REAL ESTATE CYCLES, ASSET REDISTRIBUTION AND THE DYNAMICS OF A CRISIS: TECHNICAL DETAILS

Online Appendix with Model Details, Extensions and Robustness Tests

In this extension, we provide details on our benchmark model, including the first order conditions, the steady state equations and the details of the calibration process.

Next, we conduct six robustness analysis and compare the results of our benchmark analysis with these six alternatives. In addition, some of the diagrammatic representations of the benchmark model that we could not include in the main manuscript due to brevity is also included here.

1 FIRST ORDER CONDITIONS

We can summarize the representative worker's problem by the following set of first-order conditions, where $\beta^t \lambda_t^w$ is the lagrange multiplier attached to the workers' budget constraint at time t. We denote the derivative of an utility function $u_t^w(.)$ with respect to a variable z with $u_{zt}^w(.)$.

$$c_t^w : \beta^t u_{ct}^w(c_t^w, 1 - h_t^w, l_t^w) = \beta^t \lambda_t^w \quad (1)$$

$$h_t^w : \beta^t u_{ht}^w(c_t^w, 1 - h_t^w, l_t^w) = \beta^t \lambda_t^w w_t(1 - \tau_{ht}) \quad (2)$$

$$l_{t+1}^w : \beta^{t+1} E_t\{u_{lt+1}^w(c_{t+1}^w, 1 - h_{t+1}^w, l_{t+1}^w) + q_{t+1}(1 - \tau_{lt+1}^w)\lambda_{t+1}^w\} = \beta^t q_t \lambda_t^w \quad (3)$$

$$a_{t+1} : \beta^{t+1} E_t \lambda_{t+1}^w (1 + r_{t+1}(1 - \tau_{at+1}) = \beta^t \lambda_t^w \quad (4)$$

Equations (1) and (2) combined tells us that in equilibrium, the marginal rate of substitution between consumption and leisure of the worker equals the after-tax marginal product of labor. Equations (1) and (3) together summarize the intertemporal condition for investment in land and tells us that the present discounted value of lifetime utility that would stem from withholding one unit of consumption today and investing in land that yields a future stream of consumption (after deducting the appropriate tax), should at the margin, equal the marginal utility lost in consumption forgone. Equations (1) and (4) tells us that in equilibrium, the present discounted value of lifetime utility that would ensue from withholding one unit of consumption today and saving it instead for consumption in future (after deducting for the tax on interest income earned) is equal to the marginal disutility that stems today from the lost consumption. Note that no-arbitrage condition implies that after tax returns on investment in land equals the after tax returns on savings at the margin, a fact we see from Equations (3) and (4). The set of first-order conditions, relevant to the entrepreneur's utility maximization problem are summarized below. $\beta^t \lambda_t^e$ is the lagrange multiplier attached to the entrepreneur's budget constraint at time t, and $\beta^t \mu_t$ denotes the lagrange multiplier attached to the collateral constraint at time t. We denote the derivative of an utility function $u_t^e(.)$ with respect to a variable z with $u_{zt}^e(.)$ and the derivative of the production function $F_t(.)$ with respect to a variable z by $F_{zt}(.)$.

$$c_t^e : \beta^t u_{ct}^e(c_t^e, 1 - h_t^e) = \beta^t \lambda_t^e \tag{5}$$

$$h_t^e : \beta^t u_{ht}^e(c_t^e, 1 - h_t^e) = \beta^t \lambda_t^e (1 - \tau_{yt}) A_t F_{h^e t}(k_t,\ l_t^e,\ h_t^{wd},\ h_t^e) \tag{6}$$

$$h_t^{wd} : \beta^t (1 - \tau_{yt}) \lambda_t^e A_t F_{h^w t}(k_t,\ l_t^e,\ h_t^{wd},\ h_t^e) = \beta^t \lambda_t^e w_t (1 - \tau_{yt}) \tag{7}$$

$$l_{t+1}^e : \left[\begin{array}{c} \left[\begin{array}{c} \beta^{t+1} E_t \{ q_{t+1} \lambda_{t+1}^e (1 - \tau_{lt+1}^e) \\ +(1 - \tau_{yt+1}) \lambda_{t+1}^e A_{t+1} F_{l^e t+1}(k_{t+1},\ l_{t+1}^e,\ h_{t+1}^{wd},\ h_{t+1}^e) \} \end{array} \right] \\ \left[\begin{array}{c} = \beta^t q_t \lambda_t^e - \beta^t \mu_t \phi q_t \\ \text{when the borrowing constraint is endogenous} \end{array} \right] \\ \left[\begin{array}{c} \beta^{t+1} E_t \{ q_{t+1} \lambda_{t+1}^e (1 - \tau_{lt+1}^e) \\ +(1 - \tau_{yt+1}) \lambda_{t+1}^e F_{l^e t+1}(k_{t+1},\ l_{t+1}^e,\ h_{t+1}^{wd},\ h_{t+1}^e) \} \end{array} \right] \\ \left[\begin{array}{c} = \beta^t q_t \lambda_t^e \\ \text{when the borrowing constraint is exogenous} \end{array} \right] \end{array} \right] \tag{8}$$

$$k_{t+1} : \left[\begin{array}{c} \left[\begin{array}{c} \beta^{t+1} E_t \{ \lambda_{t+1}^e (1 - \delta) \\ +(1 - \tau_{yt+1}) \lambda_{t+1}^e F_{kt+1}(k_{t+1},\ l_{t+1}^e,\ h_{t+1}^{wd},\ h_{t+1}^e) \} \end{array} \right] \\ \left[\begin{array}{c} = \beta^t \lambda_t^e - \beta^t \mu_t \phi \\ \text{when the borrowing constraint is endogenous} \end{array} \right] \\ \left[\begin{array}{c} \beta^{t+1} E_t \{ \lambda_{t+1}^e (1 - \delta) \\ +(1 - \tau_{yt+1}) \lambda_{t+1}^e F_{kt+1}(k_{t+1},\ l_{t+1}^e,\ h_{t+1}^{wd},\ h_{t+1}^e) \} \end{array} \right] \\ \left[\begin{array}{c} = \beta^t \lambda_t^e \\ \text{when the borrowing constraint is exogenous} \end{array} \right] \end{array} \right] \tag{9}$$

$$b_{t+1} : \beta^{t+1} E_t \lambda_{t+1}^e (1 + r_{t+1}(1 - \tau_{yt+1}) = \beta^t \lambda_t^e - \beta^t \mu_t \tag{10}$$

Equations (5) and (6) combined tells us that in equilibrium, the marginal rate of substitution between consumption and leisure for the entrepreneur equals the after-tax marginal product of entrepreneurial labor. Equations (6) and (7) together reflects the fact that in equilibrium, wage rate of worker-labor is equal to the after-tax marginal productivity of entrepreneurial labor. Equations (5) and (8), and Equations (5) and (9) together give us the equilibrium condition for investment in land and capital by the entrepreneur, which essentially tells us that in equilibrium, the present discounted value of lifetime utility obtained by withholding one unit of consumption and instead investing it in land or capital and deriving future consumption from it (after deducting the appropriate taxes) is equal to the loss in utility that ensues today due to consumption withheld. This is a standard condition except there are two sources of deriving benefits from investment: firstly, the entrepreneur gets the benefit of increased production when she uses investment today as an input in the production process tomorrow (this is reflected in the marginal product of land and capital), secondly, the entrepreneur can use the investment in land and capital as a collateral asset that helps the entrepreneur in boosting her borrowing capability. This second source of benefit that the entrepreneur derives by additional investment results from the collateral constraint being a function of the net worth of the entrepreneur and is unique to models with endogenous collateral constraints. Note that no arbitrage implies that the after tax returns from investment in land and capital are equalized at the margin (Equations (8) and (9)). Equations (5) and (10) together provides the intertemporal condition for borrowing. $\mu_t > 0$ implies that in equilibrium the borrowing constraint binds. Analytically, we can derive the condition for $\mu_t > 0$ in the steady state (Proposition 1).

First order conditions of the modified model-allowing for explicit home production

In our robustness test, we modify the benchmark model to consider home production explicitly. We state below the first order conditions assuming a log-linear utility function:

$$c_t^{wm} : \beta^t \frac{1}{c_t^{wm}} = \beta^t \lambda_t^w \tag{11}$$

$$c_t^{wn} : \beta^t \frac{\alpha_2}{c_t^{wn}} = \beta^t \lambda_t^{wn} \tag{12}$$

where $\beta^t \lambda_t^{wn}$ is the lagrange multiplier associated with the home production function.

$$h_t^{wm} : \beta^t \frac{\alpha_1}{1 - h_t^{wm} - h_t^{wn}} = \beta^t \lambda_t^w w_t (1 - \tau_{ht}) \tag{13}$$

$$h_t^{wn} : \beta^t \frac{\alpha_1}{1 - h_t^{wm} - h_t^{wn}} = \beta^t \lambda_t^{wn} \frac{c_t^{wn}}{h_t^{wn}} (1 - \alpha_3) \tag{14}$$

$$l_{t+1}^w : \beta^{t+1} \{\lambda_{t+1}^{wn} \alpha_3 \frac{c_{t+1}^{wn}}{l_{t+1}^w} + q_{t+1}(1 - \tau_{lt+1}^w)\lambda_{t+1}^w\} = \beta^t q_t \lambda_t^w \tag{15}$$

Substituting for the value of λ_{t+1}^{wn} from equation (12) in equation (15), we get:

$$l_{t+1}^w : \beta^{t+1} \{\alpha_2 \alpha_3 \frac{1}{l_{t+1}^w} + q_{t+1}(1 - \tau_{lt+1}^w)\lambda_{t+1}^w\} = \beta^t q_t \lambda_t^w \tag{16}$$

which is similar to our benchmark model except for the term α_3.

The remaining first order conditions are same as in our benchmark model.

Modifications to the first order conditions when we allow quadratic adjustment costs in investment in land:

$$\begin{aligned} l_{t+1}^w : \beta^{t+1} E_t\{u_{lt+1}^w(c_{t+1}^w, 1 - h_{t+1}^w, l_{t+1}^w) + q_{t+1}((1 - \tau_{lt+1}^w) \\ + \tfrac{\psi}{2}(1 - \tfrac{l_{t+2}^{w2}}{l_{t+1}^{w2}}))\lambda_{t+1}^w\} = \beta^t q_t \lambda_t^w (1 - \psi((1 - \tfrac{l_{t+1}^w}{l_t^w})) \end{aligned} \tag{17}$$

$$\begin{aligned} \beta^{t+1} E_t\{q_{t+1}\lambda_{t+1}^e((1 - \tau_{lt+1}^e) + \tfrac{\psi}{2}(1 - \tfrac{l_{t+2}^{e2}}{l_{t+1}^{e2}})) \\ +(1 - \tau_{yt+1})\lambda_{t+1}^e A_{t+1} F_{l^e t+1}(k_{t+1},\ l_{t+1}^e,\ h_{t+1}^{wd},\ h_{t+1}^e)\} \\ = \beta^t q_t \lambda_t^e (1 - \psi((1 - \tfrac{l_{t+1}^e}{l_t^e})) - \beta^t \mu_t \phi q_t \\ \text{when the borrowing constraint is endogenous} \end{aligned} \tag{18}$$

First order conditions of the modified model with housing preferences (Liu, Wang and Zha, 2013):

In our robustness test, we modify the benchmark model to allow for preference shocks to housing, and take away the taxes on land holdings of the households. The problems of the entrepreneur and the government[1] remains the same. Assuming log-linear preferences, the first order condition for the households reduce to:

$$c_t^w : \beta^t u_{ct}^w(c_t^w, 1 - h_t^w, \varphi_t l_t^w) = \beta^t \lambda_t^w \tag{19}$$

$$h_t^w : \beta^t u_{ht}^w(c_t^w, 1 - h_t^w, l_t^w) = \beta^t \lambda_t^w w_t (1 - \tau_{ht}) \tag{20}$$

$$l_{t+1}^w : \beta^{t+1} E_t\{u_{lt+1}^w(c_{t+1}^w, 1 - h_{t+1}^w, l_{t+1}^w) + q_{t+1}\lambda_{t+1}^w\} = \beta^t q_t \lambda_t^w \tag{21}$$

$$a_{t+1} : \beta^{t+1} E_t \lambda_{t+1}^w (1 + r_{t+1}(1 - \tau_{at+1}) = \beta^t \lambda_t^w \tag{22}$$

[1] The land tax revenues for the government now comes from the entrepreneurs.

where $\beta^t \lambda_t^w$ is the lagrange multiplier. Given our functional form, this yields the following:

$$c_t^w : \beta^t \frac{1}{c_t^w} = \beta^t \lambda_t^w \tag{23}$$

$$l_{t+1}^w : \beta^{t+1} E_t \{ \frac{\varphi_{t+1}}{c_{t+1}^w} + q_{t+1} \lambda_{t+1}^w \} = \beta^t q_t \lambda_t^w \tag{24}$$

Combining the two, we get the equation with respect to household land holding as:

$$\beta^{t+1} E_t \left(\frac{\varphi_{t+1}}{c_{t+1}^w} + q_{t+1} \frac{1}{c_{t+1}^w} \right) = \beta^t \frac{1}{c_t^w}$$

2 STEADY STATE EQUATIONS

The first order conditions can be converted to the following steady-state conditions by detrending the variables with respect to the long-term trend growth rate, $(1+g_z)$. Note that in the following equations we also take into account the fact that by our assumption, population of both workers and entrepreneurs grow every period at a rate, η. The steady-state variables are denoted without the time subscript.

$$\alpha_1 = \frac{w}{c^w}(1-\tau_h)(1-h^w) \tag{25}$$

$$\alpha_2 = \frac{ql^w}{c^w}(\frac{1}{\beta\eta} - 1 + \tau_l^w) \tag{26}$$

$$\beta = \frac{1+g_z}{1+(1-\tau_a)r} \tag{27}$$

$$\delta = \frac{x}{k} + 1 - \eta(1+g_z) \tag{28}$$

$$\alpha_1 = (1-\theta_k-\theta_{le}-\theta_{hw})\frac{y}{c^e}(1-\tau_y)\frac{1-h^e}{h^e} \tag{29}$$

$$\theta_k = \left[\frac{1-\phi}{1-\tau_y}\left(\frac{1+g_z}{\beta}-1\right)+\delta+\phi r\right]\frac{k}{y} \tag{30}$$

$$\theta_{le} = \frac{\left(\theta_k\frac{y}{k}-\delta-\frac{\eta(1+g_z)(1-\tau_{le})-1}{1-\tau_y}\right)}{\eta(1+g_z)}\frac{ql^e}{y} \tag{31}$$

$$\theta_{hw} = \frac{wh^{wd}}{y} \tag{32}$$

$$\phi = \frac{\frac{b}{y}}{\frac{k}{y}+\frac{ql^e}{y\eta(1+g_z)}} \tag{33}$$

$$y = Ak^{\theta_k}l^{e\theta_{le}}h^{wd\theta_{hw}}h^{e(1-\theta_k-\theta_{le}-\theta_{hw})} \tag{34}$$

Similarly, we can write the detrended goods market clearing condition, loans market clearing condition, the land market clearing condition, the labor market clearing condition, the budget constraint of the government and the budget constraint of the workers in equilibrium (where the inequality gets replaced by equality) as:

$$\xi c^w + (c^e + \eta(1+g_z)k - (1-\delta)k) + g = y \tag{35}$$

$$b = \xi a \tag{36}$$

$$\xi l^w + l^e = 1 \tag{37}$$

$$h^{wd} = \xi h^w \tag{38}$$

$$\begin{bmatrix} \xi\left(wh^w\tau_h + r\tau_a a + \tau_l^w q l^w\right) \\ +\tau_y(y - wh_t^{wd} - \delta k - rb) + \tau_l^e q l^e \end{bmatrix} = g_t + \xi Tr^w + Tr^e \tag{39}$$

$$\begin{bmatrix} c^w + q(\eta l^w - l^w) + \tau_l^w q l^w \\ +\eta(1+g_z)a \end{bmatrix} = \begin{bmatrix} wl^w(1-\tau_h) \\ +(1+r(1-\tau_a)a + Tr^w \end{bmatrix} \tag{40}$$

Steady state conditions of the modified model-allowing for explicit home production

We just state the equations that are different from our benchmark model:

$$\alpha_1 = \frac{w}{c^{wm}}(1-\tau_h)(1-h^{wm}-h^{wn}) \tag{41}$$

$$\frac{\alpha_1}{\alpha_{2*}(1-\alpha_3)} = \frac{(1-h^{wm}-h^{wn})}{h^{wn}} \tag{42}$$

$$\alpha_2\alpha_3 = \frac{ql^w}{c^{wm}}(\frac{1}{\beta\eta} - 1 + \tau_l^w) \tag{43}$$

3 DATA & CALIBRATION DETAILS

3.1 Benchmark

The main source of our data is the Japan Statistical Yearbooks. We make some adjustments to the national accounts and the balance sheet to conform to our model.[2]

The aggregate consumption in the model is the sum of consumption by workers and entrepreneurs. Ours is a closed economy setup. So, to match the model to the national income accounts figures from Japan we add net exports to private consumption in the data and set this equal to aggregate consumption. We also adjust consumption for net indirect business taxes. On investment front, since we do not have public investment in our model, the aggregate investment of entrepreneurs is taken as the sum of public and private investment. Output is the sum of aggregate consumption, investment and government expenditure that is identical to GDP net of indirect business taxes.

The two important stock variables in the model are land and capital. The aggregate value of land held by the entrepreneurs is taken as the average value of all land underlying commercial properties in Japan. Similarly, value of land held by the workers is the total value of land underlying residential structures. Note that as Figures 2 and 3 pointed out, in the data commercial and residential land prices are different from each other. However, in our model, we consider a unique land price and we match it to the average land price of total land holdings in Japan that is calculated as the weighted average of the price of land underlying the commercial and residential buildings in all of Japan. To get the quantity of land held by each group, we first calculate total land holdings of the economy as a sum of the land underlying residential structures and commercial structures. In accordance to our model, we normalize the total land holdings to unity and assess the fraction of commercial land holding that comprises the entrepreneurial land. The remaining is residential land held by workers. Aggregate capital stock is the sum of private and public capital. The other stock variable is borrowing taken from Bank of Japan and estimated as the sum of total lending by all commercial banks in Japan (including trust banks and long term credit banks)[3] and net change in other liabilities. As for

[2] Modifications are guided by similar modifications in Hayashi and Prescott (2002).

[3] Note that we do not include foreign direct investment and loans by foreign banks because the data is only available since 1989 while our period of interest begins in 1980. While this otherwise might be an important issue, our results are not particularly affected as we only need the steady state debt to output ratio to get an estimate of the loan to value ratio or ϕ that we hold constant in our numerical

the remaining variables, ratio of entrepreneurs to working population is 12% in accordance with the population census of Statistical Bureau. My measure of entrepreneurs is the self-employed. The population census also gives us the employed and manufacturing hours (taken as labor hours). **Tables A** and **B** provide a summary of adjustments made to the national income accounts and the balance sheet of Japan to match our model. Note that since we abstract from the agricultural sector, we adjust output and aggregate land value to reflect this[4].

3.2 Housing preference shocks using Business Cycle Accounting "Wedge" methodology

The Business Cycle Accounting "Wedge" (BCA) methodology of Chari, Kehoe and McGrattan (2007) rests on two facts: (a) one can show that detailed models of frictions are equivalent to a prototype business cycle model, where these frictions appear as "wedges" or time varying productivity and time varying taxes that create a "wedge" between the marginal benefit and marginal cost conditions, thus resulting in an equilibrium that is not the first-best; (b) by construction, all "frictions" or wedges jointly fed into a model would exactly yield the data.

Therefore, a full scale business cycle accounting implementation requires specifying an appropriate prototype business cycle model with relevant wedges to study a particular friction.

A challenge for implementing BCA is the unobservability of the wedges in the data. Therefore, the first task of implementation is to use the first order conditions of the model along with the macroeconomic data and back out the wedges or frictions using maximum likelihood techniques. The evaluation rests on feeding these estimated wedges one by one and in various combinations in the model to ascertain to what extent these combinations can explain the data. For a complete implementation of the BCA architecture, we would need to redefine all "taxes" as "wedges" and re-estimate them from the first order conditions and the data keeping in mind that expectations play a role as well (for details, check Chari, Kehoe, and McGrattan (2007)).

Here we go with a modest approach, following the initial works of Chari, Kehoe and McGrattan (2002).

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exercise.

[4] The agricultural sector is subject to a different set of taxation policies that include a number of subsidies as well as different rules of taxation, including the tax rate. Taxes paid by the agricultural sector, once we net out the subsidies, is negligible and did not vary much during our period of interest. Abstracting from the agricultural sector simplifies the model and allows us to focus on the land taxation policies that did vary significantly during 1980 to 2000.

We keep TFP, taxes on entrepreneurial land holding and the government expenditure as in the benchmark model[5]. In addition, we retain the parameters of the benchmark model as well. Then, the only wedge that we need to calculate following the BCA architecture is the "housing preference shock" or φ_{t+1} that we cannot directly see in the data.

In the model, the φ_{t+1} is given to us by the equation:

$$\beta E_t\{\frac{\varphi_{t+1}}{c^w_{t+1}} + \frac{q_{t+1}}{c^w_{t+1}}\} = \frac{q_t}{c^w_t}$$

which can be modified as:

$$\beta E_t \left(\frac{\varphi_{t+1}}{\frac{c^w_{t+1}}{y_{t+1}}} + \frac{q_{t+1}}{\frac{c^w_{t+1}}{y_{t+1}}} \right) \frac{y_{t+1}}{y_t} = \frac{q_t}{\frac{c^w_t}{yt}}$$

A challenge for estimating φ_{t+1} is the fact that it is within an expectation operator. Here, we simplify the job by assuming a deterministic version of the equation above. Assuming a deterministic version helps us circumvent the problem about the expectations operator, and now, given β as in the benchmark model, the time series of evolution of land prices q_t and the time series of the share of household consumption in output, or $\frac{c^w_t}{yt}$[6], we can back out the time series of φ_{t+1}. Once we have the time series of the housing preference shock or φ_{t+1}, we follow Liu, Wang and Zha (2013) to posit an AR1 process underlying the housing preference shock:

$$\ln \varphi_t = \rho_\varphi \ln \varphi_{t-1} + \sigma_\varphi \varepsilon_{\varphi t}$$

where ρ_φ is the persistence parameter, σ_φ is the standard deviation and $\varepsilon_{\varphi t}$ is an i.i.d standard normal distribution. We estimate $\rho_\varphi = 0.9895$ and standard deviation measure $\sigma_\varphi = 0.1014$.

Two points are worth noting: first, we turn off all the shocks of the model, except the housing preference shocks to ascertain the role of housing preference shocks in accounting for the observed fluctuations in land prices, output and land redistribution. This is close to the "accounting procedure" of a traditional BCA analysis. Next, we feed four shocks jointly - productivity shocks, shocks to housing preferences, time series of tax on entrepreneurial land holding and time varying government consumption. In a traditional BCA, all shocks jointly exactly replicate the data. We will not get that here because our procedure is not designed to

[5] In our benchmark, the credit market conditions were held at a constant, something we retain in our alternative model as well.

[6] The time series of $\frac{c^w_t}{y_t}$ is kept as in the benchmark model.

do that. For example, we pick the time series of tax on entrepreneur land holdings from the data, we do not back it out from the model- something that would be needed to be done for each wedge to get the data back exactly. Our modified procedure allows us to examine the implication of adding a housing preference shock in our benchmark model. The BCA procedure is a tool used to get the time series of this housing preference shock that we cannot get directly from data.

4 ROBUSTNESS TESTS

To test the robustness of the results, we conduct the following checks: (1) allowing alternative persistence of shocks, (2) allowing for changes in financial climate, manifest in time varying loan-to-value ratio ϕ_t, (3) allowing alternative modeling framework–a) considering production of household services as opposed to direct consumption of land and b) considering frictions in land redistributions, (4) allowing alternative definition of "output", (5) allowing alternative parameterization, and finally (6) reestimating the model where land is not a collateral, the only collateral is the capital stock of the entrepreneurs.

4.1 Alternative persistence of shocks

Does the predictions improve if the shocks are expected to be permanent? The results of the augmented Dickey-Fuller test on stochastic process for TFP and land-holding taxes (**Table 1-a** and **1-b**) indicate that we cannot reject the null hypothesis of presence of unit roots. Further, Johansen Cointegration test results (**Table 1-c**) indicate no cointegration between the two processes. Assuming persistence markedly improves the model's ability to match land prices (**Figure 3** & **Table 2)** and we are able to explain almost one-third of the eighties price increase and almost entirely the nineties price drop. For example, jointly feeding the two shocks, the model now predicts an increase by 24% in land prices in the eighties and a decline by 46.5% in the nineties. Predictions regarding land reallocation also improves**.** Specifically, the model does a better of of matching the decline in entrepreneurial land holding of the nineties as compared to the benchmark. Our model now predicts a fall by 48% during the nineties as compared to 52% predicted by the benchmark. This improvement is the result of better predicting the decline in land prices that deter the entrepreneurs from selling land as compared to the benchmark where land prices did not register a sufficient decline. However, output fluctuations significantly overshoots the data.

4.2 Alternative explanations of the business cycle: The role of evolution of loan to value ratio ϕ_t

In our previous analysis, we have assumed no change in the loan to value ratio or ϕ_t. However, since the late 1970s, the Japanese economy has witnessed gradual liberalization of its economy that picked up steam in the eighties (Horiuchi, 1996) and domestic lending received a boost with formation of Jusens-niche housing loan companies–that expanded domestic loans to the real estate sector (Hoshi and Kashyap, 2010). Since then Japan has faced a severe credit crunch with a reduction of loan availability to the Japanese firms (Peek and Rosengren 2001, 2005). These developments in the Japanese financial markets suggest that the assumption that the loan to value ratio or ϕ_t is constant is perhaps a strong one and therefore we relax this assumption in this section. We first track the evolution of ϕ_t during the sample period.

Given the assumption that the borrowing constraint holds with equality, we calculate ϕ_t from equation 7:

$$\phi_t = \frac{b_{t+1}}{(k_{t+1} + q_t l^e_{t+1})}$$

where b_{t+1} or borrowings are measured as the net change in aggregate bank loans plus net change in other liabilities as gathered from Japanese balance sheet data(**Figure 4)**[7].Two points stand out: (a) ϕ_t is continuously increasing through the eighties till 1996 (with a temporary decline in 1993) and (b) ϕ_t shows a decline after reaching a peak in 1996 and the decline continues through 1999 with a slight upward turn in 2000 (the end of my sample period). We can interpret the increase as a continual relaxation of lending standards in Japan (possibly resulting from liberalization of the bond market complemented by increased domestic lending to the small and medium scale and the real estate sector). Note that the eventually tightening of the credit constraint did not happen till 1996 consistent with the micro evidence presented by Hayashi and Prescott (2002). Defining a stochastic process for the deviation of ϕ_t from its steady state value $\overline{\phi}$ such that

$$\widetilde{\phi}_t = \rho_\phi \widetilde{\phi_{t-1}} + \widetilde{\epsilon}_{\phi t} \text{ where } \widetilde{\phi}_t = \phi_t - \overline{\phi}$$

and feeding it into the benchmark model (given the data on $\frac{b_{t+1}}{(k_{t+1}+q_t l^e_{t+1})}$ which helps us pin down the time series of ϕ_t, we estimate $\rho_\phi = 0.93$.), we find that allowing ϕ_t to vary improves the benchmark model's performance with respect to accounting for land price, but the model now

[7] For illustration purposes, I have set the measure of ϕ_t in year 1980 to 1 and express the time series as an index to bring out better the evolution of ϕ_t over time.

performs worse in terms of output. In particular, the model fails to account for the drop in output in the nineties which is expected given that ϕ_t increased continuously through the eighties and nineties and registered only marginal drop since 1998. An increasing ϕ_t is conducive to an easing of borrowing constraint which, ceteris paribus, should improve output and boost land prices. Even if we allow all the exogenous factors to vary simultaneously, the overall model performance improves only marginally. What the findings tell us is that despite a gradually relaxed borrowing climate in the 1990s, the Japanese economy was failing, undermining the efforts of financial liberalization. Some other culprit was at play.

4.3 Alternative modeling framework

4.3.1 Allowing for explicit home production

In my benchmark model, we assume that the worker values land directly and to this end, we include the land holdings of the worker in the utility function. An alternative way of thinking about this idea would be to assume that the workers value land for the household services that it renders (in literature, this is referred to as "home production" (Greenwood, Rogerson & Wright, 1993) or "non-market" goods (McGrattan, Rogerson & Wright, 1997)) To incorporate this feature, I modify my benchmark model to assume that workers consume both market and non-market goods denoted by c_t^{wm} and c_t^{wn} respectively. Leisure is the time left after devoting some time (h_t^{wm}) to market production and some time (h_t^{wn}) to home production. Given these modifications, utility function of the worker now becomes:

$$u_t^w(c_t^{wm}, 1-h_t^{wm}-h_t^{wn}, c_t^{wn}) = \log\, c_t^{wm} + \alpha_1 \log\, (1-h_t^{wm}-h_t^{wn}) + \alpha_2 \log\, (c_t^{wn}) \tag{44}$$

where α_2 is the marginal rate of substitution between market and non-market or home good. Non-market or home good production function is given by (assumed to be of Cobb-Douglas form):

$$c_t^{wn} = A_t l_t^{w\alpha_3} h_t^{wn(1-\alpha_3)} \tag{45}$$

where α_3 is the share of land in the non-market good. To keep matters simple, I assume the same technology for the market good and the non-market or home good. Adding home production in this simple form has the advantage that the first order condition with respect to worker's investment in land (l_{t+1}^w-l_t^w) does not change except for the inclusion of a new parameter α_3[8] that we calibrate from the steady state. We do

[8] Interested readers can check Appendix 2

not have explicit data on what fraction of time is spent by households in house work that is needed to calibrate α_3. Literature has addressed this issue in a variety of ways. Greenwood et. al. (1993) reports that households in US spend 25% of their time on non-market activity and 33% on market activity. McGrattan et. al. (1997) puts hours spent on non-market activity at 12% of total time. We address this by keeping the parameter α_1 the same as in our benchmark model. This helps us pin down the share of market good consumption as a share of output in the steady state (c_t^w/y) and consequently, the share of non-market consumption in output as aggregate consumption share minus the share of market good in consumption. Then we calibrate α_3 from the steady state to 0.1. The parameters of the production function and the loan to output ratio remain as in the benchmark model. The model predictions (**Table 4**) and the conclusions are consistent with my previous findings , namely TFP and land tax variations do a good job of explaining output and land redistribution (in fact, for land redistribution, we see a significant overshooting in the post bubble phase of the nineties) but fails to significantly account for land price fluctuations[9].

4.3.2 Allowing frictions in land investment

In our benchmark model, land gets unambiguously allocated between households and entrepreneurs without any constraint on reallocation. However, not all residential land can be used for commercial purposes and vice-versa due to zoning laws which merits introduction of frictions in land investment. At the same time, adjustment costs have been further credited with generating larger volatility in observed data (Boldrin, Christiano, Fisher, 2001; Bloom 2009, Liu, Waggoner and Zha, 2011).

As shown by Wang and Wen (2012) collateralized borrowing constraint at the firm level (or entrepreneur level in our model) can give rise to convex adjustment costs at the aggregate level, something that our benchmark model allows for as well. In addition, to allow for frictions in land investment explicitly, we modify the budget constraint of the workers and entrepreneurs to include an adjustment cost in land investment following literature on adjustment costs in physical capital investment (Boldrin, Christiano & Fisher, 2001, Cooper & Haltiwanger, 2006):

$$\begin{aligned} c_t^w + q_t(l_{t+1}^w - l_t^w) + \tfrac{\psi}{2} q_t\left(\tfrac{l_{t+1}^w - l_t^w}{l_t^w}\right)^2 l_t^w + \tau_{lt}^w q_t l_t^w + a_{t+1} \\ \leq w_t h_t^w (1-\tau_{ht}) + (1 + r_t(1-\tau_{at}))a_t + Tr_t^w \end{aligned}$$

[9] I have also tried alternative calibrations of the parameters α_1, α_2 and α_3 and the results are robust.

(workers' modified budget constraint)

$$c_t^e + q_t(l_{t+1}^e - l_t^e) + \tau_{lt}^e q_t l_t^e + \frac{\psi}{2} q_t (\frac{l_{t+1}^e - l_t^e}{l_t^e})^2 l_t^e + (k_{t+1} - (1-\delta)k_t)$$
$$\leq (1-\tau_{yt})(y_t - w_t h_t^{wd} - \delta k_t - r_t b_t) + b_{t+1} - b_t + Tr_t^e$$

(entrepreneurs' modified budget constraint)

The idea here is to capture the fact that due to zoning laws prevalent in most countries (including Japan), residential land cannot be costlessly converted to commercial land and vice versa. The quadratic costs capture this friction and we expect it to temper land reallocation incentives. This adjustment cost in land reallocation is similar in spirit to a "property transactions tax" as suggested by Miao, Wang and Zhao (2014).

Next comes the question of calibrating the adjustment cost parameter ψ. To measure the adjustment cost of land investment in our data, we pick a value of ψ that allows us to match the ratio of the volatility of the land share of the entrepreneur to the household to the volatility of the land prices as in the data. This yields a value of $\psi = 0.91$ and we report the basic results with this measure.

Next, we look at literature to see how our measure of the adjustment cost in land reallocation matches up with values in literature. A caveat here is that most of the past literature has focused on quadratic adjustment cost in physical capital investment so the values we discuss here may not be entirely suitable to discuss cost of land adjustment, though certainly this is a good starting point. Hall (2004) measures sector-wise adjustment cost of capital and experiments with a set of values. My measure of $\psi = 0.91$ is in the ball-park of the mean of all manufacturing sector as measured by Hall (2004) which is much higher than the estimate of Liu, Wang and Zha (2013) who report an adjustment cost parameter of 0.18 but within the bound of (0.1 - 5.0) suggested by Liu, Waggoner and Zha (2011). Since a higher adjustment cost parameter has the potential for generating a higher volatility in asset prices, we further experiment with a range of values, with $\psi = 2.2$ (Shapiro, 1986), $\psi = 4.0$ (Smets and Wouters, 2007). While all of these values are in the bound suggested by suggested by Liu, Waggoner and Zha (2011), we also experiment with an outlier, fixing $\psi = 20$ as suggested by Gilchrist and Himmelberg (1995).

We outline the data, benchmark and results under alternative parameters of the adjustment cost function in **Table 5**.

Allowing for adjustment costs in asset reallocation partially improves our model's ability to match the data, but partially (**Table 5).** Miao, Wang and Zhou (2014) argue that property transaction taxes have the potential to stabilize financial market movements by reducing the incentive of property trading through an increased cost to buyers and a reduced dollar benefit to sellers. Our results imply the same. As we increase the value of the adjustment cost parameter making it more costly to trade land, volatility of land holdings by the entrepreneur goes down. As expected, an increase in adjustment cost of land reallocation leads to an increase in land prices. Output volatility is reduced due to a decline in land reallocation, a factor that affects output through the structure of the production function where entrepreneurial land is a factor input. Compared to the benchmark case ($\psi = 0$), the model's ability to match land price fluctuations improve as adjustment cost parameter is increased, but still even when we consider a very high adjustment cost of ($\psi = 20$), the price fluctuating falls short of the data, getting about one-third of it. While the inability to do better might surprise us given the potential expectation about the role of adjustment costs in explaining asset price volatility, this supports current research and is consistent with the findings of Boldrin, Christiano and Fisher (2001) who show that only restricting capital supply in a standard RBC model is not enough to generate asset price premiums and Iraola and Santos (2011) who use an adjustment cost parameter as high as 8 to find that price markups and leverage are typically the key determinants of asset price volatility, and adjustment costs play a limited role.

4.4 Definition of "output" & strength of the financial accelerator- a caveat

Large part of the success of the financial accelerator in my model comes from the "redistribution mechanism" that transfers land from residential to commercial uses and vice-versa. My measure of output y_t till now does not include the consumption generated by residential land holding. Since the model significantly over-predicts the decline in commercial land holdings in the nineties as compared to data, this opens up the possibility that it would also over-predict the home production[10]. If so, how strong is the amplification if we measure total output as market plus non-market production, that is $y_t + c_t^{wn}$? The answer as **Table 6** seems to suggest is "not quite strong". The impact of land redistribution on market output is tempered by the opposite impact on home good. For example, during the nineties, while decline in commercial land holding reduces market output y_t, the redistributed land increases home good c_t^{wn} hence the aggregate impact is tempered.

[10]This happens since decline in commercial land, by construction, implies an increase in residential land holding.

4.5 Alternative parameterization

4.5.1 Alternative parameterization of loan to value ratio

In Section 4.5.1., we calibrated the parameters of our model to match the mean values from our data during the period 1980 to 1984 that we deemed to be the steady state. Since the results of a DSGE model is sensitive to parameterization, a concern is: how robust are our findings if we allow alternative parameterization?

We experiment with three parameters that play an important role in our model: the loan to value ratio ϕ, and the auto-correlation and the standard deviation of the TFP shock (ρ_A, σ_A). We re-estimate these parameters to match the second-order moments from the data. Our choice to focus on these three parameters is guided by previous literature (see Iacoviello 2005). From a robustness standpoint, note that our steady state measure of ϕ was much lower than that estimated by Iacoviello (2005) (see Table 1 of manuscript). It is therefore of interest to re-estimate this parameter to match the second moment and report the results of our model. In this section we set ϕ to mimic the ratio of the standard deviation in borrowings to output ratio to the standard deviation of total wealth holdings as a share of output $\left(\frac{\sigma_{\frac{b}{y}}}{\sigma_{\frac{k+ql^e}{y}}}\right)$. The re-estimated value of ϕ is .91.

Second, we focus on the evolution of the TFP process. While the popular methodology is to calculate TFP as the Solow residual given the production function (we also adopt this methodology in our benchmark model), this methodology has been criticized by some critics on grounds that it introduces to much variability in the model (see Mendoza 1991), or that they may not be a good measure of productivity in the presence of adjustment costs (see McCallum 1989) or in the absence of constant returns to scale (see Hall 1988). Hence, one alternative used by Mendoza 1991, is to measure the autocorrelation and standard deviation directly from output data. As a robustness check, we also follow this approach and estimate the first order autocorrelation as $\rho_A = .97$ and standard deviation $\sigma_A = 4.3\%$. With this new set of parameters, we re-calculate our model predictions and state some findings in Table 7-A.

4.5.2 Alternative calibration of model parameters

In our parametrization exercise above, the value of β is calibrated to 0.9877 (rounded up to 0.99) to match an interest rate of 4.25%. This is higher than a β of 0.976 suggested by Hayashi and Prescott (2002) and Davis and Heathcote (2004), though it is matches up with the rate of time preference as suggested by Alting, Christiano, Eichenbaum and Linde (2011) who suggest a value of 0.9926, Miao, Wang and Zhou (2014) who assume a value of 0.99 same as Iacoviello (2005) who assumes that patient households have a rate of time preference of 0.99. In recent real estate cycle literature, Tao, Waggoner and Zha (2014) put the bounds on β to be between $(0.9615 - 0.9975)$ suggesting that our benchmark parameter is closer to the upper bound.

What happens to our benchmark results if we instead choose a rate of time preference of 0.976 which is suggested by Hayashi and Prescott (2002) and closer to the lower bound of Tao, Waggoner and Zha (2014) ?

The first thing to note that to match a β of 0.976, we need to set interest rate at 7.2% which is higher than 4.25% that was prevalent during the 1980-1984 period that we take as our steady state. A change in β also implies a change in other parameters as evidenced from the steady state equations in Appendix 3, particularly α_2 (elasticity of substitution between consumption and land) that changes to 0.103 as opposed to 0.0471 in the benchmark, share of capital in output θ_k that increases to 0.40 (as opposed to 0.37), share of entrepreneurial land in output that increases to 0.079 (as opposed to 0.04) and the share of aggregate labor that falls to 0.52 (as opposed to 0.59). The other parameters remain unchanged.

With an increase in risk aversion, and an increase in the share of land in output, the model predicts a marginally improved land price volatility. However increased share of entrepreneurial land in output combined with a greater elasticity of substitution between consumption and household land holding generates higher output and land reallocation volatility, overshooting the data (Table 7B).

4.6 The role of land as a collateral

In our main manuscript, we show how an amplification of shocks can be achieved by replacing an exogenous collateral constraint with an endogenous one. Could we achieve the same degree of amplification with capital alone as a collateral? We follow Liu, Wang and Zha (2013) and modify the benchmark model to include a quadratic adjustment cost of investment in capital:

$$k_{t+1} = (1-\delta)k_t + \left[1 - \frac{\Omega}{2}\left(\frac{i_t}{i_{t-1}} - \overline{\lambda}_i\right)^2\right] i_{t-1}$$

where i_t denotes per capita investment, $\overline{\lambda}_i$ denotes the steady-state growth rate of investment and Ω is the adjustment cost parameter.

The budget constraint of the entrepreneur now includes an investment-specific technical change parameter Q_t :

$$c_t^e + q_t(l_{t+1}^e - l_t^e) + \tau_{lt}^e q_t l_t^e + \frac{i_t}{Q_t} \leq (1 - \tau_{yt})(y_t - w_t h_t^{wd} - \delta k_t - r_t b_t) + b_{t+1} - b_t + Tr_t^e$$

where:

$$Q_t = Q_t^p v_{qt}$$

For simplicity, we keep permanent component Q_t^p a constant, and the transitory component follows an AR1 process:

$$\ln v_{qt} = \rho_{vq} \ln v_{qt-1} + \sigma_{vq} \epsilon_{vqt}$$

where ϵ_{vqt} follows an i.i.d. normal distribution. Note that this modification introduces the possible role of a fourth shock, the investment specific technological change in our model (but we hold that a constant for analytical simplicity).

In addition, the endogenous borrowing constraint is now modified to be of the form:

$$b_{t+1} \leq \phi_t(q_{kt} k_{t+1})$$

where q_{kt} is the price of the capital in terms of output.

This is an extreme form of the endogenous borrowing constraint of Liu, Wang and Zha (2013) who allow for both land and capital as collateral in their robustness tests, but puts weights on each to ascertain their relative importance. In our benchmark specification, there is an equal weight on both land and capital and in the alternative framework above, land does not contribute to collateral.

In terms of calibration, the parameter $\overline{\lambda}_i$ is set to 2.15%, the steady-state growth rate of investment. As for the adjustment cost, we set $\Omega = 0.1753$, a value we take from Liu, Wang and Zha (2013). Now, we solve the model using usual log-linearization techniques and feed in shocks to TFP, the time-varying taxes on land holding and government expenditure. The difference between our benchmark and this alternative model is two-fold (a) the alternative model does not have land in the collateral constraint. An entrepreneur's ability to borrow depends solely on the value of capital that the entrepreneur owns, (b) the alternative model allows for adjustment cost in investment. This has the potential to better match asset price fluctuations, though there is a catch-22 situation here - on the one hand, a high adjustment cost parameter is necessary to generate volatility in asset prices that are comparable to the data; on the other hand, too high an adjustment cost results in investment smoothing and can compromise the model's ability to generate output volatility. Matching both asset price as well as output volatility remains a challenge.

The results of this robustness analysis are outlined in Table 8. In addition to the data and benchmark, we input two alternatives - (a) model results where only capital acts as a collateral in column 4 and (b) results of a model with exogenous collateral constraint where neither capital nor land acts as a collateral asset. The results tell us that a model with only capital is not quite successful in replicating the data and performs only marginally better than a model with completely exogenous collateral constraint.

This is not surprising given that the bulk of our model performance comes from land taxes which affect land holdings directly and the effect is much amplified when land affects collateral. When we take away this role of land, land taxes are no different from any other shocks that, even though it affects redistribution of capital, is not as effective as it is on affecting redistribution of land holding between the constrained and the unconstrained agent, particularly when the constrained agent has a dual incentive to hold land as in the benchmark. Our calibration results are also consistent with Liu, Wang and Zha (2013) that land is a non-trivial collateral asset.

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TABLE A: National Income Accounts
Data and Model adjustments

National income accounts	**Data** (with respect to output)	**Model adjustments** (with respect to output adjusted for NIBT)
Product side		
Consumption	.691	.679
-Private	.592	.58
-Government	.099	.099
Investment	.299	.32
-Private	.241	.32
-Government	.058	0
Net Exports	.010	0
Total Expenditure	1	1
Income side		
Compensation of employees	.55	.59
Operating surplus	.25	.27
Depreciation of capital	.13	.14
NIBT: Indirect business taxes (net of subsidies)	.06	0
Statistical Discrepancy	.01	
Total Income	1	1

TABLE B: Balance Sheet
Data and Model adjustments

Balance sheet	**Data** (with respect to output adjusted for NIBT)	**Model adjustments** (with respect to output adjusted for NIBT)
Capital	2.446	2.446
-Private	2.146	2.446
-Government	.3	0
Land value	3.63	3.63
-Corporate	.91	.91
-Housing	2.72	2.72
Corporate sector borrowing	2.2	2.2

Note for Tables A and B: We make adjustments to the national income data and to balance sheet to make the data compatible with our model. We concentrate on the mean value of the variables during the period 1980 to 1984. First, aggregate GDP is adjusted for net indirect business taxes (NIBT) and we subtract value of agricultural production, an adjustment that is necessary as we do not include agricultural land in our accounting. Consumption is adjusted to include net exports (our model is that of a closed economy) and NIBT is deducted. For the income side, the net indirect business taxes are added to the compensation of employees and the operating surplus.

In our model, there is no public investment, so aggregate investment is all private investment. In a similar vein, the balance sheet corresponding to the model does not include public capital. Aggregate capital is private capital. Aggregate land is taken as sum of the value of land underlying the residences and the corporate buildings.

Data Source: Japan Statistical Yearbooks 1980 to 2000 collected from the Statistical Bureau of Japan.

Robustness Test 01-Assuming persistence of exogenous shocks

Table 1-a: Null hypothesis: Agents expect shocks to productivity to be permanent

Augmented Dickey-Fuller test	
t-statistic	-1.19*
probability	.8668

Table 1-b: Null hypothesis: Agents expect shocks to land holding taxes to be permanent

Augmented Dickey-Fuller test	
t-statistic	-2.26*
probability	.4207

Table 1-c: Co-integration of productivity and land holding taxes

Johansen co-integration test

Hypothesis		Eigenvalue	t-statistic
No. of CE(s)	0	.58	24.4***
	At most 1	.35	8.1***

Note: The data for the analysis comes from the Japan Statistical Yearbooks. TFP is based on the author's calculations and land holding taxes are from Ishi (2001).

Robustness Test 4.1. -Assuming persistence of shocks

TABLE 2: Business cycle implications: Assuming permanent shocks

	Data	Model		
		TFP	**Land tax**	**Joint**
1980:1991				
Output				
Percentage change	9.29%	18.92%	22.15%	22.14%
Mean growth rate	.82%	1.63%	1.89%	1.9%
Standard deviation	1.04%	3.27%	3.38%	3.76%
Land Price				
Percentage change	76.25%	6.91%	16.2%	24.24%
Mean growth rate	5.67%	.62%	1.46%	2.09%
Standard deviation	9.32%	1.4%	4.44%	4.73%
Entrepreneur's land holding				
Percentage change	20.17%	18.64%	14.51%	35.86%
Mean growth rate	1.83%	1.65%	1.25%	2.97%
Standard deviation	5.92%	4.39%	1.47%	5.7%
1991:2000				
Output				
Percentage change	-15.46%	-30.9%	-46.56%	-45.46%
Mean growth rate	-1.59%	-3.28%	-6.2%	-5.82%
Standard deviation	2.07%	4.46%	3.5%	4.5%
Land Price				
Percentage change	-47%	-12.13%	-41%	-46.53%
Mean growth rate	-7.33%	-1.23%	-5.54%	-6.41%
Standard deviation	3.18%	2.4%	4.29%	4.9%
Entrepreneur's land holding				
Percentage change	-6.45%	-26.3%	-29.77%	-48.24%
Mean growth rate	-.13%	-2.08%	-3.13%	-4.98%
Standard deviation	1.98%	6.16%	3.58%	9.14%
Correlations with output				
Land Price	.85	.94	.98	.95
Entrepreneur's land holding	.35	.73	.81	.61

Note: The data is collected from the Japan Statistical Yearbooks. The model predictions are based on the author's calculations and model solutions

Robustness Test 4.2. -Accounting for changing financial environment

TABLE 3: Business cycle implications: Data and Benchmark Model assuming evolving ϕ_t

	Data	**Model**	
		ϕ_t	**Joint**
1980:1991			
Output			
Percentage change	9.29%	1%	15.8%
Mean growth rate	.82%	.091%	1.37%
Standard deviation	1.04%	.05%	2.29%
Land Price			
Percentage change	76.25%	1.5%	2.55%
Mean growth rate	5.67%	.14%	.23%
Standard deviation	9.32%	.08%	.44%
Entrepreneur's land holding			
Percentage change	20.17%	3.66%	35.17%
Mean growth rate	1.83%	.33%	2.86%
Standard deviation	5.92%	.02%	4.42%
1991:2000			
Output			
Percentage change	-15.46%	.64%	-26.5%
Mean growth rate	-1.59%	.08%	-2.8%
Standard deviation	2.07%	.09%	3.17%
Land Price			
Percentage change	-47%	-3.9%	-4.85%
Mean growth rate	-7.33%	-.38%	-.6%
Standard deviation	3.18%	1.27%	.55%
Entrepreneur's land holding			
Percentage change	-6.45%	-.99%	-51.37%
Mean growth rate	-.13%	-.06%	-6%
Standard deviation	1.98%	.65%	7.14%
Correlations with output			
Land price	.85	.38	.81
Entrepreneur's land holding	.35	.82	.94

Robustness Test 4.3.1 - Assuming a model with home production

TABLE 4: Business cycle implications: Data and Alternative Model

	Data	Model	
1980:1991		**Benchmark No Home Production**	**Alternative Home Production**
Output			
Percentage change	9.29%		16.25%
Mean growth rate	.82%		1.53%
Standard deviation	1.04%		2.34%
Land price			
Percentage change	76.25%		1.14%
Mean growth rate	5.67%		.1%
Standard deviation	9.32%		.55%
Entrepreneur's land holding			
Percentage change	20.17%		34.37%
Mean growth rate	1.83%		2.78%
Standard deviation	5.92%		4.62%
1991:2000			
Output			
Percentage change	-15.46%		-28.3%
Mean growth rate	-1.59%		-3.2%
Standard deviation	2.07%		3.25%
Land price			
Percentage change	-47%		-3.62%
Mean growth rate	-7.33%		-.47%
Standard deviation	3.18%		.65%
Entrepreneur's land holding			
Percentage change	-6.45%		-53.02%
Mean growth rate	-.13%		-6.36%
Standard deviation	1.98%		7.2%
Correlations with output			
Land price	.85		.64
Entrepreneur's land holding	.35		.95

Robustness Test 4.3.2 - Assuming frictions in the land market

TABLE 5: Business cycle implications: Data and Alternative Model

	Data	**Alternative Model**				
				$\psi =$		
1980:1991		0	0.91	2.2	4.0	20
			Output			
Percentage change	9.29%	14.65%	14.46%	12.21%	11.17%	4.32%
Mean growth rate	.82%	1.27%	1.24%	1.16%	1.02%	0.54%
Standard deviation	1.04%	2.26%	2.19%	2.02%	1.87%	0.84%
			Land Price			
Percentage change	76.25%	1.03%	3.26%	6.64%	10.73%	20.62%
Mean growth rate	5.67%	0.09%	0.31%	0.56%	0.89%	2.95%
Standard deviation	9.32%	0.45%	0.58%	0.67%	0.95%	1.22%
			Entrepreneur's land holding			
Percentage change	20.17%	33.65%	30.34%	28.36%	20.16%	10.13%
Mean growth rate	1.83%	2.76%	2.47%	2.35%	1.98%	0.84%
Standard deviation	5.92%	4.38%	4.26%	3.92%	3.03%	2.14%
1991:2000						
			Output			
Percentage change	-15.46%	-27.1%	-26.60%	-20.92%	-17.86%	-6.91%
Mean growth rate	-1.59%	-2.90%	-2.78%	-2.32%	-1.94%	-0.87%
Standard deviation	2.07%	3.14%	3.11%	2.56%	2.11%	1.14%
			Land Price			
Percentage change	-47%	-3.43%	-3.87%	-7.15%	-9.36%	-16.13%
Mean growth rate	-7.33%	-0.41%	-0.52%	-0.76%	-1.23%	-2.34%
Standard deviation	3.18%	0.53%	0.76%	1.01%	1.98%	2.16%
			Entrepreneur's land holding			
Percentage change	-6.45%	-52.00%	-46.02%	-35.65%	-28.19%	-9.36%
Mean growth rate	-.13%	-6.14%	-5.78%	-4.96%	-4.02%	-2.22%
Standard deviation	1.98%	7.09%	6.1%	5.02%	4.12%	3.86%
Correlations with output						
Land price	.85	0.62	.68	0.69	0.65	0.55
Entrepreneur's land holding	.35	0.94	.89	0.80	0.75	0.59

Robustness Test 4.4. - Assuming alternative definition of output

Table 6: Alternative output measure (output includes market & non-market output)

Strength of the financial accelerator			
	Data	Model (credit constraint)	
Output (market+non-market)		Exogenous	Endogenous
1980:1991	10.23%	5.31%	6.46%
1991:2000	-7.77%	-3.84%	-4.52%

Robustness Test 4.5.1 - Alternative parameterization of loan to value ratio and exogenous shocks

Table 7-A: Business cycle implications

	Data	**Alternative Model**			
		TFP	**Land tax**	**Joint**	
1980:1991 (% change)				**Benchmark**	**Alternative**
Output	9.29%	15.91%	3.15%	14.65%	18.65%
Land price	76.25%	2.86%	.82%	1.03%	3.04%
Entrepreneur's land holding	20.17%	15.63%	18.51%	33.65%	34.28%
1991:2000 (% change)					
Output	-15.46%	-26.43%	-8.06%	-27.10%	-34.21%
Land price	-47%	-9.32%	-3.12%	-3.43%	-6.23%
Entrepreneur's land holding	-6.45%	-21.2%	-37.16%	-52.00%	-43.15%
			Correlations with output		
Land price	.85	.89	.82	0.62	.75
Entrepreneur's land holding	.35	.7	.86	0.94	.87

Robustness Test 4.5.2 - Alternative parameters of risk preference

Table 7-B: Business cycle implications

	Data	**Model**	
		TFP & Land Tax Shocks	
1980:1991 (% change)		**Benchmark**	**Alternative**
Output	9.29%	14.65%	15.63%
Land price	76.25%	1.03%	3.86%
Entrepreneur's land holding	20.17%	33.65%	35.14%
1991:2000 (% change)			
Output	-15.46%	-27.10%	-28.26%
Land price	-47%	-3.43%	-5.65%
Entrepreneur's land holding	-6.45%	-52.00%	-53.17%
Correlations with output			
Land price	.85	.62	.63
Entrepreneur's land holding	.35	.94	0.95

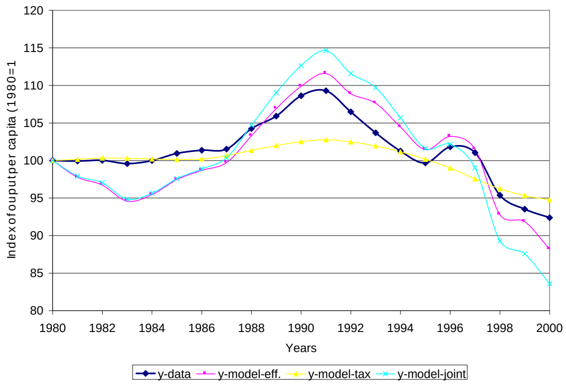
Robustness Test 4.6 - Land's role as a collateral asset
Table 8: Data and Model Predictions

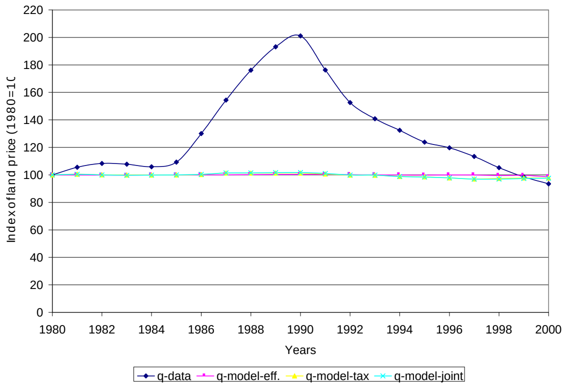
	Data	Model		
		TFP & Land Tax Shocks		
1980:1991 (% change)		Benchmark		Alternative
		Land	Only Capital	Exogenous
Output	9.29%	14.65%	4.83%	4.30%
Land price	76.25%	1.03%	0.76%	0.29%
Entrepreneur's land holding	20.17%	33.65%	2.96%	2.58%
1991:2000 (% change)				
Output	-15.46%	-27.10%	-4.95%	-4.51%
Land price	-47%	-3.43%	-1.78%	-1.38%
Entrepreneur's land holding	-6.45%	-52.00%	-3.85%	-3.50%
Correlations with output				
Land price	0.85	0.62	0.60	0.52
Entrepreneur's land holding	0.35	0.94	0.91	0.90

Note: The data is collected from the Japan Statistical Yearbooks. The model predictions are based on the author's calculations and model solutions

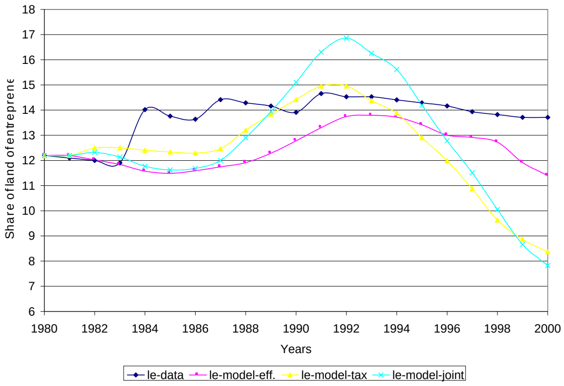
Benchmark model
Figure1: Accounting for data

Per capita output
Land price





Entrepreneurs' land holding

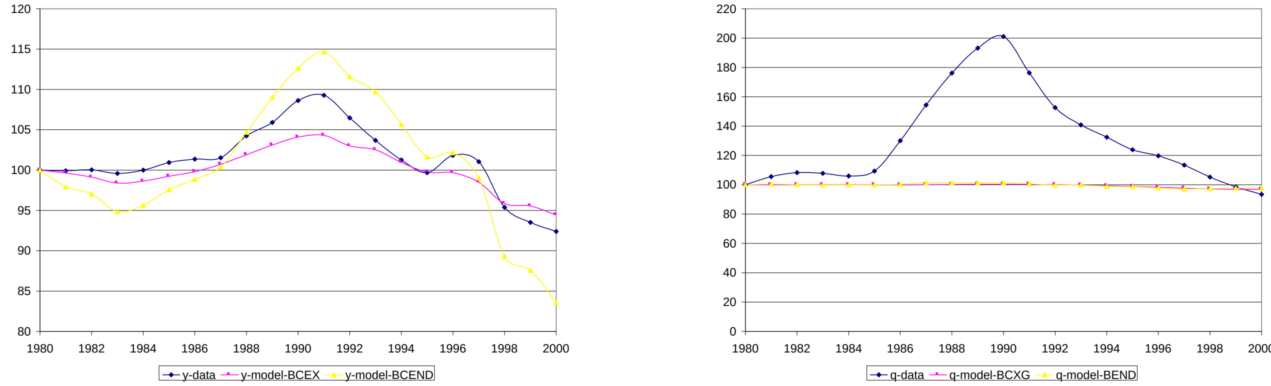


Note: In Figure 8 we plot the model predictions feeding in time series of TFP and land holding taxes (as outlined in Figures 5 and 6) one by one and in unison. The stochastic process is outlined in Table 3.

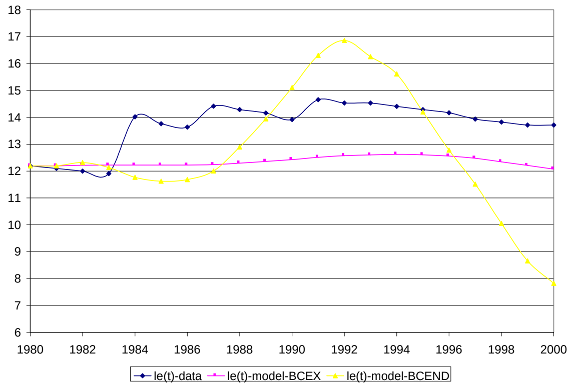
Data Source: The data is collected from the Japan Statistical Yearbooks. The model predictions are based on the author's calculations and model solutions

Strength of the financial accelerator mechanism
Figure 2 :Accounting for data in the benchmark model and an alternative with exogenous credit constraint

Per capita output
Land Price



Entrepreneurs' land holding

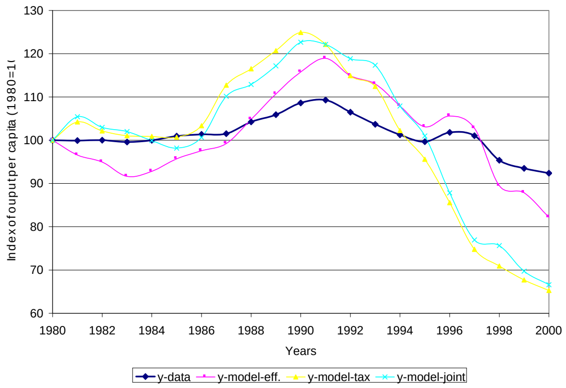


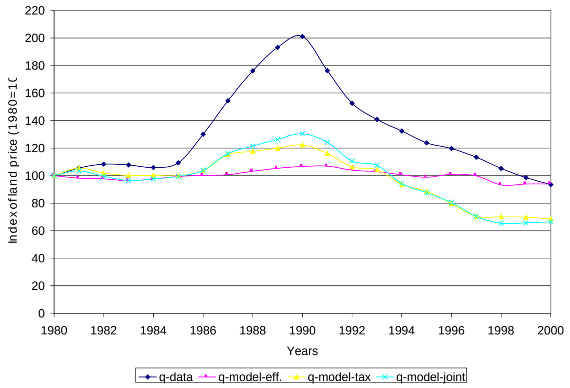
Note: In Figure 9 we plot the model predictions feeding in TFP and land holding taxes jointly in our benchmark model. Next, we compare the results when we consider exogenous credit constraints as compared to endogenous constraint (benchmark model). The comparison provides us quantitative evidence of amplification caused by the financial accelerator that theory tells us to expect.

Data Source: The data is collected from the Japan Statistical Yearbooks. The model predictions are based on the author's calculations and model solutions

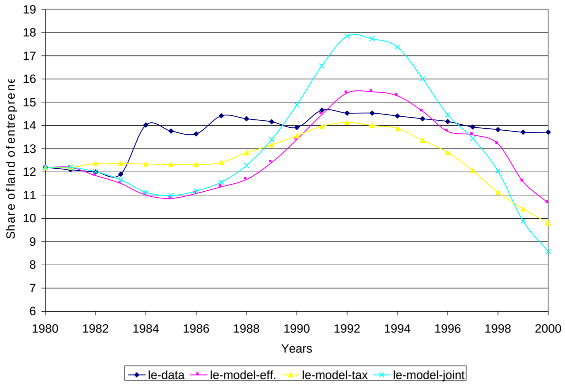
Robustness Tests: Alternative Persistence
Figure 3: Accounting for data assuming permanent shocks

Per capita output
Land price





Entrepreneurs' land holding



Note: In Figure 10 we plot the model predictions assuming that the economic agents expect shocks to TFP and changes in land holding taxes to be permanent and compare the results with the data.

Data Source: The data is collected from the Japan Statistical Yearbooks. The model predictions are based on the author's calculations and model solutions

Robustness Test-Alternative explanation of Japanese boom and bust

Figure 4: The evolution of loan-to-value ratio ϕ_t

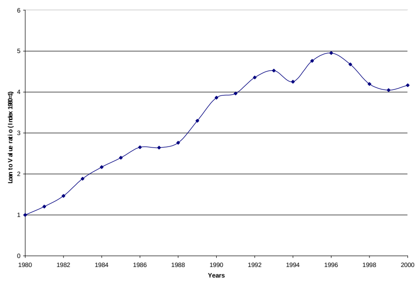
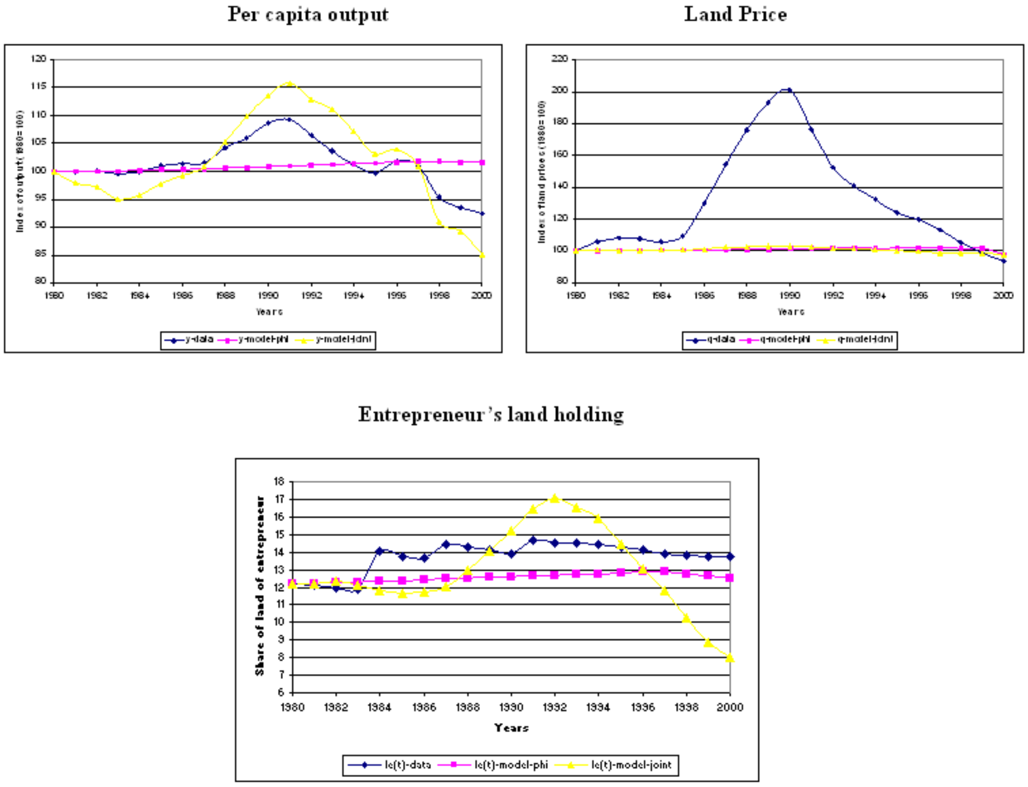


Figure 5: Accounting for data- Allowing loan-to-value ratio ϕ_t to evolve over time



Note: We calculate and plot in Figure 11 the loan-to-value ratio $\phi_t = \frac{b_{t+1}}{(k_{t+1}+q_t l^e_{t+1})}$ where b_{t+1} or borrowings are the net increase in aggregate bank loans plus net increase in other liabilities and the denominator is the sum of value of capital and the value of entrepreneurial land holdings. In Figure 12 we plot the model predictions feeding in time varying loan to value ratio ϕ_t in our benchmark model. Next, we feed in all three shocks–including

TFP, variations in land taxes as well as ϕ_t jointly and compute the model predictions.

Data Source: The data is collected from the Japan Statistical Yearbooks. The model predictions are based on the author's calculations and model solutions