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CREDIT, LAND SPECULATION, AND LOW-INTEREST-RATE POLICY

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ABSTRACT

This paper analyses the impact of credit expansions arising from increases in collateral values or lower interest rate policies on long-run productivity and economic growth in a two-sector endogenous growth economy with credit frictions, with the driver of growth lying in one sector (manufacturing) but not in the other (real estate). We show that it is not so much aggregate credit expansion that matters for long-run productivity and economic growth but sectoral credit expansions. Credit expansions associated mainly with relaxation of real estate financing (capital investment financing) will be productivity- and growth-retarding (enhancing). Without financial regulations, low interest rates and more expansionary monetary policy may so encourage land speculation using leverage that productive capital investment and economic growth are decreased. Unlike in standard macroeconomic models, in ours, the equilibrium price of land will be finite even if the safe rate of interest is less than the rate of output growth.

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Section 1. Introduction

Financial liberalization and expansionary monetary policy have been widely supported as leading to enhanced economic growth. The experience has been otherwise. Verner (2019) showed that rapid expansion in credit systematically predicts growth slowdowns.¹ The credit expansion of the early part of this century suggests an explanation: credit went disproportionately into real estate—so much so that the associated real estate boom crowded out more productive investments in other sectors. Müller and Verner (2023) confirm that this is typical: using a novel database on the sectoral distribution of private credit for 117 countries starting in 1940, they show that credit expansions to the construction and real estate industries systematically predict subsequent productivity and economic slowdowns, while credit expansions to the manufacturing sector are associated with higher productivity and stronger macroeconomic performance.² Banerjee, Mehrotra, and Zampolli (2024), who study emerging market economies, also show empirically that the larger the credit expansion to construction and real estate, the bigger the drop in labour productivity growth and TFP growth because productivity gains are generally smaller in these sectors, suggesting that credit expansion to the real estate sector reduces growth. On the other hand, productivity growth tends to be higher in countries with a greater share of loans to the manufacturing sector.

This paper presents a model that is consistent with these empirical findings. Key is endogenous growth, originating in only one sector (“manufacturing”) but with spillovers to the other (“real estate”). In such situations, there is no presumption for the optimality of market allocations. To the contrary, there is a presumption that the government should try to divert resources to the growth-generating sector. Under Harold Wilson, Nickolas Kaldor had pushed for a selective employment tax to redirect resources towards manufacturing, which he believed exhibited greater returns to scale and more learning. (Kaldor, 1966)

We provide a parsimonious and tractable framework for examining these questions, a two-sector overlapping generations model with credit frictions, which enables us to contrast

¹ Mian, Sufi, and Verner (2017) also found empirically that an increase in the household debt-to-GDP ratio predicts lower GDP growth.

² Chakraborty, Goldstein, and MacKinlay (2018) empirically studied the effect of housing prices on bank commercial lending and firm investment in the U.S. in the period between 1988 and 2006. They found housing price booms led to crowding-out of commercial investment due to decreased lending by banks to credit-constrained firms. They conclude that housing price booms have negative spillovers to the real economy.

partial equilibrium short run effects with long run effects. Thus, lowering collateral requirements or interest rates might seem to enhance the ability of entrepreneurs to finance their investments; but if looser monetary policy or financial liberalization simultaneously results in an increase in land prices, investment may be diverted to real estate, and the net effect is to crowd out productive investments, lowering growth. We provide conditions under which the crowding out effect dominates. This will be so, for instance, when collateral requirements for real estate are lowered but not those of productive investments (not surprisingly), or even when the interest rate is lowered, when collateral requirements for real estate are lower than for manufacturing. Again, not surprisingly, we show that under such conditions, more rapid expansion of the money supply leading to low interest rates may not lead to higher growth because more funds unevenly flow into the real estate sector, rather than the productive sector, contrary to the suggestion of Tobin (1965). In his work, as with much of monetary economics, there are only two stores of value, money and capital. With monetary easing policy, more funds will be channelled into productive capital; here, land is an alternative asset, suggesting that the macroeconomic consequences are markedly different between two-asset models of capital and money such as Tobin (1965) and our three-asset model of capital, money, and land.

Our model also provides insight into how a real estate boom will affect the macroeconomy in the short and long term. Normally, one would have thought that an increase in productivity—an expansion of today’s production possibilities curve—is unambiguously welfare enhancing. It turns out that that is not the case. We show that a real estate boom has markedly different effects in the short term and in the long term, i.e., it generates temporary output and asset price booms but, it reduces growth in the long run and thus lowers the wages and welfare of future generations.

Furthermore, our model with credit frictions also provides a resolution to a longstanding conundrum: In standard balanced growth models, where land productivity increases with the growth of the economy, equilibrium only exists when the rate of interest exceeds the rate of growth, because otherwise, land prices would be infinite. But, as Blanchard (2019) and others have shown, in the past century of U.S data, the return to government debt has been lower than the growth rate of output.³ Still, land prices are finite. In our model, the interest rate

³ Implied in standard models that the economy is also dynamically inefficient, inconsistent with dynastic growth models.

received by non-entrepreneurial households is less than the rate of growth, but that in turn is still less than the (leveraged rate of) return to land (which is equal to the leveraged return to capital).

Section 2. The model: endogenous growth with credit, money, and land

2.1 The environment

We use a variant of the standard two-period overlapping generations model where there is a competitive economy with productive capital, land and labor. Time is discrete and extends from zero to infinity ($t = 0, 1, \dots$). In each period agents arrive and live for two periods. Each agent is endowed with one unit of labor when young, and supplies it inelastically, receiving wage income, w_t . A fraction η of the young are entrepreneurs who have investment opportunities. The remaining fraction $1 - \eta$ are worker/savers (hereafter referred to as simply savers) who don't have investment opportunities. To simplify the analysis, all agents consume only in the second period, i.e., $u_t^i = c_{t+1}^i \geq 0$, where u_t^i is the utility of agent i , and i is the index for each agent.⁴

There are two sectors in our model, a productive sector, which in our simplified two-sector setting one can think of as manufacturing (in the model of the text, the only sector that uses capital; more generally, the capital-intensive sector) and a real estate sector (which in the simplified version of our model, only uses land).

We focus on the case where only entrepreneurs participate in the real estate market. One interpretation of this assumption is that there is considerable land heterogeneity and savers are less informed about real estate, with high costs associated with obtaining the relevant information, making real estate unattractive for them. In section 4.2, we will examine the case where both agents participate in the real estate market and discuss further our assumption of limited asset market participation.

The budget constraint of entrepreneurial agent i is given by

$$(1a) \quad k_{t+1}^i + P_t x_t^i + Q_t m_t^i = w_t + b_t^i \text{ and } c_{t+1}^i = R^c k_{t+1}^i + R_t^x P_t x_t^i + Q_{t+1} m_t^i - (1 + r_t) b_t^i,$$

⁴ In Appendix of our working paper version (Hirano and Stiglitz 2024), we also study a case in which each agent has log-utility over consumption in both young and old periods, respectively. We show that the results are unchanged. See Appendix of Hirano and Stiglitz (2024) for detail.

where k_{t+1}^i and x_t^i and m_t^i are the entrepreneur's capital investment and land holdings and money holdings at date t . b_t^i is the amount of borrowing at date t if $b_t^i > 0$, and lending if $b_t^i < 0$. $R_t^c \equiv R_{t+1} + 1 - \delta$ is the total return per unit of capital investment made at date t , where R_t is the rental rate of capital at date t , and δ is the depreciation rate of capital. P_t and D_{t+1} are the price of land at date t and land rents at date $t + 1$ in terms of consumption goods. Q_t is the price of money in terms of consumption goods ($1/Q_t$ is the price level). R_t^x is the unleveraged return to land,

$$(1b) \quad R_t^x \equiv \frac{D_{t+1}}{P_t} + \frac{P_{t+1}}{P_t},$$

i.e., the return per dollar spent on land holdings without using borrowing between date t and $t + 1$. It is a key endogenous variable, depending critically on P_t and P_{t+1} .

Similarly, the budget constraint of savers can be written as

$$(1c) \quad Q_t m_t^i = w_t + b_t^i \text{ and } c_{t+1}^i = Q_{t+1} m_t^i - (1 + r_t) b_t^i + T_t^i,$$

where T_t^i is a lump sum transfer payment from the government to old savers.⁵ Since savers don't have investment opportunities and don't participate in the real estate market, their behavior is simple, i.e., they lend their savings to entrepreneurs and/or hold money.

Since there is no risk associated with savers holding money or (by assumption) lending to entrepreneurs⁶, in equilibrium, the rates of returns must be the same.

$$(2) \quad 1 + r_t = \frac{Q_{t+1}}{Q_t}.$$

$\frac{Q_{t+1}}{Q_t}$ is the rate of return of a unit of money.⁷

We assume credit frictions. The entrepreneurs cannot borrow unless they have collateral. The borrowing constraint is

⁵ We can also consider a case where government makes payments to old entrepreneurs. So long as T_t^i cannot be pledged as collateral (e.g., social security payments are not allowed to be collateralized), our analysis applies as is; if it can be pledged as collateral, the analysis can be easily modified.

⁶ If there is a finite support to the distribution of returns to entrepreneurial projects, the "zero" risk assumption can be translated into a maximum acceptable level of leverage.

⁷ (2) implies that if $r_t > 0$, there is deflation. More generally, if there is a "convenience" return to holding money, cr , as is conventionally assumed, (2) becomes $1 + r_t = \frac{Q_{t+1}}{Q_t} + cr$, and so long as $r_t < cr$, the price level is increasing.

$$(3a) \quad (1 + r_t)b_t^i \leq \theta R_t^c k_{t+1}^i + \theta^x R_t^x P_t x_t^i,$$

where the first and second terms of the right-hand side in (3a) reflect that only a fraction $\theta \in [0,1]$ of the total returns from capital investment and only a fraction $\theta^x \in [0,1]$ of the total returns from land holdings can be used as collateral. (3a) means that total debt repayment obligations cannot exceed the total value of the collateral (as evaluated at the time the loan is due).⁸⁹

We also impose the short-sale constraint, i.e., agents can't hold a negative amount of money.

$$(3b) \quad m_t^i \geq 0,$$

We now describe the production side of the economy. The productive sector exhibits standard Marshallian external increasing returns to scale in capital investment (Aoki 1970, 1971; Frankel 1962; Romer 1986.)¹⁰ In the productive sector, competitive firms produce the final consumption goods by using capital and labor. To keep things simple, we assume that the production function of each firm j is given by

$$(4a) \quad y_{tj} = (k_{tj})^\alpha (\chi(K_t)l_{tj})^{1-\alpha},$$

where k_{tj} and l_{tj} are capital and labor inputs of firm j . $\chi(K_t)$ is labor productivity, with $\chi'(K_t) > 0$, where K_t is aggregate capital stock at date t . When we aggregate over all firms,

⁸ See Stiglitz and Weiss (1986) and Hart and Moore (1994) for micro foundations of this type of debt contract. Of course, in this simplified model with no explicit risk, there are no defaults. In a more general model, even with collateral constraints, there are.

⁹ In Appendix O3, we study the case with a different type of borrowing constraint (where the amount that can be borrowed relates to the entrepreneur's current assets) and show the robustness of our main results.

¹⁰ There is a large literature justifying the presence of these Marshallian increasing returns externalities, which we will not repeat; the existence of these effects is at the center of much of the endogenous growth literature. With scale economies, large scale enables high wages, which in turn has a feedback in allowing still larger scale, and with the right parameterization (the standard one, and the one we use here), this can generate steady endogenous growth. One big advantage of this approach is that it allows individual firms to face constant returns to scale—they ignore the aggregate scale benefit because their contribution to it is so small—while there are aggregate scale economies; thus, there can exist a competitive equilibrium, but of course, because of the externality, there is a presumption that it won't be efficient.

There is an alternative strand of research, growing out of Arrow's model of learning by doing (1962), where *improvements* in technology depend on gross investment today. That there are important differences should be clear: in the case of increasing returns, should something happen that would lead to less investment in the productive sector—say a decision by workers to consume more “housing” and less manufactured goods—then there could be a fall in productivity. By contrast, in the learning model, such a decision would simply slow the rate of increase of productivity. Productivity itself would not decline. Still, with appropriate parameterizations, one can get similar results out of the different formulations. (For examples of work in this tradition, see Stiglitz 1987, Stiglitz and Greenwald 2014, and Dasgupta and Stiglitz 1988).

we get at the aggregate level returns to scale. We assume $\chi(K_t)$ takes on a particular functional form:

$$(4b) \quad \chi(K_t) = aK_t.$$

This is a key (though conventional) simplifying assumption.

In the real estate sector, one unit of land produces D_t units of consumption goods (in Appendix O2, we relax this assumption and examine a case where both labor and land are inputs for real estate). To ensure the existence of the balanced growth path, we focus on a case where there is a full spillover from the productive sector to the real estate sector, so that land productivity grows at the economy's growth rate,¹¹

$$(4c) \quad D_t = \epsilon\chi(K_t) = \epsilon aK_t,$$

where $\epsilon \geq 0$ is a parameter that captures the level of land productivity relative to labor productivity in the productive sector.¹² ϵ can also be interpreted as the parameter that captures the size of the spillover to the real estate sector from the productive sector; when ϵ is larger, with an increase in K_t , the productivity increase in the real estate sector is larger.

Apart from the introduction of land, this is the standard AK model. Aggregate output Y_t is then

$$(4d) \quad Y_t = (K_t)^\alpha (\chi(K_t)L_t)^{1-\alpha} + D_tX_t,$$

The aggregate supply of land, X_t , and labor are fixed: $X_t = X$, and $L_t = L$. We normalize L and X at unity.¹³

2.2 The behaviour of individual firms

¹¹ Appendix O3 in our working paper version (Hirano and Stiglitz 2024) also studies the case with imperfect spillovers and show the robustness of our main results.

¹² So long as the positive spillover effect on the real estate sector is a linear function of K_t , we can ensure the existence of a balanced growth path. Our approach to achieving balanced growth is similar to that taken by Greenwald and Stiglitz (2006). More generally, to obtain balanced growth, we need to construct a model so that different sectors will at least eventually grow at the same rate. It is clear from our parametrizations that the rate of growth of productivity in the productive sector equals the rate of growth of productivity in real estate.

¹³ As another interpretation, this production function corresponds to the limiting case of the CES production

function, $Y_t = \left(\gamma_1 ((K_t)^\alpha (\chi(K_t)L_t)^{1-\alpha})^{\frac{\sigma-1}{\sigma}} + \gamma_2 (\chi(K_t)X_t)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$, where σ is the elasticity of substitution between the manufacturing and real estate sectors [between $(K_t)^\alpha (\chi(K_t)L_t)^{1-\alpha}$ and $\chi(K_t)X_t$], and γ_1 and γ_2 are parameters and are set to be unity, as $\sigma \rightarrow \infty$.

In the productive sector, the individual firm ignores its tiny influence on the aggregate capital stock and thus on the productivity of its own worker. Thus, each firm employs capital and labor up to the point where its private marginal product equals the rental rate of capital and the wage rate, respectively. Using (4b), factor prices and the aggregate production function become (see Appendix A1 for derivations)

$$(5a) \quad R_t = \alpha A,$$

$$(5b) \quad w_t = (1 - \alpha)AK_t,$$

$$(5c) \quad Y_t = AK_t + \epsilon a K_t = (1 + \epsilon a^\alpha)AK_t,$$

where $A \equiv a^{1-\alpha}$. (5) holds at every momentary equilibrium, not just in steady state. The wage rate and aggregate output grow at the same rate of aggregate capital stock, so $\frac{w_{t+1}}{w_t} = \frac{K_{t+1}}{K_t} = \frac{Y_{t+1}}{Y_t}$ holds in steady state equilibrium, and the rental rate of capital is constant, with the increasing labor productivity as aggregate capital stock increases canceling out the effect of capital deepening and the diminishing returns associated with it.

2.3 The behavior of entrepreneurs and competitive equilibrium

We focus on the case where the borrowing constraint (3a) binds for entrepreneurs in equilibrium at each date, so that

$$(6) \quad R^c \equiv R + 1 - \delta = \alpha A + 1 - \delta > 1 + r_t,$$

that is, the return on capital net of depreciation is greater than the safe rate of interest, implying that entrepreneurs would want to borrow as much as they could.¹⁴ In this case, entrepreneurs would not hold money because the rate of return on money is strictly lower than the return on capital, i.e., the short-sale constraint (3b) will bind in equilibrium. As we will see below, (6) will hold in equilibrium if the money growth rate is positive.

Optimal portfolio allocations

¹⁴ Indeed, each small entrepreneur, believing that (s)he has no effect on R^c or r , would want to borrow an infinite amount to buy an infinite amount of the capital good. This, of course, ignores risk. Realistically, for many entrepreneurs, risk aversion is sufficiently low (or negative) that the binding constraint is the borrowing constraint that we focus upon. See our discussions in Appendix O2.

Entrepreneurs allocate their portfolio between capital and land, both using borrowing. Since they are perfect substitutes¹⁵, in equilibrium, the leveraged rates of returns on each must be the same (see Appendix A2 for derivations):

$$(7a) \quad \underbrace{\frac{R^c(1-\theta)}{1-\frac{\theta R^c}{1+r_t}}}_{\text{leveraged rate of return on capital investment}} = \underbrace{\frac{R_t^x(1-\theta^x)}{1-\frac{\theta^x R_t^x}{1+r_t}}}_{\text{leveraged rate of return on land speculation}}.$$

The no-arbitrage equation, (7a), is different from the standard one, and this difference is crucial for much of what follows. Solving (7a) for R_t^x yields

$$(7b) \quad R_t^x = \frac{\lambda_t}{1-\theta^x + \frac{\theta^x \lambda_t}{1+r_t}},$$

where $\lambda_t \equiv \frac{R^c(1-\theta)}{1-\frac{\theta R^c}{1+r_t}}$ is the leveraged return on capital investment. For the denominator of the

expression for the leveraged rate of return on capital investment to be positive, $1 + r_t > \theta R^c = \theta(\alpha A + 1 - \delta)$.¹⁶ Later, we will impose an assumption that ensures that that is the case. As we will show below, at the balanced growth path, (7b) can be solved for in terms of the basic technological and policy parameters of the model.

The capital-investment function

By substituting (2b) into (1a) and solving for k_{t+1}^i , we can derive the capital investment function of entrepreneurs when the borrowing constraint binds.

$$(8) \quad k_{t+1}^i = \underbrace{\frac{1}{1-\frac{\theta R^c}{1+r_t}}}_{\text{leverage}} \left[\underbrace{w_t}_{\text{income}} - \underbrace{\left(1 - \frac{\theta^x R_t^x}{1+r_t}\right) P_t x_t^i}_{\text{total down-payment in buying land}} \right],$$

¹⁵ The qualitative results would be similar if the two assets were imperfect substitutes, but the calculations would be much more complicated and less transparent.

¹⁶ When (7a) holds, the equilibrium leverage associated with land speculation $1/\left(1 - \frac{\theta^x R_t^x}{1+r_t}\right)$ is also positive and finite under Assumption 1, given below.

i.e., we can calculate an entrepreneur's capital holdings by taking his wage, subtracting what he has to pay to buy the land he holds (which depends on land leverage); and leveraging up that amount up through borrowing. $1 - \frac{\theta^x R_t^x}{1+r_t}$ is the down-payment of a unit of land purchase.

The competitive equilibrium

The competitive equilibrium is defined as a set of prices $\{P_t, Q_t, w_t, R_t, R_t^x\}_{t=0}^\infty$ and quantities $\{c_t^i, b_t^i, x_t^i, m_t^i, k_{t+1}^i, \int c_t^i di, \int b_t^i di, \int x_t^i di, \int m_t^i di, \int k_t^i di, Y_t\}_{t=0}^\infty$, given an initial K_0 , such that (i) each entrepreneur chooses land holdings, money holdings, capital investment, and borrowing to maximize utility under the budget and the borrowing constraints, and (ii) each saver lends his savings to entrepreneurs and/or hold money, and (iii) the market clearing conditions for land ($\int x_t^i di = 1$), money ($\int m_t^i di = M_t$), capital ($\int k_t^i di = K_t$), labor ($L_t = 1$), and goods ($\int c_t^i di + \int k_{t+1}^i di - (1 - \delta)K_t = Y_t$) are all satisfied.

In the initial period $t = 0$, all land is held by the initial old entrepreneurs and all money is held by the initial old savers. We assume that the government expands the money supply at a fixed rate $\mu > 0$, so

$$(9) \quad M_{t+1} = (1 + \mu)M_t,$$

where M_t is money supply at date t . While in general, μ can vary period to period, in the steady state upon which we focus, μ is constant.

We assume the government does no borrowing, and thus must finance transfer payments out of money issuance, and the only transfer payments are made to old savers:

$$(10) \quad M_{t+1} - M_t = \mu M_t = \int T_t^i di.$$

2.4 Aggregate Dynamics

We are now ready to derive aggregate dynamics. When we aggregate (8) across young entrepreneurs, we have

$$(11) \quad K_{t+1} = \frac{1}{1 - \frac{\theta R^c}{1+r_t}} \left[\eta w_t - \left(1 - \frac{\theta^x R_t^x}{1+r_t} \right) P_t \right] = \frac{1}{1 - \frac{\theta R^c}{1+r_t}} \left[\eta(1 - \alpha)AK_t - \left(1 - \frac{\theta^x R_t^x}{1+r_t} \right) P_t \right].$$

To solve the dynamics, we introduce a variable $\phi_t \equiv \frac{P_t}{AK_t}$, the ratio of the value of land relative to production in the productive sector. For shorthand, we refer to this as the relative size of land speculation. From the definition of ϕ_t , we can derive the evolution of ϕ_t .

$$(12a) \quad \phi_{t+1} = \left(\frac{P_{t+1}/P_t}{1+g_t} \right) \phi_t,$$

where $1 + g_t = \frac{K_{t+1}}{K_t}$, the growth rate of capital. The evolution of ϕ_t depends on the growth rate of output in the productive sector and that of land prices.

From the definition of R_t^x ,

$$(13) \quad \frac{P_{t+1}}{P_t} = R_t^x - \frac{D_{t+1}}{P_t} = R_t^x - \frac{\epsilon a K_{t+1}}{P_t} = R_t^x - \frac{\epsilon a}{A} \frac{AK_t}{P_t} \frac{K_{t+1}}{K_t} = R_t^x - \epsilon a^\alpha \left(\frac{1+g_t}{\phi_t} \right).$$

From (11), we can calculate the growth rate as a function of ϕ_t and r_t and the various parameters of the problem:

$$(14a) \quad 1 + g_t = \frac{A}{1 - \frac{\theta R_t^x}{1+r_t}} \left[\eta(1 - \alpha) - \left(1 - \frac{\theta^x R_t^x}{1+r_t} \right) \phi_t \right].$$

Other things being constant, a rise in ϕ_t (land speculation) crowds out savings away from capital investment, reducing the growth rate of the economy. On the other hand, an increase in θ or θ^x , or a fall in r_t increases the leverage of capital investment and decreases the down-payment of a unit of land purchase, generating more capital investment. We say that capital investment is “crowded in”. The question is what are the circumstances under which each effect dominates? Substituting (13) and (14a) into (12a) yields

$$(12b) \quad \phi_{t+1} = \frac{\phi_t R_t^x}{1+g_t} - \epsilon a^\alpha = \phi_t R_t^x / \left\{ \frac{A}{1 - \frac{\theta R_t^x}{1+r_t}} \left[\eta(1 - \alpha) - \left(1 - \frac{\theta^x R_t^x}{1+r_t} \right) \phi_t \right] \right\} - \epsilon a^\alpha.$$

The value of money is determined so that savings each period (the income of young people, both entrepreneurs and savers) equals holdings of capital, land, and money:

$$(15a) \quad Q_t M_t = w_t - K_{t+1} - P_t.$$

Using the definition of ϕ_t , (15a) can be written as

$$(15b) \quad Q_t M_t = \left\{ (1 - \alpha) - \frac{1}{1 - \frac{\theta R^c}{1 + r_t}} \left[\eta(1 - \alpha) - \left(1 - \frac{\theta^x R_t^x}{1 + r_t}\right) \phi_t \right] - \phi_t \right\} A K_t,$$

So long as the term in the large bracket is positive, the price of fiat money will be positive. Intuitively, if the savings remaining after financing capital investment and land holdings are large enough, those idle savings flow toward money holdings.

The dynamics of this economy, entailing $\{P_t, Q_t, K_t, M_t, r_t, T_t\}$ can be characterized by (2), (9), (10), (12b), (14a) and (15b).

2.5 Steady State

In steady state the real value of money grows according to

$$(16) \quad 1 + r^* = \frac{Q_{t+1}}{Q_t} = \frac{1 + g^*}{1 + \mu}.$$

As is standard in this class of models, whether inflation or deflation occurs in equilibrium depends on the relative size of g^* and μ . (12b), (14a), and (16) give three equations in three unknowns, r^* , g^* , and ϕ^* .

Steady states: unproductive land, i.e., $\epsilon = 0$

We first study a special case of $\epsilon = 0$, i.e., unproductive land. Even if land is unproductive, it can still be used as collateral and as a store of value. The steady-state growth rate is $1 + g^* =$

$$R^{x*} = \frac{\lambda}{1 - \theta^x + \frac{\theta^x \lambda}{1 + r^*}}, \text{ where it will be recalled } \lambda \equiv \frac{R^c(1 - \theta)}{1 - \frac{\theta R^c}{1 + r^*}}. \text{ Using (16), we have } (1 + r^*)(1 + \mu) = \frac{\lambda}{1 - \theta^x + \frac{\theta^x \lambda}{1 + r^*}}, \text{ which, after much simplifying, can be solved for } r^*, \text{ and hence we can now}$$

solve for g^* and ϕ^* explicitly:

$$(17a) \quad 1 + r^* = \frac{R^c}{1 - \theta^x} \left[\frac{1 - \theta}{1 + \mu} - (\theta^x - \theta) \right].$$

$$(17b) \quad \phi^* = \frac{\eta(1 - \alpha)}{1 - \theta^x(1 + \mu)} - \frac{R^c(1 - \theta)}{A(1 - \theta^x)}.$$

$$(17c) \quad 1 + g^* = \frac{R^c}{1 - \theta^x} [1 - \theta - (\theta^x - \theta)(1 + \mu)].$$

i.e., steady state growth depends in a simple way on the leverage variables, the rate of growth of money, and the total return per unit of capital investment. Assumption 2 below guarantees that ϕ^* is positive.

Note that there is another steady state with $\phi_t = 0$ for all t —effectively a “landless” economy. But as we will see below, such a “landless” equilibrium cannot exist with positive ϵ .

General case

The more general case is not solved so simply. By rearranging (12b), (14a), and (16), we can derive the quadratic equation for ϕ^* (see Appendix A3 for detail). We can show there that when $\epsilon > 0$, one of the solutions is positive and the other one is negative (when $\epsilon = 0$, the other one is zero). Solving $\phi^* > 0$ yields

$$(18b) \quad \phi^* = \frac{-Y_2 + \sqrt{Y_2^2 + 4A[1 - \theta^x(1 + \mu)]\epsilon a^\alpha \left\{ \eta(1 - \alpha)A + A\theta^x(1 + \mu)\epsilon a^\alpha + \frac{R^C(1 - \theta)}{1 - \theta^x}\theta^x(1 + \mu) \right\}}}{2A[1 - \theta^x(1 + \mu)]},$$

where

$$Y_2 = -\eta(1 - \alpha)A - A\theta^x(1 + \mu)\epsilon a^\alpha + A\epsilon a^\alpha[1 - \theta^x(1 + \mu)] + \frac{R^C(1 - \theta)}{1 - \theta^x}[1 - \theta^x(1 + \mu)].$$

(17a) and (17c) can also be written as

$$(18a) \quad 1 + r^* = \frac{R^C}{1 - \theta^x} \left[\frac{1 - \theta}{(1 + \mu)(1 + \frac{\epsilon a^\alpha}{\phi^*})} - (\theta^x - \theta) \right],$$

$$(18c) \quad 1 + g^* = (1 + r^*)(1 + \mu) = \frac{R^C}{1 - \theta^x} \left[\frac{1 - \theta}{(1 + \frac{\epsilon a^\alpha}{\phi^*})} - (\theta^x - \theta)(1 + \mu) \right].$$

The critical variables, g^* , r^* , and ϕ^* are functions of the parameters $\{a, \alpha, \epsilon, \eta\}$ and the policy variables $\{\theta^x, \theta, \mu\}$.

2.6 Existence of equilibrium

In the rest of our analysis, to obtain clear economic intuition, we focus on the case with ϵ sufficiently small, i.e., the relative productivity of the real estate sector to the productive sector is sufficiently low.¹⁷

To ensure the existence of equilibrium, we make the following assumptions. For the equilibrium leverage associated with capital investment to be finite, we impose a constraint on the maximum rate of money growth.

Assumption 1. $1 > \theta^x(1 + \mu)$, or $1 + \mu < 1/\theta^x$ ¹⁸.

We also impose constraints on parameter values to ensure $\phi^* > 0$ and $Q_t > 0$, respectively. A necessary and sufficient condition for these inequalities to hold simultaneously is

Assumption 2. $A(1 - \alpha) + \frac{R^c(\theta^x - \theta)(1 + \mu)}{1 - \theta^x} > \frac{\eta(1 - \alpha)A}{1 - \theta^x(1 + \mu)} > \frac{R^c(1 - \theta)}{1 - \theta^x}$.

The inequality on the left-hand side ensures $Q_t > 0$, and the inequality on the right-hand side ensures $\phi^* > 0$. We can easily find that there are relevant parameter values for which Assumption 2 holds, and for Assumption 1 to simultaneously hold.¹⁹

We can also verify that the borrowing and short-sale constraints, (2a) and (2b), bind in equilibrium, i.e., using (18a), (6) can be written as $(1 + \mu) \left(1 + \frac{\epsilon a^\alpha}{\phi^*}\right) > 0$, which is true under Assumptions 1 and 2 if $1 + \mu > 0$.

We obtain the following Proposition.

Proposition 1 Uniqueness of balanced growth path

¹⁷ Our working paper version (Hirano and Stiglitz 2024) presents numerical analyses for the case of large ϵ .

¹⁸ If the rate of increase of the money supply is too high, the interest rate gets sufficiently low that equilibrium leverage will become infinite.

¹⁹ Note that the inequality $A(1 - \alpha) + \frac{R^c(\theta^x - \theta)(1 + \mu)}{1 - \theta^x} > \frac{R^c(1 - \theta)}{1 - \theta^x}$ can be written as (using (6))

$\left(1 - 2\alpha - \frac{1 - \delta}{A}\right)(1 - \theta^x) + \left(\alpha + \frac{1 - \delta}{A}\right)\mu(\theta^x - \theta) > 0$. An easily satisfied set of sufficient conditions for this to hold is that $\left\{A > \frac{1 - \delta}{1 - 2\alpha}, \alpha < \frac{1}{2} \text{ and } \theta^x \geq \theta\right\}$. By choosing η appropriately and ensuring that $1 + \mu < 1/\theta^x$, we can verify that there are relevant parameters for which Assumptions 1 and 2 are simultaneously satisfied.

Under Assumption 1 and 2, for ϵ sufficiently small, there exists a unique balanced growth path where the relative size of land speculation $\phi^* > 0$, economic growth rate $1 + g^*$, the interest rate $1 + r^*$, which equals the rate of return on fiat money $\frac{Q_{t+1}}{Q_t}$, are constant over time. Moreover, g^* , ϕ^* , and r^* converge to the values given in (17a), (17b), and (17c), as $\epsilon \rightarrow 0$.

2.7 Comparative dynamics

(17a), (17b), and (17c) allow us to conduct comparative statics with changes in the market/policy parameters. We are particularly interested impacts on growth. We can see how growth is affected by changes in the interest rate or collateral requirements by decomposing the effects of changes into a direct (partial equilibrium) effect and a general equilibrium effect, where the latter represents the impact on the equilibrium level of speculation, through (12b):

$$(14b) \quad 1 + g^* = \underbrace{\frac{1}{1 - \frac{\theta R^c}{1 + r^*}}}_{\text{PE effect 1}} \left(\eta(1 - \alpha) - \underbrace{\left(1 - \frac{\theta^x R^{x*}}{1 + r^*}\right)}_{\text{PE effect 2}} \underbrace{\phi^*}_{\text{GE effect}} \right) A.$$

where it will be recalled $R^{x*} = \frac{\lambda}{1 - \theta^x + \frac{\theta^x \lambda}{1 + r^*}}$, where $\lambda \equiv \frac{R^c(1 - \theta)}{1 - \frac{\theta R^c}{1 + r^*}}$. PE effect 1 represents the direct leverage effect, with investment and growth increasing with a rise in θ or with a decline in r^* . PE effect 2 represents the effect on capital investments through changes in the equilibrium down-payment in buying a unit of land. With increases in θ^{20} or θ^x or with a decrease in the interest rate caused by an increase in μ , the equilibrium down-payment in buying land decreases, allowing the financing of more capital investments. On the other hand, the GE effect represents the effect on capital investments as a result of changes in the relative size of land speculation. The various effects sometimes pull in different directions; nonetheless, we are able to establish:

Proposition 2 Impact of changes in the collateral values on long-run economic growth in a monetary economy

²⁰ If θ increases, a portfolio shift will occur from land speculation to capital investment. For the leveraged return on land and capital to remain equal, R^{x*} must increase. As the unleveraged rate of return on a unit of land increases, it raises the collateral value of land, thereby reducing the equilibrium down-payment in buying a unit of land.

(2-i) For ϵ sufficiently small, $\frac{d(1+g^*)}{d\theta^x} < 0$, with $\frac{d\phi^*}{d\theta^x} > 0$ ²¹ and $\frac{d(1+r^*)}{d\theta^x} < 0$.

That is, with greater θ^x , land speculation increases, which produces a crowding-out effect. On the other hand, the interest rate declines,²² which increases equilibrium leverage with capital investment and decreases the down-payment on a unit of land, producing a crowding-in effect. Nonetheless, the crowding-out effect dominates the crowding-in effect: the increase in land speculation is so great that productivity and economic growth are impaired even though the interest rate has decreased.

(2-ii) For ϵ sufficiently small, $\frac{d(1+g^*)}{d\theta} > 0$, with $\frac{d\phi^*}{d\theta} > 0$ and $\frac{d(1+r^*)}{d\theta} > 0$.

That is, an increase in the collateral value of capital investment increases leverage, which finances more capital investment, thereby increasing productivity and economic growth, even though there is an endogenous rise in the interest rate and in our measure of relative land speculation ϕ^* .²³

Next, we examine the effect of low-interest-rate policy. As $\epsilon \rightarrow 0$, we obtain

$$(19) \quad 1 + g^* = R^{x*} = \frac{\lambda}{1 - \theta^x + \frac{\theta^x \lambda}{1 + r^*}} = \frac{R^c(1 - \theta)(1 + r^*)}{(1 - \theta^x)(1 + r^*) + R^c(\theta^x - \theta)}.$$

Then, differentiating (19) with regard to r^* directly leads to the following Lemma.

Lemma 1 For ϵ sufficiently small, $\text{sign} \frac{d(1+g^*)}{dr^*} = \text{sign}(\theta^x - \theta)$.

That is, if land is sufficiently unproductive, the long-run impact of low interest rates on economic growth depends on the relative size of θ^x and θ . When $\theta^x > \theta$, the crowding-out effect caused by low interest rates (with land prices increasing) dominates the crowding-in effects; low interest rates encourage land speculation with leverage more than capital

²¹ From (17b), we have $\frac{d\phi^*}{d\theta^x} = \frac{\eta(1-\alpha)(1+\mu)}{[1-\theta^x(1+\mu)]^2} - \frac{R^c(1-\theta)}{A(1-\theta^x)^2} > 0$ if and only if $\frac{\eta(1-\alpha)(1+\mu)}{[1-\theta^x(1+\mu)]^2} > \frac{R^c(1-\theta)}{A(1-\theta^x)^2}$. This inequality condition can be written as $\frac{\eta(1-\alpha)}{[1-\theta^x(1+\mu)]} > \frac{(\alpha A + 1 - \delta)(1-\theta)}{A(1-\theta^x)} \frac{[1-\theta^x(1+\mu)]}{(1-\theta^x)(1+\mu)}$, which holds under Assumption 2 because $\frac{[1-\theta^x(1+\mu)]}{(1-\theta^x)(1+\mu)} < 1$ if $\mu > 0$.

²² From (16), with a decline in g^* , interest rates have to decline if there is to be a steady state.

²³ This occurs because the increased leverage in capital investment allows more funds to be available for land speculation.

investment, reducing long-run productivity and economic growth. On the other hand, when $\theta^x < \theta$, just the opposite is true.

Moreover, from (17a) and (17b), we know $\frac{d(1+r^*)}{d\mu} < 0$ and $\frac{d\phi^*}{d\mu} > 0$. That is, an increase in money growth rate reduces the interest rate and increases the relative size of land speculation.²⁴ Then, these results and Lemma 1 lead to the following Proposition.

Proposition 3 Impact of monetary policy on long-run economic growth

For ϵ sufficiently small, $\text{sign} \frac{\partial(1+g^*)}{\partial\mu} = \text{sign}(\theta - \theta^x)$.

That is, the long-run impact of expansionary monetary policy (keeping all other parameters constant) on economic growth depends on the relative size of θ^x and θ .

It should be noted that although we have focused on the case of $\epsilon \rightarrow 0$, as we study in Appendix O3, if we employ a different type of borrowing constraints, which is $b_t^i \leq \theta k_{t+1}^i + \theta^x P_t x_t^i$, i.e., this collateral constraint is set as a fraction of this year's value of land, then, regardless of the size of ϵ , we can analytically show $\frac{d(1+g^*)}{d\theta^x} < 0$, $\frac{d(1+g^*)}{d\theta} > 0$, and $\text{sign} \frac{\partial(1+g^*)}{\partial\mu} = \text{sign}(\theta - \theta^x)$. Intuitively, because the interest rate is not involved with the constraint, changes in r_t do not impact the crowding-in PE effects 1 and 2. Therefore, when $\theta^x > \theta$, low interest rates caused by expansionary monetary policy end up increasing the size of land speculation, thereby negative impacting long-run economic growth.

Comparison with the standard view of more expansionary monetary policy (Tobin (1965))

Proposition 3 is in sharp contrast with the conventional view of expansionary monetary policy in which there is a presumption that easier monetary and credit policies (e.g. a faster rate of expansion of the money supply or lower collateral requirements) leads to more capital investment. See, e.g., Tobin (1965). Tobin claimed that an increase in the money growth rate leads to higher inflation rates and reduced rates of return on fiat money, inducing a portfolio

²⁴ In Appendix A4, we derive insights on how changes in market/policy parameters $\{\mu, \theta, \theta^x\}$ affect the Credit/GDP ratio.

shift from money to real capital, thereby leading to higher long run economic growth. This effect is called the “Tobin Effect”.²⁵²⁶

Tobin (and much of the related subsequent literature on money and growth) was correct that higher rates of money growth lead to higher rates of inflation; but he ignored the existence of land, and the shift away from money may (and often does) lead to a demand for more land rather than more real investment. Our model can validate Tobin’s claim in a landless economy, i.e., one where $\epsilon = 0$ and $P_t = 0$. From (14a), when $P_t = 0$, at the balanced growth path, the growth rate of the economy can be written as

$$(20) \quad 1 + g^* \equiv \frac{K_{t+1}}{K_t} = \frac{\eta(1-\alpha)A}{1 - \frac{\theta R^c}{1+r^*}}.$$

It is clear from (20) that a reduction in the interest rate relaxes the borrowing constraint, financing more capital investment and leading to higher economic growth. By substituting (20) into (16) and solving for $1 + r^*$, we have the standard result.

$$(21) \quad 1 + r^* = \frac{Q_{t+1}}{Q_t} = \frac{\eta(1-\alpha)A}{1+\mu} + \theta R^c.$$

That is, an increase in the money growth rate increases the inflation rate and lowers the long run interest rate. We summarize this result as the following Proposition.

Proposition 4 Replication of the Tobin’s claim in a model with credit frictions

Consider a special case with $\epsilon = 0$ and $P_t = 0$, i.e., the landless economy. Then, for $\theta > 0$, we have $\frac{d(1+g^*)}{d\mu} > 0$, with $\frac{d(1+r^*)}{d\mu} < 0$.

Because decreased interest rates relax the borrowing constraint of entrepreneurs, more capital investment is financed and productivity and economic growth are higher.

²⁵ Brunnermeier and Sannikov (2016) revive Tobin’s intuition in a two-asset model of capital and money with incomplete markets, i.e., higher inflation due to higher money growth lowers the real interest rate on money and induces the portfolio choice towards capital investment. They conclude that moderate inflation boosts the growth rate of the economy and welfare. It should be noted that their model also abstracts from the existence of land.

²⁶ There is, of course, a large literature identifying other effects on higher inflation, arguing that it is bad for economic growth. The simple growth model we present here is consonant with that investigated by Tobin, as we show below.

The central message to be drawn from our analysis is that the effect of a low-interest-rate policy differs markedly between the two-asset model of capital and money studied in Tobin (1965) and our three-asset model of capital, money, and land. In particular, a loosening of monetary policy or of collateral requirements may so increase land speculation that resources are diverted from capital investment and growth may be impaired—consistent with the experiences in numerous countries and the studies cited in the introduction. To ensure that easier credit leads to more investment, at the same time as monetary easing, financial regulations on the real estate sector (or taxes we discuss in the conclusion) need also be introduced, i.e., $\theta > \theta^x$ so that more funds can flow into capital investment rather than land speculation.

2.8 Welfare implications

Changes in the market/policy parameters $\{\mu, \theta^x, \theta\}$ can affect agents of different generations and types differently. For instance, consider a policy change which results in the price of land and money going up initially but the growth rate slowing. Older entrepreneurs and savers who hold land and money at time 0 are better off because of the capital gains. The first generation's welfare, whether that of the saver or the entrepreneur, depends simply on $1 + r^*$ and the leveraged return, respectively, given their wages w_0 (K_0 is given). The welfare of subsequent generations depends also on wages they earn. Although entrepreneurs and savers in the first few generations may be better off or worse off depending on changes in the rates of returns each type earns, generations far enough into the future will be worse off so long as long-run growth rate of the economy and wages are lowered. This implies that without financial regulations, a low-interest-rate policy can be harmful to the future generations.

2.9 Dynamics

Looking at the difference equations for $\{P_t, K_t, Q_t, M_t, r_t, T_t\}$ [defined by (2), (9), (10), (12b), (14a) and (15b)], it is clear that if the price of land at time 0 jumps to $P_0 = AK_0\phi^*$, and the price of money jumps to $Q_0 = \left\{ (1 - \alpha) - \frac{1}{1 - \frac{\theta R^c}{1 + r^*}} \left[\eta(1 - \alpha) - \left(1 - \frac{\theta^x R^{x*}}{1 + r^*} \right) \phi^* \right] - \phi^* \right\} \frac{AK_0}{M_0}$, then there is a steady state equilibrium where all the dynamical equations are satisfied for all $t \geq 0$.

More generally, we show in Appendix A5 that the dynamics can be reduced to the two-dimensional dynamical system, with $\phi_{t+1} = \psi(\phi_t, 1 + r_t)$ and $1 + r_{t+1} = \omega(\phi_t, 1 + r_t)$,

where both ϕ_t and $1 + r_t$ are variables that can jump in value. We can show that there is a dynamic equilibrium path in which ϕ_t and $1 + r_t$ jump to their steady state value at $t = 0$. This rational expectations path always exists under our Assumptions 1 and 2.

Proposition 6: Existence of rational expectations path without transitional dynamics

There exists a rational expectations path along which the economy achieves the balanced growth path immediately without transitional dynamics.²⁷

2.10 Temporary output and asset price booms and their long-lasting negative effects on future generations

So far, we have examined how changes in the market/policy parameters $\{\mu, \theta^x, \theta\}$ affect long-run growth. We can also analyze the short-run and long-run effects on the economy of a real estate boom brought on by an increase in productivity in the real estate sector. Normally, one would have thought that an increase in productivity—an expansion of today’s production possibilities curve—is unambiguously welfare enhancing. It turns out that that is not the case.

Suppose that at the beginning of date s , there is an unexpected permanent increase in ϵ , generating a real estate boom. With this shock, the size of land speculation increases, while the growth rate of aggregate capital decreases (see Appendix A6 for the derivations). This means that land prices at date s , P_s , rise, given K_s . Since aggregate output at date s , Y_s , simultaneously increases, it appears as if the productivity shock has given rise to an asset and economic boom at the macroeconomic level. But the productivity shock has had sectoral consequences; the rise in ϕ^* crowds out capital investment in the productive sector, therefore reducing K_{s+1} and the growth rate of capital thereafter, compared to what it would have been had the shock not occurred. Accordingly, eventually output is lower than it otherwise would have been. In other words, a boom in the real estate sector has markedly different effects in the short term and in the long term.²⁸ We summarize this implication as the following Proposition.

²⁷ In the different borrowing constraint we study in Appendix O3, we can prove that there exists a unique rational expectations path along which the economy achieves the balanced growth path immediately without transitional dynamics and this is the only possible rational expectations trajectory.

²⁸ Even if the productivity increase is temporary, in our framework with endogenous growth, this leads to a decrease in capital investment and lowers the level of capital accumulation permanently, thereby leading to decreased wages and welfare of future generations.

Proposition 7 The productivity increase in the real estate sector generates temporary output and asset price booms but, it reduces the growth rate and thus lowers the wages and welfare of future generations.

Whether social welfare (as assessed, for instance, by a standard utilitarian social welfare function, discounting future generations utility) is increased or decreased depends on the discount rate. With sufficiently low discount rates, social welfare is decreased.²⁹

Section 3. Equilibrium with finite land prices, low interest rates, and high returns to capital

In standard macroeconomic theory, if r is very low, in particular less than the growth rate, there is a problem. There is dynamic inefficiency. Such an equilibrium can easily arise in life-cycle models without land. But if there exists an asset like land (a non-reproducible asset), with fixed returns no matter how small, as r goes to zero, its market value becomes infinite, which of course cannot be an equilibrium. The only possible equilibria entail $r > g$.

But as we mentioned in the introduction, it has been the norm in the U.S economy that the return on government bonds has been less than the growth rate. The model we propose is at least theoretically consistent with this empirical observation.

At the balanced growth path, we know that $1 + r^* = \frac{1+g^*}{1+\mu}$. It is obvious that $1 + g^* > 1 + r^*$ if $\mu > 0$. We also know from (14c) that $1 + g^* = R^{x^*}/[1 + (\epsilon a^\alpha/\phi^*)]$. So long as $\epsilon > 0$, $R^{x^*} > 1 + g^*$. Moreover, $R^c > R^{x^*}$ if $\theta^x > \theta$. Therefore, if $\theta^x > \theta$ and $\mu > 0$, $R^c > 1 + g^* > 1 + r^*$ holds at the balanced growth path. When $\epsilon \rightarrow 0$, $1 + g^* \rightarrow R^{x^*}$ and the same argument applies. We summarize this result as the following Proposition.

Proposition 8 Finite land prices with low interest rates

If $\theta^x > \theta$, $\epsilon \geq 0$, and $\mu > 0$, the return to capital $> 1 + g^* > 1 + r^*$ holds at the balanced growth path and P^* is finite.

Section 4. Discussions

Discussion 1. Concerning assumption of limited asset market participation

²⁹ As Ramsey (1928) argued, there is no ethical justification for discounting future generations.

There is a good justification for our assumption of limited asset market participation by one part of the population, those we have referred to as workers. There is considerable land heterogeneity and workers are less informed about real estate (with high costs associated with obtaining the relevant information), making real estate unattractive for them. For instance, there are real estate ventures yielding a zero return and those yielding a positive return, and because non-entrepreneurial workers can't distinguish between them, they do not invest in real estate; the expected return is just too low.

If there are a finite number of projects, the informed will select the good projects (on average), leaving a disproportionate share of bad projects for the uninformed, so that even if the expected returns of the informed is equal to or greater than other investment opportunities, that of the uninformed is less even than government bonds. This effect is strengthened if we had, more realistically, assumed all individuals are risk averse.

There are other reasons for limited participation in the real estate market. For instance, people have different attitudes toward risk. The real estate market is obviously more risky than the (real) return on government bonds, so very risk averse agents don't participate in the real estate market.

It should be obvious that this assumption is crucial. If both entrepreneurs and savers participate in the real estate market, then, the no-arbitrage condition will be changed to $1 + r_t = \frac{D_{t+1}}{P_t} + \frac{P_{t+1}}{P_t}$ (a standard one), in which case the discount rate will be $1 + r^*$ on the steady-state growth path. If this is the case, at the steady-state growth path, the land price-rent ratio can be written as

$$\frac{P_t}{D_t} = \frac{1+g^*}{1+r^*-(1+g^*)}.$$

In the case where $1 + g^* > 1 + r^*$, which is empirically true in the past century of U.S data (see Blanchard (2019)), the ratio would become infinite and hence, there is no equilibrium.

Moreover, in steady state, (16) holds. If we substitute (16) into the above price-dividend ratio, we obtain

$$\frac{P_t}{D_t} = \frac{1+g^*}{\frac{1+g^*}{1+\mu}-(1+g^*)}.$$

For the existence of equilibrium, $\mu < 0$, i.e., the growth rate of money must be negative, otherwise no equilibrium exists. Of course, in the real world, $\mu > 0$, i.e., the money supply has expanded.

Discussion 2. Related literature

Our paper is related to the vast modern literatures on credit and financial frictions, land, monetary economics, OLG, and endogenous growth. It brings together in a parsimonious model key insights from each, noting how, in many instances, standard results are overturned once these more constrained models are extended. A key lesson is that we need to be careful in drawing implications for monetary policy in models without land; without endogenous growth; without a sensitivity to how monetary policy affects sectoral allocations (something that a model with a single sector obviously cannot do), and without credit frictions.

The modern macro-finance literature, including seminal papers by Stiglitz and Weiss (1981), Bernanke (1983), and Diamond (1984), emphasizes the role of credit and the restrictions in the provision of credit to entrepreneurs. By putting credit at the center stage of macroeconomic analysis, the literature has deepened our understanding of how credit-driven macroeconomic fluctuations occur (see Greenwald, Stiglitz, and Weiss 1984; Stiglitz and Weiss 1986, 1992; Woodford 1988; Bernanke and Gertler 1989; and Greenwald and Stiglitz 1993 and Stiglitz and Greenwald 2003 for earlier work). The focus of these papers was on total credit availability. In contrast, our paper emphasizes sectoral credit expansion, not total credit expansion.

Based on the above fundamental theoretical papers, Kiyotaki and Moore (1997) advanced the literature by incorporating asset prices explicitly (see also Bernanke, Gertler, and Gilchrist 1999). In their paper and many of subsequent papers,³⁰ land plays an important role as collateral. An increase in the value of land relaxes borrowing constraints of entrepreneurs

³⁰ More recent macro-finance papers include Krishnamurthy (2003), who shows that the collateral amplification mechanism suggested by Kiyotaki and Moore (1997) is not robust to the introduction of markets that allow entrepreneurs to hedge against aggregate shocks, while Bocola and Lorenzoni (2023) show that they may not hedge negative aggregate shocks because insuring those states may be too costly for them and the resulting competitive equilibrium features too much exposure of entrepreneurs to aggregate risk; Hirano and Toda (2025), who show the inevitability of asset price bubbles in workhorse macroeconomic models; Bolton, Santos, and Scheinkman (2021), who show that easy financial conditions lead to financial fragility; and Allen, Barlevy, and Gale (2022), who show that by introducing costly default exogenously, borrowers undertake excessively risky investments, during asset booms and misallocation of resources occurs. A comprehensive literature review is too large for this paper; for a more complete discussion, see the 2022 Nobel Memorial Prize in Economics <https://www.nobelprize.org/uploads/2022/10/advanced-economicsciencesprize2022-2.pdf>

who have productive investment opportunities, allowing them to make more of their productive investments, increasing the efficiency of macroeconomy. But it is assumed by model construction that the only thing productive entrepreneurs can do with borrowed funds is to engage in entrepreneurial activity with high returns. In contrast, in our model, entrepreneurs may use borrowed funds for land speculation as well as for productive investment. An increase in the collateral value of land produces a “crowding in” effect, as in their model, but through a quite different mechanism, i.e., in our model, a lower downpayment to buy real estate leaves more funds available for capital investment. More importantly, unlike their model, the increase in the collateral value of land produces a general equilibrium “crowding out” effect, as entrepreneurs’ portfolios shift toward land speculation, rather than productive investments, with the increased land speculation crowding out more productive capital investments. We provide the conditions under which the crowding out effect of land speculation outweighs the crowding in effect, suggesting a strong presumption that the former effect normally dominates, a result consistent with empirical results and common interpretations of many recent episodes of credit expansions (Verner [2019](#); Müller and Verner [2023](#); Banerjee, Mehrotra, and Zampolli [2024](#)).

Our paper is also related to the effect of land in overlapping generations models. There are two substantial differences of our paper from that literature. First, it is well known in the standard overlapping generations model with land that land holdings crowd out capital accumulation (Deaton and Laroque [2001](#); Mountford [2004](#)). There is *only* a crowding out effect. Here, we introduce three more features to that standard model: there are two sectors, the real estate sector and the productive sector; there is standard Marshallian external increasing returns to scale in capital investment, centered on the productive sector, that generates endogenous growth but whose benefits spillover into the rest of the economy; and there are “financial frictions”—limits in the extent to which entrepreneurs can borrow and workers can engage in real estate speculation. In this setting, more realistic than that of the standard OLG models, we show that land speculation may not only crowd out productive investment, but also lead to lower *rates* of growth, with effects of credit expansions depending on its sectoral allocation; but (typically only partially offsetting this crowding out effect), the increase in collateral values associated with land speculation may provide additional collateral needed by entrepreneurs to make productive investments. Second, the welfare implications of the existence of land in our paper are markedly different from those in standard overlapping generations models with land. In the standard model with exogenous

growth (including no growth), the existence of land eliminates inefficient equilibria (thus resolving the over-savings problem raised by Diamond 1965), thereby increasing welfare (McCallum 1987). In contrast, in our model with endogenous growth, the very existence of land may reduce welfare by lowering *rates of growth*.³¹ Most importantly, monetary policies and financial de-regulations that expand credit to the real estate sector can be harmful to long-run growth and welfare.

5. Concluding remarks

This paper begins with the hypothesis that some sectors of the economy generate more learning (more economies of scale, more likely to enhance endogenous growth) than others, and that the productivity benefits of that sector spillover to others.³² Because of these within and cross-sector externalities, market allocations are not likely to be efficient. There is room for government intervention, e.g., here, given that the source of productivity growth is the “productive” (manufacturing) sector, it seems natural to expand that sector at the expense of the real estate sector. That, effectively, is what credit expansion does when there are weaker collateral requirements there, but it does just the opposite when there are tighter collateral requirements.

Intervention can, of course, take many other forms. For instance, government could impose a tax on the real estate sector, so that the return to holding land is reduced to $(1 - \tau)D$, with the revenues used to subsidize the productive sector, increasing after tax “output” to $(1 + \hat{\tau})Y$, where τ and $\hat{\tau}$ are chosen to balance the budget, effectively increasing A . Our analysis can be used to establish conditions under which an increase in τ leads a reduction in equilibrium land speculation ϕ^* , and the direct effect of that is, of course, to increase g^* .

There are two central messages of this paper. First, it is not so much aggregate credit expansion that matters for long-run productivity and economic growth but sectoral credit expansions. Credit expansions associated mainly with relaxation of real estate financing (of

³¹ In the standard model with exogenous growth, the existence of land lowers steady state welfare, if equilibria without land are dynamically efficient, precisely because land speculation crowds out productive investments. Taxes on the returns to land thereby increase steady state welfare, but only by increasing steady state consumption. In contrast, in our model with endogenous growth, the existence of land may lower economic growth and welfare, regardless of whether the economy without land is or is not dynamically efficient.

³² In our review of the literature, we omitted a discussion of the vast literature on endogenous growth, either that based on learning-by-doing or that (as here) related to agglomeration economies. Here, we note the smaller literature on cross-sector spillovers and differential learning. See, in particular, Greenwald and Stiglitz (2006) and Stiglitz and Greenwald (2014) and the works cited there.

capital investment financing) will be productivity-and growth-reducing (enhancing) in the long run. An extension of our model can be used to derive a theoretical rationale for the role of ex-ante tighter financial regulations during credit expansions (see Borio and Lowe 2002; Lorenzoni 2008; Jeanne and Korinek 2019).

Second, and relatedly, lower interest rates may (as happened in the run-up to the 2008 financial crisis) induce more real estate speculation than productive capital investment; indeed the latter may be reduced, and with it economic growth—just the opposite of what was intended and predicted by many of the standard models which ignored the presence of land as an alternative (unproductive) store of value. Hence, to ensure enhanced growth, looser monetary policy has to be accompanied by financial regulations that ensure that funds flow into the productive sectors of the economy.

Appendix

A1. Derivations of (5a), (5b), and (5c)

The production function of each firm j is given by (4a). Each firm maximizes its profit π_{tj} by choosing k_{tj} and n_{tj} , respectively. That is, the profit is given by

$$(A1-1) \quad \pi_{tj} = y_{tj} - w_t n_{tj} - R_t k_{tj}$$

Each firm chooses k_{tj} and n_{tj} , taking $\chi(K_t)$ as given.

From the first-order necessary conditions, we can derive the demand equations for capital, labor, and land of each firm j , respectively, which we write as:

$$(A1-2) \quad R_t = \alpha (k_{tj})^{\alpha-1} (\chi(K_t) l_{tj})^{1-\alpha}$$

$$(A1-3) \quad w_t = (1 - \alpha) (k_{tj})^{\alpha} (\chi(K_t) l_{tj})^{-\alpha} \chi(K_t)$$

Due to homogeneity of degree one, (A1-2), (A1-3), and (4a) become

$$(A1-4) \quad R_t = \alpha (K_t)^{\alpha-1} (\chi(K_t) L_t)^{1-\alpha}$$

$$(A1-5) \quad w_t = (1 - \alpha) (K_t)^{\alpha} (\chi(K_t) L_t)^{-\alpha} \chi(K_t)$$

$$(A1-6) \quad Y_t = (K_t)^\alpha (\chi(K_t)L_t)^{1-\alpha}$$

Substituting (4b) into (A1-4), (A1-5), and (A1-6) respectively, yields (5a), (5b) and (5c).

A2. Deriving optimal portfolio selection

We construct the Lagrangian function,

$$(A2-1) \quad \mathcal{L}_t^i = R^c k_{t+1}^i + R_t^x P_t x_t^i + Q_{t+1} m_t^i - (1 + r_t)(k_{t+1}^i + P_t x_t^i + Q_t m_t^i - w_t) \\ + \Lambda_{1,t}^i [\theta R^c k_{t+1}^i + \theta^x R_t^x P_t x_t^i - (1 + r_t)(k_{t+1}^i + P_t x_t^i + Q_t m_t^i - w_t)] + \Lambda_{2,t}^i m_t^i$$

where $\Lambda_{1,t}^i \geq 0$ $\Lambda_{2,t}^i \geq 0$ are the Lagrangian multiplier associated with the borrowing and short-sale constraints.

The first-order necessary conditions are:

$$(A2-2) \quad \frac{\partial \mathcal{L}_t^i}{\partial k_{t+1}^i} = R^c - (1 + r_t) + \Lambda_{1,t}^i [\theta R^c - (1 + r_t)] = 0$$

$$(A2-3) \quad \frac{\partial \mathcal{L}_t^i}{\partial P_t x_t^i} = R_t^x - (1 + r_t) + \Lambda_{1,t}^i [\theta^x R_t^x - (1 + r_t)] = 0$$

$$(A2-4) \quad \frac{\partial \mathcal{L}_t^i}{\partial Q_t m_t^i} = \frac{Q_{t+1}}{Q_t} - (1 + r_t) - \Lambda_{1,t}^i (1 + r_t) + \frac{\Lambda_{2,t}^i}{Q_t} = 0$$

Complementary slackness conditions:

$$(A2-5a) \quad \Lambda_{1,t}^i [\theta R^c k_{t+1}^i + \theta^x R_t^x P_t x_t^i - (1 + r_t)(k_{t+1}^i + P_t x_t^i - w_t)] = 0 \text{ and } \Lambda_{1,t}^i \geq 0.$$

$$(A2-5b) \quad \Lambda_{2,t}^i m_t^i \geq 0 \text{ and } m_t^i \geq 0.$$

By rearranging (A2-2), we have

$$(A2-6) \quad \Lambda_{1,t}^i = \frac{R^c - (1 + r_t)}{1 + r_t - \theta R^c}$$

Similarly, from (A2-3), we have

$$(A2-7) \quad \Lambda_{1,t}^i = \frac{R_t^x - (1 + r_t)}{1 + r_t - \theta^x R_t^x}$$

It follows that if and only if $R^c > 1 + r_t$ and $R_t^x > 1 + r_t$, $\Lambda_{1,t}^i > 0$, i.e., the borrowing constraint binds, provided that $1 + r_t > \theta R^c$ and $1 + r_t > \theta^x R_t^x$, which is ensured by Assumption 1. Also, in equilibrium, (2) holds. Then, from (A2-4), we have $\Lambda_{1,t}^i(1 + r_t) = \frac{\Lambda_{2,t}^i}{Q_t}$. Therefore, when $\Lambda_{1,t}^i > 0$, $\Lambda_{2,t}^i > 0$, i.e., the short-sale constraint binds.

From (A2-6) and (A2-7),

$$(A2-8) \quad \frac{R^c - (1 + r_t)}{1 + r_t - \theta R^c} = \frac{R_t^x - (1 + r_t)}{1 + r_t - \theta^x R_t^x},$$

which can be written as

$$(A2-9) \quad \frac{R^c(1 - \theta) - (1 + r_t) + \theta R^c}{1 + r_t - \theta R^c} = \frac{R_t^x(1 - \theta^x) - (1 + r_t) + \theta^x R_t^x}{1 + r_t - \theta^x R_t^x},$$

which is equivalent to (7b),

A3. The existence of a unique balanced growth path in closed economy model

At the balanced growth path, we know that

$$(16) \quad 1 + r^* = \frac{1 + g^*}{1 + \mu}.$$

$$(12b) \quad 1 + g^* = \frac{\lambda}{1 - \theta^x + \frac{\theta^x \lambda}{1 + r^*}} / (1 + \epsilon a^\alpha / \phi^*).$$

where, it will be recalled, $\lambda \equiv \frac{R^c(1 - \theta)}{1 - \frac{\theta R^c}{1 + r^*}}$. It follows from straightforward substitution that

$$(18a) \quad 1 + r^* = \frac{R^c}{1 - \theta^x} \left[\frac{1 - \theta}{(1 + \mu)(1 + \epsilon a^\alpha / \phi^*)} - (\theta^x - \theta) \right].$$

Using (18a), we have

$$(A4-1) \quad 1 - \theta^x + \frac{\theta^x \lambda}{1 + r^*} = \frac{1 - \theta^x}{1 - \theta^x(1 + \mu)(1 + \epsilon a^\alpha / \phi^*)}.$$

Substituting (A4-1) into (12b) yields the quadratic equations regarding ϕ^* .

$$(A4-2) \quad A[1 - \theta^x(1 + \mu)](\phi^*)^2 + \left\{ -\eta(1 - \alpha)A - A\theta^x(1 + \mu)\epsilon a^\alpha + A\epsilon a^\alpha[1 - \theta^x(1 + \mu)] + \frac{R^c(1 - \theta)}{1 - \theta^x}[1 - \theta^x(1 + \mu)] \right\} \phi^* - \epsilon a^\alpha \left\{ \eta(1 - \alpha)A + A\theta^x(1 + \mu)\epsilon a^\alpha + \frac{R^c(1 - \theta)}{1 - \theta^x}\theta^x(1 + \mu) \right\} = 0.$$

Since the left-hand side of (A4-2) is a convex function of ϕ^* , with the negative value at $\phi^* = 0$, it is clear from (A4-2) that if $\epsilon > 0$, one of the solutions is positive and the other one is negative. When $\epsilon = 0$, the other solution is zero. Hence, for $\epsilon \geq 0$, there exists a unique balanced growth path in which $\phi^* > 0$ is constant. It is obvious from (18a) and (12b) that when $\phi^* > 0$ is constant, $1 + r^*$ and $1 + g^*$ are constant and are uniquely determined.

A4. Credit/GDP ratio

When the borrowing constraint binds, the Credit/GDP ratio on the balanced growth path can be written as

$$(A6-1) \quad \frac{B_t}{Y_t} = \frac{\theta R^c}{1 + r^*} \frac{K_{t+1}}{Y_t} + \frac{\theta^x R^x}{1 + r^*} \frac{P_t}{Y_t}.$$

Since $1 + r^* = \frac{1 + g^*}{1 + \mu}$ and $\frac{\theta^x R^x}{1 + r^*} = \theta^x(1 + \mu)$ on the balanced growth path, (A6-1) can be written as

$$(A6-2) \quad \frac{B_t}{Y_t} = \frac{\theta R^c(1 + \mu)}{A} + \theta^x \phi^*(1 + \mu).$$

We know from (17b) that ϕ^* is increasing functions of θ or θ^x or $1 + \mu$ for small ϵ . Hence, we obtain the following Proposition.

Proposition A1 For ϵ sufficiently small, the Credit/GDP ratio defined as $\frac{B_t}{Y_t}$ rises as θ or θ^x or $1 + \mu$ increases.

What drives our result is that faster expansion of the money supply lowers interest rates, effectively loosening the borrowing constraint.

This result, together with Proposition 2 and 3, has empirical implications. With those increases in the collateral values or a reduction in the interest rate caused by an increase in the money growth rate, Credit/GDP ratios rise but their impact on long-run productivity growth and economic growth can be markedly different depending on the source of the credit

expansion. If the ratios increase mainly with the relaxation in real estate financing (in capital investment financing), productivity and economic growth slow down (speed up) in the long run. Sectoral credit allocation plays a key role for productivity and economic growth.

A5. Dynamic stability

As noted in the main text, the dynamics of this economy can be characterized by (2), (9), (10), (12b), (14a) and (15b).

Using (7b), (12b) can be written as

$$(A5-1) \quad \phi_{t+1} = \left(\frac{\frac{\lambda_t}{1-\theta^x + \frac{\theta^x \lambda_t}{1+r_t}}}{\frac{1}{1-\frac{\theta R^c}{1+r_t}} \left[\eta(1-\alpha) - \left(\frac{1-\theta^x}{1-\theta^x + \frac{\theta^x \lambda_t}{1+r_t}} \right) \phi_t \right] A} \right) \phi_t - \epsilon a^\alpha = \psi(\phi_t, 1+r_t).$$

$$\text{where } \lambda_t \equiv \frac{R^c(1-\theta)}{1-\frac{\theta R^c}{1+r_t}}.$$

Using (9), (14a), and (15b), (2) can be written as

$$(A5-2) \quad 1+r_t = \frac{Q_{t+1}}{Q_t} = \frac{1}{1+\mu} \left[\frac{\left\{ (1-\alpha) - \frac{1}{1-\frac{\theta R^c}{1+r_{t+1}}} \left[\eta(1-\alpha) - \left(\frac{1-\theta^x}{1-\theta^x + \frac{\theta^x \lambda_{t+1}}{1+r_{t+1}}} \right) \phi_{t+1} \right] - \phi_{t+1} \right\}}{\left\{ (1-\alpha) - \frac{1}{1-\frac{\theta R^c}{1+r_t}} \left[\eta(1-\alpha) - \left(\frac{1-\theta^x}{1-\theta^x + \frac{\theta^x \lambda_t}{1+r_t}} \right) \phi_t \right] - \phi_t \right\}} \right] \left\{ \frac{1}{1-\frac{\theta R^c}{1+r_t}} \left[\eta(1-\alpha) - \left(\frac{1-\theta^x}{1-\theta^x + \frac{\theta^x \lambda_t}{1+r_t}} \right) \phi_t \right] A \right\},$$

giving r_{t+1} as a function of $\{r_t, \phi_t, \phi_{t+1}\}$. Using (A5-1), we have

$$(A5-3) \quad 1+r_{t+1} = \omega(\phi_t, 1+r_t).$$

Hence, the dynamics of the monetary economy can be characterized by (A5-1) and (A5-3), so it is reduced to the two-dimensional dynamical system, where both ϕ_t and $1+r_t$ are jump variables.

We know from the analysis in Appendix A3 that there exists a unique balanced growth path (steady state). Hence, there exists a rational expectation path along which the economy instantly achieves the balanced growth path.

A6. Proof of Proposition 7

By differentiating (18b) and (18c), we obtain

$$\lim_{\epsilon \rightarrow 0} \frac{d\phi^*}{d\epsilon} = \frac{\frac{R^c(1-\theta)A[1-\theta^x(1+\mu)]^2}{1-\theta^x} + A\theta^x(1+\mu)\eta(1-\alpha)}{[1-\theta^x(1+\mu)]\left\{\eta(1-\alpha)A - \frac{R^c(1-\theta)[1-\theta^x(1+\mu)]}{1-\theta^x}\right\}} > 0.$$

$$\lim_{\epsilon \rightarrow 0} \frac{d(1+g^*)}{d\epsilon} = -\frac{R^c(1-\theta)}{(1-\theta^x)\phi^*} < 0.$$

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Online Appendix

In the main text, we presented a bare-bones model integrating credit frictions and endogenous growth. For tractability, we have made a number of simplifying assumptions concerning preferences and technology. For instance, the real estate sector uses land only, agents have linear utility over consumption only when old, and workers cannot invest in real estate. In this on-line appendix, we show that the results can be generalized.

O1. Robustness: More general production functions for real estate sector

In this appendix, we extend the bare-bones model to the situation where both labor and land are inputs into real estate.

In the real estate sector, competitive firms produce the final consumption goods by using labor and land as factors for production. The aggregate production function is given by

$$(O1-1) \quad Y_t = D_t(N_t^X)^\rho(X)^{1-\rho},$$

where N_t^X is labor input in the real estate sector.

The wage rates in the real estate sector and the productive sector are, respectively, given by

$$(O1-2) \quad w_t^X = \rho D_t(N_t^X)^{\rho-1}(X)^{1-\rho},$$

$$(O1-3) \quad w_t^K = (1 - \alpha)A(N_t^K)^{-\alpha}K_t,$$

where N_t^K is labor input in the productive sector.

The labor market clearing condition is

$$(O1-4) \quad N_t^X + N_t^K = N = 1.$$

We first consider a case where labor mobility is possible between the two sectors. Then, in equilibrium, the wage rates must be equal, i.e., $w_t^X = w_t^K \equiv w_t$. Considering $D_t = \epsilon a K_t$ and $X = 1$, we have

$$(O1-5) \quad (1 - \alpha)A(N_t^K)^{-\alpha}K_t = \rho \epsilon a K_t (N_t^X)^{\rho-1},$$

which can be written as

$$(O1-6) \quad (1 - \alpha)A(1 - N_t^X)^{-\alpha} = \rho\epsilon a(N_t^X)^{\rho-1}.$$

The left-hand side is a convex function of N_t^X with a positive slope and a positive intercept $(1 - \alpha)A$ at $N_t^X = 0$ and goes to infinity as N_t^X goes to 1, while the right-hand side is also a convex function of N_t^X with a negative slope and goes to infinity as N_t^X goes to zero and becomes equal to $\rho\epsilon a$ at $N_t^X = 1$. Hence, N_t^X is uniquely determined and is constant, and so is N_t^K .

Hence, total incomes of entrepreneurs from the two sectors can be written as

$$(O1-7) \quad \eta w_t^X N^X + \eta w_t^K N^K = \eta w_t = \eta(1 - \alpha)A(N^K)^{-\alpha} K_t.$$

Next, we examine a case where labor mobility is not possible. In this case, total wage incomes can be written as

$$(O1-8) \quad \eta w_t^X N^X + \eta w_t^K N^K = \eta[\rho\epsilon a(N^X)^{\rho-1} + (1 - \alpha)A(N^K)^{-\alpha}]K_t.$$

In (O1-7) and (O1-8), total incomes of entrepreneurs are a linear function of aggregate capital stock K_t . Hence, the analysis in the main text will apply by replacing ηw_t in (11) with (O1-7) or (O1-8).

O2. Robustness: *Weakening the assumptions of limited participation in the credit market and credit frictions*

We need to distinguish between the return on a safe asset (a government bond. If there is uncertainty about the rate of inflation, bonds that are not inflation protected are still risky.) and a return on a risky investment. Both land and capital are risky, and not surprisingly, on average yield substantially higher returns than government bonds. This is what we would expect in equilibrium. Credit frictions inevitably follow, not only from asymmetries of information, but also from limited liability (or more generally, even in the absence of limited liability, the limited ability to recover funds.)

Think, for a moment, of workers as infinitely risk averse. Then they would only be willing to lend a limited amount either to an entrepreneur buying capital or buying land. There is a natural limit on leverage, even in the absence of policy. Those limits on leverage will, of course, mean that even with diminishing returns in production, the average return on capital

and on land will remain above the safe rate of interest. Similar results would hold in a model with highly risk averse workers.

The model we have formulated here captures in a simple way these credit frictions, though crucially, we have not explicitly modelled either asymmetries of information or risk aversion. But it explains clearly why, for instance, there can be an equilibrium with productive land having a finite price, even if r is very low. The non-entrepreneurial savers see (rightly) land holdings as risky, and so even if r were zero, they would only have a finite demand for it, and its price would be finite.

Similarly, if government were to issue an excessive number of bonds, capital accumulation would be limited, the return on capital would increase, and the private sector could issue an increasing number of safe bonds: there is thus a limit to the *equilibrium* issuance of bonds by government at low interest rates at an interest rate less than g . Thus, while it might *seem* that with low r , government debt *could* be unbounded, the interest rate is low only because government borrowing is limited.

Thus, what have been posed as critical conundrums in the literature are really a reflection of the oversimplifications employed in the models in which they arise and the attempt to interpret the real world's data through the lens of those models.

O3. Robustness: Analysis of a different borrowing constraint

For the robustness of our main results, we study the case with a different borrowing constraint.

$$(O3-1) \quad b_t^i \leq \theta k_{t+1}^i + \theta^x P_t x_t^i.$$

This collateral constraint is set as a fraction of this year's value of land.

With this borrowing constraint, (7a) changes to

$$(O3-2) \quad \underbrace{\frac{R_t^c - (1+r_t)\theta}{1-\theta}}_{\text{leveraged rate of return on capital investment}} = \underbrace{\frac{R_t^x - (1+r_t)\theta^x}{1-\theta^x}}_{\text{leveraged rate of return on land speculation}}.$$

Solving for R_t^x yields

$$(O3-3) \quad R_t^x = \left(\frac{R_t^c - (1+r_t)\theta}{1-\theta} \right) (1 - \theta^x) + (1 + r_t)\theta^x = \frac{R_t^c(1-\theta^x) + (1+r_t)(\theta^x - \theta)}{1-\theta}.$$

The capital-investment function of entrepreneurs (8) changes to

$$(O3-4) \quad k_{t+1}^i = \frac{1}{\underbrace{1-\theta}_{\text{leverage}}} \left[\underbrace{w_t}_{\text{saving}} - \underbrace{(1-\theta^x)P_t x_t^i}_{\text{total down-payment in buying land}} \right].$$

The dynamics equations of (11), (14a), (12b), and (15b) change to

$$(O3-5) \quad K_{t+1} = \frac{1}{1-\theta} [\eta w_t - (1 - \theta^x)P_t] = \frac{1}{1-\theta} [\eta(1 - \alpha)AK_t - (1 - \theta^x)P_t].$$

$$(O3-6) \quad 1 + g_t \equiv \frac{K_{t+1}}{K_t} = \frac{1}{1-\theta} [\eta(1 - \alpha) - (1 - \theta^x)\phi_t]A.$$

$$(O3-7) \quad \phi_{t+1} = \phi_t R_t^x / \left\{ \frac{1}{1-\theta} [\eta(1 - \alpha) - (1 - \theta^x)\phi_t]A \right\} - \epsilon a^\alpha.$$

$$(O3-8) \quad Q_t M_t = \left\{ (1 - \alpha) - \frac{1}{1-\theta} [\eta(1 - \alpha) - (1 - \theta^x)\phi_t] - \phi_t \right\} AK_t,$$

The dynamics of this economy, entailing $\{P_t, K_t, Q_t, M_t, r_t, T_t\}$ can be characterized by (2), (9), (10), (O3-6), (O3-7), and (O3-8).

First, we proceed with our analysis by focusing on steady states.

Steady states: unproductive land, i.e., $\epsilon = 0$

When $\epsilon = 0$, we obtain

$$(O3-9) \quad 1 + r^* = \frac{R^c(1-\theta^x)}{1-\theta^x + \mu(1-\theta)}.$$

$$(O3-10) \quad \phi^* = \frac{\eta(1-\alpha)}{1-\theta^x} - \frac{R^c(1-\theta^x)(1+\mu)}{A[1-\theta^x + \mu(1-\theta)]}.$$

$$(O3-11) \quad 1 + g^* = \frac{R^c(1-\theta^x)(1+\mu)}{1-\theta^x + \mu(1-\theta)}.$$

General case

In steady state, the real value of money grows according to

$$(16) \quad 1 + r^* = \frac{Q_{t+1}}{Q_t} = \frac{1+g^*}{1+\mu}.$$

(16), (O3-6), and (O3-7) give three equations in three unknowns, r^* , g^* , and ϕ^* . By rearranging them, we can derive the quadratic equation for ϕ^* .

$$(O3-12) \quad \frac{A(1-\theta^x)H}{1-\theta}(\phi^*)^2 + \left[-\frac{A\eta s(1-\alpha)H}{1-\theta} + R^c(1-\theta^x)(1+\mu) + (1-\theta^x)(1+\mu)\epsilon a^\alpha \right] \phi^* - A\eta(1-\alpha)(1+\mu)\epsilon a^\alpha = 0,$$

where $H = 1 - \theta^x + \mu(1 - \theta)$. Since the left-hand side of (O3-9) is a convex function of ϕ^* , with the negative intercept, there exists a unique value of $\phi^* > 0$, while the other solution is negative (when $\epsilon = 0$, the other solution is $\phi^* = 0$). Solving for the positive $\phi^* > 0$ yields

$$(O3-13) \quad \phi^* = \frac{-Y + \sqrt{Y^2 + 4\frac{A(1-\theta^x)H}{1-\theta}A\eta(1-\alpha)(1+\mu)\epsilon a^\alpha}}{2\frac{A(1-\theta^x)H}{1-\theta}},$$

$$\text{where } Y = -\frac{A\eta(1-\alpha)H}{1-\theta} + R^c(1-\theta^x)(1+\mu) + (1-\theta^x)(1+\mu)\epsilon a^\alpha.$$

By substituting (O3-13) into (O3-6), we obtain the steady-state growth rate of aggregate capital.

$$(O3-14) \quad 1 + g^* = \frac{A}{1-\theta} \left[\eta(1-\alpha) - (1-\theta^x) \frac{-Y + \sqrt{Y^2 + 4\frac{A(1-\theta^x)H}{1-\theta}A\eta(1-\alpha)(1+\mu)\epsilon a^\alpha}}{2\frac{A(1-\theta^x)H}{1-\theta}} \right].$$

The steady-state interest rate is given by

$$(O3-15) \quad 1 + r^* = \frac{A}{(1+\mu)(1-\theta)} \left[\eta(1-\alpha) - (1-\theta^x) \frac{-Y + \sqrt{Y^2 + 4\frac{A(1-\theta^x)H}{1-\theta}A\eta(1-\alpha)(1+\mu)\epsilon a^\alpha}}{2\frac{A(1-\theta^x)H}{1-\theta}} \right].$$

For ϕ^* to be positive, even when $\epsilon = 0$, we make the following assumption.

Assumption 3. $\frac{\eta(1-\alpha)A}{1-\theta^x} > \frac{R^c(1-\theta)(1+\mu)}{1-\theta^x + \mu(1-\theta)}.$

Also, for Q_t to be positive, we impose conditions on the parameter values so that the following inequality condition must be satisfied.

Assumption 4. $A(1 - \alpha) - \frac{A}{1-\theta} [\eta(1 - \alpha) - (1 - \theta^x)\phi^*] - \phi^* = A(1 - \alpha) - (1 + g^*) - A\phi^* > 0$, where $1 + g^*$ and ϕ^* are given by (O3-14) and (O3-15).

For instance, when $\epsilon \rightarrow 0$, Assumption 4 can be written as

Assumption 4'. $A(1 - \alpha) > \frac{\eta(1-\alpha)A}{1-\theta^x}$.

Combining Assumptions 3 and 4' leads to

$$A(1 - \alpha) > \frac{\eta(1-\alpha)A}{1-\theta^x} > \frac{R^c(1-\theta)(1+\mu)}{1-\theta^x+\mu(1-\theta)}.$$

Then, $A(1 - \alpha) > \frac{R^c(1-\theta)(1+\mu)}{1-\theta^x+\mu(1-\theta)}$ can be written as

$$(1 - \alpha)[1 - \theta^x + \mu(1 - \theta)] > \left(\alpha + \frac{1-\delta}{A}\right)(1 - \theta)(1 + \mu),$$

which is likely to be satisfied as δ and/or A are large enough, and α is small enough.

Therefore, by choosing η appropriately, we can verify that there are relevant parameters for which Assumptions 3 and 4' are simultaneously satisfied.

Then, we obtain the following Proposition.

Proposition A2 Existence of balanced growth path

Under Assumption 3 and 4, for $\epsilon \geq 0$, there exists a unique balanced growth path where the relative size of land speculation $\phi^* > 0$, economic growth rate $1 + g^*$, the interest rate $1 + r^*$, which equals the rate of return on fiat money $\frac{Q_{t+1}}{Q_t}$, are constant over time. ϕ^* , $1 + g^*$, and $1 + r^*$ are given by (O3-13), (O3-14), and (O3-15), respectively.

Comparative statics

(O3-13), (O3-14), and (O3-15) allow us to conduct comparative statics assessing the effects of changes in the market/policy parameters, with results and intuitions analogous to the ones in the main text. We can obtain the following results concerning comparative statics and dynamic stability.

Proposition A3 Impact of changes in the collateral values or in monetary policy

Under Assumption 3 and 4, for $\epsilon \geq 0$, we have

$$(A3-i) \frac{d(1+g^*)}{d\theta^x} < 0, \text{ with } \frac{d\phi^*}{d\theta^x} > 0 \text{ and } \frac{d(1+r^*)}{d\theta^x} < 0.$$

$$(A3-ii) \text{sign} \frac{d(1+g^*)}{d\mu} = \text{sign}(\theta - \theta^x), \text{ with } \text{sign} \frac{d\phi^*}{d\mu} = \text{sign}(\theta^x - \theta) \text{ and } \frac{d(1+r^*)}{d\mu} < 0.$$

$$(A3-iii) \frac{d(1+g^*)}{d\theta} > 0, \text{ with } \frac{d\phi^*}{d\theta} > 0 \text{ and } \frac{d(1+r^*)}{d\theta} > 0.$$

Proof:

Since direct calculations using (O3-13), (O3-14), and (O3-15) are complicated, we will take another route for comparative statics. Since $1 + g^*$ is determined according to (O3-6), we will examine how $(1 - \theta^x)\phi^*$ is affected by changes in $\{\mu, \theta^x, \theta\}$.

(O3-12) is equivalent to

$$\Omega((1 - \theta^x)\phi^*) \equiv \frac{AH}{(1-\theta)(1-\theta^x)(1+\mu)} ((1 - \theta^x)\phi^*)^2 + \left[-\frac{A\eta s(1-\alpha)H}{(1-\theta)(1-\theta^x)(1+\mu)} + R^c + \epsilon a^\alpha \right] (1 - \theta^x)\phi^* - A\eta(1 - \alpha)\epsilon a^\alpha = 0.$$

Since Ω is a convex function of $(1 - \theta^x)\phi^*$, with the negative intercept, there exists a unique value of $(1 - \theta^x)\phi^* > 0$, while the other solution is negative, i.e., $\phi^* < 0$. In addition, for any value of $(1 - \theta^x)\phi^* < A\eta(1 - \alpha)$ (otherwise $1 + g^*$ would be negative in (O3-6), the following results are obtained.

First, concerning (A3-i), we have

$$\frac{d\Omega}{d\theta^x} = \frac{AH\mu(1-\theta)}{(1-\theta)(1+\mu)(1-\theta^x)^2} ((1 - \theta^x)\phi^* - A\eta(1 - \alpha))(1 - \theta^x)\phi^* < 0.$$

This means $\frac{d(1-\theta^x)\phi^*}{d\theta^x} > 0$ (implies $\frac{d\phi^*}{d\theta^x} > 0$). Therefore, $\frac{d(1+g^*)}{d\theta^x} < 0$.

Second, concerning (A3-ii), we have

$$\frac{d\Omega}{d\mu} = \frac{AH(\theta^x - \theta)}{(1-\theta)(1-\theta^x)(1+\mu)^2} ((1 - \theta^x)\phi^* - A\eta(1 - \alpha))(1 - \theta^x)\phi^*.$$

This means $\text{sgn} \frac{d(1-\theta^x)\phi^*}{d\mu} = \text{sgn}(\theta^x - \theta)$. Therefore, $\text{sign} \frac{d(1+g^*)}{d\mu} = \text{sign}(\theta - \theta^x)$.

For $\frac{d(1+r^*)}{d\mu} < 0$, in the steady-state equilibrium, we know

$$1 + r^* = \frac{1+g^*}{1+\mu} = \frac{R^c(1-\theta^x)\phi^*}{[(1+\mu)(1-\theta) - (\theta^x - \theta)]\phi^* + (1+\mu)(1-\theta)\epsilon a\alpha}.$$

When $\theta^x < \theta$, $\frac{d\phi^*}{d\mu} < 0$. Therefore, the right hand side of the above equation decreases as μ increases. On the other hand, when $\theta^x > \theta$, $\frac{d(1+g^*)}{d\mu} < 0$. Therefore, it is obvious that the interest rate decreases.

Finally, concerning (A3-iii), we have

$$\frac{d\Omega}{d\theta} = \frac{AH(1-\theta^x)}{(1+\mu)(1-\theta^x)(1-\theta)^2} ((1-\theta^x)\phi^* - A\eta(1-\alpha))(1-\theta^x)\phi^* < 0.$$

This means $\frac{d(1-\theta^x)\phi^*}{d\theta} > 0$, i.e., $\frac{d\phi^*}{d\theta} > 0$.

Also,

$$1 + g^* = \frac{R^c(1-\theta^x)(1+\mu)\phi^*}{[(1+\mu)(1-\theta) - (\theta^x - \theta)]\phi^* + (1+\mu)(1-\theta)\epsilon a\alpha}.$$

Since we know that $\frac{d\phi^*}{d\theta} > 0$, the right-hand side of the above equation is an increasing function of θ . Therefore, $\frac{d(1+g^*)}{d\theta} > 0$.

Dynamic stability

We can analyse dynamic stability. The following Proposition summarizes it.

Proposition A4 Uniqueness of Rational Expectations Trajectory

There exists a unique rational expectations path along which the economy achieves the balanced growth path immediately without transitional dynamics. The economy immediately converges to that path, through the setting of the initial price of land, $P_0 = AK_0\phi^*$.

Proof

Using (O3-3), (O3-7) can be written as

$$\phi_{t+1} = \left(\frac{\frac{R^C(1-\theta^x) + (1+r_t)(\theta^x - \theta)}{1-\theta}}{\frac{1}{1-\theta}[\eta(1-\alpha) - (1-\theta^x)\phi_t]A} \right) \phi_t - \epsilon a^\alpha = \psi(\phi_t, 1+r_t).$$

Using (O3-6) and (O3-8), (16) can be written as

$$1 + r_t = \frac{Q_{t+1}}{Q_t} = \frac{1}{1+\mu} \left[\frac{\left\{ (1-\alpha) + (1-\eta)e(a)^\alpha - \frac{1}{1-\theta}[\eta(1-\alpha) - (1-\theta^x)\phi_{t+1}] - \phi_{t+1} \right\}}{\left\{ (1-\alpha) + (1-\eta)e(a)^\alpha - \frac{1}{1-\theta}[\eta(1-\alpha) - (1-\theta^x)\phi_t] - \phi_t \right\}} \right] \left\{ \frac{1}{1-\theta}[\eta(1-\alpha) - (1-\theta^x)\phi_t]A \right\} = \omega(\phi_t, \phi_{t+1}),$$

giving $1 + r_t$ as a function of $\{\phi_t, \phi_{t+1}\}$.

Hence, by substituting the relation $1 + r_t = \omega(\phi_t, \phi_{t+1})$ into $\phi_{t+1} = \psi(\phi_t, 1 + r_t)$, the dynamical system is reduced to the one-dimensional dynamical system for ϕ_t . From Proposition A2, we know that for $\epsilon > 0$, there exists a unique steady-state value of $\phi^* > 0$ (the other steady-state value is negative), and $\phi_{t+1} = -\epsilon a^\alpha < 0$ when $\phi_t = 0$, and ϕ_t is a jump variable. Therefore, the only possible rational expectations trajectory is one that immediately achieves the steady state without transitional dynamics.