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Land collateral and labor market dynamics in France

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ABSTRACT

The value of land in the balance sheet of French firms correlates positively with their hiring and investment flows. To explore the relationship between these variables, we develop a macroeconomic model with firms that are subject to both credit and labor market frictions. The value of collateral is driven by the forward-looking dynamics of the land price, which reacts endogenously to fundamental and non-fundamental (sunspot) shocks. We calibrate the model to French data and find that land price shocks give rise to significant amplification and hump-shaped responses of investment, vacancies and unemployment that are in line with the data. We show that both the endogenous movements in the firms' discount factor and the sluggish response of the land price are key elements that drive the results.

1. Introduction

Recent evidence suggests that real estate collateral is an important determinant of firms' employment decisions. Using administrative data for French firms, Chaney et al. (2013) show that shocks to the value of real estate have sizeable effects on employment and investment. The impact of collateral on investment appears to be larger for French firms than for the US firms covered by the Compustat database (Chaney et al., 2012).[1] Moreover, investment appears to be considerably more sensitive to cash-flow variations in France, which suggests that French firms may be more financially constrained. To better understand how the labor market responds to shocks to the firms' collateral value, this paper builds a canonical macroeconomic model with financially constrained firms and search frictions in the labor market. We calibrate the model to France and relate its business-cycle features to those in the data. In particular, we find that the model response to a shock to collateral value features amplification and propagation that are in line with those obtained from a VAR analysis.

Our business–cycle model features collateral constraints and forward–looking land prices as in Kiyotaki and Moore (1997) and Kocherlakota (2000), on the one hand, and labor market frictions similar to Mortensen and Pissarides (1999), on the other hand. Firms hold productive land and capital, and they borrow in an international credit market, using land and (a fraction of) capital as collateral.[2] In the labor market, firms post vacancies and they are matched with unemployed workers who are hired for production in the subsequent period.

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[1] Specifically, a 1$ increase in collateral value raises investment for US firms by 0.06$, whereas the effect for French firms is about three times as large. Of course, the two firm samples are not directly comparable, since Compustat does not cover private (and smaller) firms which are more bank-dependent. Further studies on the role of financial constraints on employment based on US firm-level data are Benmelech et al. (2011) and Chodorow-Reich (2014).

[2] Our focus on land (as opposed to real estate) builds on Davis and Heathcote (2007), who show that fluctuations in US firms' real estate are largely driven by those in the land value. This is also what we find in French data.

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To uncover the business–cycle relationships between collateral prices, investment and labor market dynamics, we introduce three types of shocks into our model: (i) TFP shocks; (ii) shocks to the collateral constraint ("financial shocks"); and (iii) shocks to the transaction price of land ("land price shocks"). We think of (ii) as any disruptions in financial markets that change the amount of funds channeled from lenders to borrowers. Although shocks (i) (as in, e.g., Kocherlakota, 2000) and (ii) alone induce endogenous movements in land prices, this amplification channel is quantitatively too small to account for the observed volatility in the data. We think of shock (iii) as a short-cut to describe movements in the demand for land, without making the underlying mechanism explicit. This allows us to distinguish explicitly between those events that change the value of land collateral and other types of financial shocks that directly affect the intermediation between borrowers and lenders, as in the recent literature (e.g., Kiyotaki et al., 2011; Liu et al., 2013; Justiniano et al., 2013).

When we calibrate our model to the French economy, we find that the dynamic response to shocks of type (iii) is especially relevant and exhibits large amplification and hump-shaped responses of vacancies, unemployment and investment. The responses differ notably because the land price shock significantly relaxes the credit constraint and thus takes an impact on the firms' discount factor. We show that the dynamics of the firms' discount factor plays a key role in the response of hiring which is a new amplification channel relative to the existing macro-labor literature. The explanation is that constrained firms react to a relaxation of credit constraints by augmenting current profit income at the expense of future income, which raises the discount factor and induces firms to expand investment and hiring faster.

Besides this channel, the key factor behind the propagation result is that the unique steady-state equilibrium is locally indeterminate, which means that the land price not only depends on fundamentals but also reacts to self-fulfilling beliefs (sunspots). The intuition for this result is a "pecuniary externality" in the collateral constraint: if firms expect the land price to go up in the future, they expect relaxed credit constraints which induces them to borrow and invest more, and hence to demand more inputs which in turn bids up the land price. As a consequence, the initial expectation is fulfilled. In the absence of sunspot shocks, on the other hand, the land price reacts to fundamental shocks in a sluggish fashion. This sluggish adjustment accounts for a slow build up of collateral capacity and hence to a hump-shaped response of investment and vacancies to a (fundamental) land price shock. In contrast, pure sunspot shocks or shocks to the collateral constraint generate dynamics that are at odds with the data. Our paper departs from the literature reviewed below by showing that the dynamics of investment and labor market variables under fundamental shocks to the land price are empirically relevant when the steady state is locally indeterminate.

Our work relates to a recent literature that incorporates financial frictions into macroeconomic models with search frictions in the labor market. In an early contribution, Wasmer and Weil (2004) introduce frictional search in the credit market and obtain a financial accelerator effect, while Dromel et al. (2010) show how unemployment becomes persistent under credit market frictions in a related model. Petrosky-Nadeau and Wasmer (2013) consider a stochastic version of a similar model, generating a dynamic financial multiplier which amplifies the impact of productivity shocks on labor market tightness significantly.

Monacelli et al. (2011) introduce borrowing constraints into a macroeconomic model with labor search frictions; while they argue that these constraints do not directly prevent firms from hiring, they show that higher debt improves firms' bargaining position, which takes a negative (positive) effect on wages (job creation). Boeri et al. (2013) let unconstrained firms choose an optimal level of leverage, together with job creation and job destruction; they show that credit market conditions have an effect on job creation *and* on job destruction. As in our paper, financial conditions take a direct impact on job creation of financially constrained firms in Petrosky-Nadeau (2014) who focuses on the amplification and propagation of productivity shocks but does not consider the dynamics of collateral value.

Closely related to our paper is Liu et al. (2013a) who consider a quantitative macroeconomic model with labor and credit market frictions in which shocks to land prices affect the firms' collateral capacity. Estimating their model to US data, they also obtain labor market amplification of land price shocks, although their model does not generate hump-shaped impulse responses for vacancies. Also, different from our model, they include consumption habits as well as shocks to wage setting and to the matching function.[3] On the other hand, multiplicity and self-fulfilling beliefs play a key role in the paper of Miao et al. (2013) who show how a collapsing stock market bubble tightens credit constraints which induces firms to cut on hiring.

The rest of the paper is organized as follows. The next section reviews the role of firms' land collateral for the business cycle in France. Section 3 introduces the model and Section 4 characterizes the dynamic equilibrium. In Section 5, we calibrate the model to France to analyze its business cycle features.

2. Land value and labor market dynamics in france

In this section we discuss the role of firms' land collateral for business cycle dynamics in the French economy. We begin with a descriptive analysis by showing some key correlation and volatility patterns. We then conduct a VAR analysis to understand how shocks to the market value of land held by the firms affect the labor market.

[3] Also, unlike our model, households hold land, which contributes to amplification through a "labor channel", induced by wage rigidities due to non-separable utility between consumption goods and housing services. Such a channel is absent in our model.

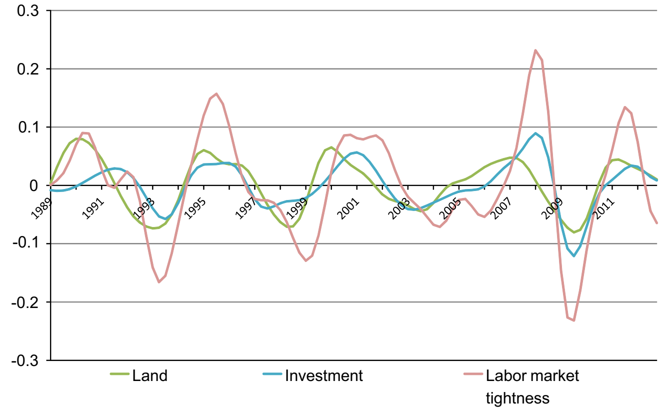

Fig. 1. Land at market value, investment, and labor market tightness (cyclical components) in France.

Table 1
Comovement and relative volatilities.

Variable	Output	Land	Investment	Vacancies	Unemployment	Tightness	Credit liabilities	Real wage
Output	**1.000**	0.460	0.793	0.692	−0.645	0.840	0.349	−0.011
Land		**1.000**	0.570	0.760	−0.402	0.647	0.096	0.082
Investment			**1.000**	0.710	−0.689	0.879	0.379	0.124
Vacancies				**1.000**	−0.468	0.839	0.057	0.044
Unemployment					**1.000**	−0.867	−0.771	0.401
Tightness						**1.000**	0.523	−0.164
Credit liabilities							**1.000**	−0.075
Real wage								**1.000**
Std. dev. relative to output	**1.000**	**3.874**	**3.304**	**5.228**	**4.683**	**8.933**	**2.940**	**0.439**

Notes: All statistics are based on quarterly variables over the period 1978–2011, except credit market liabilities (since 1996), vacancies and market tightness (since 1989). See the text and Appendix A for details.

2.1. *Descriptive statistics*

We gather data from national accounts (output, investment, credit market liabilities, and land at market value for the non-financial business sector) as well as from labor market statistics (employment, unemployment and vacancies). All time series are available at quarterly frequencies, except data on firm's balance sheet which are available at annual frequency. Due to data availability, we restrict the analysis to the period 1978q1–2011q4. We are mainly interested in the role of the market value of land held by non-financial firms; the market value matters in our model as it reflects the liquidation value taken into account by creditors.

The French national statistics institution (INSEE) provides annual data since 1978 on the market value of non-financial firms' assets and liabilities and notably land. We derive land at market value at the end of each quarter for French firms by linearly interpolating end of the year values. This is arguably a good approximation as we find, using a quarterly available residential real estate price index on a sub-period (1996q1–2011q4), that the evolution of French real estate is close to linear within a year and shows only few intra-year trend reversals. Furthermore, the volume of land owned by firms at the aggregate level does not change significantly during a year, so that such volume effects are unlikely to drive the series of land at market value. Our key labor market indicator is labor market tightness, defined as the ratio between vacancies and unemployment, which is available for France from 1989 onwards. The aggregate real wage is calculated as the product between labor productivity and the labor income share. All time series are seasonally adjusted and expressed in logs, and all nominal variables are deflated with the GDP deflator. As we cannot reject the hypothesis that our main series have unit roots, we detrend all series using the band pass filter of Christiano and Fitzgerald (2003) implemented in Stata.[4] More details on the data sources and further descriptive statistics are reported in Appendix A.

Fig. 1 shows time series for the firms' land value, investment and labor market tightness. Notably all three series are positively correlated. While investment and land value are about equally volatile, labor market tightness shows considerably higher volatility.

[4] Specifically, the aim is to remove all fluctuations shorter than 1.5 and longer than 8 years, which is standard practice in the business-cycle literature. A periodogram analysis shows that the Christiano–Fitzgerald filter does a better job than the Hodrick–Prescott filter in that respect. We also note that drifts have been removed from all variables.

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These findings are also confirmed in Table 1 which reports correlation coefficients and standard deviations relative to output for several variables. It is notable that the land value as well as unemployment and vacancies are much more volatile than output. Particularly, labor market tightness is almost 9 times as volatile as output, which is comparable to the figure for the US economy. Unsurprisingly, the land value, investment and labor market tightness are highly procyclical, and the land value is strongly positively correlated with vacancies and tightness. The real wage is much more stable than output and acyclical.

It is also interesting to point out some differences with the US economy for which we report comparable statistics in Appendix A. Over the same time period, the business cycle is considerably more stable in France. Relative to output, however, the French economy has generated almost the same labor market volatility as the US economy. While the land value is more volatile in the US, it correlates less strongly with labor market tightness than it does in France. Another noteworthy difference is that the number of vacancies is highly negatively correlated to unemployment in the US, whereas the negative relation is weaker in France (see also Justiniano and Michelacci, 2011). We further observe that credit market liabilities are more correlated to labor market variables in France than in the US. One possible explanation could be the well documented fact that firms in France (as in other European countries) rely more on credit financing than in the US.

2.2. VAR analysis

In order to study the dynamic relationships between firms' land value, vacancies, unemployment and investment, we estimate a vector autoregression (VAR) model with these four variables. Our estimations are performed with the above-described quarterly French data for the period 1989q1–2011q4. This study aims at assessing the impact of a structural shock to the land value on labor market variables and investment. We estimate the reduced-form VAR $A(L)x_t = \varepsilon_t$, where the 4×1 vector x_t includes the detrended log values of land, vacancies, unemployment and investment, ε_t is a vector of shocks and $A(L)$ is a lag polynomial matrix with $A(0)$ being the identity matrix.

We are interested in identifying the structural shock on firms' land value, that is to say isolating the land shock component uncorrelated with the contemporaneous shocks affecting the labor market or investment, and tracing its effect on the three other variables. We argue that this structural shock on firms' land holdings value appropriately reflects the effect of the land price shock introduced in our theoretical framework. We recover the structural shocks through the Cholesky decomposition of the estimates of the variance–covariance matrix. We order the shock to firms' land value first in this decomposition, thereby allowing labor market variables and firms' investment to have feedback effects on the land value through their lagged values but not through their contemporaneous values.[5]

Impulse response functions to a one-standard-deviation land value shock are presented in Fig. 2. Vacancies and investment react positively to a positive land value shock, whereas unemployment reacts negatively.

The land value adjustments following the initial shock (leading to a 1% increase in land value) exhibit a hump-shaped pattern, peaking at roughly 9% above its steady-state value four quarters after the shock. Vacancies almost do not react on impact, but in subsequent quarters the variable follows a similar pattern as the land value, peaking at roughly 11% above its steady-state value five quarters after the shock. Unemployment almost does not react on impact either, and the adjustment is also hump-shaped and a bit more sluggish with a trough at roughly −10% about seven quarters after the shock. We observe a slight positive response of investment in the period of the shock and also a more moderate hump-shaped adjustment than for the three other variables.[6]

Overall, the results show that structural shocks to firms' land value drive labor market variables and investment and that the shock has significant long-lasting and hump-shaped effects on land value, labor market variables and investment.

3. The model

We consider a small open economy comprising a unit mass of firms and a unit mass of workers. Firm owners hold and accumulate capital, buy land, hire workers and borrow in an international credit market at fixed interest rate R, where borrowing is subject to collateral constraints.[7] Firms produce a common consumption/investment goods from the inputs capital, labor and land. While capital can be accumulated, the aggregate supply of land is fixed and normalized to one. Land is traded at price Q_t in period t, and the price of capital and consumption goods is normalized to unity. Workers consume their labor income; neither do they hold land, nor are they active in the credit market. While the markets for capital and land are frictionless, the market for labor is subject to search frictions. Finally, there is a government redistributing income from employed to unemployed workers.

[5] The VAR is estimated with lag lengths of four quarters for each equation. Changing the lag lengths has little effect on the results. Note also that the results are not sensitive to the ordering of the three remaining variables.

[6] For comparison, we also consider a similar VAR model where labor market tightness replaces vacancies. The results turn out to be very similar: labor market tightness peaks about 6 quarters after the shock with somewhat higher amplification than vacancies, whereas the responses of the other variables remain unchanged.

[7] The assumption of a small open economy is a reasonable abstraction for a country like France. An alternative model framework would be a closed economy in which worker households are more patient than firm owners and provide credit to borrowing-constrained firms. We conjecture that the results would be rather similar.

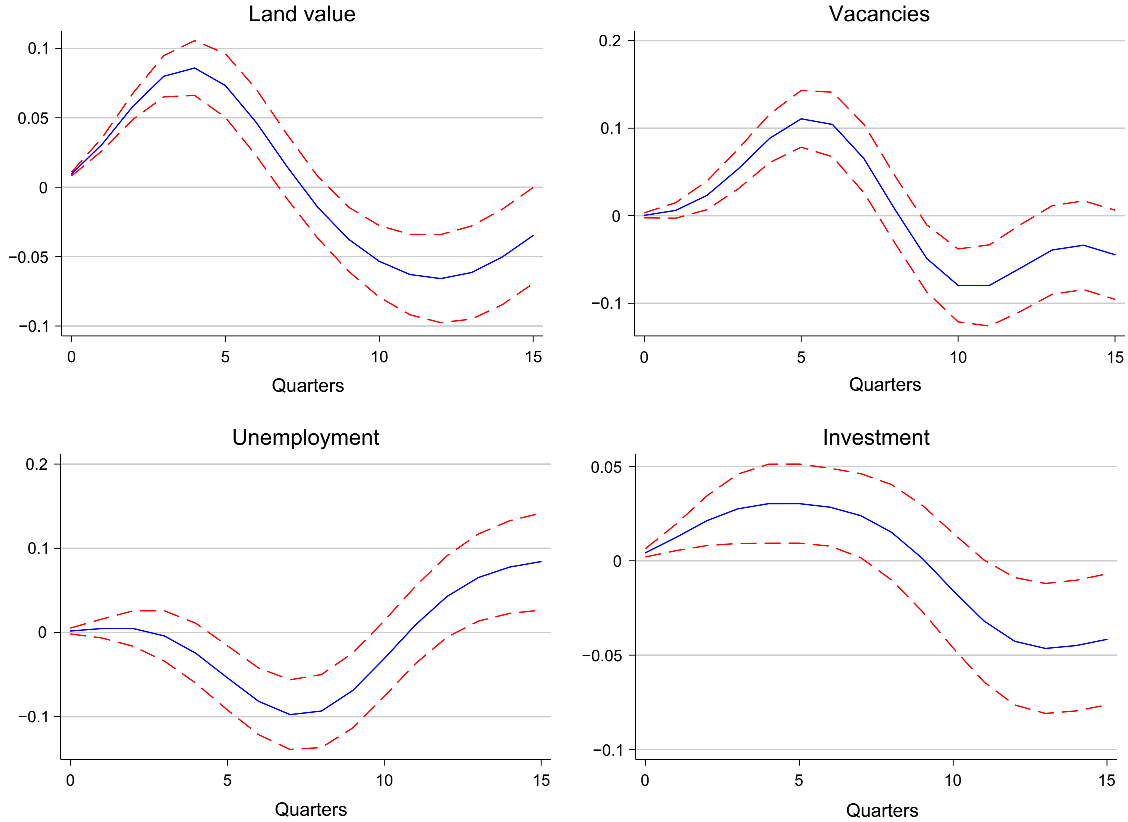

Fig. 2. Impulse response functions to a one-standard-deviation land value shock. *Note*: Dotted lines are 95% confidence bands.

3.1. Firms

Firms use capital K_t, labor N_t and land L_t to produce final output with concave and constant-returns technology $Y_t = A_t F(L_t, K_t, N_t)$ where A_t is aggregate TFP. All three inputs are installed in the period prior to production. Firms also enter the period with credit market liabilities B_t. Since there are only aggregate shocks, all firms are identical, so we treat the firm as a representative firm and we do not distinguish in our notation between aggregate and firm-level variables.

The owner of the representative firm consumes C_t in period t and has preferences

$$\sum_{t=0}^{\infty} \beta^t u(C_t), \tag{1}$$

where u is a strictly increasing and concave function. In period t the firm faces the budget constraint:

$$B_{t+1} + Y_t = C_t + T_t Q_t (L_{t+1} - L_t) + (1+R) B_t + W_t N_t + I_t + \phi_K I_t^{1+\eta_K} I_{t-1}^{-\eta_K} + \phi_N H_t^{\eta_N} N_t^{1-\eta_N}, \tag{2}$$

where I_t is the investment flow, H_t is the hiring flow, $\phi_K \geq 0$ and $\phi_N \geq 0$ control for investment and employment adjustment costs, and B_t is credit redeemed in period t. Adjustment costs are convex in investment growth I_t/I_{t-1} and in the hiring rate H_t/N_t; that is, we require $\eta_K \geq 1$ and $\eta_N \geq 1$. W_t is the real wage which is bargained bilaterally between the firm and each individual worker. As we see below, the outcome of this bargain depends only on aggregate quantities but is independent of the firm's individual factor choices (L_t, K_t, N_t). Hence the firm takes W_t as given when it decides about factor inputs. T_t is an exogenous “land wedge” variable which affects the transaction costs of land. It plays the same role as a tax on land sales (which is not paid in equilibrium). We later introduce shocks to this variable to capture any events that take an impact on land demand and hence on the land price. In particular, we investigate the effects of a decline in the land wedge T_t, which triggers an increase in land price Q_t, on investment and labor market variables.

Borrowing is subject to a collateral constraint of the form

$$\Psi_t [Q_{t+1} L_{t+1} + \omega (1-\delta) K_{t+1}] \geq (1+R) B_{t+1}, \tag{3}$$

where Ψ_t is a collateral constraint parameter which we interpret as financial market conditions and which may be subject to financial shocks. The term in squared brackets represents collateral of the firm which comprises all land holdings and also a fraction $\omega \in [0,1]$ of the capital stock that can be pledged to the firm's creditors.

Capital and employment respectively adjust according to

$$K_{t+1} = (1-\delta)K_t + I_t, \tag{4}$$

$$N_{t+1} = (1-s)N_t + H_t, \tag{5}$$

where s is an exogenous separation rate.[8] The firm's problem is to maximize the owner's utility (1) subject to (2)–(5). Write λ_t, ι_t, μ_t and ν_t for the Lagrange multipliers on these four constraints. The first-order conditions with respect to C_t, I_t, K_{t+1}, L_{t+1}, H_t, B_{t+1} and N_{t+1} are

$$\lambda_t = u'(C_t), \tag{6}$$

$$\mu_t = \lambda_t \left[1 + \phi_K(1+\eta_K)\left\{\frac{I_t}{I_{t-1}}\right\}^{\eta_K}\right] - \beta\lambda_{t+1}\phi_K\eta_K\left\{\frac{I_{t+1}}{I_t}\right\}^{1+\eta_K}, \tag{7}$$

$$\mu_t = \beta(1-\delta)\mu_{t+1} + \beta\lambda_{t+1}\frac{\partial Y_{t+1}}{\partial K_{t+1}} + \omega(1-\delta)\iota_t\Psi_t, \tag{8}$$

$$\lambda_t Q_t T_t = \beta\lambda_{t+1}\left[\frac{\partial Y_{t+1}}{\partial L_{t+1}} + Q_{t+1}T_{t+1}\right] + \iota_t\Psi_t Q_{t+1}, \tag{9}$$

$$\nu_t = \lambda_t\phi_N\eta_N h_t^{\eta_N-1}, \tag{10}$$

$$\lambda_t = \beta(1+R)\lambda_{t+1} + \iota_t(1+R), \tag{11}$$

$$\nu_t = \beta(1-s)\nu_{t+1} + \beta\lambda_{t+1}\left[\frac{\partial Y_{t+1}}{\partial N_{t+1}} - W_{t+1} + \phi_N(\eta_N-1)h_{t+1}^{\eta_N}\right]. \tag{12}$$

Define $M_{t+1}^f \equiv \beta\lambda_{t+1}/\lambda_t$ as the firm's discount factor and write $J_t \equiv \nu_{t-1}/(M_t^f\lambda_{t-1})$ for the firm's value of an additional worker in period t in units of the consumption good. With $h_t = H_t/N_t$ denoting the hiring rate, (10) and (12) can be rewritten as

$$\phi_N\eta_N h_t^{\eta_N-1} = M_{t+1}^f J_{t+1}, \tag{13}$$

$$J_t = \frac{\partial Y_t}{\partial N_t} - W_t + \phi_N(\eta_N-1)h_t^{\eta_N} + (1-s)M_{t+1}^f J_{t+1}. \tag{14}$$

Eq. (13) is a standard job-creation condition which links firms' hiring behavior to the discounted job value. Eq. (14) shows that the job value is a forward-looking variable which depends on expectations about productivity and wages. The third term on the right-hand side reflects the reduction in future hiring costs from an additional employee.

3.2. Workers

Workers are able to pool idiosyncratic unemployment risk within a large family. The representative worker family consumes income $C_t^W = W_t N_t + \tau W_t(1-N_t) - T_t^W$, where τ is the wage replacement ratio and T_t^W are lump-sum taxes that are set by the government to finance these transfers. The worker household enjoys utility

$$\sum_{t=0}^{\infty}\beta^t u_W(C_t^W), \tag{15}$$

with strictly increasing and concave u_W, possibly different from the utility function of firm owners. Employment adjusts according to $N_{t+1} = (1-s)N_t + f_t(1-N_t(1-s))$ where f_t is the job-finding rate for unemployed workers.[9] If χ_t is the marginal utility value of an additional worker in period t, we have

$$\chi_t = \lambda_t^W(1-\tau)W_t + \beta(1-s)(1-f_t)\chi_{t+1},$$

where $\lambda_t^W = u'(C_t^W)$. Defining $\Omega_t \equiv \chi_t/\lambda_t^W$ for the value of a worker in consumption units and $M_{t+1}^W \equiv \beta\lambda_{t+1}^W/\lambda_t^W$ for the worker's discount factor, we obtain

$$\Omega_t = (1-\tau)W_t + (1-s)(1-f_t)M_{t+1}^W\Omega_{t+1}. \tag{16}$$

[8] By focusing on hiring flows, we keep the separation rate fixed for convenience. Given that shocks to the separation rate play a larger role in Europe than in the US (cf. Justiniano and Michelacci, 2011), it should be interesting to investigate how shocks to s_t affect the dynamic responses in this model.

[9] It is assumed that a separated worker can search for reemployment within the same period. This is a reasonable modeling assumption for a quarterly calibration.

3.3. The labor market

The labor market is subject to search frictions. All separations (hires) go to (come from) the unemployment pool, so there are neither job-to-job transitions nor transitions into and out of the labor force. Given that the flow of newly employed workers equals the flow of hires in period t, the rate at which any of the $1-N_t(1-s)$ unemployed workers finds a job is linked to aggregate hires according to $f_t = H_t/[1-N_t(1-s)]$. While firms in this model decide the number of hires, we can also think of them as posting vacancies and anticipating how many of their vacancies are filled according to a standard matching process.[10] That is, the aggregate vacancies V_t posted by firms are matched with $1-N_t(1-s)$ job seekers through a matching technology, such that the job-finding rate is an increasing and concave function of the vacancy–unemployment ratio (market tightness) $\theta_t = V_t/[1-N_t(1-s)]$, i.e. $f_t = f(\theta_t)$ with $f' > 0$ and $f'' < 0$. This implies that market tightness (and therefore vacancies) are determined from

$$f(\theta_t)[1-N_t(1-s)] = H_t. \tag{17}$$

Any worker matched to a firm bargains with the firm about the real wage W_t in any period t. To render the bargaining outcome independent of the individual firm's factor choices (K_t, N_t, L_t), we assume that there is a secondary market for capital and land at which firms can buy and sell these factors of production after wage bargaining but before the production stage.[11] This assumption implies that the marginal product of labor is only determined by aggregate market conditions so that the firm essentially operates under constant returns in the given period. Hence, although our model features multi-worker firms whose production technology has decreasing returns to labor, the usual difficulties with intrafirm bargaining in those situations (e.g. Stole and Zwiebel, 1996; Smith, 1999) disappear.[12] The Nash bargaining problem between the firm and each of its workers is then to maximize $\Omega_t^{\gamma} J_t^{1-\gamma}$, where γ is the worker's bargaining power. Eqs. (14) and (16) imply that

$$\gamma J_t = (1-\gamma)\Omega_t. \tag{18}$$

4. Equilibrium

Equilibrium in the land market is simply $L_t = 1$. Goods market equilibrium follows from workers' and firms' budget constraints as

$$Y_t = C_t + C_t^W + (1+R)B_t - B_{t+1} + I_t + \phi_K I_t^{1+\eta_K} I_{t-1}^{-\eta_K} + \phi_N H_t^{\eta_N} N_t^{1-\eta_N}. \tag{19}$$

The right-hand side includes consumption expenditures, net exports (that is, net capital exports) and investment on capital goods and for recruitment expenditures. The left-hand side is final output from market production. Finally, the government's budget is balanced, $T_t^W = \tau W_t(1-N_t)$ so that consumption of the worker household equals aggregate gross labor income $C_t^W = W_t N_t$.

Assume that $\tilde{\beta} \equiv 1/(1+R) > \beta$ which implies that the borrowing constraint binds in and around the steady state:

$$B_{t+1} = \tilde{\beta} \Psi_t \left[Q_{t+1} + \omega(1-\delta) K_{t+1} \right]. \tag{20}$$

Definition. Given a shock process for (A_t, Ψ_t, T_t), a competitive equilibrium with binding borrowing constraints are lists of firm plans, $(C_t, K_t, N_t, L_t, H_t, I_t)$, wages and land prices (W_t, Q_t), vacancy–unemployment ratios (θ_t), and job values for firms and workers (J_t, Ω_t), such that for all $t \geq 0$:

(i) Firm owners maximize their utility (1) subject to budget constraints (2), borrowing constraints (3), and factor adjustment (4) and (5).
(ii) The land and the goods market are in equilibrium: $L_t = 1$ and Eq. (19).
(iii) Labor market flows are consistent: Eq. (17).
(iv) Wages satisfy the Nash bargaining solution (18) where J_t and Ω_t satisfy (14) and (16).

[10] A difference between our model (with hiring costs) and standard search and matching models (with vacancy costs) is that only in the latter case employment adjustment costs are linked to aggregate labor market conditions via the aggregate matching function. Such a link is absent in our model.

[11] Specifically, the timing within each period t is as follows. (1) Firms and workers bargain over the wage; (2) Firms trade capital and land in the secondary market; (3) firms produce, hire, invest, buy/sell land at price Q_t, then repay the outstanding debt and borrow.

[12] Formally, because of constant returns, $Y_t = N_t G(L_t/N_t, K_t/N_t)$ where G is an increasing and concave production function in intensive form. Prices for land and for capital in the secondary market are $P_t^L = G_1'(l_t^*, k_t^*) + Q_t$ and $P_t^K = G_2'(l_t^*, k_t^*) + 1 - \delta$ with aggregate $l_t^* = L_t/N_t$, $k_t^* = K_t/N_t$ taken as given by the firm. It is then optimal for the firm to hold ℓ_t^* units of land and k_t^* units of capital per employed worker. Therefore, the marginal profit per worker is $G(l_t^*, k_t^*) + l_t^*(Q_t - P_t^L) + k_t^*(1-\delta-P_t^K)$ which is identical to the marginal product for labor and independent of individual factor choices. In equilibrium, no trade in the secondary market is required since no wage negotiations fail. See Chapter 1.6 in Pissarides (2000) and Cahuc and Wasmer (2001) for similar arguments.

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In Appendix B we characterize equilibrium by a set of 16 equations in the 16 variables

$$(C_t, C_t^w, \lambda_t, \lambda_t^w, \mu_t, Y_t, K_t, N_t, \theta_t, J_t, \Omega_t, W_t, B_t, Q_t, h_t = H_t/N_t, I_t),$$

given the exogenous processes for A_t, Ψ_t and T_t. The predetermined state variables are (I_{t-1}, K_t, B_t, N_t). In Appendix B we prove that the model has a unique steady state equilibrium and we show the following:

Proposition 1. *A steady state equilibrium is unique. If $\omega > 0$, an increase of the collateral constraint parameter Ψ (or a decrease of the interest rate $R = 1/\tilde{\beta} - 1$) has a positive effect on the steady-state values of output Y, employment N, capital K, market tightness θ, the real wage W and the land price Q. Changes of the land wedge T affect the land price, but have no effect on output and on the labor market.*

An implication of this proposition is that an improvement of financial condition, expressed by a relaxation of borrowing constraints, leads to a boom in the land price as well as to a tighter labor market and lower unemployment. Put differently, a permanent financial shock triggers a co-movement of the firms' land value and of the labor market. Land price shocks, on the other hand, cannot have permanent real effects. In the next section we explore the business-cycle implications of these different shocks to the firms' collateral constraint.

Before we do that, it is instructive to take a closer look at the first-order condition for hiring, (13), rewritten as

$$\phi_N \eta_N (h_t)^{\eta_N - 1} = \underbrace{\frac{\beta u'(C_{t+1})}{u'(C_t)}}_{= M_{t+1}^f} J_{t+1}. \tag{21}$$

As is well known from the literature on labor market volatility originating from Shimer (2005), volatility and propagation in hiring must largely be explained by the dynamics of the expected job value J_{t+1}, when the discount factor M_{t+1} is either constant due to a linear utility framework or moves little due to a representative household assumption (as in Andolfatto, 1996). Amplification of the job value is difficult to generate, unless wages are rigid and the flow job surplus is small relative to labor productivity. Other authors argue that variations in job creation costs on the left-hand side also account for labor market volatility and that financial frictions contribute to this mechanism (e.g. Petrosky-Nadeau, 2014). In our model, financial frictions in combination with sluggish adjustment of land collateral give rise to another channel contributing to labor market volatility and propagation, with much of the action going through movements in the discount factor.

When firms have an interest to smoothen profit income (dividend payments) over time, constrained firms react to a relaxation of collateral constraints in period t by an increase in current profit income C_t relative to future income C_{t+1} which raises the discount factor on the right-hand side of (21) and thus triggers a rise in hiring. This mechanism depends on our modeling assumption that firms are operated by independent owners who desire a smooth dividend stream, which is in line with the finance literature (cf. Lintner, 1956; Guttman et al., 2010; Leary and Michaely, 2011) but absent in standard macroeconomic models with a representative household. A similar mechanism would be at work if there is a representative capitalist family, earning aggregate profit income which is more volatile than aggregate consumption.[13]

To see the discount factor channel in our model more clearly, we can use the Euler equation (11) to write the discount factor as follows:

$$M_{t+1}^f = \frac{\beta \lambda_{t+1}}{\lambda_t} = \tilde{\beta} - \frac{\iota_t}{\lambda_t}, \tag{22}$$

where $\lambda_t = u'(C_t)$ is marginal utility, ι_t is the multiplier on the collateral constraint (3) and $\tilde{\beta} = (1+R)^{-1}$. Eqs. (21) and (22) show that, other things equal, when the credit constraint relaxes, that is, when ι_t goes down, hirings h_t go up. So essentially, one expects that shocks relaxing the credit constraint by a lot should make hirings very responsive. Consistent with the literature (e.g. Kocherlakota, 2000), the response of the land price to TFP shocks is not quantitatively significant in our model. As a consequence, a shock to TFP has little direct impact on the credit constraint and hence cannot be amplified much through this channel. In contrast, a land wedge shock that has a bigger impact on the land price, has much stronger labor market responses. To the extent that such shocks propagate through several periods, they also raise the job value (which depends positively on future discount factors via (14)) which additionally stimulates hiring incentives. This is exactly what happens in our model, as further illustrated with the simulations of the calibrated model that we present in the next section.

5. Calibration and quantitative results

In this section we calibrate the model to the French economy. We explore the reaction of the model economy to different shocks and show that especially shocks to the land price contribute to amplification and propagation of investment and labor market variables that are in line with the data.

[13] Relatedly, separate groups of workers and capital owners can help to address asset-pricing puzzles in the macro-finance literature (cf. Danthine and Donaldson, 2002; Guvenen, 2009).

Table 2
Parameter values.

Parameter	Value	Description
δ	0.027	Capital depreciation rate
A	1	Total factor productivity
σ	2	Firms' and workers' relative risk aversion
$\tilde{\beta}$	0.99	Lenders' discount factor
β	0.98	Firms' and workers' discount factor
ξ	0.02	Output elasticity to land
ζ	0.37	Output elasticity to capital
s	0.02	Separation rate
α	0.50	Matching function elasticity
m	0.214	Matching function scale
τ	0.58	Wage replacement ratio
γ	0.91	Workers' bargaining power
η_K	15	Convexity capital installation costs
ϕ_K	0.10	Scale capital installation costs
η_N	1.13	Convexity hiring costs
ϕ_N	0.54	Scale hiring costs
Ψ	1.25	Collateral constraint parameter
ω	0.30	Share of capital collateralized

5.1. *Calibration*

We choose Cobb–Douglas functional forms $Y_t = A_t F(L_t, K_t, N_t) = A_t L_t^{\xi} K_t^{\zeta} N_t^{1-\xi-\zeta}$ for the production function and $f(\theta_t) = m\theta_t^{1-\alpha}$ for the matching function. Utility functions for workers and firm owners are identical, $u(C) = u_w(C) = C^{1-\sigma}/(1-\sigma)$ with coefficient of relative risk aversion equal to $\sigma = 2$.

We calibrate the model at quarterly frequency. All real and financial variables are matched to targets obtained from the INSEE data for the non-financial business sector.[14] For more details about the calibration, see Appendix C. All parameter choices are summarized in Table 2.

Technology and financial parameters. The share of capital that serves as collateral is set at $\omega = 0.3$ (see further discussion below). The depreciation rate is $\delta = 2.7\%$ which gives rise to 10.5% annual depreciation. Given the steady-state ratios that are fixed at their actual average values $K/Y = 7.31$, $B/Y = 5.56$, $Q/Y = 2.35$ (see Table 4), we calibrate $\tilde{\beta} = 0.99$ (which corresponds to a 4% annual interest rate) and $\beta = 0.98$ to match the capital and land shares in output $\zeta = 0.37$ and $\xi = 0.02$. It follows that $\Psi = 1.25$. Regarding the investment installation costs, we set the level parameter $\phi_K = 0.1$ to target an investment share in output of 22% and we set the convexity parameter $\eta_K = 15$ to replicate investment volatility relative to that of the land value under land price shocks. It follows that Tobin's q equals 1.13.

Labor market parameters. The matching function elasticity is set to $\alpha = 0.5$ which is in the range of plausible values for this parameter (Petrongolo and Pissarides, 2001). As Shimer (2005), we arbitrarily normalize tightness[15] in steady state to $\theta = 1$ and set the matching efficiency parameter $m = 0.214$ to target a mean quarterly job–finding rate of $f(\theta) = 0.21$. The quarterly separation rate is set to $s = 0.021$. Both quarterly worker flow rates correspond to the monthly estimates in Table 2 of Elsby et al. (2013), giving rise to a steady-state unemployment rate of $1-N = s(1-f)/s + f(1-s) = 7.2\%$.[16] We set unemployment income τ at 58.2% of wage income (see Table 1 in Justiniano and Michelacci, 2011), and the wage-to-income ratio at $WN/Y = 0.7$, which is the labor income share in France (cf. Table 4). Regarding hiring costs, we deliberately choose $\eta_N = 1.1$ and we calibrate $\phi_N = 0.54$ so that recruitment costs per hire in steady state are 14% of quarterly wages (cf. Hall and Milgrom, 2008). It follows from the other calibration targets that the worker bargaining power parameter is $\gamma = 0.91$ (see Appendix C).

One interesting aspect of our calibrated model is that, all other parameter values fixed as in Table 2, the unique steady state is determinate when $\omega > 0.4$ but becomes indeterminate when $\omega \le 0.4$. The intuition for why indeterminacy arises is tightly linked to the fact that the collateral constraint depends on the market price of land which is a forward-looking variable that can possibly react to self-fulfilling beliefs. Intuitively, if all firms expect the land price to be larger in future periods, they expect abundant credit which enables them to invest more and hence to demand more inputs which in turn will bid up input prices. As a consequence, the land price goes up and the initial expectation is fulfilled. Of course, the force of this "pecuniary externality" depends on the level of the collateral constraint parameter Ψ. With our calibration strategy, and given the calibration targets for B/Y, K/Y and Q/Y, a lower share of capital used as collateral, ω, translates into a higher value for Ψ. Essentially, indeterminacy arises in our calibration when firms can borrow more than the market value of the

[14] In particular, output Y is measured as gross value added. Land $QL = Q$ is land at market value, and credit B are all credit market liabilities. Capital K is structures plus equipment and software at current cost basis. The labor income share is calculated as compensation of employees divided by gross value added net of indirect taxes.

[15] The steady-state value of θ plays no role for the log-linearized model dynamics.

[16] Since separated workers can search for re-employment within the same quarter, the unemployment rate is slightly lower than its data average.

land they possess, which is in line with evidence for the French (as well as for the US) non-financial business sector.[17] There exists, to our knowledge, no source that documents the relative share of land and capital in collateralized lending to French firms, so it is a difficult task to calibrate parameter ω. Given that much of the firms' equipment capital is firm- or industry-specific with low resale value, however, we suspect that the capital share in collateral value is in reality rather low. In that sense our calibrated value of capital's contribution to collateral of about 30% appears reasonable and conservative.

Although the steady-state is indeterminate when parameters are calibrated according to Table 2, it turns out that pure sunspot shocks to the land price generate responses of investment and labor market variables that are at odds with the data, as we illustrate in the next section. In addition, leverage shocks do not help account for the data either, which is in line with recent literature (for example, see Kiyotaki et al., 2011; Liu et al., 2013; Justiniano et al., 2013). This is why our main results, that are presented in the following section, rely on fundamental shocks to the land price, that is, shocks to the land wedge parameter T.

5.2. Main results

We now show that the responses of the linearized model to land price shocks are empirically relevant when the steady state is indeterminate. We report the impulse response functions of the model economy under a negative shock to the land wedge T which follows an $AR(1)$ process with autocorrelation coefficient equal to 0.98.

In Fig. 3, investment, vacancies and tightness are procyclical while unemployment is countercyclical, which is in line with the data. In addition, investment and labor market variables respond in an hump-shaped manner, which is broadly consistent with the VAR evidence we present in Section 2.2. Investment and labor market variables reach their peaks around the 5th quarter, except for unemployment which peaks later, as does its estimated VAR response. The reason why indeterminacy is key to obtain hump-shaped responses is as follows. When the steady state is indeterminate, the land price reacts to fundamental shocks in a sluggish way because those shocks do not affect the price immediately – only current sunspot shocks can affect the land price contemporaneously. If sunspot shocks are shut down, then the land price actually does not move at $t=1$, that is, when the land wedge shock hits the economy, as shown in the left panel of Fig. 3. At $t=1$, however, investment, vacancies and tightness shoot up because next period's land price (that is, at $t=2$) goes up and the credit constraint hence relaxes at impact. In subsequent periods, the land price gradually increases further in response to the persistent land price shock, which further relaxes the credit constraint and enhances the incentives both to invest in capital and to create more vacancies. In that sense, the gradual response of the land price to a land wedge shock under indeterminacy is key for our amplification and propagation results.

Complementing the impulse response analysis, we also find that the model with only land price shocks does a reasonably good job at replicating standard deviations and co-movements with output, see Table 3. Unsurprisingly, the pure land price shock generates too much volatility of the land value relative to output, and also investment turns out to be too volatile. We expect that TFP shocks on top of land price shocks can help to improve on these volatilities. As an additional exercise, we feed in a TFP shock simultaneously with a land price shock and find that the standard deviations of the model's moments listed in Table 3 become much closer to their data counterparts. It is also worth noting that our model can account for the wage rigidity that is observed in the data, although wages are strongly procyclical in the model while they are acyclical in French data. Essentially, wage rigidity arises in this model because the marginal productivity of labor turns out to be rather unresponsive to land wedge shocks.

For comparison purposes, we report in Fig. 4 the economy's responses to a TFP shock in the indeterminate model.[18] Similar to the effect of a land wedge shock, the land price also responds in a sluggish way to an increase in TFP when sunspot shocks are shut down. However, there are key differences between Figs. 3 and 4. The first difference is that under TFP shocks investment in capital and in hirings crowd out land investment, essentially because investing in capital is subject to highly convex adjustment costs while land investment is not. As a consequence, the land price falls below the steady state in the first periods after the TFP shock, before moving up so that the credit constraint slightly relaxes later on. In addition, under TFP shocks the land price is much less volatile than output. For example, the land price's standard deviation is about half of output's for our calibrated parameters. Hence TFP shocks alone cannot reproduce the observed volatility and co-movement of land prices. Therefore, although the mechanism that makes the land price response sluggish in the indeterminate model is also present under alternative sources of disturbances, we argue that movements in the land investment wedge are empirically more relevant to understand how land price movements affect investment and the labor market in France than TFP shocks.

To illustrate the role of indeterminacy for our results, Fig. 5 shows the responses of the economy when it is subjected to land price or TFP shocks and when calibrated as in Table 2 except that $\omega=0.44$, which in turn implies that the steady state is now determinate. It can be seen that the determinate model generates monotonic responses of labor market variables to both land price and TFP shocks, in contrast with the indeterminate model. This is because the response of the land price is monotonic from $t=2$ onwards in both panels of Fig. 5, which essentially implies that the credit constraint relaxes more at

[17] Under our calibration, the share of collateralized real estate - land value plus structures - is about 64%.

[18] Like the land price shock in Fig. 3, the shock to TFP is assumed to follow an $AR(1)$ process with autocorrelation coefficient 0.98. We make the same assumption regarding leverage shocks in Fig. 6 below, while the sunspot innovations have zero autocorrelation.

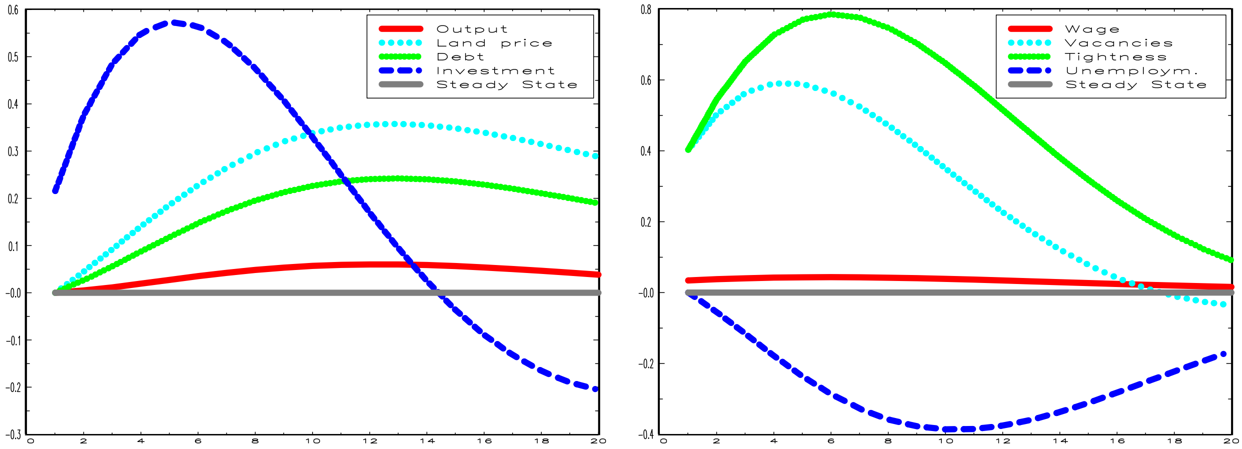

Fig. 3. Impulse responses to a positive land price shock in the indeterminate model.

Table 3
Standard deviations relative to output and correlations with output under land price shocks in the indeterminate model.

Variable	Stand. deviation		Correlation	
	Model	Data	Model	Data
Land value	6.06	3.87	0.29	0.46
Investment	5.89	3.30	0.38	0.79
Debt	3.53	2.94	0.55	0.35
Vacancies	5.76	5.23	0.57	0.69
Unemployment	4.65	4.68	-0.90	-0.65
Tightness	8.66	8.93	0.75	0.84
Wage	0.72	0.44	0.92	-0.01

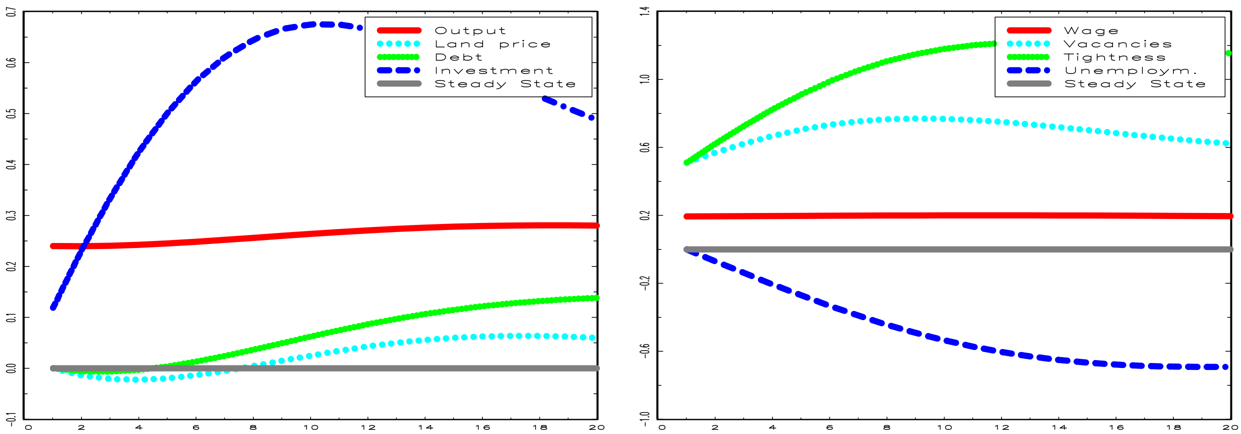

Fig. 4. Impulse responses to a positive TFP shock in the indeterminate model.

impact than in subsequent periods. In particular, the determinate model generates virtually no propagation for vacancies and unemployment. While vacancies and market tightness peak on impact, their response flattens out in the quarter after the shock, in spite of more persistent responses of output, debt, land price and investment. As a consequence, the responses of investment and the labor market are not hump-shaped, in sharp contrast with the responses in the indeterminate model shown in Fig. 3 that are more in line with the VAR evidence.

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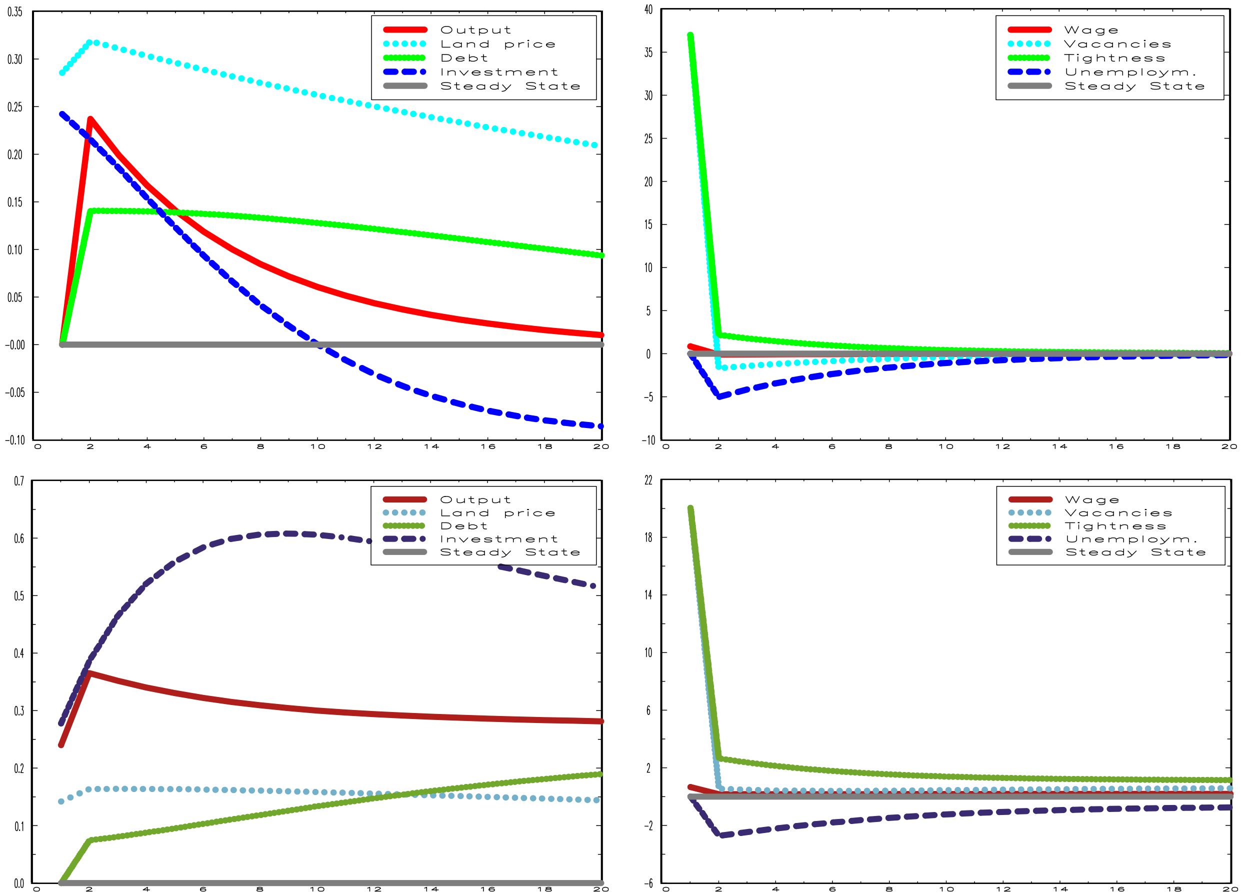

Fig. 5. Impulse responses to a land price shock (top) and to a TFP shock (bottom) in the determinate model.

To further highlight the importance of land price shocks for plausible model dynamics, we now report the economy's responses to pure sunspot and leverage shocks in the indeterminate model. Absent land wedge shocks, the model lacks the amplification mechanism and generates essentially monotonic responses of the labor market variables. This can be seen in Fig. 6 which graphs the dynamics triggered by a fundamental shock to the leverage parameter Ψ_t (top) and by a sunspot shock (bottom) both hitting the economy at $t=1$, under the calibration presented in Table 2. In addition, the corresponding (unreported) moments under leverage and sunspot shocks are at odds with French data. More precisely, the labor market variables are much too volatile compared to output and lack any propagation, while the land price is not volatile enough. In addition, investment and vacancies are negatively correlated with output while tightness is acyclical. In Fig. 6, the undershooting of vacancies and tightness in response to leverage or sunspot shocks in the first period can be explained by the fact that firm owners desire faster consumption growth in that period which lowers the discount factor. To make sense of both panels in Fig. 6, it is important to keep in mind that investment adjustment costs are more convex than hiring adjustment costs in our calibration, which partially explains why investment crowds out hiring in Fig. 6. While none of these shocks alone can account for plausible impulse responses, their joint interaction with land price shocks might still be important to account for overall business cycle dynamics and this should be the object of further analysis that goes beyond examining impulse responses to a single shock.

Finally, it is also worth mentioning that the role that the endogenous land price plays in the credit constraint (3) is important. This means that periods of land price booms are periods in which credit is more abundant because there is more collateral. If we would assume, rather counter-factually, that lenders do not take into account possible changes in the market value of land when deciding how much to lend to firms, so that a constant land price would enter (3), then no relaxation of the credit constraint would happen during land price booms and our quantitative results would disappear.

The main lesson from these results is that the indeterminate model provides a propagation mechanism by which financial shocks to the collateral value induce firms to borrow more, to invest more and to create more vacancies over several quarters after the shock hits the economy. This mechanism, for which the sluggish endogenous land price dynamics is key, gives rise to much more volatile and persistent responses of the labor market than those that can be generated by productivity shocks or by a determinate model in which such endogenous land price propagation is absent.

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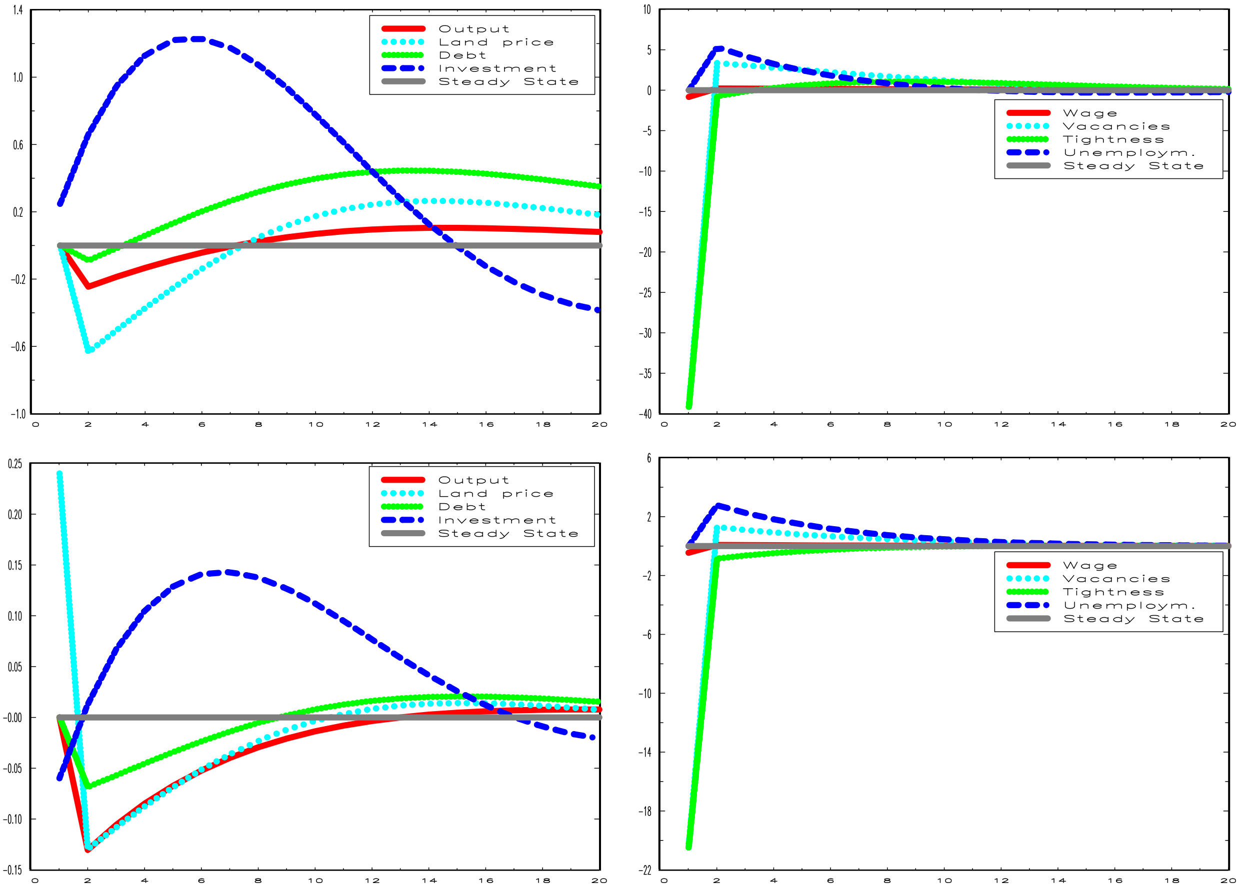

Fig. 6. Impulse responses to leverage shock (top) and sunspot shock (bottom) in the indeterminate model.

6. Conclusions

In this paper, we provide a macroeconomic model in which firms are subject to labor and credit market frictions and use land and capital as collateralizable assets in borrowing. When calibrated on French data, a key property of the model is that it generates an indeterminate steady state provided that the share of capital that is accepted as collateral is sufficiently low. Our main finding is that the indeterminate model generates amplification and hump-shaped propagation of fundamental land price shocks that are empirically relevant. In particular, it replicates the data patterns that investment, vacancies and unemployment follow after a land price shock hits the economy. In contrast, TFP shocks, leverage shocks or pure sunspot shocks generate impulse responses that are at odds with the data.

In unreported analysis, we show that similar results also hold for the same model calibrated on US data. Although the amplification result is broadly in line with Liu et al. (2013a) who estimate a larger model with Bayesian methods, there are key differences that should be stressed. First, there is a new channel that amplifies financial shocks to the labor market via the discount factor of credit-constrained firms. Second, our model generates local indeterminacy, which may not be easily be picked up by standard Bayesian estimation techniques. Third, the indeterminacy is precisely the reason why the labor market responses to land price shocks are hump-shaped and exhibit considerable persistence which is in line with the data. In view of these differences, further research that allows determinate and indeterminate models to compete in the parameter estimations seems promising to uncover how the various shocks affect investment and labor market dynamics. In addition, it remains an open question to what extent these results can be extended to European economies that have been subject to larger real-estate swings, like Spain and the UK, and whether countries with milder land price movements, like Germany, look any different.

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Appendix A. Data sources and further descriptive statistics

This appendix reports the data sources and some further statistics. For comparison with the business cycle in France, we also report some statistics for similarly constructed variables for the United States.

For France, data on output (gross value added) and investment for the non-financial business sector are obtained from the INSEE and are available at quarterly frequency. Credit market liabilities are also available at the INSEE but only at annual frequency and since 1996. Quarterly unemployment series are from the INSEE, and quarterly data on vacancies are derived from the INSEE series on the number of job opportunities registered at the French national agency for employment which are only available since 1989q1. The labor income series are quarterly available in the national accounts produced by the INSEE. We derive the income share dividing the labor income by the gross added value minus indirect taxes (the quarterly series are also from the national accounts). The labor productivity corresponds to the gross added value net of indirect taxes divided by the number of employees in the non-financial firms; we can thus obtain quarterly real wages multiplying the labor share by the labor productivity.

For the US, quarterly series of output, investment and credit market liabilities series for non-financial business are taken from the Flow of Funds Accounts of the Federal Reserve Board. We calculate land at market value series by subtracting structures at current cost to real estate at market value. Quarterly series on the number of unemployed come from the Bureau of Labor Statistics (BLS). The number of vacancies is taken from the Job Openings and Labor Turnover Survey (JOLTS) series built by the BLS combined with the composite Help-Wanted Index of (Barnichon, 2010). Based on the Flow of Funds Accounts of the Federal Reserve Board and the BLS data, we compute labor share, labor productivity and real wages series in the same way as for France.

Table 4 reports some sample averages over the full time period. With respect to these statistics, the two countries are rather similar. One striking difference is the higher credit-to-output ratio in France which reflects that non-financial firms seem to depend more heavily on external finance in this country.

Table 5 shows cross-correlations and relative standard deviations for the US economy of our key aggregate variables which are detrended in the same way as the time series for France. The last row in the table shows that the business cycle is considerably more volatile in the US than in France. The correlation coefficients point at some common patterns as in the corresponding Table 1 for France, but also to noteworthy differences. For instance, the number of vacancies is highly negatively correlated to unemployment in the US, whereas the negative relation is much weaker in France.

Table 4
Sample averages.

Variable	France	US
Land-output ratio	2.352	2.456
Capital-output ratio	7.307	6.948
Credit-output ratio	5.557	4.081
Investment rate	0.184	0.148
Depreciation rate	0.027	0.016
Labor income share	0.700	0.609
Profit margin	0.291	0.251

Notes: All statistics are based on the period 1978–2011, except credit market liabilities in France (since 1996).

Table 5
Comovement and volatility in the United States.

Variable	Output	Land	Investment	Vacancies	Unemployment	Tightness	Credit liabilities	Real wage
Output	**1.000**	0.540	0.897	0.915	−0.945	0.956	0.255	0.597
Land		**1.000**	0.577	0.394	−0.612	0.551	0.234	0.311
Investment			**1.000**	0.807	−0.916	0.899	0.480	0.698
Vacancies				**1.000**	−0.907	0.958	−0.019	0.525
Unemployment					**1.000**	−0.987	−0.316	−0.563
Tightness						**1.000**	0.230	0.575
Credit liabilities							**1.000**	0.646
Real wage								**1.000**
Std. dev. relative to output	**1.000**	**5.901**	**3.003**	**5.791**	**5.000**	**11.001**	**1.184**	**0.417**
Std. dev. relative to France	**1.869**	**2.848**	**1.699**	**2.071**	**1.996**	**2.302**	**0.753**	**1.774**

Appendix B. Equilibrium and Proof of Proposition 1

Using (11) to solve for $\iota_t = \tilde{\beta}\lambda_t - \beta\lambda_{t+1}$ and substitute in the other first-order conditions, we obtain the following set of equilibrium conditions:

$$\lambda_t = u'(C_t), \tag{23}$$

$$\mu_t = \lambda_t\left[1+\phi_K(1+\eta_K)\left\{\frac{I_t}{I_{t-1}}\right\}^{\eta_K}\right] - \beta\lambda_{t+1}\phi_K\eta_K\left\{\frac{I_{t+1}}{I_t}\right\}^{1+\eta_K}, \tag{24}$$

$$\mu_t = \beta(1-\delta)\mu_{t+1} + \beta\lambda_{t+1}\frac{\partial Y_{t+1}}{\partial K_{t+1}} + \omega(1-\delta)\Psi_t\left(\tilde{\beta}\lambda_t - \beta\lambda_{t+1}\right), \tag{25}$$

$$\lambda_t Q_t T_t = \beta\lambda_{t+1}\left[\frac{\partial Y_{t+1}}{\partial L_{t+1}} + Q_{t+1}T_{t+1}\right] + \Psi_t\left(\tilde{\beta}\lambda_t - \beta\lambda_{t+1}\right)Q_{t+1}, \tag{26}$$

$$M^f_{t+1}J_{t+1} = \phi_N\eta_N h_t^{\eta_N - 1}, \tag{27}$$

$$J_t = \frac{\partial Y_t}{\partial N_t} - W_t + \phi_N(\eta_N - 1)h_t^{\eta_N} + (1-s)M^f_{t+1}J_{t+1}, \tag{28}$$

$$\Omega_t = (1-\tau)W_t + (1-s)(1-f(\theta_t))M^w_{t+1}\Omega_{t+1}, \tag{29}$$

$$\gamma J_t = (1-\gamma)\Omega_t, \tag{30}$$

$$B_{t+1} + Y_t = C_t + C_t^w + (1+R)B_t + I_t + \phi_K I_t^{1+\eta_K} I_{t-1}^{-\eta_K} + \phi_N h_t^{\eta_N} N_t, \tag{31}$$

$$B_{t+1} = \tilde{\beta}\Psi_t\left[Q_{t+1} + \omega(1-\delta)K_{t+1}\right], \tag{32}$$

$$K_{t+1} = I_t + (1-\delta)K_t, \tag{33}$$

$$N_{t+1} = (h_t + 1 - s)N_t, \tag{34}$$

$$Y_t = A_t F(1, K_t, N_t), \tag{35}$$

$$h_t = f(\theta_t)\frac{1 - N_t(1-s)}{N_t}, \tag{36}$$

$$\lambda_t^w = u_w'(C_t^w), \tag{37}$$

$$C_t^w = W_t N_t. \tag{38}$$

Steady-state values satisfy

$$\lambda = u'(C), \tag{39}$$

$$\mu/\lambda = 1 + \phi_K + \phi_K\eta_K(1-\beta), \tag{40}$$

$$\beta\frac{\lambda}{\mu}F_K = 1 - \beta(1-\delta) - \omega\Psi(1-\delta)\left(\tilde{\beta} - \beta\right)\frac{\lambda}{\mu}, \tag{41}$$

$$\beta F_L = Q[(1-\beta)T - \Psi(\tilde{\beta} - \beta)], \tag{42}$$

$$\beta J = \phi_N\eta_N h^{\eta_N - 1}, \tag{43}$$

$$J[1-\beta(1-s)] = \phi_N(\eta_N - 1)h^{\eta_N} + F_N - W, \tag{44}$$

$$(1-\tau)W = \Omega\left[1 - \beta(1-s)(1-f(\theta))\right], \tag{45}$$

$$\gamma J = (1-\gamma)\Omega, \tag{46}$$

$$Y = C + C_w + RB + (1+\phi_K)I + \phi_N h^{\eta_N} N, \tag{47}$$

$$B = \tilde{\beta}\Psi\left[Q + \omega(1-\delta)K\right], \tag{48}$$

$$I=\delta K, \tag{49}$$

$$h=s, \tag{50}$$

$$Y=AF(1,K,N), \tag{51}$$

$$h=f(\theta)\frac{1-N(1-s)}{N}, \tag{52}$$

$$\lambda_w=u_w'(C_w), \tag{53}$$

$$C_w=WN. \tag{54}$$

The following proposition, stated in Section 4 of the main text, is established from the above steady-state relationship.

Proposition 1. *A steady state equilibrium is unique. If $\omega>0$, an increase of the collateral constraint parameter Ψ (or a decrease of the interest rate $R=1/\tilde{\beta}-1$) has a positive effect on the steady-state values of output Y, employment N, capital K, market tightness θ, the real wage W and the land price Q. Changes of the land wedge T affect the land price, but have no effect on output and on the labor market.*

Proof. Uniqueness of the steady state follows by inspection of Eqs. (39)–(54), which can be solved recursively. The hiring rate is given by (50) while the job values J and Ω follow from (43) and (46). The marginal product of capital F_K and the marginal product of labor minus the wage F_N-W are determined uniquely from (41) and (44), where μ/λ (that is, Tobin's q) is determined from (40). From (52), the job-finding rate f is a decreasing function of $1/N$ so that, substituting for f in (45), it follows that the wage W is also a decreasing function of $1/N$. Because of constant returns, F_K and F_N (for given land supply $L=1$) are functions of K/N and $L/N=1/N$. Both functions are increasing in $1/N$ while F_K (F_N) is decreasing (increasing) in K/N. Hence, F_N-W and F_K uniquely determine the steady-state levels of N and K. Then market tightness and the real wage follow from (52) and (45), so that workers' consumption C_w and marginal utility λ_w follow from (52) and (45). The land price Q and borrowing B are determined from (42) and (48). Finally, with output Y determined from (51) and investment I given in (49), firms' C and λ follow from (47) and (39).

To prove the second and third assertions we use a similar argument. From the previous paragraph, F_N is independent of Ψ and $R=1/\tilde{\beta}-1$, while (41) implies that F_K decreases (increases) in Ψ (R) if $\omega>0$, and F_K is independent of these financial variables if $\omega=0$. Hence, if and only if $\omega>0$, an increase of Ψ (or a decrease of R) increases both N and K (this follows because F_K and F_N-W are both increasing in $1/N$, F_K decreases in K/N and F_N-W increases in K/N.). Hence (45), (51) and (52) imply that W, θ and Y are increasing if $\omega>0$ and independent of Ψ and R otherwise. The increase of N and K (for $\omega>0$) implies that F_L increases. Hence, (42) implies that the land price Q increases for any $\omega\geq 0$. Finally, marginal products F_L, F_K and F_N are independent of the land wedge T, so that positive changes in the land wedge affect negatively Q through (42) but have no real effects. □

Appendix C. Calibration details

In view of Eq. (48), the borrowing constraint parameter follows from

$$\Psi=\frac{1}{\tilde{\beta}}\frac{B/Y}{Q/Y+\omega(1-\delta)K/Y}$$

and the calibration targets in Table 4.

From the first-order condition for investment (40) we obtain Tobin's q:

$$q\equiv 1+\phi_K+\phi_K\eta_K(1-\beta). \tag{55}$$

We use ϕ_K to calibrate the share of investment cost in output, while η_K is used to target investment volatility relative to output volatility.

From the first-order conditions for capital and land, Eqs. (41) and (42) the capital and land shares in output follow from the other targets:

$$\zeta=\frac{qK}{\beta Y}\left[1-\beta(1-\delta)-\omega(1-\delta)\frac{\Psi}{q}\left(\tilde{\beta}-\beta\right)\right]. \tag{56}$$

$$\xi=\frac{Q}{\beta Y}\left(1-\beta-\Psi(\tilde{\beta}-\beta)\right). \tag{57}$$

From the calibration target, we obtain $\tilde{\phi}_N=\phi_N\cdot N/Y$:

$$\frac{c(H,N)}{H}=0.14\cdot W\Rightarrow\tilde{\phi}_N h^{\eta_N}=0.14\frac{WN}{Y}h,$$

where $c(H,N)=\phi_N h^{\eta_N} N$ is total hiring cost, and we can use that $h=s$ in steady state. Given that

$$\frac{Y}{N}=A^{1/(1-\zeta)}\left(\frac{K}{Y}\right)^{\zeta/(1-\zeta)}N^{-\xi/(1-\zeta)},$$

this yields ϕ_N.

In steady state, the first-order condition for vacancies, Eq. (43), implies

$$\frac{JN}{Y}=\frac{1}{\beta}\tilde{\phi}_N\eta_N h^{\eta_N-1}.$$

Therefore parameter γ follows from (45) and (46) which can be rewritten in terms of the calibration targets and the other parameters:

$$\frac{\gamma}{1-\gamma}=\frac{(1-\tau)\frac{WN}{Y}}{[1-\beta(1-s)(1-f)]\frac{JN}{Y}}.$$

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