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Real Business Cycles and the Animal Spirits Hypothesis in a Cash-in-Advance Economy

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Abstract

This paper examines the dynamical properties of a one-sector cash-in-advance constraint model with constant returns to scale. Its aim is to overcome some of the difficulties encountered by earlier models in establishing the empirical relevance of indeterminacy and sunspots as means to understand the business cycle. It is shown that, in opposition to available results, indeterminacy occurs for values of the intertemporal elasticity of substitution in consumption consistent with the bulk of empirical estimates. It is also shown that sunspot shocks do not necessarily generate countercyclical movements in consumption. In addition, considering simultaneously beliefs and technological disturbances, it turns out that the model performs as well as real sunspot models with increasing returns to scale in matching the business cycle.

Keywords: Money, Indeterminacy, Sunspots, Business Cycle.

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1 Introduction

The present contribution studies the dynamical properties of a competitive one-sector real business cycle model with money introduced by imposing a cash-in-advance constraint. Our aim is to examine the empirical plausibility of indeterminacy and to assess the relevance of sunspots for business cycle considerations.

Recent research in macroeconomics, following the contributions of Benhabib and Farmer (1994) and Farmer and Guo (1994), has focused on models in which business cycles are driven by self-fulfilling changes in agents' beliefs.¹ In such models, indeterminacy and sunspot equilibria arise as a consequence of some market imperfections. In most studies, these market imperfections come from increasing returns to scale, often triggered by positive external effects in production. While early results relied on empirically unrealistic scale economies, more recent researches have demonstrated that the magnitude of increasing returns needed to induce indeterminacy is consistent with the empirical estimates provided, for instance, by Basu and Fernald (1997).²

Even though it is fair to say that these models offer a plausible theory in which economic fluctuations are the consequence of animal spirits, they nonetheless suffer from two weaknesses.

Most studies assume that the households' utility function is logarithmic in consumption, which is equivalent to setting the intertemporal elasticity of substitution (IES) in consumption equal to one. Noticeable exceptions are Bennett and Farmer (2000) and Harrison (2001) who consider non-separable preferences and a more generalized CRRA utility function, respectively. Allowing these flexibilities, they find a negative relation between the degree of increasing return needed for indeterminacy and the IES. Consequently, setting the IES significantly greater than one, they are able to generate indeterminacy with empirically plausible scale economies. Yet, this requisite is at odds with the empirical evidence which suggests that the IES is much lower than unity, many estimates being indeed below 0.5 (see, *e.g.*, Kocherlakota (1996) and Campbell (1999)).³

The second weakness of these models is their inability to match various moments of key macroeconomics variables. In particular, for reasonable values of the externality parameters, they generate a time series for consumption that is countercyclical, which is not consistent with the data. This point has been documented by many authors, including Benhabib and Farmer (1996), Harrison (2001) and Schmitt-Grohé (2001). This counterfactual result relies on the fact that when consumption and

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

²Examples include, on a first strand, Wen (1998) who builds on a real business cycle model with variable capacity utilization, Schmitt-Grohé (2001) who considers countercyclical mark-ups and, on a second strand, Benhabib and Farmer (1996), Harrison and Weder (2000a), Harrison and Weder (2000b), Harrison (2001) who adopt two-sector settings with either aggregate or sector-specific externalities.

³Notice that models in which the utility function is logarithmic in consumption, actually almost all sunspots models, are subject to the same criticism.

leisure are normal goods, the household's intratemporal first-order condition, which equates the marginal rate of substitution between consumption and leisure with the real wage, forces consumption and hours worked, hence output, to move in opposite directions.

The previous considerations cast some doubts on the empirical relevance of indeterminacy and expectations-driven business cycle. Yet, productive externalities are not the only market imperfections allowing the occurrence of indeterminacy and sunspots. For instance, the use of money as a medium of exchange is a well known source of multiplicity. Recently, Farmer (1997) builds on this idea by developing a business cycle model that includes real money balances as an argument of the utility function. Clearly, Farmer sought to produce a realistic calibrated model with multiple equilibria and *constant* returns to scale. However, it turns out that for standard parameter values, Farmer's model does not produce indeterminacy. As a matter of fact, implausible returns to scale remain necessary (see Sossounov (2000)).

We know that a money-in-the-utility function specification, as Farmer's one, must represent a reduced form indirect utility function for some underlying environment where agents get utility from goods and leisure and face some exchange constraints involving money. In this paper, we focus on *monetary* imperfections captured by a cash-in-advance (CIA) constraint on consumption. More precisely, we study the basic (no externalities) monetary Real Business Cycle model of Cooley and Hansen (1989) with constant returns to scale extended to account for non-logarithmic utility in consumption. It then follows that the description of equilibrium dynamics requires *three* state variables. To overcome the analytical difficulties raised by the dimension of the equilibrium system, we introduce a criterion particularly suitable for assessing indeterminacy. We establish that this constant returns to scale model exhibits indeterminacy for values of the IES in accordance with the bulk of empirical estimates, that is below 0.5. Then, we evaluate the ability of the model to fit the data. Numerical simulations indicate that fluctuations solely driven by sunspot disturbances are not necessarily accompanied by countercyclical movements in consumption. The intuition for this result is the following. Provided that the CIA constraint binds in equilibrium, the marginal rate of substitution between consumption and leisure is not equal to the real wage. Consequently, a spontaneous increase in consumption does not necessarily requires a fall in hours worked.⁴ However, to generate realistic fluctuations in other respects, it reveals that some source of fundamental uncertainty must be introduced. Allowing belief and productivity shocks, we show that this "simple" one-sector model with constant returns to scale perform as well as more "complex" real (one or two-sector) models with increasing returns to scale.

⁴Barinci and Chéron (2001) build on a related idea and demonstrate that a model with heterogeneous households and borrowing constraint outperform standard sunspots models in explaining business cycle facts, notably procyclical consumption.

The remainder of this note is organized as follows. Section 2 presents the model. Section 3 deals with the local dynamics. Section 4 discusses the cyclical properties. Section 5 provides some concluding remarks.

2 The Model

Environment

The economy consists of households, firms and a monetary authority.

The representative household chooses sequences of consumption $\{c_t\}$, hours worked $\{l_t\}$, capital stock $\{k_{t+1}\}$ and cash balances $\{m_{t+1}\}$ to solve

$$\begin{aligned} \max_{\{c_t, l_t, k_{t+1}, m_{t+1}\}} \quad & E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{c^{1-\sigma}}{1-\sigma} - A \frac{l^{1+\chi}}{1+\chi} \right\} \\ \text{s.t.} \quad & c_t + k_{t+1} + \frac{m_{t+1}}{p_t} = w_t l_t + (r_t + 1 - \delta)k_t + \frac{m_t}{p_t} \end{aligned} \quad (1)$$

$$c_t \leq \frac{m_t}{p_t} \quad (2)$$

for E the rational expectation operator, $A > 0$, $\sigma > 0$, $\chi > 0$, $\beta \in (0, 1)$ the discount factor, $\delta \in (0, 1)$ the depreciation rate of capital, p_t the price level, r_t the real return on capital and w_t the real wage. (1) is the usual intertemporal budget constraint; (2) is the cash-in-advance constraint (hereafter CIA). Let λ_t and μ_t denote the Lagrange multipliers associated with the budget constraint (1) and the CIA constraint (2), respectively. The first-order conditions for the household are:

$$c_t^{-\sigma} = \lambda_t + \mu_t \quad (3)$$

$$A l_t^{\chi} = \lambda_t w_t \quad (4)$$

$$\lambda_t = \beta E_t [\lambda_{t+1} (r_{t+1} + 1 - \delta)] \quad (5)$$

$$\lambda_t = \beta E_t \left[(\lambda_{t+1} + \mu_{t+1}) \frac{p_t}{p_{t+1}} \right] \quad (6)$$

$$\mu_t \left(\frac{m_t}{p_t} - c_t \right) = 0, \quad \mu_t \geq 0 \quad (7)$$

along with the budget constraint (1) and the transversality conditions omitted for simplicity.

On the production side, the technology of the representative firm is described by the Cobb-Douglas production function:

$$z K^{\alpha} L^{1-\alpha}, \quad \alpha \in (0, 1)$$

for L and K the aggregate labor and capital factors, respectively; z is the state of technology which evolves as:

$$\log z_t = \rho_z \log z_{t-1} + (1 - \rho_z) \log z^* + \sigma_z \zeta_t \quad (8)$$

where $0 \leq \rho_z < 1$, $\sigma_z \geq 0$ and ζ_t is a zero-mean i.i.d. random variable with unit variance. Markets being perfectly competitive, profit maximization implies that factors are paid according to their marginal productivities:

$$r_t = z_t \alpha K_t^{\alpha-1} L_t^{1-\alpha} \quad (9)$$

$$w_t = z_t (1 - \alpha) K_t^\alpha L_t^{-\alpha} \quad (10)$$

Lastly, as we do not study the effects of the monetary policy shocks, we assume that the monetary authority plays a fairly limited role: it supplies a constant quantity of money $M_t = M$, $\forall t \geq 0$.

Equilibrium

Let the CIA constraint holds with equality⁵ and consider the market clearing conditions: $K_t = k_t$, $L_t = l_t$, $m_t = M$, $\forall t \geq 0$.⁶ It is straightforward to see that an equilibrium is a sequence $\{(c_t, k_t, l_t) \in R_{++}^3\}$ which satisfies:

$$\frac{l_t^{\chi+\alpha}}{z_t k_t^\alpha} = \beta E_t \left[\left(z_{t+1} \alpha k_{t+1}^{\alpha-1} l_{t+1}^{1-\alpha} + 1 - \delta \right) \frac{l_{t+1}^{\chi+\alpha}}{z_{t+1} k_{t+1}^\alpha} \right] \quad (11)$$

$$\frac{A l_t^{\chi+\alpha}}{z_t (1 - \alpha) k_t^\alpha} = \beta E_t \left[\frac{c_{t+1}^{1-\sigma}}{c_t} \right] \quad (12)$$

$$k_{t+1} = z_t k_t^\alpha l_t^{1-\alpha} + (1 - \delta) k_t - c_t \quad (13)$$

along with the transversality conditions.

It should be emphasized that if one assumes that the household's utility is logarithmic in consumption, *i.e.*, $\sigma = 1$, the dimension of the equilibrium system (11)-(13) would actually be lowered. In fact, in such circumstances (12) would boil down to a static relation defining, for instance, c_t as a function of l_t and k_t .⁷

3 Local dynamics

In this section we carry out the analysis of the local (deterministic) dynamics of the equilibrium system (11)-(13) around its stationary solution (c^*, l^*, k^*, z^*) . According

⁵It is not difficult to see that this will be the case at a steady state. Indeed, if a steady state exists, it satisfies $r - \delta > 0$ (see equation (5)). Thus, at a steady state, the gross return on capital, $r + 1 - \delta$, is greater than the gross return on money which is equal to 1 (no inflation) as the quantity of money is constant. Thus, along a stationary equilibrium, the household is not willing to carry cash from one period to the next. Otherwise stated, the CIA constraint is binding. A continuity argument ensures that the CIA is binding in a "small" neighborhood of a steady state.

⁶Walras' law ensures equilibrium on the good market.

⁷In addition, it is not difficult to see that the equilibrium is bound to be determinate.

to the usual procedure we study the first order Taylor expansion of the equilibrium system (11)-(13) evaluated at the steady state. Letting J denotes the Jacobian matrix of the linearized system and T , Σ and D be the trace, the sum of the principal minors of order two and the determinant of the J , respectively, we obtain:

$$Q(\psi) = -\psi^3 + T\psi^2 - \Sigma\psi + D$$

$$\begin{aligned} T &= 1 + \beta^{-1} + \frac{1}{1-\sigma} + \frac{\nu}{\chi + \eta} \\ \Sigma &= \beta^{-1} + \frac{1}{1-\sigma} + \frac{1}{\beta(1-\sigma)} + \nu \frac{1+\chi}{(\chi + \eta)(1-\sigma)} \\ D &= \frac{1}{\beta(1-\sigma)} \end{aligned}$$

for $\rho \equiv \beta^{-1} - 1 + \delta$, $\eta \equiv \beta\rho(1-\alpha) + \alpha$ and $\nu \equiv (\frac{\rho}{\alpha} - \delta)\beta\rho(1-\alpha) > 0$.

Since one variable is predetermined and the others are free, indeterminacy occurs when J has at least two roots located inside the unit circle.

Case 1: $\sigma < 1$. As $Q(1) = -\nu \frac{\sigma+\chi}{(\chi+\eta)(1-\sigma)} < 0$ and $Q(0) > 0$, by continuity $\psi_1 \in (0, 1)$. Now, noticing that $\psi_1\psi_2\psi_3 = D > 1$, $\psi_1 \in (0, 1)$ implies $|\psi_2||\psi_3| > 1$. It follows that at least one root is located outside the unit circle, and this notably precludes the appearance of two complex eigenvalues with norm lesser than one. In addition, whenever the eigenvalues are real, it implies along with $Q(-1) > 0$ and $T = \psi_1 + \psi_2 + \psi_3 > 0$ that $\psi_i > 1$, $i = 2, 3$. One finally concludes that if $\sigma < 1$ the equilibrium is bound to be locally unique.

Case 2: $\sigma > 1$. In this alternative case, one deduces from $Q(1) > 0$ and $Q(0) < 0$ that $\psi_1 \in (0, 1)$, $\psi_2 > 1$ and $\psi_3 < 0$. It follows that indeterminacy requires $\psi_3 \in (-1, 0)$, that is $Q(-1) > 0$. This will be the case if:

$$\sigma > 2 + \frac{\nu\chi}{2(1 + \beta^{-1})(\chi + \eta) + \nu} \equiv 2 + \Delta \quad (14)$$

As Δ is positive, indeterminacy emerges for values of the IES lesser than 0.5. In opposition to available results (see the discussion in the introductory section), one sees that the values of the IES that place the economy within the indeterminacy region are in accordance with the recent empirical estimates (see, *e.g.*, Campbell (1999)). It is worthy to note that such low values are nowadays fairly standard in the RBC literature (see, *e.g.*, King and Rebelo (1999) who set $\sigma = 3$). How the “critical” IES depends on the shape of the utility function? Setting $\chi = 0$, *i.e.*, assuming an infinite labor supply elasticity, the “critical” IES is equal to 0.5. On the other hand, letting χ increases without bound, *i.e.*, lowering the labor supply elasticity, Δ converges to $\nu/2(1 + 1/\beta)$. For example, setting $\beta = 0.93$, $\delta = 0.1$, $\alpha = 0.3$, the “critical” IES converges to 0.4999.

We conclude that indeterminacy appears more likely empirically plausible is the current model than in real models which require “high” IES and elasticity of the labor supply in order to generate indeterminacy with realistic increasing returns.

4 Business cycle properties

This section addresses the question of whether the predictions of the model are consistent with the data.

It is well-known that some time series properties of real sunspot models are not consistent with the business cycles data. For example, for plausible degrees of increasing returns, they generate time series for consumption that are countercyclical (see, *e.g.*, Benhabib and Farmer (1996) and Schmitt-Grohé (2001)). In fact, in a walrasian model, the marginal rate of substitution between consumption and leisure equates the real wage. As a consequence, beliefs shocks that shift the labor-supply schedule along the (downward-sloping) labor-demand schedule, tend to force consumption and hours worked to move in opposite directions.⁸

In the current model, as long as the CIA constraint is binding, the marginal rate of substitution between consumption and leisure does not equate the real wage. Thus, a spontaneous increase in consumption (optimistic beliefs) does not necessarily translates into a fall in hours worked. Indeed, the increase in consumption reflects a decrease in the weight of the CIA constraint in the household’ objective, *i.e.*, a decrease of the Lagrange multiplier associated with this CIA constraint ($\searrow \mu_t$). Hence, it is possible that the decrease in the marginal utility in consumption would be sustained by an increase in the weight of the budget constraint, *i.e.*, a rise of the multiplier associated with the budget constraint ($\nearrow \lambda_t$). In such a case, the value of the real wage is improved, and this entails higher hours worked (see equations (3) and (4)).

In order to evaluate the ability of the model to replicate the business cycle we follow the RBC approach. Model parameters reported in table 1 are calibrated in a fairly standard way.

Table 1: PARAMETERS

β	δ	α	σ	χ
0.99	0.025	0.3	3	0

⁸This explains the counterfactual behavior of consumption observed in the Benhabib and Farmer’s (1996) model. In Schmitt-Grohé (2001), the assumption of a countercyclical markup could allow for a procyclical consumption since animal spirits affect the labor-demand. Nevertheless, for plausible parameter values, the consumption remains “slightly” negatively correlated with the output.

The average value for hours worked being set to $l^* = 0.2$, equations (11) and (13) give long-run values for the capital stock and the consumption. Even though it is not currently necessary, as an infinite value for the labor supply elasticity is usually assumed in the literature, we set $\chi = 0$.⁹ Thus, indeterminacy results when $\sigma > 2$ (see (14)). Following King and Rebelo (1999), we fix $\sigma = 3$ (IES = 1/3). As a benchmark, we examine how the model responds to sunspot shocks. Table 2 shows that our “endogenous business cycle” (EBC) CIA model produces a procyclical consumption.¹⁰ Nonetheless, it suffers from two stringent weaknesses: the investment is countercyclical and the volatilities of consumption and investment relatively to that of output are hugely overestimated. These counterfactual results come from the fact that even though a sunspot shock induces a simultaneous increase in consumption and hours worked, the rise of hours is so low that it generates a quite small increase in output. Consequently, a strong increase in consumption is sustained by a strong decrease in investment: investment is countercyclical, and relative volatilities are overestimated. This actually suggests that technological disturbances (supply shocks) must be added in order for the model to be consistent with the data. Technological parameters are set to $\rho_z = 0.95$ and $\sigma_z = 0.007$ (see Prescott [1986]). In addition, since we now consider two sources of uncertainty, the covariance matrix between technology and belief shocks has to be calibrated. Let $\rho_{e\zeta} \in [-1, 1]$ denotes the correlation between beliefs and technological shocks. Table 2 compares several possible moments when the correlation parameter takes three values: $\rho_{e\zeta} \in \{-1, 0, 1\}$. In each cases, we calibrate σ_z/σ_e so that the model replicates the relative standard deviation of consumption to that of output, for σ_e the standard deviation of the belief shock. It is seen in Table 2 that our CIA model generate realistic aggregate fluctuations provided that the correlation between beliefs and technological disturbances is positive which is equivalent of saying that sunspots are overreactions to news about fundamentals. For comparison purposes, we report the dynamical properties of the Benhabib and Farmer’s (1996) model generated with $\rho_{e\zeta} = 1$ are also reported. One then can see that *our monetary model with constant returns to scale performs as well as a more “intricate” two-sector real model with increasing returns.*

5 Concluding remarks

This paper has examined a cash-in-advance one-sector model in which indeterminacy occurs for *constant* returns to scale and values of the intertemporal elasticity of substitution in consumption consistent with the bulk of empirical estimates. Indeterminacy appears then more likely empirically plausible in this model than in real

⁹An infinite labor supply elasticity can be justified by the indivisible labor and employment lottery assumptions (see Hansen (1985)).

¹⁰Empirical properties for the US are taken from Cooley and Prescott (1995). All series (empirical and simulated) are logged and detrended using the Hodrick-Prescott filter.

(one and two-sector) models. However, the model was not found to endogenously produce a procyclical consumption in a satisfactory way. This supports the wisdom that animal spirits (demand shocks) cannot be invoked solely to explain the business cycle. Whenever sunspots and technological disturbances (supply shocks) are simultaneously allowed, the model performs equally as well as existing real sunspot models with increasing returns.

Table 2: COMOVEMENTS

	US (data)	BF	CIA ($\sigma_z > 0$)		CIA (EBC)
			$\rho_{e\zeta} = 1$	$\rho_{e\zeta} = 0$	$\rho_{e\zeta} = 0$
			$\frac{\sigma_z}{\sigma_{e\zeta}} = 1$	$\frac{\sigma_z}{\sigma_{e\zeta}} = 0.9$	$\frac{\sigma_z}{\sigma_{e\zeta}} = 1.1$
			$\frac{\sigma_z}{\sigma_{e\zeta}} = 0.7$	$\frac{\sigma_z}{\sigma_{e\zeta}} = 0.9$	$\frac{\sigma_z}{\sigma_{e\zeta}} = 1.1$
Consumption c					
(1)	0.74	0.74	0.74	0.74	0.74
(2)	0.83	0.51	0.52	0.22	0
Investment i					
(1)	4.79	3.45	4.05	4.96	5.51
(2)	0.91	0.83	0.81	0.84	0.86
Hours Worked l					
(1)	0.94	0.89	0.55	0.51	0.48
(2)	0.74	0.70	0.88	0.88	0.88

(1): $\sigma(x)/\sigma(y)$, (2): $cor(x, y)$, y : real per capita output.

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