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Secular stagnation, financial frictions, and land prices

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ABSTRACT

We explore a model in which large transitory financial shocks can generate persistent slumps in output, land prices, and interest rate. The propagation channel works through a high sensitivity of land prices with respect to fundamental, achieved by a high complementarity between land services and consumption in households' preference. When this complementarity is disciplined by micro-level evidence, the equilibrium features non-linear dynamics between two steady states. Large transitory financial shocks push the economy into a constrained region in which low interest rate makes firm unwilling to save out of the financial friction, leading to a secular stagnation. (JEL codes: E13, E32, E44)

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1. Introduction

Recovery from a financial crisis can be painfully slow, even if the crisis itself does not last long. This is especially the case when the crisis is compounded with a collapse of asset prices, particularly in the real-estate sector. A prominent example is the 2008 Great Recession, during which both the financial and the real-estate sectors experienced tremendous distress, followed by persistent slumps in the values of real-estates. The financial crisis also featured much greater declines in macroeconomic activities and a much slower recovery relative to previous postwar recessions (Fig. 1), a phenomenon termed "secular stagnation".

The joint occurrence of financial distress, house price busts, and secular stagnation is not unique to the Great Recession. Historical stagnation events such as the 1990 Japanese financial crisis and the 1930 Great Depression, are both renowned for dramatic collapses of the financial and real-estate sector, as well as the economic stagnation that followed it. Formal econometric evidences (Cerra and Saxena, 2008; Jordá et al., 2015; Reinhart and Rogoff, 2009) also show that housing-financial crisis tends to be deeper and more protracted, and are often associated with prolonged asset market collapse. These empirical patterns suggest that financial frictions and real-estate price collapses are systematically related to subsequent economic stagnations. However, formal theories are lacking in this regard, partly due to the fact that standard real business cycle models cannot generate large propagation of relatively short-lived recessions.[2]

This paper fills this gap by proposing such a framework in which large financial shocks in the style of Jermann and Quadrini (2012) can generate strong propagation through persistent slumps in asset, particularly real-estate, prices. The key

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[2] Beyond real business cycle frameworks, there are recent works showing that financial shocks can be quantitatively important when incorporated into frameworks with nominal rigidities (see, for example Gertler and Karadi, 2011 and Christiano et al., 2014) or with banking panics (Gertler and Kiyotaki, 2015).

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idea is that strong propagation of shocks requires asset prices to be sufficiently sensitive to economic fundamental; and this high sensitivity can be achieved by a "land consumption channel" which exploits the fact that land services are highly complementarity to consumption in households' preferences.

More specifically, the land consumption channel refers to the fact that land, in addition to being a production factor and a collateral asset, also serves a consumption role: it provides services (housing) valued by the households. If land services and consumption are highly complementary, households' demand for land would be highly sensitive to economic fundamental, which determines consumption. As land is an important form of collateral asset (Liu et al., 2013), this high sensitivity feeds into the firm sector, strengthening the two-way feedback between borrowing capacity and macroeconomic conditions as in Kiyotaki and Moore (1997), which leads to strong amplification and propagation.

The paper consists of a theoretical part and a quantitative part. First, I embed the land consumption channel into a standard neoclassic growth model. In the model, both the household and the firm are subject to collateral constraints and their borrowing capacities are linked to land holdings. I then prove that multiple steady states can arise if consumption and land services are sufficiently complementary in the household's preference. These different steady states are characterized by different level of physical capital, hence there is no room for self-fulfilling fluctuations. Despite that, the model features interesting nonlinear responses to fundamental shocks such as productivity and credit shocks. Small shocks tend to move the economy around the unconstrained steady state, which corresponds to the usual steady state of a standard growth model. Large negative financial shocks, like what was observed in 2008, push the economy into a constrained steady state in which both the household and the firm are *permanently* borrowing-constrained.

The property that the firm is permanently constrained does not result from exogenous restrictions on its capital structure,[3] but rather due to general equilibrium forces that depresses both the land prices and the interest rates. In the model, the firm has a rich set of asset instruments from which it can choose to "grow out of" the borrowing constraint. However, at the constrained steady state it has little incentive to do so: Land, due to its low value, does not serve as an effective tool to relax the collateral constraint. Capital is not very attractive either because of its low productive value, as the firm is constrained in financing working capital and hiring complementary labor. Lastly and perhaps most importantly, at the constrained steady state the returns to financial assets (interest rate) is low because the household's demand for credit is tightly constrained by the depressed real-estate value. The low interest rate in turn implies little incentive for the firm to hold financial assets.

The second part of the paper quantifies the land consumption channel. The key step is to quantitatively discipline the degree of complementarity between consumption and housing services. For the land consumption channel to matter quantitatively, we require a relatively low degree of substitutability between land services and consumption. Most works based on micro-level data and structural estimation typically find a value between 0.1 and 0.6. I calibrate the model using a recent structural estimate by Li, Liu, Yang and Yao (2016), which lies at the high end of micro estimates. After quantifying the model, I find that the law of motion for capital is indeed S-shaped with multiple steady states. This leads to asymmetric recovery speeds across recessions of different sizes.

Next I assess the model's ability to quantitatively account for the secular stagnation. I identify three sources of shocks: a credit shock as in Jermann and Quadrini (2012), a housing demand shock as in, say, Liu et al. (2013), and a standard productivity shock. This is broadly consistent with narratives of the Great Recession that emphasizes the effect of disruptions of credit supply and the impact of house price busts. I estimate the shocks using data on interest rates spreads and land price dynamics during the recession. I then examine how well the model does in accounting for various macroeconomic aggregates during and after the recession. I find that the model can match post-recession data remarkably well. It is able to account for most of the output declines by 2016 (12.4% v.s. 16.7% in the data). Financial shocks alone, albeit short-lived, can generate large output declines during the recession, triggering the economy to shift to the constrained steady state. In contrast, an otherwise identical model but without the land consumption channel generates an immediate recovery right after the recession. In this sense, the land consumption channel proposed in this paper improves upon the ability of neoclassic models in accounting for the secular stagnation.

Related Literature

The paper is related to two strands of literature: one on financial frictions and the other on secular stagnation. There is an extensive and rapid-growing literature on macroeconomic effects of financial frictions, pioneered by Bernanke and Gertler (1989) and Kiyotaki and Moore (1997). This paper draws on a series of papers that examines how land price dynamics contribute to business cycle fluctuations through financial frictions (for example, see Guerrieri and Iacoviello 2017; Iacoviello 2005; Liu et al. 2016; 2013). Different from these papers, this paper focuses on explaining the secular stagnation. To this end it exploits the fact that consumption and land could be highly complementarity, which leads to steady-state multiplicity, in contrast to existing works which all feature a unique steady state. This paper also builds on recent works by Mendoza (2010), Jermann and Quadrini (2012), and Bianchi (2016), in which collateral constraints not only affect business investment but also affect working capital. However, these papers do not have a land sector and all exhibit a unique steady state. This paper is also related to Schmitt-Grohé and Uribe (2020) who argues that collateral constraints introduce aggregate non-convexity which gives rise to equilibrium multiplicity and self-fulfilling fluctuations. Unlike Schmitt-Grohé and Uribe (2020),

[3] The literature has proposed various ways such restrictions can be imposed such as finite life span, differential discounting, or tax benefits of debt. See Quadrini (2011).

in this model there is no self-fulfilling fluctuations across multiple steady states, as different steady states are characterized by different levels of physical capital.

The paper is also related to the literature on secular stagnation. Benigno and Fornaro (2018) propose a notion of stagnation traps in which weak productivity growth interacts with zero lower bound and lead to a permanent liquidity trap. Eggertsson et al. (2019) propose a demand-driven explanation of the secular stagnation where persistently low natural rate of interest results from shocks that alter households' life-saving decisions. Borağan Aruoba et al. (2017) utilizes a New-Keynesian model to conduct a formal econometric study of the likelihood that the US economy transits into a low-interest-rate region. Complementary to these papers, I propose a neoclassic explanation of the secular stagnation, which does not rely on zero-lower-bound or price rigidity. Relatedly, Taschereau-Dumouchel and Schaal (2016a,b) illustrate, using global-game techniques, how coordination failures among firms lead to steady-state multiplicity. Instead, this paper focuses on the financial channel and illustrates a novel role of interest rate in propagating secular stagnation.

2. The model

There is a representative household and a representative firm owned by the household. The commodity space consists of consumption goods, physical capital, labor, and land. Land is modeled as a factor in fixed supply $\bar{L}$. The household's utility depends on consumption, labor and land service (housing). Goods production requires capital, labor and land. Both the household and the firm can be potentially borrowing constrained and they can use land and capital as collateral. The household discounts future consumption at rate β.

2.1. The firm sector

The representative firm produces goods using capital, labor and land as inputs. The production function is given by:

$$F(z_t, k_{t-1}, n_{1t}, l_{1t}) = z_t\left[l_{1t}^{\gamma}k_{t-1}^{1-\gamma}\right]^{\alpha} n_{1t}^{1-\alpha} \tag{1}$$

where z_t denotes the level of productivity, k_t, n_{1t},and l_{1t} denote the inputs of capital, labor, and land, respectively, and the parameter $\alpha \in (0,1)$ and $\gamma \in (0,1)$ measures the output shares of these production factors. Capital evolves according to:

$$k_t = (1-\delta)k_{t-1} + i_t \tag{2}$$

where i_t is investment at time t and δ is the depreciation rate.

The firm starts each period with certain amount of intertemporal debt b_{1t-1}, capital stock k_{t-1}, and land holding l_{1t-1}. Its production revenue is given by the production function $F(z_t, k_{t-1}, n_t, l_{1t})$. Dividend d_t is distributed after making investment decisions i_t, debt issuance decisions $\frac{b_{1t}}{R_t}$, and land allocation decisions l_{1t}. The budget constraint is given by:

$$b_{1t-1} + d_t + i_t + p_t(l_{1t} - l_{1t-1}) \leq F(z_t, k_{t-1}, n_{1t}, l_{1t}) - w_t n_{1t} + \frac{b_{1t}}{R_t} \tag{3}$$

The financial friction is modeled as in Mendoza (2010), Jermann and Quadrini (2012), and Bianchi (2016). In addition to financing intertemporal debt, the firm is also required to finance its working capital needs using intra-period loan. The incorporation of working capital, as shown in Jermann and Quadrini (2012), provides important quantitative improvement to macroeconomic models. Specifically, let $\tilde{b}_t$ denote the amount of working capital loan in period t. The working capital loan needs to cover the payments made bond holders, equity holds, capital producers, land sellers, and workers at the beginning of a period, and thus:

$$\tilde{b}_t \geq b_{1t-1} - \frac{b_{1t}}{R_t} + d_t + i_t + p_t(l_{1t} - l_{1t-1}) + w_t n_{1t} \tag{4}$$

Using the firm's budget constraint 3, one can verify that the working-capital loan is equal to firm's revenue, i.e., $\tilde{b}_t = F(z_t, k_{t-1}, n_{1t}, l_{1t})$. The Firm's total borrowing capacity, including both intertemporal and intratemporal loans, is limited by a fraction of the collateral asset. This gives rise to the following collateral constraint:

$$\frac{b_{1t}}{R_t} + F(z_t, k_{t-1}, n_{1t}, l_{1t}) = \frac{b_{1t}}{R_t} + \tilde{b}_t \leq \xi_{1t} p_t l_{1t} + \kappa_t k_t \tag{5}$$

The firm's borrowing capacity is limited by a fraction of the value of the collateral assets-land and capital. For generalization purposes I allow different pledgeability for land and for capital, proxied by ξ_{1t} and κ_t respectively. The coefficients (ξ_{1t}, κ_t), together with the coefficient on the household's borrowing constraint, can be time-varying and their fluctuations are interpreted as "credit shocks" (Jermann and Quadrini, 2012).

Denote the firm's value function in period t by $V_{1t}(b_{1t-1}, k_{t-1}, l_{1t-1})$, where $\mathbf{s_{1t}} = \{z_t, \xi_{1t}, \kappa_t, \omega_t\}$ is the vector of exogenous shocks relevant to the firm. The firm's recursive problem is given by:

$$V_{1t}(b_{1t-1}, k_{t-1}, l_{1t-1}, \mathbf{s_{1t}}) = \max_{\{d_t, n_t, k_t, b_{1t}, l_{1t}\}} d_t + \beta E[\Lambda_{t,t+1} V_{1t+1}(b_{1t}, k_t, l_{1t}, \mathbf{s_{1t+1}})] \tag{6}$$

subject to the budget constraint Eq. (3); the law of motion for capital Eq. (2); the collateral constraint 5. In equilibrium, the stochastic discount factor $\Lambda_{t,t+1}$ is equal to the household's marginal rate of substitution between period t and $t+1$.[4]

2.2. The household sector and general equilibrium

The representative household's utility function is a generalized version of the Greenwood-Hercowitz-Huffman (GHH) preference, incorporating a taste for housing services, which is assumed to be proportional to his land holding l_{2t}:

$$U(c_t - G(n_{2t}), l_{2t}) \tag{7}$$

The advantage of using a GHH specification is that it delivers realistic responses of employment over the business cycle without introducing additional labor market frictions which could complicate the analysis. We propose a constant elasticity of substitution(CES) form with respect to the (composite) consumption and land services:

$$U(\hat{c}_t, l_{2t}) = \frac{\left[(1-\omega)\hat{c}_t^{1-1/\sigma} + \omega l_{2t}^{1-1/\sigma}\right]^{\frac{1-1/\eta}{1-1/\sigma}}}{1-1/\eta} \tag{8}$$

Where $\hat{c}_t$ denotes composite consumption $c_t - G(n_{2t})$. ω is the preference weight on land.[5] η measures the intertemporal elasticity of substitution across different periods. σ denotes the intratemporal elasticity of substitution between (composite) consumption and land services and is a key parameters that we quantify using cross-sectional evidences in the quantification section.

The household starts each period with certain amount of land holding l_{2t-1} and bonds b_{2t-1}. His income includes wage earnings $w_t n_{2t}$ and dividend income d_t. In each period he chooses consumption and next period asset holdings subject to the following budget constraint:

$$b_{2t-1} + c_t + p_t(l_{2t} - l_{2t-1}) \le d_t + w_t n_{2t} + \frac{b_{2t}}{R_t} \tag{9}$$

Like the firm, the household is also constrained in borrowing and can use his land holding as collateral:

$$\frac{b_{2t}}{R_t} \le \xi_{2t} p_t l_{2t} \tag{10}$$

The household's value function is given by $V_{2t}(b_{2t-1}, l_{2t-1}, \xi_{2t})$. The household's recursive problem is given by:

$$V_{2t}(b_{2t-1}, l_{2t-1}, \xi_{2t}) = \max_{c_t, n_t, b_{2t}, l_{2t}} u(c_t, n_t, l_{2t}) + \beta E[V_{2t+1}(b_{2t}, l_{2t}, \xi_{2t+1})] \tag{11}$$

Subject to the budget constraints 9 and the collateral constraint 10 and given initial land and bond holdings.

Market Clearing and Equilibrium. A competitive equilibrium is defined in a standard way in which the firm and the household maximize their respective objectives given market prices, the markets for goods, labor, land and bonds all clear, and the firm's pricing kernel is equal to the household's intertemporal marginal rate of substitution.

2.3. Model characterizations

This section characterizes the equilibrium conditions of the model and makes some important observations on the model's equilibrium properties, which will be useful later.

2.3.1. The aggregate collateral constraint

We start by presenting the first order conditions for the firm and the household. Let $\lambda_t^i, i \in \{f, h\}$ be the multiplier associated to the firm's budget constraint 3 and the household's budget constraint 9 respectively; and Let $\mu_t^i, i \in \{f, h\}$ be the multipliers of the firm's credit constraint 5 and the household's credit constraint 10. Then the firm's first order conditions are given by:

$$1 = \lambda_t^f \tag{12}$$

$$(F_{nt} - w_t)\lambda_t^f = \mu_t^f F_{nt} \tag{13}$$

$$1 - \kappa\mu_t^f = \beta E\left[\Lambda_{t,t+1}\left[\lambda_{t+1}^f(F_{kt+1} + (1-\delta)) - \mu_{t+1}^f F_{kt+1}\right]\right] \tag{14}$$

[4] An alternative model specification under which land distribution is not part of state variables would be to assume a land rental market. Appendix A.1 describes in detail such an economy.

[5] When $\omega = 0$, it becomes a standard GHH preference.

$$p_t - \xi_{1t} p_t \mu_t^f = \beta E\left[\Lambda_{t,t+1} \lambda_{t+1}^f p_{t+1}\right] + \left(\lambda_t^f - \mu_t^f\right) F_{lt} \tag{15}$$

$$1 - \mu_t^f = \beta E[\Lambda_{t,t+1} R_t] \tag{16}$$

And the household's first order conditions are given by:

$$U_{ct} = \lambda_t^h \tag{17}$$

$$w_t U_{ct} = U_{nt} \tag{18}$$

$$1 - \frac{\mu_t^h}{\lambda_t^h} = \beta E\left[\frac{\lambda_{t+1}^h}{\lambda_t^h} R_t\right] \tag{19}$$

$$p_t \lambda_t^h = U_{lt} + \xi_{2t} p_t \mu_t^h + E\left[p_{t+1} \lambda_{t+1}^h\right] \tag{20}$$

comparing the firm's bond first order condition (Eq. (16)) and household's bond first order condition (Eq. (19)) delivers the following observation:

$$1 - \frac{\mu_t^h}{\lambda_t^h} = \beta E\left[\frac{\lambda_{t+1}^h}{\lambda_t^h} R_t\right] = \beta E[\Lambda_{t,t+1} R_t] = 1 - \mu_t^f \tag{21}$$

With the middle inequality holds because the firm's pricing kernel is equal to the household's marginal rate of substitution in equilibrium. Hence we have:

$$\frac{\mu_t^h}{\lambda_t^h} = \mu_t^f$$

Given that the budget multiplier $\lambda_t^h = u_{ct} > 0$ is always strictly positive, we have:

Proposition 2.1. *the firm's credit constraint 5 binds if and only if the household's credit constraint 10 binds:*

$$\mu_t^h > 0 \Longleftrightarrow \mu_t^f > 0$$

This proposition works through general equilibrium forces whereby a tightening of the household collateral constraint leads to movements in the firm's pricing kernel and the equilibrium interest rate, which makes borrowing attractive to the firm. Consider a tightening of the household collateral constraint at time t. This has two impacts. First, the household consumption in period t decreases, driving down the intertemporal rate of substitution, as well as the firm's priving kernel $\Lambda_{t,t+1} = \frac{U'(c_{t+1})}{U'(c_t)}$. This makes dividend payment at time t more valuable than future dividend payments, inducing the firm to pay out more dividends today.

Additionally, a tight household collateral constraint implies depressed demand of borrowing coming from the household side, thus the equilibrim interest rate R_t must fall. With this reduced cost of borrowing, firm's incentive to borrow increases further. Thus, with greater incentive to issue dividend and lower cost of borrowing, the firm levers up until the point that its borrowing constraint is binding.

Given that the collateral constraints must bind for both parties at the same time, we can sum up the household's and the firm's collateral constraint. Substituting in the bonds market clearing $b_{1t} + b_{2t} = 0$, we arrive at an *aggregate collateral constraint*:

$$F(z_t, k_{t-1}, n_{1t}, l_{1t}) \le \xi_{1t} p_t l_{1t} + \xi_{2t} p l_{2t} + \kappa_t k_t \tag{aggregate collateral constraint}$$

The household's borrowing capacity matters for the firm because the more the household is able to borrow, the more financial assets the firm can accumulate. In a nonstochastic steady state we can show, using the firm's bond first order condition, that the steady-state interest rate is negatively related to the tightness of the collateral constraints:

Proposition 2.2. *The steady-state interest rate is decreasing in the tightness of the firm's collateral constraint*

$$R = \frac{1 - \mu^f}{\beta} \tag{22}$$

Suppose in some steady state the collateral constraint does not bind, then the interest rate R is equal to $1/\beta$ as in a standard model. If the collateral constraint does bind, there would be a positive labor wedge $w < F_n$. As a result both the household and the firm have extra incentives to accumulate financial assets, and this drives up asset prices and pushes down the interest rate.

2.3.2. Single-agent representation

It appears that the model is quite complicated to solve with endogenous and evolving distributions of capital, land, and bond across the household and the firm. However, inspecting the first order conditions for the household and the firm, one will realize that the pre-determined land distribution $\{l_{1t-1}, l_{2t-1}\}$ and bond distribution $\{b_{1t-1}, b_{2t-1}\}$ does not enter into those conditions. Also one could aggregate the budget and credit constraints across both parties to cancel out these distributional variables in the aggregate. Thus, we only need to keep track of aggregate capital as the only endogenous state variable.

Intuitively, since the household is the owner of the firm and there are no frictions in transferring resources across the two parties through equity, asset ownerhips become irrelevant. With this observation the model then boils down to a standard growth model with a representative agent, augmented with an endogenous land sector and a collateral constraint:

Proposition 2.3. *The model is isomorphic to a representative-agent model where the private agent solves the following recursive problem:*

$$\begin{aligned} V(k, K, \mathbf{s}) &= \max_{c,l_1,l_2,n,k'} U(c, n, l_2) + \beta E_{\mathbf{s}'|\mathbf{s}} V(k', K', \mathbf{s}') \\ c + k' - (1-\delta)k &\leq F(z, k, l_1, n) \\ l_1 + l_2 &= \bar{L} \\ F(z, k, n, l_1) &\leq \xi_1 p(K, \mathbf{s}) l_1 + \xi_2 p(K, \mathbf{s}) l_2 + \kappa k' \\ K' &= \Omega(K, \mathbf{s}) \end{aligned}$$

Where K is the aggregate capital stock whose law of motion is governed by the equilibrium function $\Omega(.)$, $\mathbf{s} = \{z, \xi_1, \xi_2, \kappa, \omega\}$ is the vector of shocks that follows certain exogenously specified processes, and the land pricing function $p(.)$ is pinned down implicitly through an intertemporal Euler equation.

Thus, without the collateral constraint the model would display aggregate dynamics identical to a standard growth model. By merely introducing a single aggregate collateral constraint we are able to substantially alter the implication of the model. In particular, the model now features multiple steady states and hence strong non-linear dynamics.

3. Steady state analysis

We adopt the following strategy to characterize the steady states: fix any land price p, There exists a system of equations (collected in the appendix A) that solves the steady-state allocation. This defines an implicit mapping from land prices to corresponding real allocations. In particular, denote $l_1(p)$ and $l_2(p)$ as the implicit mapping from p to l_1 (firm's land demand function) and l_2 (household's land demand function). With these demand functions, we can define an *aggregate land demand* function $L(p) = l_1(p) + l_2(p)$. And a vector $(c, k, n, l_1, l_2, p, \lambda)$ is a steady state if and only if the associated firm demand function and household demand function equals to the aggregate supply $\bar{L}$:

$$L(p) = l_1(p) + l_2(p) = \bar{L}$$

To proceed, we assume that the labor disutility function G takes the following standard form:

Assumption 1. The labor disutility function $G(.)$ takes the following form:

$$G(n) = \chi \frac{n^{1+1/\nu}}{1+1/\nu}$$

When there is no collateral constraint, both the firm's demand and the household demand function are monotonically decreasing, reflecting the conventional price effect: demand for land falls as its price increases. With collateral constraints, it is possible to obtain multiple steady states. To do so, we need to show that exists an upward sloping proportion of the demand function: as land price increases, demand for land increase as well. As shown by the following lemma, this upward-sloping proportion comes from household demand if consumption and housing are sufficiently complementary.

Lemma 3.1. *Suppose σ is sufficiently small (consumption and land are sufficiently complementary in the household's utility function). Then for some combination of loan-to-value ratios such that the collateral constraint just holds as equality at p_{ss} (but not binding), the left derivative of household demand $l_2(p)$ at $p = p_{ss}$ is strictly positive:*

$$l_2'^{-}(p_{ss}) > 0$$

This lemma is the key theoretical result of the paper and requires that the consumption and land services are sufficiently complementary. To see the intuition, focus on the household first order condition for land:

$$\underbrace{\frac{1-\omega}{\omega}\left(\frac{\hat{c}}{l_2}\right)^{\frac{1}{\sigma}}}_{\text{Consumption benefit}} + \underbrace{\xi_2 p \lambda}_{\text{Collateral benefit}} \underbrace{-(1-\beta)p}_{\text{User cost}} = 0 \tag{23}$$

The household demands land as it provides valuable services and relaxes his borrowing constraint. In equilibrium these benefits should equal to the net cost (current price minus future discounted price) for holding the land. Note that, the

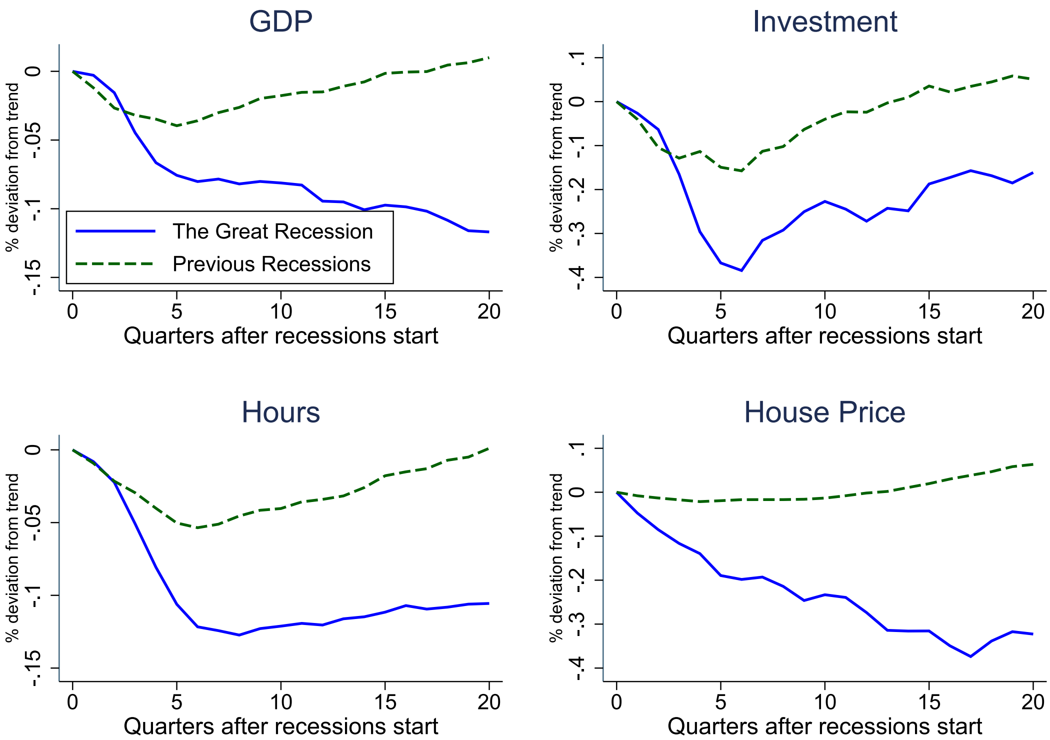

Fig. 1. Great recession vs. other postwar recessions. *Note*: This figure plots linearly detrended aggregate variables in the five-year window following the Great Recession (solid blue curve) and previous recessions (dashed green curve). Previous recessions include the 2000 recession, the 1990 recession, the 1981 recession, the 1973 recession, and the 1960 recession. Starting point is normalized to 0. GDP is the real GDP per capita. Investment is the real private gross investment. Labor is the total hours available from U.S. Bureau of Labor Statistics. House price is the Case-Shiller real home price index. Following an average postwar recession, major macroeconomic variables fully recovered in five years. Yet, the impact of the Great Recession is much more persistent: GDP and housing price kept declining relative to trends; Labor barely recovered; Investment recovered somewhat but was still 20 percent below trend five years after. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

magnitude of the consumption benefit depends on σ, which captures the degree of complementarity between (composite) consumption and land in the household utility function. As land and consumption becomes more complementarity ($\sigma \to 0$), household's land demand l_2 moves more strongly with composite consumption $\hat{c}$, less so with respect to the two other forces, leading to an upward-sloping relation between land demand and steady state land prices.

Unlike the household's demand, the firm's demand for land is always downward-sloping given the Cobb-Douglas production function. Thus, for the aggregate demand to be upward sloping, we need the household demand component to overpower the firm component. This is guaranteed by 1) a sufficiently strong complementarity between consumption and land σ and 2) a sufficiently small land share in production function γ.

Theorem 1. *Suppose σ and γ are sufficiently small. Then for some combination of loan-to-value ratios, there exists:*

1. *a unique unconstrained steady state, in which the collateral constraint is slack*
2. *at least two constrained steady states, where the collateral constraints bind.*

The theorem is illustrated in Fig. 2. It suffices to show that for some combination of the loan to value ratios, 1) the collateral constraint is slack at the frictionless steady state and 2) there exists some $p_1 < p_2 < p_3 < p_{ss}$ such that $L(p_1) > 0$, $L(p_2) < 0$, and $L(p_3) > 0$. This is depicted as the solid red curve in Fig. 2. These statements coupled with continuity implies that there exists a frictionless steady state A and at least two other constrained steady states B and C.[6] Details of the proof is delegated to the appendix.

Interest Rates and Bond Distributions. In view of proposition 2.2, we know that the steady-state interests is decreasing in the tightness of the collateral constraint. This means that the multiple steady states obtained previously can be ranked in terms of interest rates, and that constrained steady states necessarily have lower interest rate than the unconstrained steady state.

[6] It can be shown that the level of capital stock is lower in the constrained steady states compared to the unconstrained steady state. There are two forces at work here. First, the collateral constriant limits production, reducing returns to accumulate capital. Second, the collateral constraint introduces a labor wedge. With lower labor, returns to capital further decreases. These two forces overpowers the counteracting force that capital can serve as collateral, and implies lower capital stock at the constraint steady state.

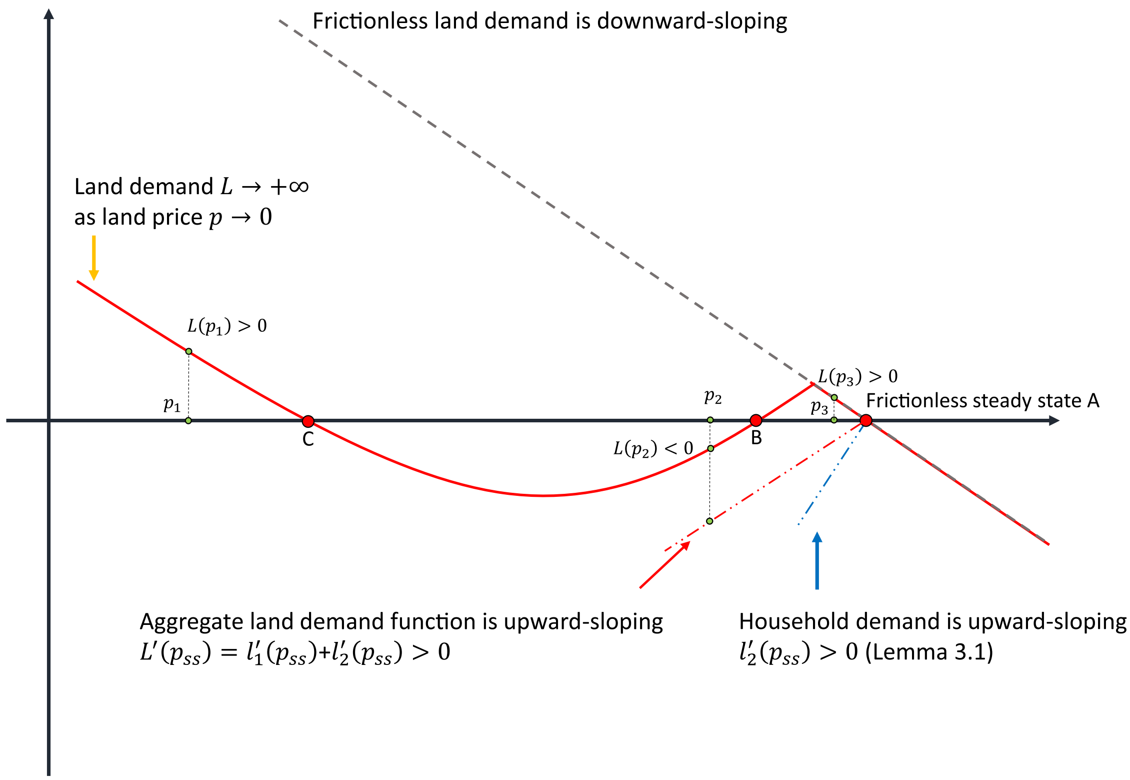

Fig. 2. Graphical illustration of Theorem 1. *Note*: This figure plots a graphical illustration of theorem 1. We need to show that there exists some $p_1 < p_2 < p_3 < p_{ss}$ such that $L(p_1) > 0$, $L(p_2) < 0$, and $L(p_3) > 0$ (solid red curve). We first show that the household demand function is upward-sloping at A by Lemma 3.1 (blue dashed line). Thus the aggregate land demand is also upward-sloping (red dashed line) since the firm demand is dominated by the household demand, guaranteed by a sufficiently small land share γ. Thus we can pick a desired p_2. By continuity, we can relax the collateral constraint by a little bit and $L(p_2) < 0$ still holds. This allows us to pick a value of p_3 sufficiently close to the frictionless level p_{ss} such that the collateral constraint is slack. For p_1, note that when capital is pledgeable $\kappa > 0$, output will be strictly positive even if land price p tends to zero. Thus we can pick p_1 sufficiently low and get positive demand for land: $L(p_1) > 0$. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Corollary 1.

1. *At the unconstrained steady state, the risk-free interest rate is equal to the inverse of rate of time preference.* $R^u = \frac{1}{\beta}$. *The bond distribution is indeterminate within a certain interval.*
2. *At constrained steady states, the risk free rate is less than the inverse of rate of time preference.* $R^c < \frac{1}{\beta}$. *The household is a net borrower in the intertemporal debt market.*

$$b_2^c = R^c \xi_2 p^c l_2^c \tag{24}$$

Where p^c *and* l_2^c *are the land price and household land holding associated with the constrained steady state. a*

We conclude the section with a comment on bond distribution. At the constrained steady state the household is a net borrower whereas the firm is a net saver in the intertemporal asset market. To validate this prediction, we use flow-of-funds data to construct a measure of the households' net debt. This is not a trivial task because we need to not only compute households' issuances of debt but also their holdings of debt securities, which in turn includes both direct holdings and indirect holdings of debt through pension funds, insurance companies, and mutual funds. After aggregating various components we find that the net household's debt to (quarterly) GDP ratio is around 30% after the Great Recession. This confirms the model prediction that households is a net borrower at the constrained steady state. In the quantitative section (Section 5.3) we will further examine the dynamics of household's net borrowing during and after the recession, and show that it is roughly consistent with the data.

4. Quantification

4.1. Calibration

This section describes the calibration strategy and presents the quantitative findings. The model is calibrated to the US economy and most of the model parameters are identified under the assumption that the economy is at the unconstrained

Table 1
Calibration.

Parameters		Value	Source
Discount factor	β	0.99	Quarterly model
Intertemporal elasticity	η	0.5	Standard
Disutility of working	χ	2.41	Steady state labor equal to 0.33
Frisch Elasticity	ν	4	Macro Studies
Pref. weight	ω	0.27	Land value/GDP = 1.06
Depreciation	δ	2.5%	Standard
Capital share	α	0.35	Standard
Land share	γ	0.086	Relative share of commercial land
Intratemporal Elasticity	σ	0.487	Micro estimates (e.g. Li et al., 2016)
Loan-to-value ratio	ξ_1, ξ_2	0.035,0.03	Post-recession output gap and household net debt
Aggregate land stock	$\bar{L}$	1	Normalization

steady state before the Great Recession, and shifts to the stable constrained steady state after that. We verify ex-post that this is indeed the case. The discount factor β is set to 0.99 as the model is calibrated to quarterly frequency. The intertemporal elasticity of substitution η is set to standard value of 0.5. The labor share $1-\alpha$ is set to 0.65, or $\alpha = 0.35$. The labor disutility parameter χ is set so that at the unconstrained steady state labor input is one third. The Frisch elasticity is set to 4, consistent with the macro literature. A relatively high Frisch elasticity is useful in generating realistic employment volatility at the business cycle frequency. The preference weight parameter ω and land share parameter γ are calibrated to match: 1) the land value to GDP ratio of 1.07 and 2) the relative share of residential land (versus commercial land) of 0.55. This leads to $\omega = 0.27$ and $\gamma = 0.086$. The implied gross share of land is $\gamma\alpha = 0.0301$, consistent with values used by Liu et al. (2013) and Iacoviello (2005).

The key parameter is the intratemporal elasticity of substitution between consumption and housing services σ. While studies based on macro-level data find a value (slightly) greater than one (Piazzesi, Schneider and Tuzel, 2007), most studies based on micro-level data and structural estimation typically find a value between 0.1 and 0.6 (Hanushek and Quigley (1980), Flavin and Nakagawa, 2008, Stokey, 2009). I set σ to 0.487 as in Li, Liu, Yang and Yao (2016) who argue that the identification mainly comes from cross-sectional moments and recent, more volatile, housing price data.

Next we focus on calibrating the collateral parameters. To start, we assume that the firm land is as pledgeable as capital $\xi_{1t} = \kappa_t$ (Liu et al. 2013) and denote this common collateral parameter ξ_{1t}. We first calibrate the steady state loan-to-value ratios. Because the collateral constraint does not bind at the unconstrained steady state, we cannot use normal times to calibrate these parameters. Instead, we use post-recession moments to identify these two parameters: 1) ratio of post-recession output and pre-recession output of 90%; 2) The household's net borrowing to GDP ratio of 0.3.[7] Intuitively, the former moment governs the overall tightness of ξ_1 and ξ_2, while the latter moment measures the *relative* tightness of ξ_1 and ξ_2. The calibration is summarized in Table 1.

Given that this model has occasionally binding collateral constraints, I use global method to solve for the recursive equilibrium, similar to Bianchi (2016), and the details are available in A.1.

4.2. Asymmetric propagation

In this section we explore propagation property of the model. The law of motion for capital is depicted in Fig. 3. The unique law of motion is S-shaped with three steady states. The top one and the bottom one are both locally stable. I label the top steady state the "good steady state" and the bottom one the "bad steady state". The yellow dashed line depicts the law of motion for capital in a frictionless model without any collateral constraints. The local behavior of the model around the good steady state is identical to the frictionless model. When the level of capital declines, land price drops and the collateral constraints start binding. This leads to the S-shaped portion of the law of motion. When the level of capital is sufficiently low, the economy converges to the bad steady state. In summary, the economy displays nonlinear responses to shocks of different sizes. In particular, after a big financial crisis, capital stock gets destroyed. This tends to push the economy into the gray region and thus the economy would keep declining and finally converge to the bad steady state even if the negative shock completely goes away.

In Fig. 4, I solve for the transitional dynamics of the economy starting from different levels of capital stock, as proxy for recessions of different sizes. The economy recovers quickly after a small recession (yellow dashed line). In this scenario collateral constraint never binds and the economy behaves just as a frictionless growth model. Medium recessions (blue dashed line) take significant longer to recover, while large recessions push the economy to the left of the middle unstable steady state. As a result, the contraction continues as the economy drifts to the bad steady state.

[7] Household's net borrowing is constructed in B.1.

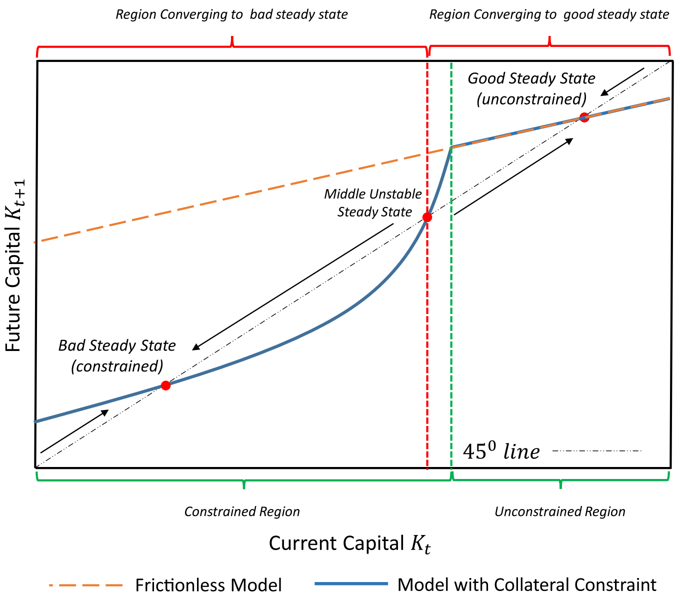

Fig. 3. Law of Motion for Capital *Note*: This figure depicts the law of motion for capital under benchmark calibration (solid blue line). The law of motion is S-shaped with three steady states. The top one (good steady state) and the bottom one (bad steady state) are both locally stable. The local behavior of the model around the good steady state is identical to the frictionless model. When the level of capital declines, land price drops and the collateral constraints start binding, pushing the economy into the bad steady state. Thus, the model features asymmetric recovery speed with respect to different sizes of negative shocks. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

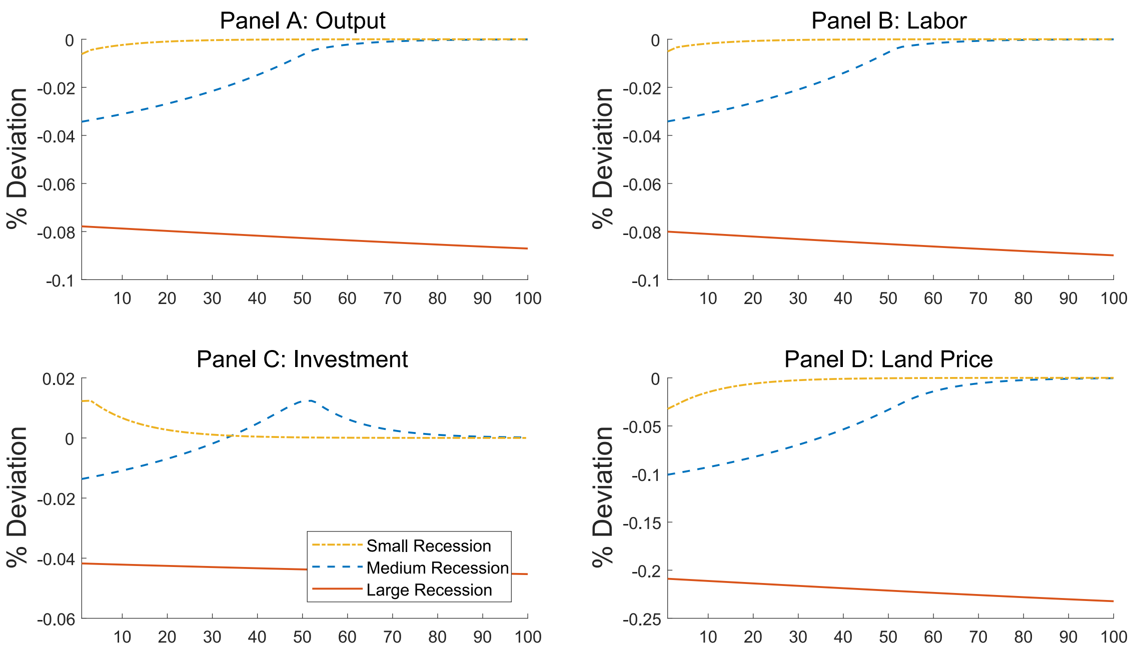

Fig. 4. Transitional dynamics under benchmark calibration. *Note*: This figure plots transition starting with different levels of initial capital. Small recession starts with 99.5% of unconstrained steady state capital. Medium recession starts at 98% and large recession starts at 96%. The model displays asymmetric recovery speeds to recessions of different sizes.

4.3. Amplification

In this section we examine the model's ability to amplify shocks. To do so we need to, as a comparison, first define an environment where no such financial acceleration mechanism presents. Consider the following "fixed-p" model where the agents' borrowing capacity is evaluated according to some "fixed" land price $\bar{p}$:

$$F(z_t, k_{t-1}, n_{1t}, l_{1t}) \le \xi_{1t}\bar{p}l_{1t} + \xi_{2t}(\bar{p}l_{2t} + k_t) \tag{25}$$

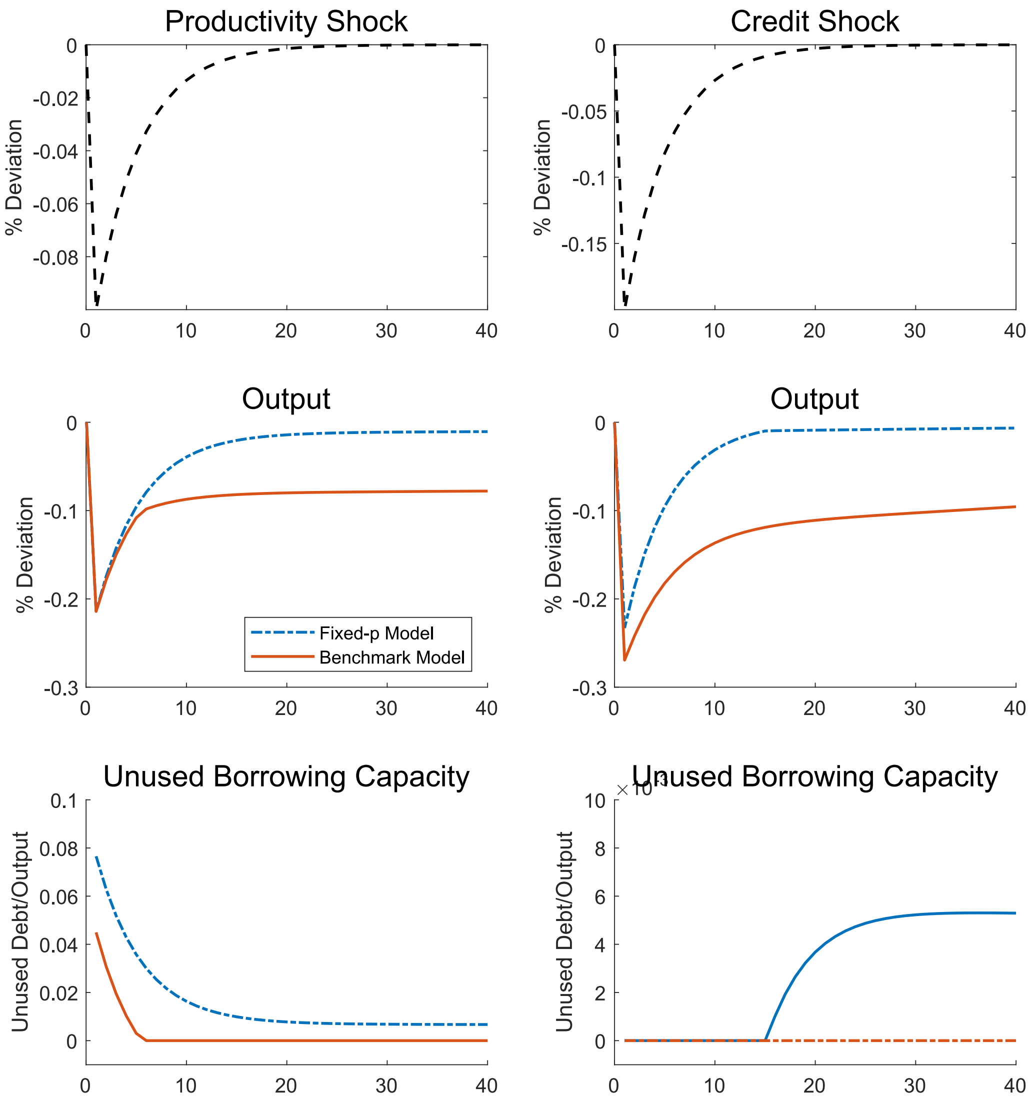

Fig. 5. Amplification of productivity and credit shocks. *Note*: This figure plots impulse responses to productivity shock (left) and credit shock (right). The left panel plots the responses of the benchmark model and the fixed-p model to the same productivity shock plotted on the top left panel; and the right panel plots the responses for the credit shock plotted on the top right panel. To facilitate comparison across the two types of shocks, I adjust the size of the productivity and credit shocks so that the magnitudes of output drops are roughly the same for the fixed-p model defined with Eq. (25).

Note that in this version the collateral constraint is still affected by credit shocks, but these shocks will not lead to a feedback loop through asset (land) prices.[8]

As shown in the left panel of Fig. 5, the model does not amplify negative productivity shocks *on impact*. This is due to the nature of working capital channel. When the productivity shock hits, the firm production shrinks, leading to lower demand for working capital loan. Thus, the demand for credit decreases substantially, making the collateral constraint slack on impact. This can be seen at the bottom left panel where we plot unused borrowing capacity defined as the difference between the debt limit and the actually borrowing, scaled by output.[9]

Although the model does not amplify productivity shocks, it does amplify other types of shocks such as credit shocks and housing demand shocks. To illustrate, in the right panel of Fig. 5 I plot the impulse response to credit shocks defined

[8] For all the excercises that follow, I set the value of $\bar{p}$ to the value of land price at the unconstrained steady state.

[9] This model does deliver amplification starting from the constrained steady state (see appendix Appendix C for details), as the collateral constraint is always binding around the constrained steady state.

as percentage deviations to steady-state values of ξ_1 and ξ_2.[10] In this case, the collateral constraint is binding and the credit shock gets amplified on impact.

5. Explaining the secular stagnation

We now assess how well the model can explain the economic stagnation following the Great Recession. To start, we follow the literature and identify three types of shocks as drivers of the Great Recession: a credit shock, a housing demand shocks, and a productivity shock. First of all, Credit shocks, which hits directly the aggregate borrowing capacity of the economy, are crucial drivers of the Great Recession (Jermann and Quadrini, 2012). Second, as argued by a series of papers that examine the macroeconomic impact of housing (e.g. Iacoviello (2005); Liu et al. (2013)), housing demand shocks lead to large swings in house prices and thus have substantial real impacts. Finally, we also include a sequence of productivity shocks as a standard source of business-cycle fluctuations. After calibrating the shocks using observable moments and feeding them into the model, we assess the quantitative capability of the model in explaining macro aggregates during and, in particular, after the recession.

5.1. Calibrating the shocks

I estimate the financial shocks $\{\xi_{1t}, \xi_{2t}, \kappa_t\}_{\{t=2007Q4 \text{ to } 2009Q4\}}$ during the crisis to target the yield spread between returns to capital and the risk-free interest rate. This spread tends to increase when there is a financial shock tightening the collateral constraint. To see this, we define the returns to capital R_t^k using the capital first order codntion as follows:

$$1 - \kappa_{1t}\mu_t^f = \beta E\left[\Lambda_{t,t+1}\left[\lambda_{t+1}^f(F_{kt+1} + (1-\delta)) - \mu_{t+1}^f F_{kt+1}\right]\right] := \beta E\left[\Lambda_{t,t+1}R_t^k\right]$$

The risk free rate R_t is given by

$$1 - \mu_t^f = \beta E[\Lambda_{t,t+1}R_t]$$

Removing expectation terms and substitute in the expression for the pricing kernel $\Lambda_{t,t+1} = \frac{u_{ct+1}}{u_{ct}}$, also note that the collateral multiplier μ_t^f is linked to the labor wedge by the first order condition of labor:

$$\mu_t^f = \frac{F_{nt} - w_t}{F_{nt}}$$

We have the following expression for the yield spread:

$$(R_t^k - R_t) \Uparrow = \frac{(1 - \kappa_{1t} \Downarrow)(F_{nt} - w_t) \Uparrow}{\beta \frac{U_{ct+1}}{U_{ct}} F_{nt}} \tag{26}$$

There are two channels through which the spread rises during recession. First, the financial shock κ_{1t} lowers the borrowing capacity and directly raises the spread. Second, the financial shock induces a bigger labor wedge $(F_{nt} - w_t) \Uparrow$ in equilibrium. This general equilibrium effect also translates into greater interest rate spread.

The financial shocks are estimated using the spread between Baa-rated corporate bond yield and the ten-year treasury note yield, following Ajello (2016) and Ferrante (2019). We set the financial shocks to match the increase in spread around 3.7% during the recession compared to its pre-crisis level, and assume that the financial shock to fully vanish by 2009. The estimated financial shock is displayed in figure 6 (panel A).

We next pose a sequence of housing demand shocks $\{\omega_t\}_{\{t=2007Q4 \text{ to } 2009Q4\}}$ to match house prices during the crisis, and set the after-recession persistence to be 0.95, consistent with Iacoviello (2005) and Liu et al. (2016, 2013).[11] The resulting housing demand shock is displayed in Fig. 6 (panel B).

Lastly, we include a sequence of productivity shocks $\{z_t\}_{\{t=2007Q4 \text{ to } 2016Q1\}}$ independently computed as the Solow residual using standard accounting methods and our calibrated model parameters regarding the production function. The computed productivity shock (panel C) displays little deterioration during the recession but gradually declines after it, consistent with Benigno and Fornaro (2018).

Although house prices are more sensitive to housing demand shocks and outputs are more sensitive to credit shocks, all moments are jointly determined in equilibrium. As our main interest is in explaining the secular stagnation after the Great Recession, we compute a version of the model without stochastic uncertainty.[12]

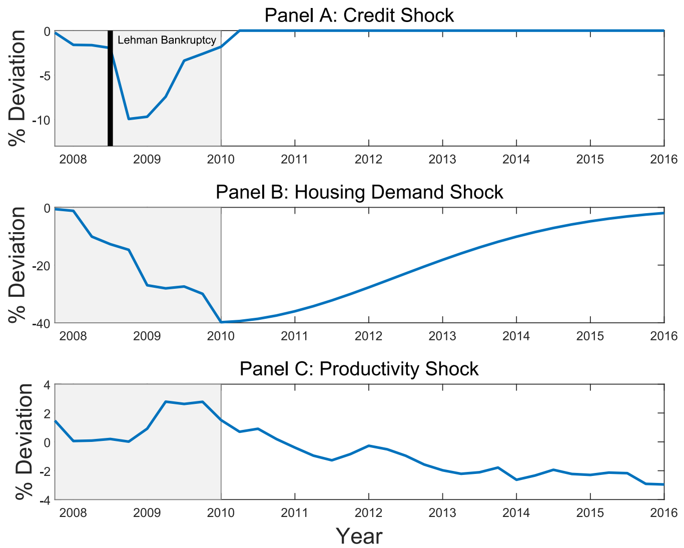

Fig. 6. Calibrated shocks. *Note*: This figure plots the calibrated credit, housing demand, and productivity shocks. The shocks are set to match interest rate spread dynamics (between 2007Q4 and 2009Q4), house price series (between 2007Q4 and 2009Q4), and an independently computed Solow residual (between 2007Q4 and 2016Q1). The credit shock experiences sharp contraction starting the third quarter of 2018, consistent with Lehman Brother's bankruptcy, and is assumed to fully vanish at the end of the recession.

5.2. The great recession and its aftermath

Fig. 7 displays the main quantitative result of the paper. Note that, by construction of shcoks we match the behavior of house prices (panel E) and interest rate spreads (panel F) *during the recession*. And we examine the model's ability in matching other *untargeted* macroeconomics series, as well as post-recession asset prices and interest rates.

We find that the model is able to account for a majority of output fluctuations during the recession, consistent with Jermann and Quadrini (2012). It is also able to generate persistence of output decline similar to the data, leading to 12.4% total declines in output by 2016 (v.s. 16.9% in the data). This is because of two reasons. First, productivity growth has been week since the recession (Benigno and Fornaro 2018). Second, and more importantly, the short-lived but severe financial crisis triggers the economy to drift to the constrained steady state, leading to persistent slumps in macroeconomic aggregates.[13]

The model also matches well labor (panel B), investment (panel C), and consumption (panel D). In particular, it successfully accounts for the empirical fact that labor declines more than output during the recession. The working capital constraint plays important role here. As firm's borrowing capacity is directly hit during the recession, their ability to hire labor gets impaired, leading to bigger declines in labor then output, consistent with the data.

Besides macroeconomic data, the model is also able to account for persistently high post-recession interest rate spreads after the recession (panel F). This is not because of the direct impact of financial shocks, which has fully recovered once the recession ends, but because the economy has entered the constrained region and the collateral constraint is always binding. The binding constraint gives rise to persistently high labor wedge which in turn leads to persistently high interest spreads (see Eq. (26)).

To isolate the role of endogenous land price, we also compute the dynamics of the fixed-p model (defined in Section 4.3) under the same sequences of shocks. The declines during the crisis are much smaller, and the economy immediately recovers after the recession ends. Almost all the post-recession stagnation comes from the slow down of productivity, which accounts for only around 5% decline in output. The collateral constraints play very little role in this model as the economy quickly recovers and the collateral constraint becomes slack right after the recession ends (and the interest rate spread becomes

[10] I adjust the size of the credit shock so that, for the fixed-p model, it creates a drop in output of roughly the same size as in the productivity shock case.

[11] Having certain persistence in housing demand is necessary to match the decline of housing prices within the recession, as the housing price is forward-looking. It is also consistent with observation that there are lingering effects of Great Recessions on the housing sector, particularly on residential investments and household spending on housing.

[12] Specifically, the shocks are unanticipated at 2007Q4 and fully anticipated thereafter.

[13] The model does a less good job in matching output behavior during the second half of the recession, mainly because measures of financial market distress (such as interest rate spread) started improving during this period. As pointed out in the literature, introducing price rigidity and zero-lower-bound could improve quantitative performances of models with financial frictions in this regard (Del Negro et al., 2017; Ferrante, 2019).

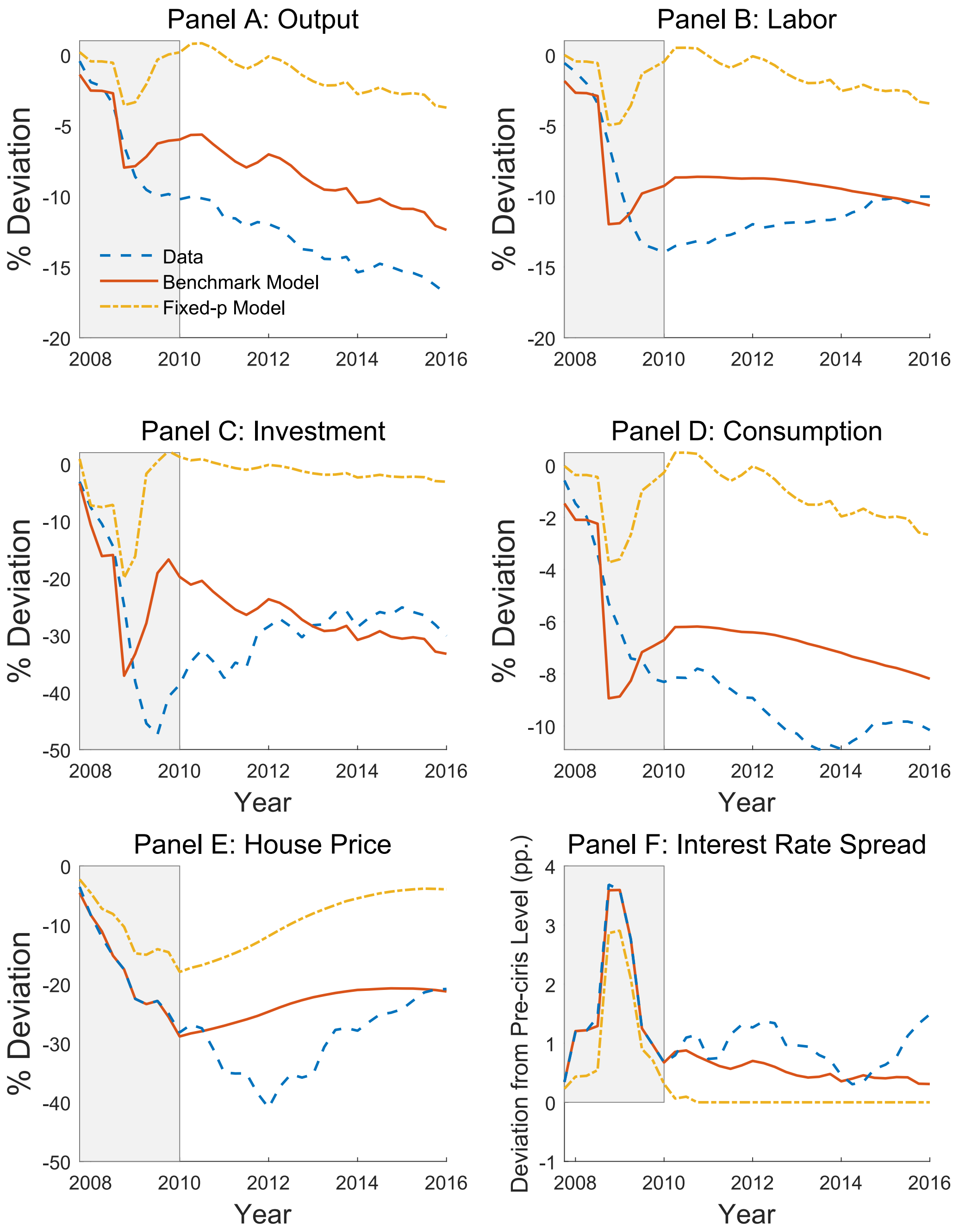

Fig. 7. The great recession and the aftermath: Model v.s. Data. *Note*: This figure plots model responses to shocks depicted in Fig. 6. The behaviors of house price and interest rate spread *within the recession* is targetted while all other time series, including post-recession house prices and interest spreads, are untargetted. The model generates strong persistence in macroeconomic aggregates, asset prices, and interest rate spreads, consistent with data. An otherwise identical fixed-p model (dashed yellow line) displays immediate recovery, similar to a standard business-cycle model. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

zero, see dashed yellow line, panel F). Thus, the fixed-p model, similar to a frictionless business-cycle model, generates very little propagation of the Great Recession.

5.3. Interest Rates and Bond Distributions

Fig. 8 plot the model-implied annualized interest rate (panel A) and household net borrowing (panel B). The model predicts that the interest rate (red solid line) drops sharply during the recession, recovers a bit when it ends, and settles

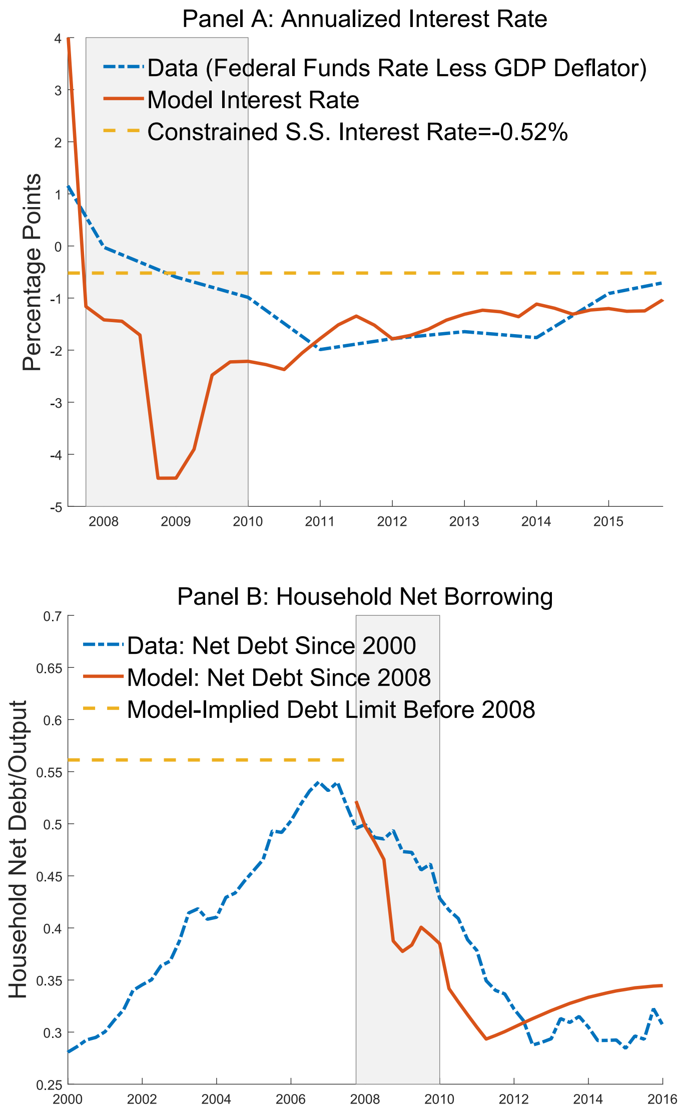

Fig. 8. Interest rate and bond distribution. *Note*: This figure plots interest rate dynamics (panel A) and household's net borrowing position (panel B). For interest rate, the model predicts a sharp drop in interest rate and a later recovery, consistent with the data. For household net borrowing, the model implies that before 2008 the household sector gradually borrows up to the implied limit (dashed yellow line), possibly due to financial innovations and relaxed lending standards. It also predicts a sharp household deleveraging during the recession, consistent with the data. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

at a permanently lower level as the economy transits to the constrained steady state.[14] This is roughly consistent with the data (blue dashed line). Two effects lead to this pattern. The first is a standard effect whereby exogenous credit shocks force both the household and the firm to deleverage, leading to lower interest rate. This effect tends to be short-lived as the deleveraging process ends. In this model, however, there is another secular effect: The economy is pushed into a constrained region in which the collateral constraint continues binding even if the exogenous credit shock goes away. This leads to a secular declines in interest rate consistent with the data.

Next we study the behavior of household's net borrowing (right panel of Fig. 8). From Corollary 1, we know that the bond distribution is indeterminate at the unconstrained steady state and is uniquely pinned down when the collateral constraint is binding. Thus we plot a model-implied debt limit prior to 2008 where the collateral constraint is slack and the exact household net debt position (Eq. (24)) after that. We then compare the two objects with the data. The figure suggests that

[14] Note that a discrepancy occurs between the model and the data in year 2019, where the decline in interest rate in the data is milder (the same occurs, less notably, in 2012.) This was primarily due to the sharp deflation in these two periods. Borağan Aruoba et al. (2017) discusses the possibility that in these two periods the US economy may have transited into a deflationary regime. While our model cannot account for this because there is no monetary aspect, the model replicates successfully the relatively long run behavior of the interest rate since 2013.

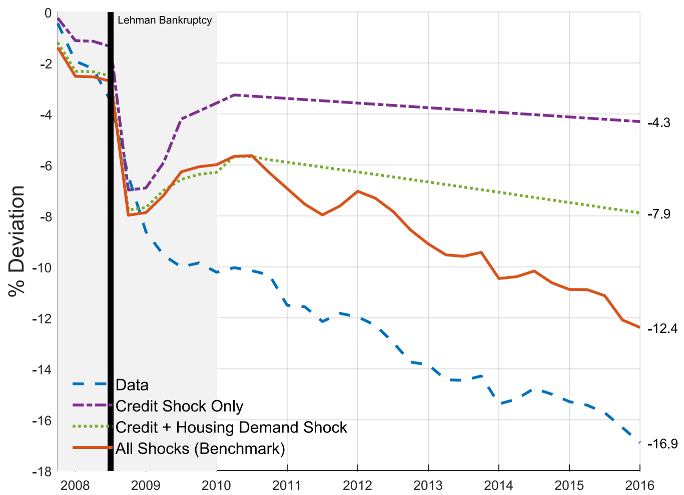

Fig. 9. The decomposition of shocks. *Note*: This figure decomposes the contribution of each shock by shutting down one shock at a time. The red solid line displays the output behavior under benchmark case, with a total of 12.4% decline in output, comparing to 16.9% in the data. If one removes the productivity shock and only considers financial and housing demand shock (green dotted line), the output behaves similar to the benchmark case during the recession, as productivity does not decline much before 2010. This case displays output decline at 7.9% level, as the economy drifts to the constrained steady state. The purple dash-dotted line depicts the case where one further takes out the housing demand shock and considers financial shocks only. In this case, the financial shocks can still generate a quite severe recession around year 2009, but displays quicker recovery relative to the other two cases due to the less depressed housing prices (demand). The financial shocks alone are also able to push the economy into the constrained region and, as a result, the economy drifts towards the constrained steady state instead of recovery in this scenario explaining around 4.3% of the output loss. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the households net borrowing has been rising prior to the recession, to the point that it almost hits the implied debt limit (yellow dashed line). And then the household sector goes through a deleveraging process where net borrowing over GDP ratio decreases from 55% to around 30%, primarily due to the falling land price and the associated shrinking borrowing capacity.

5.4. Decomposition of shocks

In this section we conduct a decomposition exercise to disentangle the roles played by credit shock, housing demand shock and productivity shock. This allows to answer a series of questions: Given that the financial crisis is short-lived and the house price has recovered, how important is the financial channel in explaining the secular stagnation? Further, what are the respective roles played by the financial shocks and weak productivity in driving the recession as well as the later stagnation?

I conduct the decomposition exercise by shutting down one shock at a time. The result is displayed in Fig. 9. The red solid line displays the output behavior under benchmark case, with a total of 12.4% decline in output, comparing to 16.9% in the data. If one removes the productivity shock and only considers financial and housing demand shock (green dotted line), the output behaves similar to the benchmark case during the recession, as productivity does not decline much before 2010 (Fig. 6, panel C). After the recession, the green dotted line does not decline as much as the benchmark case, in the absence of productivity shocks. However, it still displays output decline at 7.9% level, as the economy drifts to the constrained steady state. The purple dash-dotted line depicts the case where one further takes out the housing demand shock and considers financial shocks only. In this case, the financial shocks can still generate a quite severe recession around year 2009, but display quicker recovery relative to the other two cases due to the less depressed housing prices (demand). The financial shocks, albeit short-lived, are also able to push the economy into the constrained region and, as a result, the economy also drifts towards the constrained steady state instead of recovery in this scenario explaining around 4.3% of the output loss. We conclude that the housing-financial crisis not only accounts for most of the output fluctuations, but also has a profound impact by triggering the economy to shift into the constrained region.

6. Conclusion

This paper provides a neoclassic explanation of the secular stagnation. It proposes and quantifies a theory in which financial frictions and land price dynamics propagate a temporary crisis event into a prolonged stagnation, without relying on zero lower bound or price rigidity. The strong propagation comes from the high sensitivity of land prices with respect to economic fundamental. This sensitivity comes from a land consumption channel which exploits the fact that land and consumption are highly complementarity in the households' preferences. After quantifying the land consumption channel with micro-level evidence, I find that the model is capable of generating a secular stagnation similar to the data.

Combining the financial mechanism of this paper and nominal price rigidities could be one fruitful extension for future work. To the extent that nominal rigidities can amplify financial shocks in general (see Ajello, 2016; Del Negro et al., 2017; Ferrante, 2019), enriching the benchmark model with nominal rigidities and zero lower bounds could strengthen the mechanism discussed in this paper and thus further improve the model's quantitative performance.

The theory is presented in a purposefully simple framework with representative household and firm. Future works could extend the model with heterogeneous households to discuss the issue of wealth inequality around the Great Recession. The slow recovery in house price might provide a force that propagates not only economic stagnation, but also wealth inequality over time, as housing is the most important asset for a typical US household. We leave these extensions to future research.

Declaration of Competing Interest

None.

Appendix A. Computation and Further Quantitative Results

A1. Computation

This section describes the global algorithm used to solve the model. Given that the collateral constraints are occasionally binding in the model, I need to implment global methods to find solutions. The model is characterized by the following eight dynamic equations. In the main experiment, I only consider unanticipated shocks, thus, I remove the expectation signs in the intertemporal Eulor equations:

$$1-\kappa_t\mu_{1t}=\beta\left[\frac{u_{ct+1}}{u_{ct}}((1-\delta)+z_tF_{kt+1}(1-\mu_{1t+1}))\right] \tag{A.1}$$

$$p_t=\beta\left[\frac{u_{ct+1}}{u_{ct}}p_{t+1}\right]+z_tF_{lt}-z_tF_{lt}\mu_{1t}+\xi_{1t}p_t\mu_{1t} \tag{A.2}$$

$$z_tF_{lt}-z_tF_{lt}\mu_{1t}+\xi_{1t}p_t\mu_{1t}=u_{lt}+\xi_{2t}p_t\mu_{1t} \tag{A.3}$$

$$\mu_{1t}(z_tF(k_{t-1},l_{1t},n_t)-\xi_{1t}p_tl_{1t}-\xi_{2t}p_tl_{2t}-\kappa_tk_t)=0 \text{ with } \mu_{1t}\geq 0 \tag{A.4}$$

$$z_tF_{nt}-w_t=\mu_{1t}z_tF_{nt} \tag{A.5}$$

$$w_tu_{ct}=u_{nt}$$

$$l_{1t}+l_{2t}=\bar{L}$$

$$c_t+k_t-(1-\delta)k_{t-1}=z_tF_t.$$

These are eight equations characterizing the dynamic evolution of the eight variables $(k_t,l_{1t},l_{2t},n_t,w_t,p_t,c_t,\mu_{1t})$. And we are looking for recursive functions that solve this system of equation.

To simplify the system, we can use the last three equations to substitute out wage $w_t=\frac{u_{nt}}{u_{ct}}$, household land demand $l_{2t}=\bar{L}-l_{1t}$, and consumption $c_t=z_tF_t-k_t+(1-\delta)k_{t-1}$, we are left with five equations characterizing the evolution of five variables $(k_t,l_{1t},n_t,p_t,\mu_{1t})$. And we will look for a recursive equilibrium i.e. recursive functions $\{k_t(k_{t-1}),l_{2t}(k_{t-1}),n_t(k_{t-1}),p_t(k_{t-1}),\mu_{1t}(k_{t-1})\}$ that satisfies the above system of equations.

To do so, we adopt policy function iteraction on a discretized grip of capital. The key equilibrium object to solve is the law of motion for capital $k_t(k_{t-1})$ and the asset-pricing equation $p_t(k_{t-1})$.To do so:

1. Prestep: solve for the unconstrained steady state and obtain the unconstrained level of capital.
2. Set up the grid of capital around the unconstrained level. In practice I set the grid to be from 90% to 102% of the unconstrained-steady-state capital, so that simulations do not go beyond the grid.
3. Initiation: conjecture a set of dynamic functions[15]

$$\{k_t^{(0)}(k_{t-1}),p_t^{(0)}(k_{t-1}),\mu_t^{(0)}(k_{t-1}),n_t^{(0)}(k_{t-1}),l_{1t}^{(0)}(k_{t-1})\}$$

4. Treat the dynamic functions in step c as the future anticipated equilibrium functions and solve for the current period equilibrium functions with Eqs. (A.1) through (A.5) as follows:

[15] In the initial round we only need to conjecture the capital accumulation function and the land pricing function, and we can back out the other three variables using Eqs. (A.3), (A.4), and (A.5).

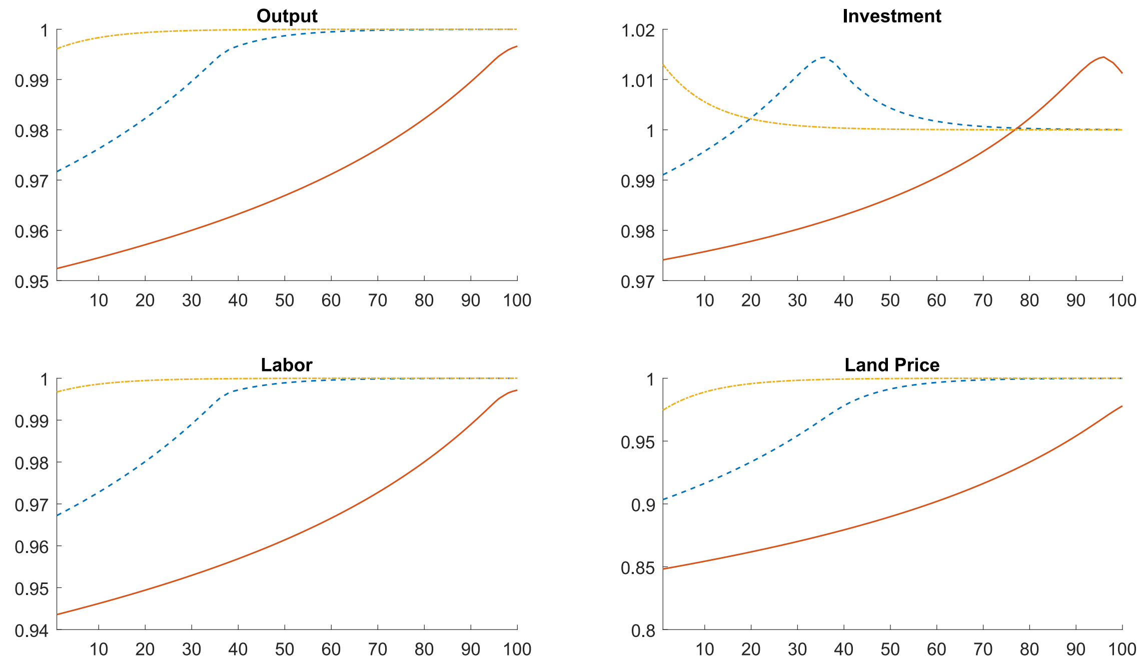

Fig. A10. Transitional dynamics with less complementarity $\eta = 0.8$. This figure plots transitional dynamics when land and consumption are more substitutable $\eta = 0.8$. In this case there is no steady-state multiplicity but the law of motion for capital is still S-shaped. As a result, medium and large recessions (Blue dashed and red solid line) can still have prolonged impact on the economy. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(a) For each grid, assume that the collateral constraint is not binding, then $\mu_{1t} = 0$. Then one can solve for (p_t, k_t, l_{1t}, n_t) with Eqs. (A.1), (A.2), (A.3), and A.5.[16]
(b) Check if the collateral constraint $z_t F(k_{t-1}, l_{1t}, n_t) - \xi_{1t} p_t l_{1t} - \xi_{2t} p_t l_{2t} - \kappa_t k_t \leq 0$ is satisfied. If yes, go to the next grid. If not, go to step iii.
(c) Solve for (p_t, k_t, l_{1t}, n_t) assuming that the collateral constraint is binding $z_t F(k_{t-1}, l_{1t}, n_t) - \xi_{1t} p_t l_{1t} - \xi_{2t} p_t l_{2t} - \kappa_t k_t = 0$. Then substitute out $\mu_{1t} = \frac{z_t F_{nt} - \frac{u_{nt}}{u_{ct}}}{z_t F_{nt}}$ from Eqs. (A.1), (A.2), and (A.3). These three equations together with the binding collateral constraint gives the solution to (p_t, k_t, l_{1t}, n_t). Then go to the next grid.

5. After solving for the new equilibrium functions

$$\{k_t^{(1)}(k_{t-1}), p_t^{(1)}(k_{t-1}), \mu_t^{(1)}(k_{t-1}), n_t^{(1)}(k_{t-1}), l_{1t}^{(1)}(k_{t-1})\},$$

check if the recursive functions are close to the initial ones. If yes, then stop. If no, go back to step c and update. The update needs to be done gradually as the model exhibits complementarity which could make it hard to achieve convergence.

A2. More results on propagation

For comparison purposes, I also present the transitional dynamics (Fig. A.10) with a relatively high value of $\eta = 0.8$, implying that consumption and land services are more substitutable. At this value of η there is no multiple steady states. Nonetheless, the law of motion for capital is still S-shaped, leading to asymmetric recovery speed with respect to small and large recessions. After recessions that destroy a sufficient amount of capital stock, the economy experiences a prolonged recovery (red solid line and blue dashed line in Fig. A.10).

The asymmetry patterns presented in Fig. 4 and Fig. A.10 rely crucially on the movements of endogenous land price and the associated tightening of the collateral constraint. To illustrate, I consider an alternative specification where agents' borrowing capacity is evaluated according to a "fixed" land price $\bar{p}$:

$$F(z_t, k_{t-1}, n_{1t}, l_{1t}) \leq \xi_{1t} \bar{p} l_{1t} + \xi_{2t}(\bar{p} l_{2t} + k_t)$$

I set the value of $\bar{p}$ to the unconstrained-steady-state level. Note that in this version land price is still endogenously determined by market clearing. However, the equilibrum land price is not used to evaluate borrowing capacity. Transitional

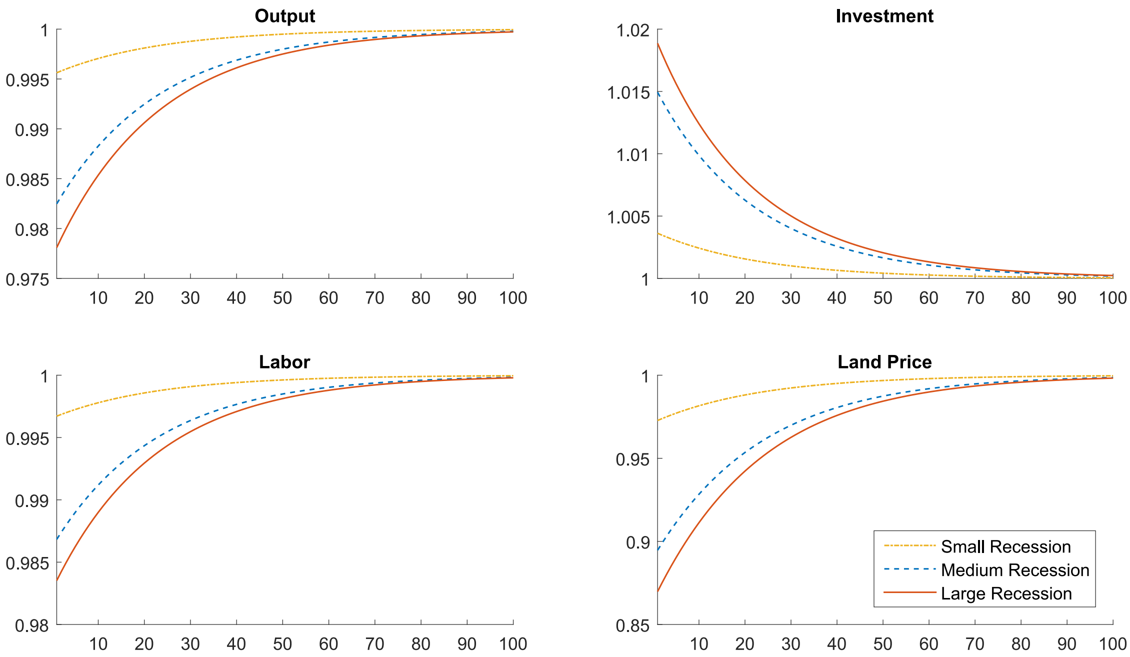

Fig. A11. Transitional dynamics in "Fixed-p" economy. This figure plots transitional dynamics in an alternative model where price of land is fixed in the collateral constraint (land price is still determined in equilibrium but the equilibrium price is not used in the constraint). The asymmetric pattern disappears and the recovery speeds are broadly similar across recessions of different sizes.

dynamics of this "fixed-p economy" is presented in Fig. A.11. The economy works just as a standard Real-business-cycle model with symmetric recovery speed across recessions of different sizes.

Appendix B. Data Appendix

B1. Construction of household net debt and firm net saving

Household Net Debt. In this section, we describe in detail how to construct a measure of household's net debt b_{2t} using Flow-of-Funds Data. To do so, we need to construct three components: direct holding of net debt, indirect holding of net debt through pension and mutual funds. We construct each component using flow-of-funds data.

In terms of direct net debt, we use information from table L.101. We collect 1) household's holding of debt and 2) household's liability. The household's holding of debt is constructed by adding up its holding of debt securities (LM154022005) and loans (FL154023005), subtracting holdings of government securities (which includes treasury securities (LM153061105) and municipal securities (LM153062005)), as there is no public debt in the model. The household liability is given by total loans(FL154123005). The direct net debt is then computed as the difference between household's liability and its holding of debt.

We also need to compute the household's indirect holding of debt through pensions and mutual fund shares. Then pension entitlements can be divided into life insurance companies (Table L.116) and dummyTXdummy-(public and private pension funds (Table L.117). Total holding of debt is computed in a similar way by adding their holdings of securities and loans, minus government securities. The net debt held indirectly through life insurance companies is adjusted by the weight of the pension entitlements relative to the total liability of such companies.[17]

The mutual fund holding of net debt is computed from information in table L.122. Note that mutual fund shares can also be held by other parties. Hence we need to adjust the level of net debt using relative share of mutual fund owned by the households available in table L.224. The household share is computed as ratio of the sum of the direct holding (LM153064205), indirect holding through pension (LM593064205), and through life insurance companies (LM543064205) adjusted by the weight of pension entitlements in the total liability of such companies.

Lastly we sum up everything from direct holding, indirect holding through pension, and indirect holding through mutual funds. This gives us the preferred measure of household's net debt position. Dividing the net debt position with quarterly GDP obtained from FRED (https://fred.stlouisfed.org/). We obtain our measure of household's net debt over GDP ratio.

[16] Instead of solving for the four variables simultaneously in a non-linear solver, I decompose the problem into two steps to make the solver more robust. Given any k_{t-1}, k_t, p_t, one can first solve for n_t and l_{1t} using Eq. (A.3) and (A.5). One can then solve for k_t and p_t given $k_t t - 1$ using Eq. (A.1) and (A.2).

[17] Since almost all pension entitlements are held exclusively by households (see Table L.227), no such adjustment is required for pension funds.

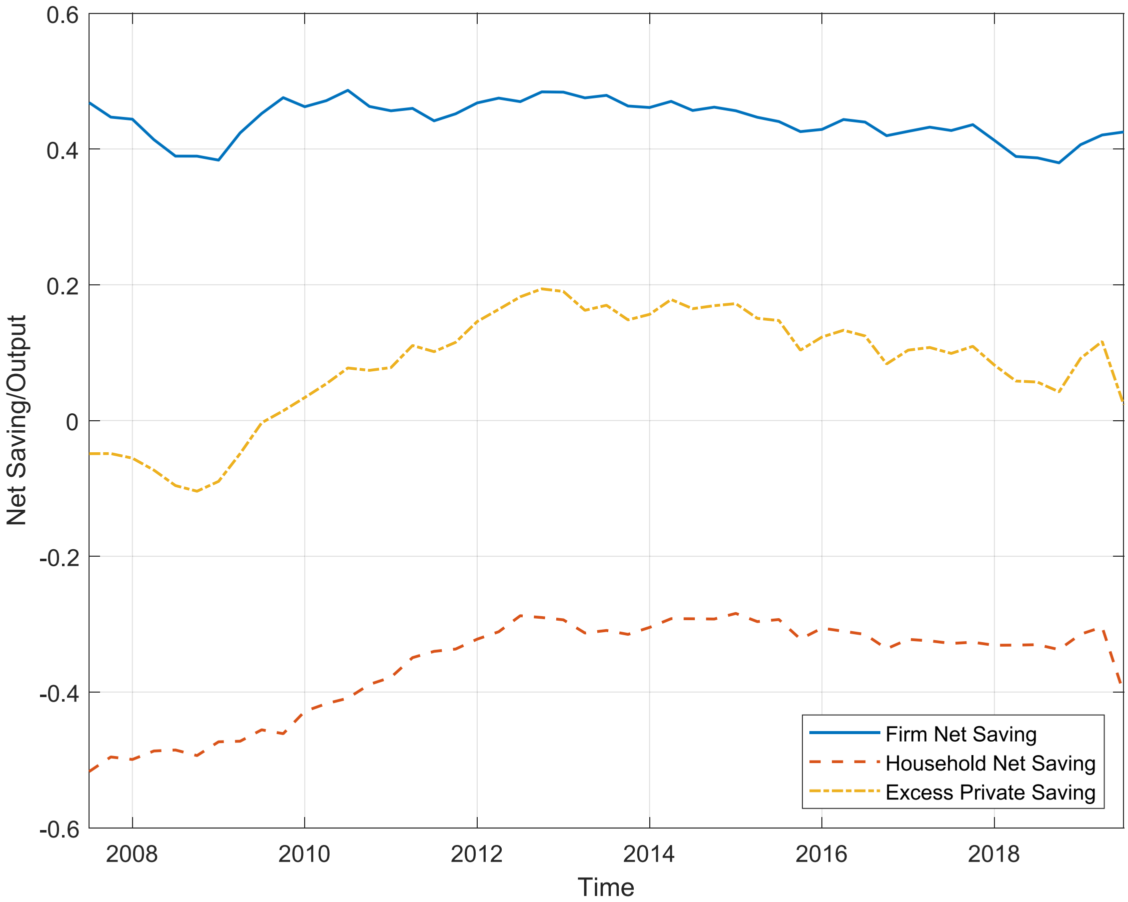

Fig. B12. Net Financial Asset Position of Firm Sector.

Firm Net Saving. As a robustness check we also independently construct measures of firm saving and compare it with the household net debt series. In Fig. B.12 I present some evidence which suggests that the firm sector has positive savings since 2007q4, the period during which the financial crisis started and the model economy transits into the constrained region. To do so, I use Flow-of-Funds data to aggregate financial asset information of nonfinancial firms (corporation and noncorporations) as well as financial firms to construct this statistic as follows.

For non-financial firms, I take data from flow-of-funds, table L.102. Their net financial position is constructed as holding of debt securities (LM144022005-LM143061105-LM143062005) + loans (FL144023005) -liability of debt securities (FL104122005-FL103162000) and loans (FL144123005). When computing each object I subtract out treasury securities and municipal securities, same as what I have done with the household sector. For financial firms, I take data from table L. 108 and similarly construct their net financial position as holding of debt securities (FL794022005-FL793061105-FL793062005) + loans (FL794023005) -liability of debt securities (FL794122005) and loans (FL794123005). The aggregate net financial position is then scaled with output.

The resulting time series (solid blue line of Fig. B.12) is positive for the model period. As a sanity check I also plot household net saving (dashed red line) and excess saving which is the sum of firm and household savings. The firm's net saving and household's net borrowing are roughly on the same scale. The excess private saving was negative before 2010, and flipped signs thereafter. This is possibly due to 1) households were going through a painful deleveraging process and 2) the government was borrowing heavily to combat the Great Recession. While I made several inference assumptions to construct net saving measures of households and firms, these measures seem to make sense overall. More refined measures can be constructed if there are more detailed dis-aggregate data, for instance, on ownership structures of firms, mutual funds, and pensions.

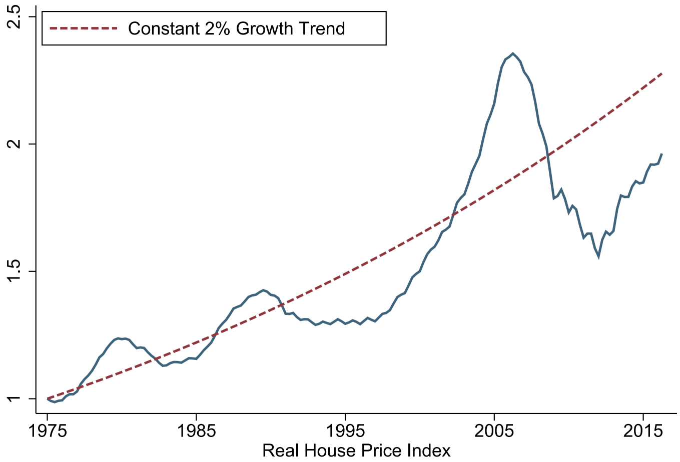

Fig. B.13. Real Housing Price and its trend. This figure plots the S&P/Case-Shiller U.S. National Home Price Index, deflated by the GDP deflator, along with its constant growth trend. The growth rate is picked to be 2%. This is the average growth rate for real GDP per capita between 1947 and 2007. It is also close to the average growth rate for real house prices between 1975 and 2006 (see Fig. 1 in Davis and Heathcote, 2007).

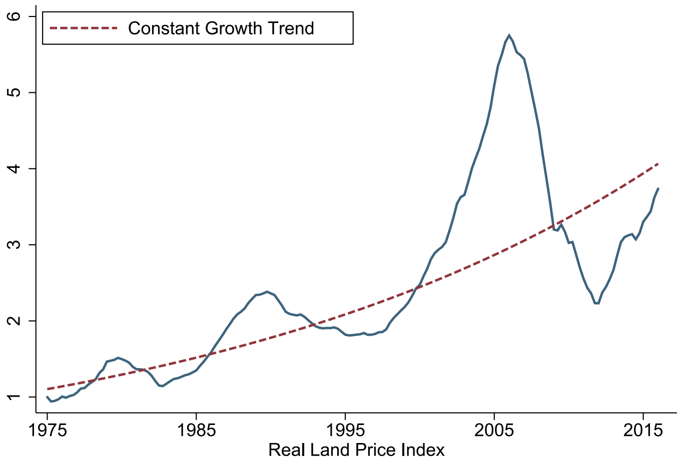

Fig. B.14. Real Land Price and its trend This figure plots the land price index available from the Lincoln Institute of Land Policy, which is constructed following Davis and Heathcote (2007), using Case-Shiller National Home Price Index and replacement cost of structures available from BEA. The data is available at http://datatoolkits.lincolninst.edu/subcenters/land-values/price-and-quantity.asp. For the constant growth trend, the growth rate of the trend is picked to match the average growth rate of real land price between 1975 and 1995.

B2. Construction of productivity shocks

In this section we describe steps to construct the series of productivity (Solow residual) consistent with the model. We start with our production function:

$$y_t = z_t \left[l_{1t}^{\gamma} k_{t-1}^{1-\gamma} \right]^{\alpha} n_{1t}^{1-\alpha}$$

The parameter values of α and γ are set according to the calibration: $\alpha = 0.35, \gamma = 0.086$. And we construct z_t as the residual of the equation.

$$z_t = \frac{y_t}{\left[l_{1t}^{\gamma} k_{t-1}^{1-\gamma} \right]^{\alpha} n_{1t}^{1-\alpha}} \tag{B.12}$$

Next we construct measures for output y_t, labor n_{1t}, capital k_{t-1}, and firm land holding l_{1t}. For output we use quarterly real GDP per capita. For labor we use total hours. For capital we assume that capital is at its initial level at year 1950 and then trace out the entire sequence of capital using the investment series as in Fig. 1. For firm holding of land we use flow of funds data. To come up with the value of land held by the firm, we use the value of real-estate (series number LM105035005 for corporate business and LM115035005 for noncorporate business) minus the value of residential and nonresidential structures (LM105012665 and LM105013665 for corporate business; FL115012665 and FL115013665 for noncorporate business). We then sum up the total value of land by both the corporate and noncorporate business and obtain a total value of land held by the firm. We also need to compute the value of land held by the household. To do so we use the value of real-estate (series number LM155035015) minus the value of residential structures (LM155012665). We then compute the land holding as follows:

$$l_{1t} = \frac{l_{1t}}{\bar{L}} = \frac{l_{1t}}{l_{1t} + l_{2t}} = \frac{p_t l_{1t}}{p_t l_{1t} + p_t l_{2t}} = \frac{\text{value of land held by firm}}{\text{value of land held by firm} + \text{value of land held by household}}$$

Since we have constructed the value of land held by the firm and the household, we can construct the series of l_{1t} using the above formula. After constructing the series of output y_t, labor n_{1t}, capital k_{t-1}, and firm land holding l_{1t}, we can compute the productivity shock as the residual from Eq. (B.12). The resulting productivity shocks are then logged and detrended using a linear trend between year 1980 and 2006 (prior to the Great Recession).

B3. Trends in house prices and land prices

In this section we present the raw time series of house price and land price from, respectively Case-Shiller National Home Price Index and Lincoln Institute of Land Policy. The trend is taken with respect to the entire sample period. It is true that if one excludes the period after 2000, one would get a much lower time trend, and house price would be back to trend by 2016. However, note that there is a time period where house and land prices were abnormally low around year 1995. If one also excludes that time period, then one would get almost the same time series as if the trend was taken with respect to the entire sample period. The fact that the model displays non-linear dynamics in a big recession (like the Great Recession) does not affect filtering, as I identify the trend with pre-Great-Recession data.

Appendix C. Additional Impulse Response Function

Fig. C.15 plots the model impulse response (IRF) function starting from the unconstrained steady state and the constrained steady state, in responses to the productivity shock in Fig. 5. The percentage deviation is with respect to each steady state. The solid red line plots the benchmark model and the dashed blue line plots the fixed-p model.Compared to the unconstrained IRF, the constrained IRF features more amplification, but less propagation. The reason is that around (and below) the constrained steady state the collateral constraint is always binding, leading to greater amplification. On the other hand, there is less propagation because the model always converges to the unique constrained steady state with a negative shock.

Appendix D. On the Role of Household Collateral Constraint

This section discusses how to link the household collateral constraint to model ingredients in Jermann and Quadrini (2012). In Jermann and Quadrini (2012) there is a tax benefit of debt and an adjustment cost of dividend, both are imporant for the financial shocks have a quantitatively important impact on aggregate economy. Without these two ingredients, financial shocks would have no impact on the aggregate economy (Proposition 2 on page 247). In this paper, there is no tax benefit of debt, nor costly adjustment of dividends. Instead, there is 1) a land (real-estate) sector which links asset prices to borrowing constraints along the lines of Kiyotaki and Moore and 2) A household collateral constraint that links asset pricing to household borrowing capacities.

Both ingredients serve to amplify and propogate the impact of financial shocks, and can be linked to the two ingredients in Jermann and Quadrini (2012) as follows. First off, the role of the tax benefit of debt in Jermann and Quadrini (2012) is to drive the effective interest rate (after tax) faced by the firm below the reciprocal of time preferences $\frac{1}{\beta}$, thus guarantees the existence of a unique constrained steady state (Proposition 1 on page 247). A binding household collateral constraint at the constrained steady state plays a similar role by driving down the real interest rate below $\frac{1}{\beta}$, therefore inducing the firm to lever up (or maintain the minimum saving to cover working capital needs), leading to a constrained steady state in this model. During normal times, on the other hand, the household collateral constraint is slack, thus the interest rate is equal to $\frac{1}{\beta}$, supporting the unconstrained steady state. Thus, one function of the household collateral constraint resembles a "state-dependent" tax benefit for the firm, imposing no tax benefit of debt in normal times and positive benefit in crisis times, therefore supporting an unconstrained and a constrained steady state.

The role of dividend adjustment cost in Jermann and Quadrini (2012) is to prevent large equity issuance when there is an adverse financial shock. In the absence of such adjustment cost, say in a standard growth model with just firm collateral constraint, adverse financial shocks cannot have a big impact on firm output, as the firm can freely adjust its capital structure. Hence wage does not fall, and household consumption is also unaffected.

This is not the case with household collateral constraint. With an adverse shock to the household collateral constraint that makes it binding, household consumption necessarily falls, this means that the pricing kernel of the firm rises during the recession. Such a rise makes the firm reluctant to issue equity because the shadow cost (relative to future issuances) is higher. Note that there is no restriction on dividend d. Instead, this force works through general equilibrium that affects the firm's pricing kernel and thus makes the firm reluctant to issue equity during crisis times. It is true that individual firms do not take into account any restrictions coming from the household side. However, **movements in the pricing kernel** would make them behave *as if* household side collateral frictions are being taken into account.

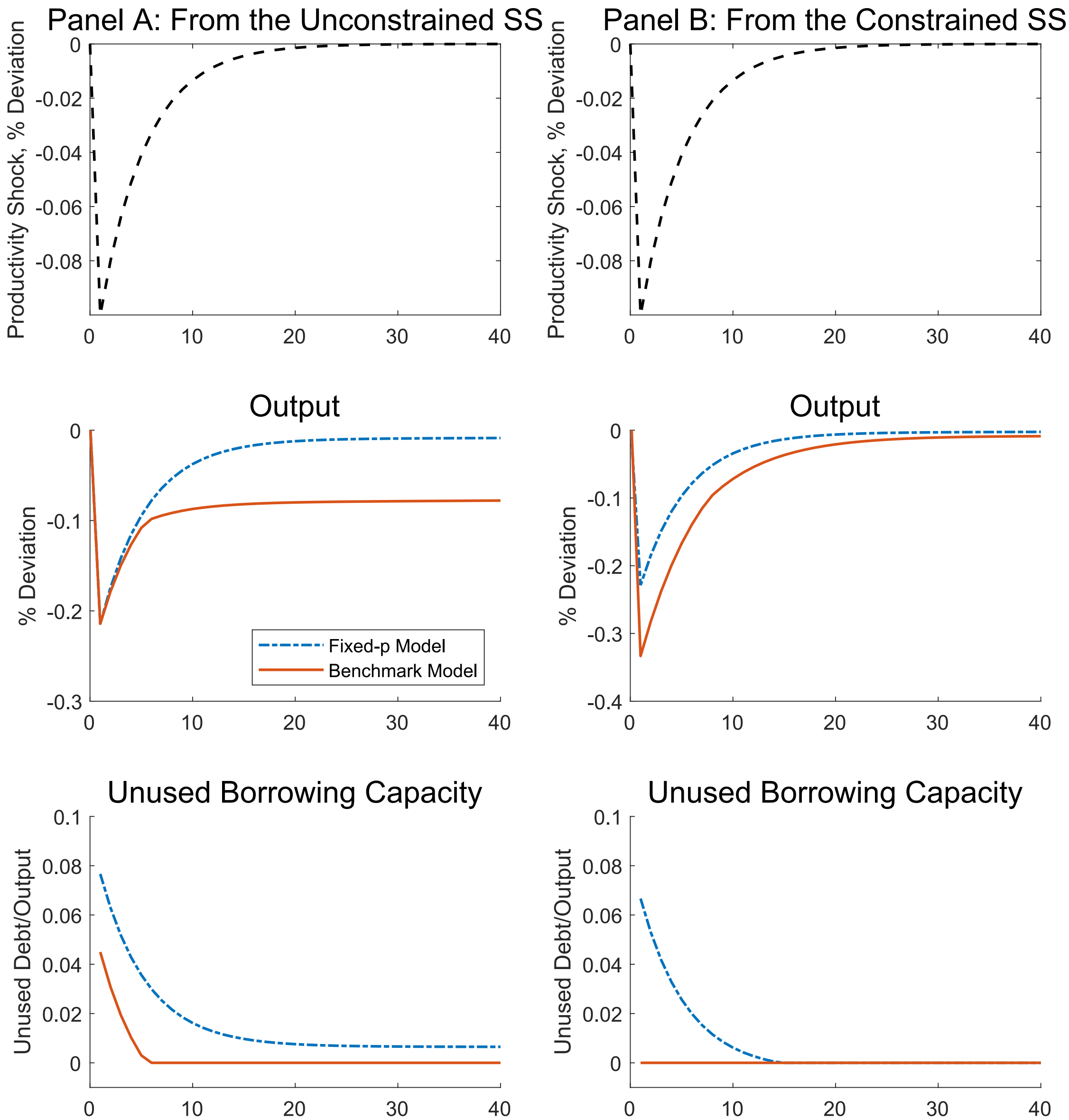

Fig. C.15. This figure plots the model impulse response function starting from the unconstrained steady state and the constraint steady state, in response to the productivity shock plotted in Fig. 5.

To be concrete on what I mean, consider the following simplified two-period version of the firm's problem:

$$\max_{d_1,d_2,n_1,n_2,k_1,b_1} d_1 + \beta M d_2$$

$$k_1 + d_1 \le F(k_0, n_1) - wn_1 + (1-\delta)k_0 - b_0 + \frac{b_1}{R}$$

$$d_2 = F(k_1, n_2) - wn_2 - b_1$$

The firm starts off with some capital k_0 and bond holding b_0. It then needs to decide on dividend payments d_1 and d_2, labor hiring n_1 and n_2 on both dates, as well as intertemporal capital accumulating k_1, and new bond issuance b_1. For simplicity I take out the land accumulation decisions. The objective function of the firm is to maximize discounted value of dividends, with the pricing kernel $M = \frac{U'(c_2)}{U'(c_1)}$ equal to the intertemporal substitution of the household consumption across the two dates.

Let us consider the benefit of equity issuance in this simplified model. Specificially consider the marginal benefit of the following perturbation: in period 1, reduce dividend payment (or equivalently, increase equity issuance) d_1 by Δ, save this amount in bond b_1 (which earns interest rate R), and distribute it to increase future dividend d_2. The benefit of this perturbation is more dividend issuance tomorrow with amount of $R\Delta$, while the cost of issuing less dividend is Δ. Thus the net discounted benefit of this perturbation is:

$$\beta MR\Delta - \Delta = (R\beta M - 1)\Delta$$

In a frictionless world, this term is always equal to 0 because the household marginal rate of substitution is always equal to the effective rate of time preference:

$$U'(c_1) = \beta RU'(c_2)$$

This translates into the firm's pricing kernel $R\beta M = R\beta\frac{U'(c_2)}{U'(c_1)} = 1$. Hence in this frictionless world, firm would be indifference between issuing equity and/or borrowing through debt.

Now consider introducing a household-side collateral constraint. Imagine a tightening of this constraint in period 1. With a tightening of the household collateral constraint, household consumption in period 1, c_1, must fall. This leads to a wedge between the marginal rate of substitution and the effective rate of time preference:

$$U'(c_1) > \beta RU'(c_2)$$

This drives down the pricing kernel of the firm $M = \frac{U'(c_2)}{U'(c_1)}$ such that the net benefit term becomes negative:

$$(R\beta M - 1)\Delta = \left(R\beta\frac{U'(c_2)}{U'(c_1)} - 1\right)\Delta < 0$$

Thus, when there is a financial shock to the household borrowing constraint, the firm tends to distribute dividend to the household. This is the sense in which movements in pricing kernel can change the firm's preference for dividend payment (equity issuance) in general equilibrium, even if individual firms do not take into account any restrictions on d that may come from individual household problem.

In this world without the firm's borrowing constraint, the firm would borrow more and use the proceeds to distribute dividends to the household when the household collateral constraint is binding. This would increase household consumption in period 1 to the point that the household collateral constraint no longer binds. This restores the equality between the marginal rate of substitution and the effective rate of time preference. And we go back to the frictionless allocation. When we impose a firm-side collateral constraint there would be a limit on how much the firm can borrow and distribute dividend, this imposes a shadow cost of borrowing. Denote the multiplier on the collateral constraint μ :

$$F(k_0, n_1) + \frac{b_1}{R} \leq \kappa k_1 \ldots \mu$$

Consider the same perturbation of less dividend issuance in period 1 and more saving for future dividend distribution. The net benefit is given by expression in the previous model minus the shadow benefit of potentially relaxing the firm collateral constraint:

$$(R\beta M - 1)\Delta + \Delta\mu = (R\beta M \downarrow -1 + \kappa\mu \uparrow)\Delta$$

Now consider a financial crisis that tightens both the household and the firm's collateral constraint. On the one hand, a tightening of the firm collateral constraint raises the multiplier μ, increasing the net benefit of equity issuance. Hence, firm tends to reduce dividend distribution (or equivalently, increase equity issuance). This is the standard reallocation effect in which borrowing constrained firms want to issue more equity to prevent production disruptions.

On the other hand, due to the simultaneous tightening on the household side collateral constraint, the pricing kernel M decreases, leading to lower benefit of dividend distribution. This is the force that prevents large equity issuance in this model. Of course, this general equilibrium force needs to be strong enough (i.e. induce sufficient movements in the pricing kernel) for the financial shocks to be quantitatively important, and in this model it is achieved through flucutations in endogenous asset prices that enters into the household and firm's collateral constraint along the lines of works by Kiyotaki and Moore (1997).

To see the role of equity adjustment cost in Jermann and Quadrini (2012), assume that the first period equity issuance is subject to a convex cost function $\varphi(d)$.[18] and consider the same perturbation of less dividend issuance and more saving as in previous models. The net benefit now is given by the net return term, the collateral term, and the adjustment cost term

$$(R\beta M - 1)\Delta + \Delta\mu - \varphi'(.)\Delta = \left(R\beta \underbrace{M\downarrow}_{\text{This paper}} -1 + \underbrace{\kappa\mu\uparrow}_{\text{Adverse financial shock}} - \underbrace{\varphi'(.)\uparrow}_{\text{Jermann and Quadrini (2012)}}\right)\Delta$$

[18] For illustration purposes we assume that second period dividend payment is not subject to adjustment costs.

with an extra term $\varphi'(.)$ capturing this equity adjustmnet cost. In this world, a tightening of the firm collateral constraint would induce more equity issuance, raising the adjustment cost. This offsets the benefit of equity issuance. Thus movements in the pricing kernel induced by household collateral constraint plays a similar role as equity issuance cost in preventing large change in the firm's capital structure in response to adverse financial shocks.

To summarize, with a tightening of the household collateral constraint, two things happens in general equilibrium. First, there is a decrease in the interest rate faced by the firm, which leads to existence of a constrained steady state. Second, there is a movement in the firm's pricing kernel induced by a wedge between household marginal rate of substitution and effective rate of time preference. This movement makes firm reluctant to tap the equity market during a financial crisis, thus serving a similar role to a dividend adjustment cost.

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