelastic. Hence, these results lead one to question the effects that financial frictions have in generating substantial levels of amplification. As for the small adjustment of land prices compared to the inelastic land supply version, log-linearization of the land supply equation (24) allows us to relate it directly to variations in total land holdings: $\tilde{q}_t = \zeta \tilde{l}_{t-1}$ where $\tilde{q}_t$ and $\tilde{l}_{t-1}$ correspond to percentage deviations from steady state for these two variables. The accumulation of aggregate land is a slow process similar to capital accumulation that explains the slow increase in land prices.

The analysis of financial shocks is simplified, since for most enforcement parameter values, the total stock of land appears to be constant for the elastic land supply case. More reallocation of capital and land than in the case of technology shocks leads to greater output amplification. The

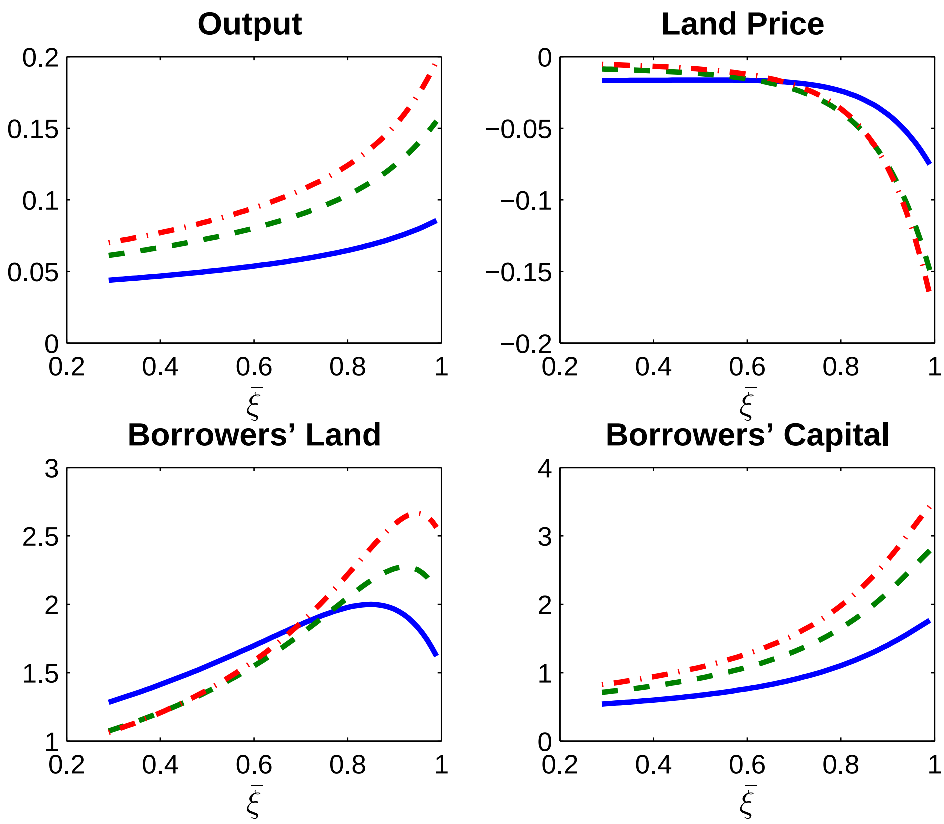

Figure 2: Amplification effects of the baseline model for which land is supplied elastically in response to a 1% temporary productivity shock for different values of the elasticity of substitution between land and capital. The *solid* line corresponds to a unitary elasticity $\varsigma = 1$, the *dashed* line to $\varsigma = 1/2$ and the *dotted* line to $\varsigma = 1/3$. Responses are all measured in percentage deviations from their steady state.

aggregate capital stock also remains equal to its pre-shock level. Borrowing increases both due to the relaxation of the borrowing constraint and through an increase in the quantity of inputs that play the role of collateral. Hence, the land price channel does not account for greater responses in borrowing and in output. The decomposition of the effects that explain a magnification of output with greater levels of the enforcement parameter will follow the lines of Mendicino (2011) in the next sub-section.

In an elastic land supply environment, responses of output to financial shocks for lower values of the elasticity of substitution between capital and land are plotted in Figure 2. Lower levels of this elasticity imply more complementarity between factors of production so that the two inputs accrue to borrowers in the same proportions and that results in a more efficient distribution of these factors of production. Greater levels of the enforcement parameter also lead to more borrowing and to much larger output responses. Following the shock, lenders disinvest massively in land and capital, so that both assets are sold to borrowers in order for lenders to lend more initially. The price of land is affected less by the fall in their demand for land. As the shock decays, they slowly re-accumulate land and capital. The gains in output responses that result from a lower value of the elasticity of substitution are substantial. Reducing it from $\varsigma = 1$ to $\varsigma = 0.5$ results in a 51% greater second-period output response. For $\varsigma = 1/3$ it reaches amplification levels that are 78% greater, when the steady-state value of the enforcement parameter is 0.7.

5.1.2 Baseline model with land only ($\psi = 1$)[10]

The version of the baseline for which land is the only asset is the one that has received the most attention in the literature. Córdoba and Ripoll (2004) show that output amplification following a productivity shock can be decomposed into four components: a productivity gap between borrowers and lenders, the collateral share in output, the output share and the redistribution of land. Analytically, the elasticity of output with respect to both types of shocks (ϵ_{Yj}) is as follows:

$$\epsilon_{YA} = \epsilon_{Yl_2}\epsilon_{l_2jA} = (f_{l_2} - f_{l_1})\,\frac{l_2}{Y}\epsilon_{l_2A} \text{ where } A = \{z, \xi\}$$

This elasticity is equal to the product of two elasticities: the elasticity of output with respect to borrowers' land ϵ_{Yl_2} and the elasticity of borrowers' land with respect to the shock ϵ_{l_2A}. The former elasticity can be replaced by the product of the productivity gap and the ratio of borrowers' land to total output Y.

Mendicino (2011) stresses the importance of the elasticity of borrowers' land with respect to the productivity shock and shows that it is inversely related to a downpayment variable that she constructs. When purchasing a unit of land, borrowers can increase their level of debt since their collateral is greater. Hence, the downpayment is just the difference between the price of land and the value of land that is collateralized, so that $dp = q - \frac{\xi E q'}{R}$. Even though the enforcement constraint differs from the one embedded in Mendicino's (2011) work, the hump-shape of second-period impulse responses across different values of the enforcement parameter remains as can be seen in Figure 3.

The price channel is critical in the amplification of a productivity shock, since both lenders and borrowers want to take advantage of greater marginal productivity levels. Greater aggregate demand for land and inelastic supply contribute significantly to pushing up the price of land. Hence, a greater expected value of the collateral asset leads to more borrowing and a greater share of land allocated to borrowers. The relaxation of the borrowing constraint stimulates borrowing and land

[10] In order to economize space, I do not present results for the baseline model with capital only ($\psi = 0$). They are available from the author.

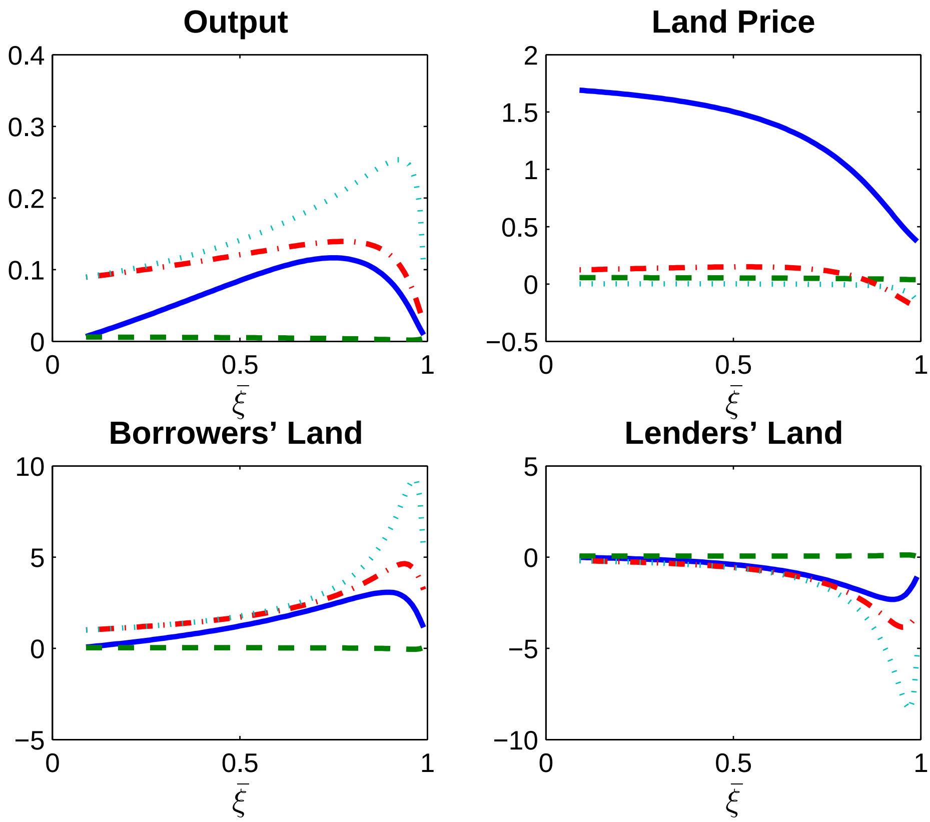

Figure 3: Amplification effects of the model for which land is the only input ($\psi = 1$) in response to a 1% temporary shock to productivity for which the *solid* line corresponds to an *inelastic* land supply and the *dashed* line to an *elastic* land supply, and to a 1% temporary financial shock for which the *dash-dotted* line corresponds to an *inelastic* land supply and the *dotted* line to an *elastic* land supply. Responses are all measured in percentage deviations from their steady state, except for the response of output to a productivity shock that singles out the exogenous amplification, so that results that are depicted correspond to $\frac{Y_2 - 0.01\Gamma(1,1) - \bar{Y}}{\bar{Y}} \cdot 100$.

reallocation ensues. For a shock of similar size, there is greater output amplification in the event of financial shocks compared to productivity shocks. It also appears that the presence of land developers curtails the effectiveness of the price channel in the short-term for the propagation of productivity shocks, as can be seen in Figure 3. Since there is a direct mapping between land prices and the quantity of land, an increase in land demand from borrowing firms results into a greater land price. In order to purchase additional land, this category of firms need to borrow more. However, lending firms only lend if they can sell some of their land at a high price which is not possible because the presence of land developers leads to a greater supply of land. Since land redistribution is minimal, output responses are much smaller than the ones generated by a model that features inelastic land supply. On the other hand, land accumulation gives rise to more persistence of shocks.

As for the effects of financial shocks on output, they are greater in the model with land developers, especially for high enforcement values. This result arises despite decreasing total land supply and land price that are proportional in equilibrium since $\zeta = 1$. In this case, an interest rate channel takes over the price channel that is effective only for productivity shocks. From equation (**??**), it appears that most changes of the interest rate can be attributed to an expected price growth. In the case of inelastic land supply there is an important land price hike following a credit shock and lenders set a higher interest rate, since they are giving up the opportunity to sell land at a higher price in the next period. Hence, facing greater borrowing costs, borrowers do not borrow as much. The presence of land developers however ensures smoother price shifts and, for some greater values of the enforcement parameter, lower land prices. In periods following the shock, aggregate land drops, but in future periods there is a slow accumulation that takes place. An interest rate that almost does not budge allows more borrowing which leads to more reallocation and an amplification of the output response. Since returns on debt are lower, lenders maintain their consumption by selling land and that explains the lower total quantity of land in the bottom-right panel of Figure 3. The lower levels of amplification, for enforcement parameters that approach one, results from the smaller productivity gap between the two types of agents.

5.2 Baseline model with elastic labor supply

In this section, I focus on the role of labor markets in accounting for the responses of output to financial shocks exclusively. Jermann and Quadrini (2012) emphasize that the *labor wedge* (the discrepancy between the marginal rate of substitution between consumption and leisure and the marginal product of labor) is strongly affected by financial shocks, so that labor demand fluctuations are the main contributors to the business cycle. I reexamine whether their results still hold in the presence of a second factor of production and collateral asset, that is land. Since hours worked can

	Elasticity of substitution (ς)		
	1	1/2	1/3
Preferences			
Inelastic labor supply	5.85	8.99	10.68
Partially non-separable	7.02	10.17	11.76
GHH	10.21	14.55	16.78

Table 6: Amplification effects of the baseline model in response to a 1% temporary financial shock with different specifications of preferences and elasticities of substitution between land and capital for output for which the enforcement parameter ($\bar{\xi} = 0.7$). Responses are all measured in percentage deviations from their steady state and multiplied by 100.

be adjusted contemporaneously, the response of output to shocks is also contemporaneous. However, since there is a one-period lag for land and capital, most effects take place in the period following the shock, so it is more interesting to examine these. With partially non-separable preferences, hours worked increase for borrowers but decrease for lenders following a positive financial shock. Table 6 presents the effects of financial shocks on output for various specifications of preferences assuming an enforcement parameter $\bar{\xi} = 0.7$. Labor fluctuations also affect the marginal product of capital and land, but the total effects are small: elastic labor supply contributes only to an increase in the response of output of respectively 20, 15 and 13% for elasticities of substitution of $\varsigma = 1$, 1/2 and 1/3.

As for the sensitivity of results to the elasticity of substitution, augmenting the model with elastic labor supply does not alter the order of importance of responses: a smaller value of ς implies a greater response. There appear to be greater income effects, however, for higher values of the enforcement parameter as illustrated in the left panel of Figure 4. The importance of real estate can also be assessed by comparing the lower line which corresponds to the model with elastic labor supply but without land. It appears that the contribution of real estate is sizable as it contributes to an additional 53% to the response of output for a Cobb-Douglas production function. Moreover, the response of output increases by an additional 45 and 68% when the elasticity of substitution is cut down to $\varsigma = 1/2$ and 1/3, respectively. Hence, both the inclusion of land in production and the level of complementarity with capital play key roles in driving business cycles.

5.2.1 Non-separable preferences

I also examine the sensitivity of results to allow non-separable preferences. Specifically, I use Greenwood, Hercowitz, and Huffman's (1988) reduced-form utility function that is derived from an

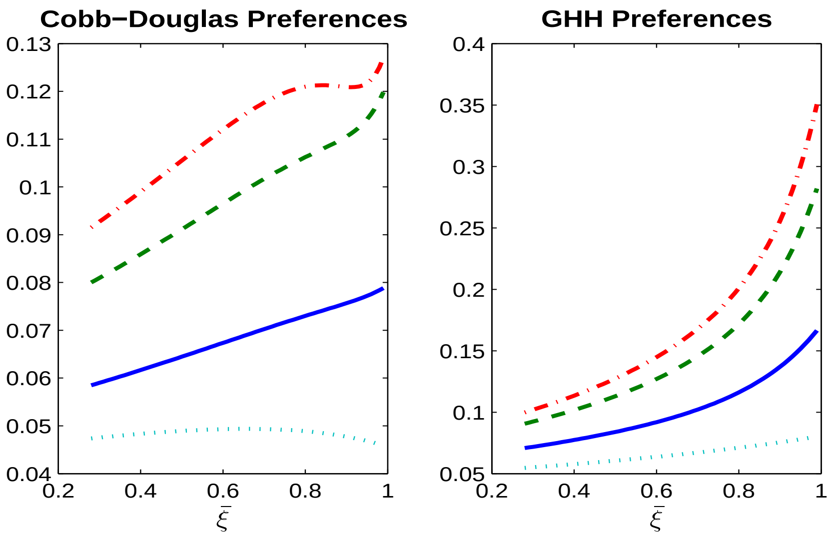

Figure 4: Amplification effects of the baseline model in response to a 1% temporary financial shock with partially non-separable preferences and GHH preferences for the consumption-leisure choice. The *solid* line corresponds to an elasticity of substitution between land and capital of $\varsigma = 1$, the *dashed* line to $\varsigma = 1/2$ and the *dash-dotted* line to $\varsigma = 1/3$. The *dotted* line corresponds to model with capital as the only asset. Responses are all measured in percentage deviations from their steady state.

optimization problem with home production:

$$u(c_{it}, n_{it}) = \frac{1}{1-\sigma}(c_{it} - \frac{B_i}{\chi} n_{it}^{\chi})^{1-\sigma}.$$

Results are presented in the right panel of Figure 4 for a calibration of χ that corresponds to the labor wage elasticity $(\chi - 1)^{-1}$ of 1.7, the value that is considered by GHH. The other parameters B_1 and B_2 are calibrated so that in steady-state investors allocate 30% of their time to work. Since the income effect is dampened, levels of output amplification are enhanced when compared to partially non-separable preferences. Hours worked have a multiplicative effect on output, particularly for high values of the enforcement parameter. My results suggest that the contribution of hours worked to output is sensitive to the specification of the utility function as in this case they contribute to a magnification of output responses by 75, 64 and 62 % for elasticities of substitution of $\varsigma = 1$, 1/2 and 1/3, respectively, as seen in Table 6. As for the importance of real estate, the addition of that asset increases the response of output by 52%. Finally, lower elasticities of substitution ($\varsigma = 1/2$ and 1/3) also result in larger output responses as they add factors of 42% and 64%, to the Cobb-Douglas production function, assuming a steady-state enforcement parameter of $\bar{\xi} = 0.7$.

6 Conclusion and extensions

In conclusion, new findings on the role of commercial land in business cycle fluctuations emerge in a framework of endogenous borrowing constraints. First, when land developers can affect commercial land supply, it appears that the price channel emphasized by Kiyotaki and Moore (1997) is no longer effective for the amplification of technology shocks. Second, for sufficiently high enforcement levels, financial shocks generate sizable output responses that are ensured by smooth variations of the interest rate. These responses are also enhanced when we allow for a greater level of complementarity between land and capital. Third, the contribution of labor fluctuations to business cycles is sensitive to the specification of the utility function. Jermann and Quadrini (2012) find that labor demand is a major contributor to business cycle fluctuations. In contrast under similar assumptions regarding preferences and borrowing constraints, my model points to a greater importance of land dynamics and its interactions with capital.

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, it appears that the introduction of financial shocks in the estimation proposed by Iacoviello and Neri (2010) may overshadow the contributions of other shocks. Liu, Wang, and Zha (2011) consider a variance decomposition that include financial shocks in a similar fashion to the ones study in this work. One identification strategy to find the value of the elasticity of substitution between land and capital would be to conduct their Bayesian estimation by setting a prior distribution for this parameter.

Although helpful in identifying an additional source of business cycle fluctuations, the effects of a financial shock bring about a negative correlation between output and land prices that is contrary to stylized facts. This result is due to the ability of firms to sell land to land developers. Future research should focus on this aspect in order to identify mechanisms that would allow land prices to increase following a positive financial shock. Interactions with the residential sector may modify the behavior of this price.

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A Data sources and construction of variables

A.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)

Variables names:	Total Employment Hours worked per worker The product of those two variables is equal to ($\mathbf{n_t}$) Source: Ohanian and Raffo (2012)

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: Non-residential fixed assets
Source: BEA, NIPA, Table 4.1-4.2
Definition: Stock of private non-residential structures and equipment and software of non-corporate and corporate non-financial firms (annually)

Variable name: Gross private domestic investment
Source: BEA, NIPA, Table 1.1.4-1.1.5
Definition: Investment in non-residential structures and equipment and software (quarterly)

Variable name: Nominal Market Value, Price and Quantity Index of Land
Source: Davis's (2009) database

Definition: 2 different 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)

Variable name: Nominal interest rate
Source: Federal Reserve Statistical Release, Flow of Funds, Table H.15
Definition: Quarterly average of 3-month Treasury bills

Variable name: Inflation
Source: Bureau of Labor Statistics
Definition: CPI

A.2 Construction of variables

A.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 Jermann and Quadrini (2012). I pick the initial value of $Capital_t$ 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.*

$$Capital_{t+1} = Capital_t - Depreciation_t + Investment_t.$$

A land component must be removed from the capital stock in order to avoid double accounting. Hence, I compute the fraction of market value of land in real estate the non-corporate and corporate non-financial sectors as well as the fraction of commercial real estate (non-residential structures) in the capital stock. The transformation of the capital stock variable is the following:

$$\mathbf{k_t} = Capital_t * \left(1 - \left(\frac{\text{Nominal market value of land}}{\text{Nominal market value of real estate}}\right) * \left(\frac{k_t^{STRUC}}{Capital_t}\right)\right).$$

I decompose $Capital_t$ into k_t^{STRUC} and $k_t^{E\&S}$. The initial values for the last quarter of 1951 of the last two variables correspond to the fraction of non-residential fixed assets of non-corporate and corporate non-financial firms for each category in 1951 ($k_{1951Q4}^{STRUC} = 0.685 * Capital_{1951Q4}$ and $k_{1951Q4}^{E\&S} = 0.315 * Capital_{1951Q4}$). The capital stock of each category is then constructed recursively ($i = \{STRUC, E\&S\}$):

$$k_{t+1}^i = k_t^i - Depreciation_t * \frac{k_t^i}{Capital_t} * dep.\ constant^i + Investment_t * SHARE\ of\ Inv._t^i.$$

The $SHARE\ of\ Inv._t^i$ consists in the ratio of investment of a non-residential category over total non-residential investment. Finally, the *dep. constant*^{i} is identified in a way such that the share of the last quarter (2010Q4) of capital stock k_t^i corresponds to its value in the data ($k_{2010Q4}^{STRUC} = 0.475 * Capital_{2010Q4}$ and $k_{2010Q4}^{E\&S} = 0.525 * Capital_{2010Q4}$).

A.2.2 Construction of the land quantity index $\mathbf{l_t}$

The weighted average of quantity indexes of land for the *non-corporate* and *corporate non-financial* sectors corresponds to $\mathbf{l_t}$.

A.2.3 Construction of the 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 $\mathbf{n_t^{SHARE}}$.

A.2.4 Construction of the land share in income$\mathbf{l_t^{SHARE}}$

Similar to the quantity indexes of land, the price of land q_t is an weighted average of the *non-corporate* and *corporate non-financial* sectors price indexes and is liquidity-adjusted by the method suggested by **?**Quan and Quigley (1991).

The definition of land share in income requires the construction of a land rental rate r_{qt}. I follow Kiyotaki and West's (2006) approach so that it is a function of the land price index, but I do not account for tax regulation changes. The land rental rate is as follows:

$$r_{qt} = q_t \left(\frac{\lambda + r_t}{1 + r_t} \right) \left(1 - \lambda \frac{1 + E(q_{t+1}/q_t)}{r_t + \lambda(1 + E(q_{t+1}/q_t)) - E(q_{t+1}/q_t)} \right) \tag{30}$$

where λ corresponds to the inverse of the average number of years that firms hold a unit of land, $E(q_{t+1})$ to the fitted value of an AR(1) process and r_t to the difference between the nominal interest rate and the expected inflation rate that is also the fitted value of an AR(1) process.[11]

The Nominal market value of land corresponds to the product of r_{qt} and $\mathbf{l_t}$.

The ratio of $\dfrac{\text{Nominal market value of land}}{\textit{National Income-Taxes on production and imports}}$ corresponds to $\mathbf{l_t^{SHARE}}$.

B Recursive formulation of the firms' problem

[11]Similar to Kiyotaki and West (2006), I assume that firms sell their land according to a Poisson process and calibrate λ so that they do so every 10 years on average.