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SUNSPOTS AND CREDIT FRICTIONS

Sharon G. Harrison
Barnard College, Columbia University

Mark Weder
University of Adelaide

We examine a general equilibrium model with collateral constraints and increasing returns to scale in production. The utility function is nonseparable, with no income effect on the consumer's choice of leisure. Unlike this model without a collateral constraint, we find that indeterminacy of equilibria is possible. Hence, business cycles can be driven by self-fulfilling expectations. This is the case for more realistic parameterizations than in previous, similar models without these features.

Keywords: Business Cycles, Credit Markets, Collateral Constraint, Sunspots

1. INTRODUCTION

Starting with Benhabib and Farmer (1994) and Farmer and Guo (1994), a large literature now exists in which a standard real-business-cycle model is modified to include sufficiently high increasing returns to scale, resulting in indeterminate equilibria driven by sunspot shocks.[1] Jaimovich (2008) and Meng and Yip (2008) (hereafter MYJ) add nonseparable preferences as in Greenwood et al. (1988) to the one-sector model with increasing returns to scale. With no income effects on leisure, they find that indeterminacy is ruled out, no matter the size of returns to scale. Here, we overturn MYJ's results by adding a collateral constraint, as in Kiyotaki and Moore (1997).[2] The addition of a collateral constrained borrowing limit allows the existence of indeterminacy and hence endogenous, expectations-driven business cycles. In addition, this indeterminacy results with empirically plausible returns to scale.

In our model, land is the only asset, and credit takes on the following form. Firms must pay for some of their inputs before production takes place, and so they must borrow within the period. This assumption appears to be relevant for the workings of typical firms. For example, evidence in Devereux and Schiantarelli (1989) suggests that firms fund a significant part of their current expenses with external funds. In our model, we restrict this funding to credit from the banking

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sector. The credit constraint stands in for a lack of contract enforcement, which limits the amount of credit firms can obtain with their collateral. If firms fail to repay debt, the creditors will seize the collateralized land and sell it.

In most previous one-sector models, whether or not indeterminacy results can be understood as follows. Upon optimistic expectations about the future, agents act upon (subjectively) higher wealth. Hence, labor supply shifts inward. In the Benhabib–Farmer–Guo setup, with increasing returns high enough to make the reduced-form labor demand upward-sloping, employment rises and the expectation is self-fulfilled. In MYJ's setup, there is no wealth effect on leisure, and so such expectations cannot be self-fulfilling.

In contrast, in our model, with a collateral constraint, indeterminacy can result with no income effect. If people become optimistic about the prospects of the economy, their demand for assets, in particular land, rises. As it is in fixed supply, the price of land surges, relaxing the credit constraint. The amount of borrowing goes up proportionately with the price of the collateralizable land. This starts positive feedback: firms are able to expand production as labor demand shifts out. Real economic activity increases, and the optimistic expectation is self-fulfilled.

We examine two versions of the model. In both, indeterminacy is possible. In the first, output is produced with labor, land, and capital. In addition, the utilization rate of capital is allowed to vary. As in Wen (1998), including capital utilization simply serves to lower the threshold level of returns to scale necessary for indeterminacy by increasing the elasticity of output with respect to labor. To further lower this threshold, the second version adds intermediate inputs into the production function, so that firms produce gross output. This increases this elasticity even more.

Indeterminacy in the second version of our model is empirically plausible in two important ways.[3] First, the threshold value of returns to scale is within the range estimated by many authors [for example, Harrison (2003)]. Second, this is the case for much lower labor supply elasticities than are typically assumed in previous work, where infinite labor supply elasticity is often used [for example, Farmer and Guo (1994) and Wen (1998)]. In sum, the lack of an income effect, the binding collateral constraint, and the inclusion of intermediate inputs in the production function all make sunspot equilibria easier to obtain.

The rest of this paper proceeds as follows. In Section 2 we outline the basic model, without intermediate inputs. Section 3 describes the steady state and calibration. In Section 4, we quantify the regions in which indeterminacy exists. Section 5 adds intermediate inputs to the model. Section 6 discusses the intuition for our results. Section 7 summarizes and suggests potential applications.

2. THE ARTIFICIAL ECONOMY

Our economy is based on Kiyotaki and Moore's (1997) model of credit frictions.[4] There is no fundamental uncertainty. The economy is populated by a continuum of (measure one) agents who have identical preferences. Each agent has access

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to a production technology. Let c_t be consumption and h_t the agents' own labor supply. Then lifetime utility is given by

$$\sum_{t=0}^{\infty} \beta^t u(c_t, h_t)$$

with period utility

$$u(c_t, h_t) = \frac{1}{1-\sigma}\left(c_t - \frac{\phi}{1+\varepsilon} h_t^{1+\varepsilon}\right)^{1-\sigma},$$

which corresponds to Greenwood et al.'s (1988) quasi-convex utility. The preferences have the property that the supply of labor is immune to income effects. β denotes the discount factor. The disutility of working is measured by ϕ, $1/\varepsilon$ corresponds to the intertemporal elasticity of substitution in labor supply, and $1/\sigma$ measures the elasticity of substitution of consumption. We restrict $0 < \beta < 1$, $\gamma > 0$, $\varepsilon > 0$, and $\sigma > 0$.

The period budget constraint is

$$w_t h_t + y_t + q_t(a_{t-1} - a_t) \geq w_t n_t + c_t + k_{t+1} - (1-\delta_t)k_t,$$

with income on the left-hand side and spending on the right-hand side. Here, w_t is the real wage, and k_t stands for the stock of capital. We assume that agents do not work for themselves, and so each hires labor services n_t. In equilibrium, $h_t = n_t$. The agents enter the period with land holdings a_{t-1}, whereas a_t denotes land holdings during production in period t. Each agent sells labor, land, and capital services and hires these services in the respective markets. Land is traded at the beginning of the period at price q_t, and is in fixed supply, which we normalize to one. Land is of the utmost importance in our model. It is required to be able to undertake production, which is the source of its demand.

As in most studies with variable capital utilization, u_t, the rate of depreciation, δ_t, is an increasing function of the utilization rate:

$$\delta_t = \frac{1}{\theta} u_t^{\theta}, \quad \theta > 1.$$

Finally, y_t is output, and its production is described by

$$y_t = a_t^{\nu}(u_t k_t)^{\alpha} n_t^{1-\alpha-\nu} Y_t^{\frac{\gamma}{1+\gamma}}.$$

Note that the producers face constant returns to scale at the private level. Y_t stands for aggregate output; and the externality in production is of size γ. All markets are perfectly competitive.

Each period, the price of land is determined in trade. Next, wages have to paid. Because the other transactions and production have not yet taken place, agents are forced to borrow working capital in advance in the form of (intratemporal)

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loans from financial intermediaries. To prevent default, the availability of credit is restricted by the endogenous borrowing constraint

$$\psi q_t a_t \geq w_t n_t, \quad 0 \leq \psi \leq 1.$$

As in Kiyotaki and Moore (1997), this constraint stands in for limited contract enforcement. Borrowers must put up valuable collateral against debt. The only asset accepted by creditors is land. If borrowers fail to repay their debt, the creditors will seize the land and sell it. Hence, an agent's loans cannot exceed the fraction ψ of the market value of the collateral. Repayment of the debt is assumed to occur within the current period, so that there is a unit opportunity cost to funds. If ψ is large, the collateral constraint will not bind and the model reduces to the standard model. Here, we assume that this constraint is binding at all times (by choice of parameterization and its effect on ψ).

The program can be compactly written as

$$\max_{\{c_t,h_t,u_t,k_{t+1},n_t,a_t\}} \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\sigma}\left(c_t - \frac{\phi}{1+\varepsilon}h_t^{1+\varepsilon}\right)^{1-\sigma}$$
$$+\lambda_t\Big[w_t h_t + a_t^{\nu} u_t^{\alpha} k_t^{\alpha} n_t^{1-\alpha-\nu} Y_t^{\frac{\gamma}{1+\gamma}} + q_t(a_{t-1}-a_t)$$
$$- w_t n_t - c_t - k_{t+1} + (1-\delta_t)k_t\Big] + \mu_t\left[\psi q_t a_t - w_t n_t\right].$$

In equilibrium, $n_t = h_t$, and the optimality conditions imply that

$$\left(c_t - \frac{\phi}{1+\varepsilon}h_t^{1+\varepsilon}\right)^{-\sigma} = \lambda_t, \tag{1}$$

$$\left(c_t - \frac{\phi}{1+\varepsilon}h_t^{1+\varepsilon}\right)^{-\sigma} \phi h_t^{\varepsilon} = \lambda_t w_t, \tag{2}$$

$$(1-\alpha-\nu)\frac{y_t}{h_t} - \frac{\lambda_t+\mu_t}{\lambda_t}w_t = 0, \tag{3}$$

$$\beta\lambda_{t+1}q_{t+1} + \lambda_t \nu \frac{y_t}{a_t} + \psi\mu_t q_t - q_t\lambda_t = 0, \tag{4}$$

$$\beta\lambda_{t+1}\left(\alpha\frac{y_{t+1}}{k_{t+1}} + 1 - \delta_{t+1}\right) - \lambda_t = 0, \tag{5}$$

$$\psi q_t a_t - w_t h_t = 0, \tag{6}$$

$$\alpha\frac{y_t}{u_t} = u_t^{\theta-1}k_t, \tag{7}$$

and

$$y_t = a_t^{\nu(1+\gamma)} u_t^{\alpha(1+\gamma)} k_t^{\alpha(1+\gamma)} h_t^{(1-\alpha-\nu)(1+\gamma)}. \tag{8}$$

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Equations (1) and (2) describe the consumption leisure trade-off. Equation (3) denotes the demand for labor; this condition is distorted by the borrowing constraint. In the absence of credit frictions, $\mu_t = 0$, and the standard condition equating the marginal product and wage results. Equation (4) describes the intertemporal demand for land. Equation (5) is the usual intertemporal Euler equation and (6) repeats the borrowing constraint. Equation (7) equates the marginal product and marginal cost of raising the utilization rate. Equation (8) is the production technology in symmetric equilibrium. Finally, we have the aggregate resource constraint

$$y_t - c_t - k_{t+1} + (1-\delta)k_t = 0 \tag{9}$$

as well as the equilibrium condition

$$a_t = 1. \tag{10}$$

3. THE STEADY STATE AND CALIBRATION

Let us now turn to the unique stationary state of this economy. Because it is not standard, we describe it in some detail. First, we discuss our calibrations of $\frac{\mu}{\lambda}$, $\frac{k}{y}$, $\frac{wh}{y}$, β, σ, and δ. Once these are set, the steady state can be computed. The intertemporal Euler equation for capital,

$$1 - \beta\left(\alpha\frac{y}{k} + 1 - \delta\right) = 0,$$

determines α. Next (3),

$$(1-\alpha-\nu)\frac{y}{wh} = 1 + \frac{\mu}{\lambda},$$

yields a value for ν. The consumption share, c/y, is determined by (9),

$$\delta = \frac{y}{k}\left(1 - \frac{c}{y}\right).$$

The intertemporal Euler equation for capital and the collateral constraint become

$$\frac{\nu}{1 - \beta - \frac{\mu}{\lambda}\psi} = \frac{aq}{y}$$

and

$$\psi\frac{qa}{y} - \frac{wh}{y} = 0.$$

These form a system of two equations in two unknowns that can be solved for $\frac{aq}{y}$ and ψ. Last,

$$\theta = \frac{1 - \beta(1-\delta)}{\beta\delta}.$$

We calibrate our economy to averages of the U.S. economy, as summarized in Table 1. The fundamental period is a quarter. In our *benchmark calibration*, we

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TABLE 1. Benchmark parameter and calibrated steady state values

Parameter	Value
σ	1
β	$1.03^{-1/4}$
δ	0.02
k/y	9
$1/\varepsilon$	2.2
μ/λ	0.255
α	0.247
θ	1.37
ν	0.0002
aq/y	23.82
wh/y	0.60
ψ	0.029

assume $\sigma = 1$, $\beta = 1.03^{-1/4}$, and $\delta = 0.02$. The capital-to-GDP ratio is set to 9, which corresponds to Maddison's (1991) annual value for the U.S. ratio of gross nonresidential capital stock to GDP. Empirical measures of the intertemporal elasticity of labor supply, $1/\varepsilon$, are largely varied. Kimball and Shapiro (2008) suggest that the Frisch elasticity of labor supply is about one. Gourinchas and Parker (2002) present estimates that range from 0.7 to 2.2. We set $1/\varepsilon = 2.2$. Hence, labor supply is significantly less elastic than is typical of models with indeterminacy (i.e., infinity), and is also less elastic than is normally assumed in real business cycle models [e.g., King et al. (1988) use an elasticity of 4].[5]

Last, we set $\mu/\lambda = 0.255$, to ensure that the credit constraint is binding. In doing this, we choose the smallest possible value of μ/λ given the rest of our calibration. One way to interpret μ/λ is as an endogenous theory of the labor wedge. We can rewrite our first order condition for labor, (3), as

$$\frac{\lambda}{\lambda+\mu}(1-\alpha-\nu)\frac{y}{h} = w$$

and consider the Chari et al. (2003) interpretation of the wedge as a tax. That is, in

$$(1-\tau)\text{MPL} = w,$$

we have $\frac{\lambda}{\lambda+\mu} = 1-\tau$, and hence a wedge of about 20%.[6]

We then log-linearize the model, reducing it to

$$\begin{bmatrix} \widehat{k}_{t+1} \\ \widehat{y}_{t+1} \\ \widehat{c}_{t+1} \end{bmatrix} = \mathbf{M} \begin{bmatrix} \widehat{k}_t \\ \widehat{y}_t \\ \widehat{c}_t \end{bmatrix}.$$

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Capital is the only predetermined variable; hence, indeterminacy requires that at least two eigenvalues of the matrix **M** are smaller than unity. We look for indeterminacy in the next section.

4. INDETERMINACY

Our main result is that indeterminacy is possible. This stands in sharp contrast to MYJ, in which indeterminacy is ruled out in the one-sector model with no income effect and no collateral constraint.

Result 1. In sharp contrast to MYJ, indeterminate equilibria result in our model with sufficiently high returns to scale.

Result 2. In our benchmark calibration, with an elasticity of substitution of consumption of $\sigma = 1$ and $1/\varepsilon = 2.2$, indeterminacy arises at returns to scale of 1.915 and higher.

Clearly, increasing returns of 1.915 are not plausible. Most studies of returns to scale suggest much smaller values. For example, Burnside et al. (1995, Table 2) adjust for utilization, as in the present model. They report a point estimate of 0.98 with a standard error of 0.34, which puts 1.915 outside of a reasonable confidence interval.

Lowering σ and/or ε, however, does reduce the threshold of scale economies, as seen in Figure 1. Here we illustrate the thresholds for indeterminacy for both $\sigma = 1$ and $\sigma = 0.5$. Attanasio and Weber (1989), Mulligan (2002), and Gruber (2006) provide support for the latter value. Still, the model requires labor supply elasticities well above 10 ($\sigma = 1$) or 3 ($\sigma = 0.5$) for plausible returns to scale. Therefore, we seek to find more empirically plausible parameterizations. Hence, in the next subsection, we examine the requirements for indeterminacy when we move away from this basic model.

5. ADDING INTERMEDIATE INPUTS

In this section, we modify the production function to account for intermediate inputs usage, by allowing final goods to be used as intermediate inputs also. We denote by m_t intermediate goods input. Therefore, technology is now described by

$$y_t = m_t^{\eta} a_t^{(1-\eta)\nu} u_t^{\alpha(1-\eta)} k_t^{\alpha(1-\eta)} n_t^{(1-\alpha-\nu)(1-\eta)} Y_t^{\frac{\gamma}{1+\gamma}}.$$

Furthermore, we assume that the endogenous borrowing constraint becomes

$$\psi q_t a_t \geq w_t n_t + m_t, \quad 0 \leq \psi \leq 1$$

and the budget constraint is now

$$w_t h_t + y_t + q_t(a_{t-1} - a_t) - m_t \geq w_t n_t + c_t + k_{t+1} - (1 - \delta_t)k_t,$$

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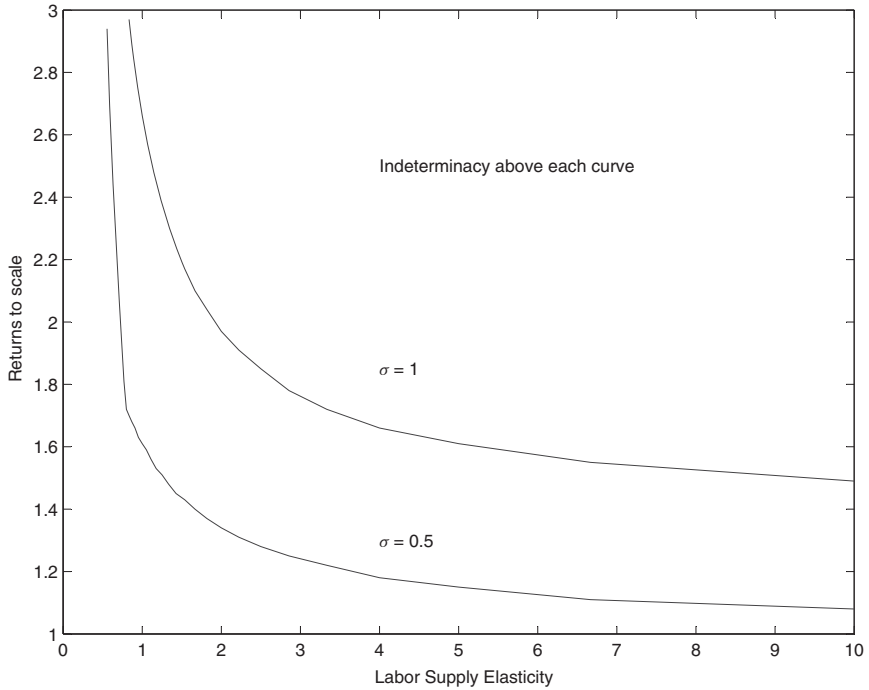


FIGURE 1. Indeterminacy with varying labor supply elasticities.

which implies that to be able begin production, agents have to obtain working capital for both the wage bill and intermediate inputs [see also Kobayashi et al. (in press)]. Essentially all first-order conditions carry through. In addition, we have

$$\eta \frac{y_t}{m_t} - \frac{\lambda_t + \mu_t}{\lambda_t} = 0,$$

which determines the demand for intermediate inputs. We adjust our *benchmark calibration* as in Table 2. Jaimovich (2007) suggests an intermediate inputs share of gross output of around 50% and a labor plus intermediate inputs share of around 85%. In this vein, we fix the share of intermediate inputs in the model to be 50% of gross output and target the wage share at 35%. We set $\mu/\lambda = 0.03$ to ensure that, given the calibration, the credit constraint binds. Thus, $\eta = 0.515$, $\nu = 0.0023$, and $\psi = 0.2351$.[7]

Figure 2 plots the indeterminacy regions for the extended model. Result 3 summarizes the results for our benchmark parameterization and for $\sigma = 0.5$.

Result 3. In our benchmark calibration of the credit model with intermediate input usage, with $\sigma = 1$ ($\sigma = 0.5$), indeterminacy arises at returns to scale of 1.205 (1.155) and higher.

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TABLE 2. Benchmark parameter and calibrated steady state values, with intermediate inputs

Parameter	Value
μ/λ	0.03
α	0.254
ν	0.0023
aq/y	3.616
wh/y	0.35
m/y	0.5
ψ	0.2351
η	0.515

The addition of intermediate inputs has lowered the threshold value of returns to scale necessary for indeterminacy. This is because, as Jaimovich (2007) discusses, with output defined as gross output, each firm's production is now dependent on that of other firms, through its use of intermediate inputs. There is hence an additional externality for each firm that is not present when output is calculated as

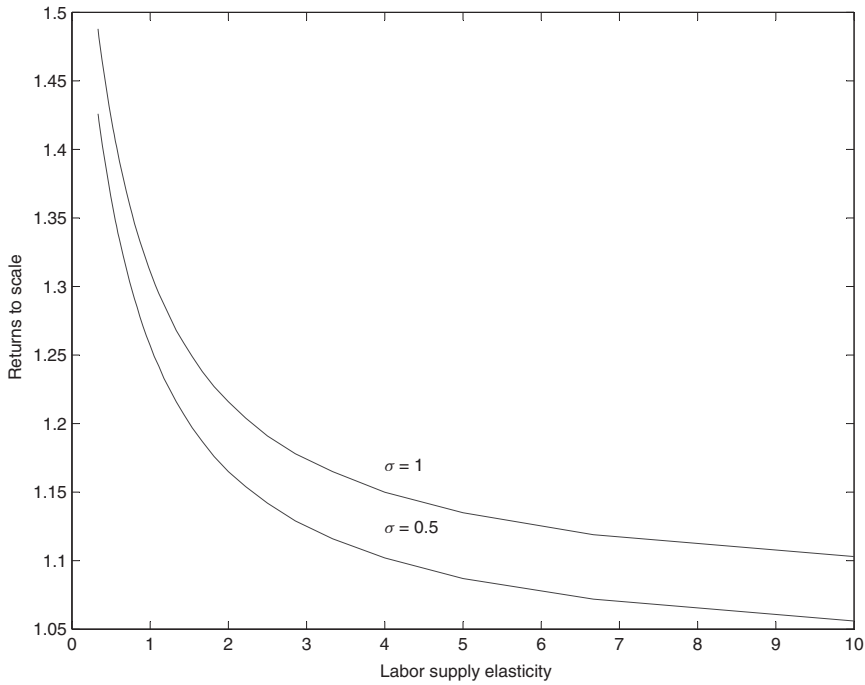


FIGURE 2. Indeterminacy with varying labor supply elasticities, with intermediate inputs.

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value added. Therefore, the minimum returns to scale needed for indeterminacy are lower than without intermediate inputs, and are lower the higher the share of intermediate output in production. This intuition is similar to that for the introduction of capacity utilization in Wen (1998).[8]

In the empirical literature, the estimate of returns to scale most relevant is that of Harrison (2003, Table 7), who estimates production functions for gross output and corrects for utilization. She estimates internal returns (standard error) to be 0.98 (0.01) and the externality to be 0.165 (0.035). Returns to scale of 1.205 are well within two standard deviations of Harrison's (2003) estimate. In addition, recall that we have $\varepsilon = 1/2.2$, whereas in all existing work that we know of, infinitely elastic labor supply is used to achieve indeterminacy with plausible returns to scale.

Infinitely elastic labor supplies are hard to defend from a microeconometric perspective [see for example Gourinchas and Parker (2002); however, Rogerson and Wallenius (2009) discuss reasons that microeconomic and macroeconomic estimates of labor-supply elasticities can differ]. Moreover, Lubik (2007) estimates a sunspot model [a version of Wen (1998)] using U.S. data. His estimates do suggest degrees of return to scale used in the theoretical literature, but these are too small for sunspot equilibria to arise, given his estimated labor supply elasticity: he finds that labor supply slopes up. That is, he rejects the indivisible labor argument of a completely elastic supply schedule in Benhabib–Farmer–Guo–Wen frameworks. In the present model, indeterminacy can arise with realistic labor supply elasticities.

For more perspective on this, and for a better comparison with Wen (1998) and Benhabib and Farmer (1996), Figure 3 looks also at very high labor supply elasticities in the present model, from 10 to 1,000. For $\sigma = 1$ (0.5), with $\varepsilon = 1/100$, minimum returns to scale are 1.072 (1.028), and when $\varepsilon = 1/1{,}000$, they are 1.069 (1.025). These values are quite close to constant returns. Comparing our results with very high labor supply elasticity to previous work, our model obtains indeterminacy at considerably lower returns to scale. Wen (1998), for example, needs returns to scale of about 1.11 to obtain indeterminacy.

6. INTUITION

Overall, our results demonstrate that indeterminacy appears at reasonable levels of both returns to scale and labor supply elasticities. But what drives our results? In particular, how can indeterminacy occur here when it is ruled out in Jaimovich? In the Benhabib–Farmer–Wen models, sunspots work as follows. Under optimistic expectations about the future, agents act upon (subjectively) higher wealth. Hence, labor supply shifts inward. With increasing returns high enough to make the reduced-form labor demand upward-sloping, employment rises and the expansionary sunspot cycle starts.

In MYJ's setup, there is no income effect on leisure, and so such expectations cannot be self-fulfilling. However, in our model, with a collateral constraint,

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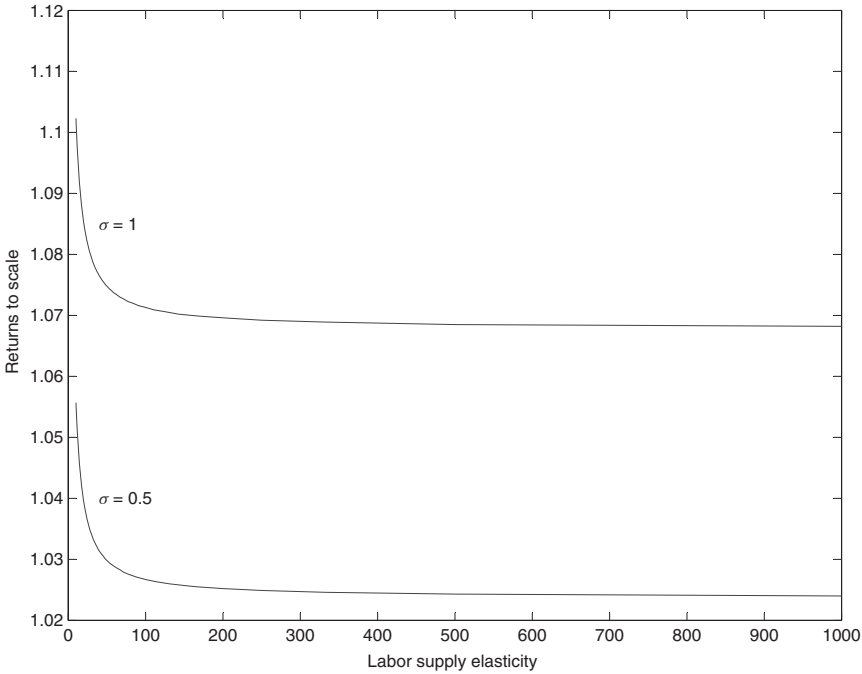


FIGURE 3. Indeterminacy with large labor supply elasticities, with intermediate inputs.

income effects are not necessary for indeterminacy to arise. Indeterminacy arises as a consequence of a relaxed credit constraint induced by optimistic expectations that drive up land prices. In particular, if people become optimistic about the prospects of the economy—for whatever extrinsic reason—their demand for assets, in particular, land, rises. As it is in fixed supply, the price of land rises, relaxing the credit constraint. Firms are able to expand production as distortions shrink: even though technology is unaffected, the labor demand shifts out. Real economic activity increases, and the optimistic expectation is self-fulfilled.

The behavior of aggregate variables under indeterminacy can be seen in Figure 4, which plots the impulse responses of the benchmark model with intermediate input usage to a one-time pessimistic shock to expectations. Increasing returns are set at 1.22, which is just above the minimum requirement for indeterminacy. GDP, hours, investment, and the price of land all fall on impact (i.e., are procyclical), and all variables are very persistent. The drop in consumption is smaller than that in output, reflecting a lower relative volatility of consumption, consistent with the data.[9] Hours also fall, and their deviation from steady state appears to be more persistent than for the other variables. The sunspot shock affects the financing possibilities of firms, and therefore their ability to hire new

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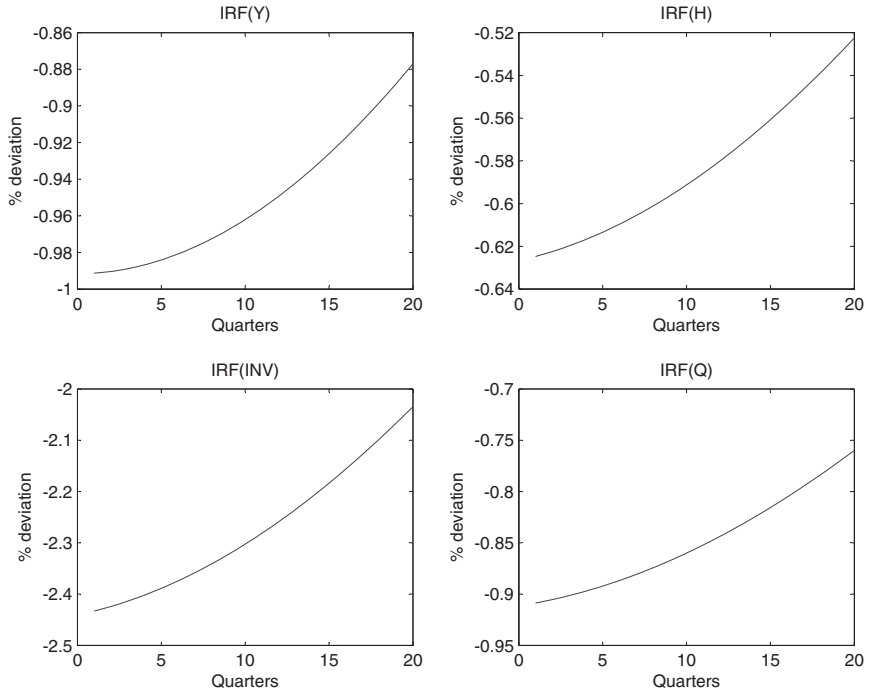


FIGURE 4. Impulse response functions.

labor. Because the borrowing limit depends on asset values, the sharp fall in land prices reduces available credit.

It should be noted that inclusion of a income effect will actually counter this mechanism. That is, a leftward shift of labor supply would diminish the expansionary nature of the sunspot shock. It may, in fact, prevent the expectation from being realized. For example, consider a version of King et al. (1988) separable preferences:

$$u(c_t, h_t) = \ln c_t - \frac{\phi}{1+\varepsilon} h_t^{1+\varepsilon}.$$

In this case, the minimum increasing returns required for indeterminacy in the benchmark parameterization with intermediate inputs increases to 1.4374 ($\sigma = 1$). Here the marginal rate of substitution between consumption and leisure is not independent of consumption. Thus, income effects are present in the labor supply decision. An optimistic sunspot, which can be interpreted as a positive wealth shock, causes a rise in leisure and a decline in labor. With returns to scale below the threshold, this actually leads to a decrease in output, thus generating a recession. Put another way, this version of the model requires much larger externalities to overturn the decline in labor supply.

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7. CONCLUSION AND FUTURE WORK

We have examined a general equilibrium model with collateral constraints and increasing returns to scale in production. With nonseparable utility, no income effect on the consumer's choice of leisure, and intermediate inputs in the production function, indeterminacy of equilibria arises for more realistic parameterization than in previous similar models without these features.

In terms of applications, we have in mind an explanation of the recent financial crisis, as well as other episodes in the economic history of the United States. In particular, the current crisis has renewed interest among macroeconomists in models with credit frictions. In particular, we are interested in the role that speculative asset market bubbles play in this context.[10] Of course, the idea that economies are inherently subject to bouts of speculation that lead to alternating booms and crises is not new,[11] but the application of a model with indeterminacy of equilibria to such an episode will add to our understanding of them.

The model certainly has applications to historical episodes as well. Harrison and Weder (2006) apply a model with indeterminacy, but without a collateral constraint, to the 1930s, finding evidence that sustained pessimism turned what might have been a recession into the Great Depression. The introduction of a collateral constraint into this framework is likely to prove productive. In addition, Harrison and Weder (2009) examine the Roaring Twenties as a time of technological progress. Evidence of optimism during that decade bodes well for our model. Although the Great Depression can be viewed as a time of pessimism in which collateral constraints were binding, their relaxation during the 1920s may provide a sound explanation for the roaring nature of that decade. In addition, it may also be more realistic to allow for intertemporal borrowing.[12] We plan to pursue these ideas in future work.

NOTES

1. See Benhabib and Farmer (1999) for an excellent survey.

2. See also Kocherlakota (2000, 2009).

3. Cordoba and Ripoll (2004) obtain indeterminacy in a version of Kiyotaki and Moore (1997). However, they focus on parametrizations with determinacy.

4. Some of its simplications follow Kobayashi and Nutahara (2007).

5. GHH preferences do not nest indivisible preferences; hence $\varepsilon = 0$ cannot be interpreted as Hansen–Rogerson. Jaimovich (2008) states that the Frisch labor supply elasticity is given by $(1 - \varepsilon h)/\varepsilon h$.

6. The value of ψ in this calibration is 0.0288. In addition, to make the model and implied calibrations comparable, we normalize the parameter ν so that it approaches zero (in the benchmark case $\nu = 0.00024$). This is motivated by observing that for a positive ν, the fixed amount of land introduces de facto decreasing returns at the private (and social) level.

7. In 2000, Total Loans and Leases at Commercial Banks were 3,488 billion current U.S. dollars (source: Federal Reserve's FRED). The sum of aggregate market vales of residential land, values of homes, and replacement cost of residential structures amounted to 27,500 billion (source Lincoln Institute of Land Policy). Hence, our value of ψ does not seem unreasonable. In addition, alowing it to increase leads to implausible values of other parameters in our model.

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8. This intuition is the key to the lowering the threshold returns to scale. Our results are quantitatively robust to excluding intermediate inputs from the collateral constraint.
9. Investment is more volatile than output.
10. See, for example, Kocherlakota (2000, 2009).
11. See for example, Minsky (1978) and Kindleberger (2000). See also Akerlof and Shiller (2009), along with Farmer's (2009) critical review.
12. Thanks to Keiichiro Kobayashi for suggesting this to us.

REFERENCES

Akerlof, George and Robert Shiller (2009) *Animal Spirits: How Human Psychology Drives the Economy, and Why It Matters for Global Capitalism*. Princeton, NJ: Princeton University Press.

Attanasio, Orazio and Guglielmo Weber (1989) Intertemporal substitution, risk aversion and the euler equation for consumption. *Economic Journal* 99 Supplement, 59–73.

Benhabib, Jess and Roger Farmer (1994) Indeterminacy and increasing returns. *Journal of Economic Theory* 63, 19–46.

Benhabib, Jess and Roger Farmer (1996) Indeterminacies and sector specific externalities. *Journal of Monetary Economics* 37, 421–444.

Benhabib, Jess and Roger Farmer (1999) Indeterminacy and sunspots in macroeconomics. In John B. Taylor and Michael Woodford (eds.), *Handbook of Macroeconomics*, vol. 1A, pp. 387–448. Amsterdam: North-Holland.

Burnside, Craig, Martin Eichenbaum, and Sergio Rebelo (1995) Capital utilization and returns to scale. *NBER Macro Annual*, 67–110.

Chari, V. V., Patrick Kehoe, and Ellen McGrattan (2003) Accounting for the Great Depression. *Federal Reserve Bank of Minneaplis Quarterly Review* 27, 2–8.

Cordoba, Juan and Marla Ripoll (2004) Credit cycles redux. *International Economic Review* 45, 1011–1046.

Devereux, Michael and Fabio Schiantarelli (1989) Investment, Financial Factors and Cash Flow: Evidence from UK Panel Data. NBER Working Paper 3116.

Farmer, Roger (2009) *Animal Spirits: How Human Psychology Drives the Economy and Why It Matters for Global Capitalism*, by George Akerlof and Robert Shiller: A Review. *The Economic Record* 85, 357–369.

Farmer, Roger and Jang-Ting Guo (1994) Real business cycles and the animal spirits hypothesis. *Journal of Economic Theory* 63, 42–72.

Gourinchas, Pierre-Olivier and Jonathan A. Parker (2002) Consumption over the life cycle. *Econometrica* 70, 47–89.

Greenwood, Jeremy, Zvi Hercowitz, and Gregory Huffman (1988) Investment, capacity utilization, and the real business cycle. *American Economic Review* 78, 402–417.

Gruber, Jonathan (2006) A Tax-Based Estimate of the Elasticity of Intertemporal Substitution. NBER Working Paper 11945.

Harrison, Sharon (2003) Returns to scale and externalities in the consumption and investment sectors. *Review of Economic Dynamics* 6**,** 963–976.

Harrison, Sharon and Mark Weder (2006) Did sunspot forces cause the Great Depression? *Journal of Monetary Economics* 53, 1327–1339.

Harrison, Sharon and Mark Weder (2009) Technological change and the roaring twenties: A neoclassical perspective. *Journal of Macroeconomics* 31, 363–375.

Jaimovich, Nir (2007) Firm dynamics and markup variations: Implications for multiple equilibria and endogenous economic fluctuations. *Journal of Economic Theory* 137, 300–325.

Jaimovich, Nir (2008) Income effects and indeterminacy in a calibrated one-sector growth model. *Journal of Economic Theory* 143, 610–623.

Kimball, Miles and Matthew Shapiro (2008) Labor Supply: Are the Income and Substitution Effects Both Large or Both Small?. NBER Working Paper 14208.

https://doi.org/10.1017/S1365100511000836 Published online by Cambridge University Press

Kindleberger, Charles P. (2000) *Manias, Panics, and Crashes: A History of Financial Crises*. New York: Wiley.

King, Robert, Charles Plosser, and Sergio Rebelo (1988) Production, growth and business cycles: I. The basic neoclassical model. *Journal of Monetary Economics* 21, 195–232.

Kiyotaki, Nobuhiro and John Moore (1997) Credit cycles. *Journal of Political Economy* 105, 211–248.

Kobayashi, Keiichiro, Tomoyuki Nakajima, and Masaru Inaba (in press) Collateral constraint and news-driven cycles. *Macroeconomic Dynamics*.

Kobayashi, Keiichiro and Kengo Nutahara (2007) Collateralized capital and news-driven cycles. *Economics Bulletin* 5, 1–9.

Kocherlakota, Narayana (2000) Creating business cycles through credit constraints. *Federal Reserve Bank of Minneapolis Quarterly Review* 24, 2–10.

Kocherlakota, Narayana (2009) Bursting Bubbles: Consequences and Cures. Working Paper, Minnesota Fed.

Lubik, Thomas (2007) The Empirics of Indeterminacy. Working Paper, Federal Reserve Bank of Richmond.

Maddison, Angus (1991) *Dynamic Forces in Capitalist Development: A Long-Run Comparative View*. Oxford, UK: Oxford University Press.

Meng, Qinglai and Chong Yip (2008) On indeterminacy in one-sector models of the business cycle with factor-generated externalities. *Journal of Macroeconomics* 30, 97–110.

Minsky, Hyman P. (1978) The Financial Instability Hypothesis: A Restatement. Paper 180, Hyman P. Minsky Archive.

Mulligan, Casey (2002) Capital, Interest, and Aggregate Intertemporal Substitution. NBER Working Paper 9373.

Rogerson, Richard and Johanna Wallenius (2009) Micro and macro elasticities in a life cycle model with taxes. *Journal of Economic Theory* 144, 2277–2292.

Wen, Yi (1998) Capacity utilization under increasing returns to scale. *Journal of Economic Theory* 81, 7–36.

https://doi.org/10.1017/S1365100511000836 Published online by Cambridge University Press