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A Note on Growth Cycles

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A Note on Growth Cycles[¤]

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Abstract

A constraint of cash-in-advance is introduced in a simple model of endogenous growth with public spending. Under lower intertemporal substitution there is room for transition dynamics and indeterminacy. Deterministic and possibly endogenous growth cycles arise.

Keywords: cash-in-advance, endogenous growth, indeterminacy.

JEL classification: D90; E32; E50.

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0.1 Introduction

Business cycle theories focus on the emergence and persistence of short run ‡uctuations. In our paper we investigate the necessary conditions for the occurrence of long run ‡uctuations, i.e. growth cycles. More precisely we are interested in the indeterminacy of endogenous growth within a monetary economy.

The seminal model of endogenous growth with public spending we adapt, is Barro (1990), where the public spending enters the production function as a positive externality. This wedge between private and social returns which are assumed to be respectively decreasing and constant, reconciles the pro…t maximization with a long run endogenous growth.

The need of money is rationalized by a simple cash-in-advance constraint according to Clower's intuition[1] (1967) and Stockman's formalization (1981).

In general economic ‡uctuations are said to be exogenous, if they are generated by shocks on the fundamentals. The Real Business Cycle literature studies these propagation mechanisms. In contrast the occurrence of endogenous ‡uctuations is due by de…nition to shocks on the beliefs. Slight departures from the Real Business Cycle models are consistent with the idea that economic ‡uctuations may be driven not only by productivity disturbances, but also the self-ful…lling beliefs of the agents.

The equilibrium indeterminacy is a kind of equilibrium multiplicity, the necessary condition for the existence of endogenous ‡uctuations. Our paper precisely focuses on the indeterminacy of the equilibrium growth rate.

The incomplete markets' theory suggests some equivalence of market perfection (or completeness), equilibrium determinacy and Pareto-optimality. Even if a priori there is no indisputable de…nition of imperfection, the failure of the …rst welfare theorem could require by de…nition the existence of imperfections. In this sense incompleteness, externalities, market power and …nancial constraints[2] can be viewed as imperfections. However an imperfection does not entail automatically indeterminacy. Literature shows examples of dynamically ine¢cient but determinate equilibria (Cass, 1972). Conversely indeterminacy, as equilibrium multiplicity, implies sub-optimality and thereby requires some imperfection.

The literature on indeterminacy of the endogenous growth equilibrium is

[1] As Clower (1967) observed: "Money buys money, goods buy money, but goods do not buy goods".

[2] For a relevant example of …nancial imperfection see among others Woodford (1986).

a narrow subset of literature on indeterminacy. A short survey is provided in Benhabib and Rustichini (1994) where externalities and monopoly power are pointed out as causes of indeterminacy. Economic theory lacks predictive power in presence of indeterminacy.

Our paper explores a new channel for growth rate indeterminacy due to a monetary imperfection, the cash-in-advance. Equilibrium multiplicity is removed if the consumer's elasticity of intertemporal substitution is high enough. Roughly speaking, the intertemporal substitution frees the consumer from the constraint.

The rest of the article is organized as follows. In the …rst section a representative consumer faces a budget constraint and a cash-in-advance and maximizes an utility function. In the second part the endogenous growth dynamics are characterized. In the third section a lower intertemporal substitution is recognized to matter for local indeterminacy.

1 The Model

The ideal neoclassical worlds of Arrow-Debreu in microeconomic theory, and of Ramsey-Cass-Koopmans in macroeconomics, are characterized by equilibrium existence, optimality, possibly uniqueness and stability. When these charming intellectual constructions are enriched by market imperfections, there is room for Keynesian patterns such as disequilibrium, equilibrium multiplicity, sub-optimality and instability.

Money integration in the general equilibrium theory is still an open issue and some anodyne aspects of the theory deal with money[3].

The following model has no ambition of providing …nal answers, but it will just shed a light on this ground. Under the play of a ‡exible transaction technology, we investigate one special money interference within a real economy and the action of a speci…c market imperfection for equilibrium multiplicity.

In general contracts become e¤ective at a given instant of time and in particular transactions as well. Timing discontinuity provides a rationale to write down equations in discrete time: monetary transactions and liquidity constraints are properly described. Therefore the continuous time setup of Barro (1990) is reset in discrete time to be augmented by a cash-in-advance constraint.

[3] See among others Grandmont (1983).

1.1 Preferences

The infinite-lived and representative agent maximizes an intertemporal utility functional

$$\sum_{t=0}^{\infty} (1+\theta)^{-t} u(c_t) \tag{1}$$

where θ measures the time preference, c_t denotes the consumption which gives him an utility $u(c_t)$ at period t: The utility function is assumed to be increasing and strictly concave. The consumer faces a budget constraint at each period

$$M_{t+1} - M_t + p_t(k_{t+1} - k_t) + p_t c_t \leq (1-\rho)(R_t k_t + W_t l_t^s) + T_t \tag{2}$$

where $M_{t+1} - M_t$ and $k_{t+1} - k_t$ denote respectively the investment in money and capital. The capital by simplicity does not depreciate. p_t is the price of the sole consumption and production good. On the right hand side of (2) the disposable income is constituted by the capital income $R_t k_t$ and the labor income $W_t l_t^s$ after the income tax ρ; and by the monetary transfers $T_t \equiv M_{t+1} - M_t$: The monetary transfers from the monetary authority to the consumer are the way to inject money into the economic system. For the sake of simplicity on the supply side we assume a constant monetary growth $1+\mu \equiv M_{t+1}/M_t$: R_t and W_t are respectively the nominal return on capital and the nominal wage. l_t^s is the amount of labor services provided by the representative agent during a period of production. We assume an inelastic labor supply $l_t^s = 1$: In real terms the budget constraint becomes

$$(1+\pi_{t+1}) m_{t+1} - m_t + k_{t+1} - k_t + c_t \leq (1-\rho)(r_t k_t + w_t) + \tau_t \tag{3}$$

where $1+\pi_{t+1} \equiv p_{t+1}/p_t$ and $m_t \equiv M_t/p_t$ denote respectively the inflation factor and the real balances. $r_t \equiv R_t/p_t$ is the real interest rate and $w_t \equiv W_t/p_t$ is the real wage. $\tau_t \equiv T_t/p_t$ denotes the real transfers[4].

[4] More generally we could consider a general taxation system with an income tax ρ_y and a value added tax ρ_v: The real budget constraint becomes

$$(1+\pi_{t+1})m_{t+1} - m_t + (1+\rho_v)(k_{t+1} - k_t + c_t) \leq (1-\rho_y)(r_t k_t + w_t) + \tau_t$$

where the value added tax applies on the final goods expenditure $k_{t+1} - k_t + c_t$: Consumption taxes must be payed cash too and the monetary constraint becomes

$$(1+\rho_v)c_t \leq m_t$$

According to the cash-in-advance assumption the consumer needs money to purchase the consumption good. Thereby he must save an amount M_t of nominal money in period $t-1$ to finance the consumption at period t. More formally

$$p_t c_t \leq M_t \tag{5}$$

or in real terms

$$c_t \leq m_t \tag{6}$$

1.2 Firm Equilibrium and Budget Equilibrium

A constant private returns to scale production function is specified as in Barro (1990)

$$F(k_t; l_t^d) = A k_t^{\alpha} (l_t^d)^{1-\alpha} g_t^{\varepsilon}$$

where l_t^d is the firm's labor demand and α is the capital share on total income. g_t is the public spending which plays as a positive externality in production, and $\varepsilon > 0$ is the relative elasticity[5].

The intensive production is obtained, by normalizing the production function by the labor services l_t^d:

$$f(h_t) \equiv F(k_t; l_t^d)/l_t^d = A(k_t/l_t^d)^{\alpha} g_t^{\varepsilon}$$

where $h_t \equiv k_t/l_t^d$.

As in Barro (1990) we set $\varepsilon = 1-\alpha$ to allow for a balanced growth. Therefore

$$f(h_t) = A h_t^{\alpha} g_t^{1-\alpha}$$

Firm equilibrium requires

$$\begin{aligned} r_t &= f'(h_t) \\ w_t &= f(h_t) - f'(h_t) h_t \end{aligned} \tag{7}$$

This model is perfectly equivalent to the model with the sole income tax provided that we set

$$1-\tau = \left(1-\tau_y\right)/(1+\tau_v) \tag{4}$$

Notice that equivalence (4) holds because both the taxes are simply proportional. Otherwise the equivalence fails (for instance if the income tax turns out to be progressive).

[5] By simplicity we consider a Cobb-Douglas specification instead of a more general production function with constant returns to scale.

Equation (7) implies

$$r_t = \alpha A h_t^{\alpha - 1} g_t^{1-\alpha}$$

Because of the inelastic labor supply at equilibrium we get $l_t^d = l_t^s = 1$. Therefore

$$h_t = k_t$$

In this model the income tax is the only way to finance public spending. Budget equilibrium requires

$$g_t = \rho\,(r_t k_t + w_t) = \rho f(k_t) = \rho A k_t^{\alpha} g_t^{1-\alpha}$$

It follows that

$$\begin{aligned} g_t &= (\rho A)^{1/\alpha} k_t \\ f(k_t) &= A^{1/\alpha} \rho^{1/\alpha - 1} k_t && (8) \\ r_t &= \alpha A^{1/\alpha} \rho^{1/\alpha - 1} \equiv r && (9) \end{aligned}$$

The production per unit of labor services is linear in the intensive capital, while the real interest rate is a constant (r) and depends on the technological parameters (α and A) and on the income tax rate (ρ).

2 Equilibrium Dynamics

The representative agent maximizes the intertemporal functional (1) under the budget constraint (3) and the liquidity constraint (6). M_0 and k_0 are given as initial conditions. The choice sequences are $\{m_t\}_{t=0}^{\infty}$, $\{k_t\}_{t=1}^{\infty}$, $\{c_t\}_{t=0}^{\infty}$. We set the Lagrangian

$$\begin{aligned} L = & \sum_{t=0}^{\infty} (1+\theta)^{-t} u(c_t) \\ & + \sum_{t=0}^{\infty} \lambda_t \left[(1-\rho)(r_t k_t + w_t) + \tau_t - (1+\pi_{t+1}) m_{t+1} + m_t - k_{t+1} + k_t - c_t\right] \\ & + \sum_{t=0}^{\infty} \mu_t \left[m_t - c_t\right] \end{aligned}$$

where λ_t and μ_t are non-negative Lagrangian multipliers.

We obtain the following necessary first order conditions which are also sufficient because of the strict concavity of the utility function.

$$\partial L/\partial m_t = 0 \tag{10}$$
$$\partial L/\partial k_t = 0 \tag{11}$$
$$\partial L/\partial c_t = 0 \tag{12}$$
$$\lim_{t \to \infty} (\lambda_t + \mu_t)\, k_t = 0 \tag{13}$$

Notice that (10) and (12) must hold for $t = 0, 1, \ldots,$ (11) must hold for $t = 1, 2, \ldots,$ and (13) is the usual transversality condition.

Rearranging (10), (11) and (12), we get the relevant Euler equation:

$$\frac{u'(c_t)}{u'(c_{t+1})} = \frac{1+\pi_t}{1+\pi_{t+1}} \frac{1+(1-\rho)\, r_t}{1+\theta} \tag{14}$$

Equation (14) can be reinterpreted as follows:

$$\frac{u'(c_t)}{u'(c_{t+1})/(1+\theta)} = \frac{1+i_t}{(1+i_{t+1})/[1+(1-\rho)\, r_{t+1}]} \tag{15}$$

where $1 + i_t = (1+\pi_t)[1+(1-\rho)\, r_t]$ is the nominal interest factor, i.e. the product of the inflation factor and the real interest factor after tax. The left-hand side of (15) is the marginal rate of substitution between the present good and the future. The right-hand side is the ratio of the price of the present good, $1 + i_t$, and the discounted price of the future good $(1+i_{t+1})/[1+(1-\rho)\, r_{t+1}]$. The presence of the nominal interest rate i_t in the price of period t depends on money immobilization decided at period $t-1$. The immobilization opportunity cost i is approximately the differential between the return on capital ($(1-\rho)\, r$) and the return on money, i.e. the negative of the inflation rate[6] $(-\pi)$.

The utility function is now assumed to display a constant elasticity of intertemporal substitution σ:

$$u(c_t) \equiv \frac{c_t^{1-1/\sigma} - 1}{1 - 1/\sigma} \tag{16}$$

In the following we will investigate the local dynamics in a neighborhood of the stationary state. If at the steady state the constraint of cash-in-advance is binding, by continuity there exists a neighborhood where this

[6] More precisely $i = [1+(1-\rho)\, r](1+\pi) - 1 \approx (1-\rho)\, r - (-\pi)$.

constraint remains binding. The right condition to observe the liquidity constraint (6) with equality is that the stationary nominal interest rate i; i.e. the opportunity cost of holding money, is strictly positive. More precisely in discrete time

$$1 + (1 - \tau)\, r > 1/(1 + \pi) \tag{17}$$

In this case the consumer prefers capital to money in his portfolio and holds the minimal amount of real balances compatible with constraint (6). We will find the restriction for parameter values under which (17) holds at steady state and in a neighborhood.

Inequality (17) implies that the nominal liquidity constraint (5) holds with equality, i.e.

$$\frac{p_{t+1}c_{t+1}}{p_t c_t} = \frac{M_{t+1}}{M_t}$$

or equivalently

$$1 + \pi_{t+1} = (1 + \mu)\, c_t/c_{t+1} \tag{18}$$

From(14), (16) and (18) we obtain the consumption dynamics:

$$\frac{c_{t+1}}{c_t} = \left[\frac{1 + (1 - \tau)\, r}{1 + \theta}\right]^{\frac{\sigma}{1-\sigma}} \left(\frac{c_t}{c_{t-1}}\right)^{-\frac{\sigma}{1-\sigma}}$$

where r is provided by (9). In terms of consumption growth rates we write

$$1 + \gamma_{t+1} = \left[\frac{1 + (1 - \tau)\, r}{1 + \theta}\right]^{\frac{\sigma}{1-\sigma}} (1 + \gamma_t)^{-\frac{\sigma}{1-\sigma}} \tag{19}$$

where $1 + \gamma_{t+1} \equiv c_{t+1}/c_t$.

3 Steady State and Balanced Growth

The steady state of dynamics (19) is the following:

$$1 + \gamma = \left[\frac{1 + (1 - \tau)\, r}{1 + \theta}\right]^{\sigma} \tag{20}$$

The impact of the time preference (θ) and of the income tax rate (τ) on the stationary growth rate is negative. The effect of the interest rate (r) and of the elasticity of intertemporal substitution (σ) is positive. The technological parameter A plays a positive role for the interest rate and then for growth, while the impact of the capital share α on total income is ambiguous.

At the steady state growth is balanced, i.e. the growth rate is the same for money, capital and consumption. Different growth rates would be incompatible with the equilibrium conditions.

The initial capital is given. Therefore the intensive capital simply grows as follows:

$$k_t = (1+\gamma)^t k_0 \tag{21}$$

where γ is the balanced growth rate.

From (8) and (21) we obtain the production dynamics:

$$f(k_t) = A^{1/\alpha} \rho^{1/\alpha - 1} (1+\gamma)^t k_0$$

We observe that at equilibrium $(1+\pi_{t+1}) m_{t+1} - m_t = \tau_t$ and that the budget constraint (3) becomes a resource constraint.

$$k_{t+1} - k_t + c_t = (1-\rho) f(k_t)$$

Along the stationary growth path ($k_1 = (1+\gamma) k_0$) we get

$$c_0 = (1-\rho) f(k_0) - \gamma k_0$$

The explicit consumption dynamics at steady state is

$$c_t = (1+\gamma)^t \left[(1-\rho) f(k_0) - \gamma k_0\right] \tag{22}$$

Real balance dynamics is similar because we assume the cash-in-advance (6) to be binding:

$$m_t = (1+\gamma)^t \left[(1-\rho) f(k_0) - \gamma k_0\right]$$

The parameter values must satisfy two restrictions at the steady state: the transversality condition and the positivity of the nominal interest rate.

(i) The transversality condition (13) can be rewritten in terms of the fundamental parameters.

$$\begin{aligned}
\lim_{t\to\infty} (\lambda_t + \mu_t) k_t &= \lim_{t\to\infty} (1+\theta)^{-t} u'(c_t) k_t = \\
&= \lim_{t\to\infty} (1+\theta)^{-t} c_t^{-1/\sigma} k_t \\
&= \lim_{t\to\infty} (1+\theta)^{-t} \left[(1+\gamma)^t c_0\right]^{-1/\sigma} (1+\gamma)^t k_0 \\
&= \lim_{t\to\infty} \left[(1+\theta)^{-1} (1+\gamma)^{1-1/\sigma}\right]^t c_0^{-1/\sigma} k_0 = 0
\end{aligned}$$

The term into the brackets must be less than one, i.e.

$$1 + \mu > (1 + \gamma)^{1 - 1/\sigma} \tag{23}$$

where γ is given by (20). Inequality (23) is the general transversality condition for a discrete time endogenous growth.

(ii) The cash-in-advance constraint is binding if and only if $1 + r > 1/(1 + \pi)$; i.e. if

$$(1 + \mu)(1 + r) > 1 + \gamma$$

where r and γ are explicitly provided by (9) and (20).

There are two major remarks on the dynamics (19).

(i) On the one hand monetary growth (μ) plays no role on growth (γ_t); i.e. money is superneutral, even during transition.

(ii) On the other hand the introduction of money via the cash-in-advance constraint is not neutral for dynamics, because we actually get a transition. In Barro (1990), as well as in the Ak model, there is no transition at all. The economy jumps from the beginning on its long run growth rate which is exactly given by (20):

$$\gamma_t = \gamma$$

a constant for every $t = 1, 2, \ldots$ In our model not only the transition exists (equation (19)), but it allows for equilibrium multiplicity.

4 Indeterminacy

The union of paths converging to one particular attractor, such as a steady state, is said to be a stable manifold. The local indeterminacy we consider, is the equilibrium multiplicity arising when the dimension of the stable manifold is strictly greater than the number of pre-determined variables.

We set $x_t \equiv 1 + \gamma_t$. Equation (19) becomes

$$\begin{aligned} x_{t+1} &= (1 + \gamma)^{1/(1-\sigma)} x_t^{-\sigma/(1-\sigma)} \\ &\equiv \varphi(x_t) \end{aligned}$$

As γ_t is a non-predetermined variable, local indeterminacy requires the stationary state to be locally stable. In other words

$$|\varphi'(1 + \gamma)| < 1$$

where 1 + ° is the balanced growth factor. Solving for the derivative, we obtain

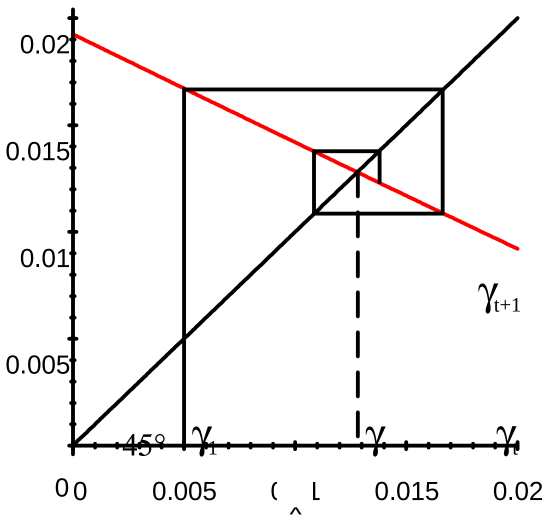
j ¡ ¾=(1 ¡ ¾)j < 1

As the elasticity of intertemporal substitution is positive, we get

0 < ¾ < 1=2 (24)

This is the range for equilibrium multiplicity. Notice that indeterminacy depends only on the taste parameter ¾: Therefore there is no room for policy to rule out this equilibrium multiplicity.

If inequality (24) holds the derivative '⁰ evaluated at the steady state is negative. Hence the transition growth factor, oscillates around the steady state and converges. Thereby for lower intertemporal substitution we observe growth cycles (see …gure).



Growth cyles.

If ¾ > 1=2; the sole solution which is compatible with the rational equilibrium requirement is the stationary state: °t = ° for every t: Rational agents who know the fundamentals, are able to compute the stationary growth and coordinate their behaviors to stay from the beginning in the steady state without deviating.

5 Conclusion

Money is no longer neutral in a simple model of endogenous growth with public spending. More precisely under a lower intertemporal substitution there is room for transition dynamics and indeterminacy. The transition growth rate ‡uctuates around the balanced one.

A higher intertemporal substitution interpreted as behavior ‡exibility, frees the consumer from the monetary constraint, i.e. from the relative e¤ects in terms of equilibrium indeterminacy.

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