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Money, Growth and Indeterminacy

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Money, Growth and Indeterminacy*

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Abstract

In this article consumers need money to reduce their transaction costs. We highlight the existence of indeterminacy under a constant money growth within an endogenous growth framework. Real indeterminacy is avoided by an alternative monetary policy such as the interest pegging. The residual price indeterminacy is also ruled out if this monetary policy is completed by a non-Ricardian fiscal policy.

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0.1 Introduction

Business cycles and growth are two major …elds of investigation in macroeconomic theory. The setup we provide allows to study the occurrence of endogenous ‡uctuations around an endogenous growth path in a monetary economy.

In literature the need of money is usually rationalized by putting money into either the objective functions such as the utility function (Sidrauski, 1967) and the production function (Dornbusch and Frenkel, 1973), or the constraints (Clower (1967), Stockman (1981)). In our work the monetary equilibrium is due to a negative impact of costly purchasing transactions.

More precisely we assume that the possession of liquidity reduces only the transaction costs of buying consumption goods without any e¤ect on the costs of the transactions involving capital goods. The rationale is that, in presence of well functioning credit markets, liquidity is not essential for buying capital (see among others Dotsey and Sarte (2000)). The purchased capital plays the role of credit collateral. The consumer without capital provides no …nancial guarantees to gain access to the credit market and needs real balances to reduce the transaction costs. In our paper the consumer endowed with money faces less obstacles during transaction and we assume for the sake of simplicity that he enjoys more consumption[1].

Growth is endogenous. A large class of models displays a linear production function as reduced form for technology, and the adoption of the Ak shortcut (Rebelo, 1991) in the paper is justi…ed to simplify the pure technological aspects and to focus instead on more complex monetary mechanisms.

Our contribution is above all an investigation about the occurrence of indeterminacy viewed as multiplicity of equilibrium growth paths, and the political solutions to select a unique equilibrium[2].

[1] The usual cash-in-advance is obtained as a limit case with in…nitely costly transaction costs. For more details see among the others Correia and Teles (1996).

[2] A dynamic general equilibrium can be viewed as a time path of prices and quantities such that all markets clear in each period. A dynamic economy may display a multiplicity of stationary states and a multiplicity of equilibrium paths converging to one particular attractor, which is usually a stationary state. A local real indeterminacy arises as a continuum of equilibrium paths in a neighborhood of the attractor, when the initial conditions (or equivalently the conditions inherited from the previous period) are not su¢cient to select a unique sequence for the real quantities.

Nominal indeterminacy (or price indeterminacy) simply means the multiplicity of equilibrium paths for nominal variables. If the real dynamics are determined by the initial

The incomplete markets' theory suggests some equivalence between market perfection (or completeness), equilibrium determinacy and Pareto-optimality. Even if a priori there is no indisputable definition of imperfection, the failure of the first welfare theorem requires by definition the existence of imperfections. In this sense incompleteness, externalities and market power, financial and monetary constraints can be viewed as imperfections. However imperfection does not entail automatically indeterminacy. Literature shows examples of dynamically inefficient but determinate equilibria (Cass, 1972). Conversely indeterminacy, as equilibrium multiplicity, implies sub-optimality and thereby requires some imperfection (see for instance Woodford, 1986a, for a financial imperfection).

Restricting attention to one-sector models displaying endogenous growth, the recent literature has identified several mechanisms at the origin of multiple equilibria. Among the others a chief type relies on the presence of increasing returns in production, which can be external (in a perfectly competitive framework) as well as internal (in a monopolistic competitive market) to the single economic units. Externalities in production as well as monopolistic competition on the one hand imply a marginal product of capital large enough for endogenous growth (Benhabib and Rustichini, 1994) and on the other hand they matter for equilibrium indeterminacy.

These models suggest that slight departures from the Real Business Cycle model are consistent with the idea that economic fluctuations may be driven not only by productivity disturbances, but also by the self-fulfilling beliefs of the agents. However such models lack predictive power and cannot therefore be helpful in shedding any light on the behavior of the economic equilibrium (Benhabib and Rustichini, 1994). An open question is whether the economic policy may only rule out the indeterminacy as condition for undesirable fluctuations or a more fine tuning is required which consists in selecting the Pareto-optimal path and coordinating the agents on the right starting point by means of some extra-signal.

In the Nineties the impact of the monetary growth rate on the endogenous growth rate has been investigated. Conclusions are not unanimous.

Marquis and Reffett (1991) enrich a basic two-sector model with human capital accumulation through a cash-in-advance constraint, and obtain a superneutrality result. The benchmark of Lucas (1988) is revised by Wang

conditions, but the initial price level is not, we observe nominal indeterminacy, because the value of the nominal variables is undefined.

and Yip (1991) to incorporate money in the production function still with a superneutrality result, and by Van der Ploeg and Alogoskou…s (1994) to introduce money in the utility function without superneutrality e¤ects. They observe instead a positive impact of money growth on real growth. To the contrary Marquis and Re¤ett (1994) within a monetary version of Romer (1990) highlight a negative e¤ect essentially because of the negative channel of the in‡ationary tax. Finally Mino and Shibata (1995) set up an overlapping-generations model with money in the utility function and …nd a positive e¤ect of money growth (and in‡ation) on the long run growth rate.

In our paper monetary imperfections are speci…ed as ‡exible transaction costs of purchase (the cash-in-advance is a limit case). The necessary conditions for endogenous growth self-ful…lling ‡uctuations are characterized for a monetary economy within a simple discrete time setting. The monetary imperfections are properly captured in discrete time. The model provides an example of local indeterminacy and ‡uctuations of money velocity and in‡ation due to shocks on the beliefs. In economies endowed with only one consumption good velocity ‡uctuations are excluded by the cash-in-advance which …x the money velocity to one. A ‡exible transaction technology generalizes the basic cash-in-advance and allows a variable velocity. In this context the in‡ation rate displays a counter-cyclical impact on consumption. We shall focus on the transmission mechanism for local real indeterminacy. The role of consumption intertemporal substitution is interpreted as a consumer's ability to make ine¤ective the monetary constraint as market imperfection and source of local indeterminacy.

A policy analysis is eventually performed. Quantity indeterminacy is avoided by an alternative monetary policy (interest pegging), while the residual price indeterminacy ruled out by a complementary non-Ricardian …scal policy.

The rest of the article is organized as follows. In the …rst section the model is set. The consumer maximizes an intertemporal utility functional and faces a budget constraint which incorporates the transaction costs. In the second section we transform the market clearing equations in a two-dimensional dynamic system where the velocity of money and the consumption-capital ratio are the key-variables. In the third section we analyze the balanced endogenous growth as well as the counter-cyclical role of velocity under a constant money growth. The following section is dedicated to the equilibrium multiplicity. Local indeterminacy arises under stronger imperfections (higher transaction costs) and lower intertemporal substitution which is interpreted as a consumer's difficulty to bypass them. A numerical example is detailed to identify the local indeterminacy region in the parameter space. We show that the interest pegging constitutes an alternative monetary policy to rule out any endogenous business cycles. The last section focuses on the nominal indeterminacy and the role of fiscal policy to cancel out this residual price multiplicity.

1 The model

The ideal neoclassical worlds of Arrow-Debreu on the microeconomic side, and of Ramsey-Cass-Koopmans on the macroeconomic side, are characterized by existence, optimality, sometime uniqueness and stability of the general equilibrium. When these charming intellectual constructions are enriched in a very broad sense by market imperfections, there is room for Keynesian features such as disequilibrium phenomena, equilibrium multiplicity, sub-optimality and instability.

The introduction of money in the general equilibrium theory is not a plain task. The cash-in-advance as well as the transaction technology we assume, are intellectual expedients which capture only a part of money complexity.

The following model will not provide definitive answers, but will shed a light on both these grounds. Under the play of a flexible transaction technology, we will investigate one special interference of money within a real economy and the action of a specific market imperfection for equilibrium multiplicity.

From now on $m_t \equiv M_{t-1}/p_t$ will denote the real balances. The velocity of circulation of money with respect to consumption is properly defined by

$$v_t = c_t/m_t \tag{1}$$

according to the quantity identity[3]. The transaction costs of consumption purchase are assumed to be homogeneous of degree one in consumption and money:

$$S(c_t, m_t) \equiv s(c_t/m_t)\, c_t$$

where $s_t = s(v_t)$ represents the transaction cost to buy one unit of consumption good. The money employed in period t to purchase c_t at price p_t is set aside at the end of period $t-1$:

[3] The money velocity v_t is defined with respect to consumption: $M_{t-1}v_t \equiv p_t c_t$; i.e. $v_t \equiv c_t/(M_{t-1}/p_t)$.

Assumption 1. The intensive transaction cost function $s(v)$ satisfies the constraints

$$\begin{aligned} s(0) &= 0 & (2)\\ s'(v) &> 0 & (3)\\ 2s'(v) + s''(v) &> 0 & (4)\\ 2s'(v) + vs''(v) &> 0 & (5)\end{aligned}$$

The first equality means that if the agent does not consume or he is not financially constrained, he pays no transaction cost. The first inequality claims that more the individual is financially constrained, i.e. the lower is the ratio c_t/m_t, the higher turns out to be the transaction cost per consumption unit. Inequalities (4) and (5) are mild restrictions and require the transaction costs to be not too concave. For instance they are satisfied by every convex function. The power function

$$s(v_t) = v_t^{\alpha}$$

satisfies (2), (3) and (5) whatever $\alpha > 0$, and satisfies (4) for $\alpha > 1 - 2v$.

The problem a representative agent faces consists in selecting the functions $m_t \equiv M_{t-1}/p_t$, k_t, c_t (intertemporal trajectories for real balances, productive capital and consumption), in order to maximize the usual intertemporal utility functional

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

under a budget constraint which incorporates the consumption transaction costs[4]

$$(1+\pi_{t+1})\, m_{t+1} + k_{t+1} + [1 + s(c_t/m_t)]\, c_t \le (1+r_t)\, k_t + m_t + \tau_t \qquad (6)$$

[4] A more general model would also take in account the capital transaction costs. Formally the budget constraint would be arranged as follows:

$$\begin{aligned}&(1+\pi_{t+1})\, m_{t+1} + [1 + s_k((k_{t+1} - k_t)/m_t)](k_{t+1} - k_t) + [1 + s_c(c_t/m_t)]\, c_t\\ \le\ & r_t k_t + m_t + \tau_t\end{aligned}$$

Dynamics turn out to be more complicated. However our results hold by continuity, if the intensive capital transaction costs s_k are sufficiently close to zero in the function space (because of well functioning credit markets), and they are dominated by the intensive consumption transaction costs s_c.

Tastes at period t are represented by the utility function $u(c_t)$ and the rate of time preference θ. Utility gets the usual CES form. The elasticity of intertemporal substitution is set equal to σ:

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

For the sake of simplicity in (6) we assume that the capital does not depreciate[5].

The inflation factor and the real interest rate are denoted respectively by $1 + \pi_{t+1} \equiv p_{t+1}/p_t$ and r_t. $\tau_t \equiv (M_t - M_{t-1})/p_t$ represents the real transfers from the monetary authority to consumers at period t. As above a simple monetary rule is adopted: $1 + \mu = M_t/M_{t-1}$. Initial conditions are specified by the nominal money M_0 and capital k_0.

2 Dynamic System

Setting the infinite horizon Lagrangian and rearranging the first order conditions, we obtain the Euler condition, which describes the evolution of consumption across the time.

$$\frac{c_{t+1}}{c_t} = \left[\frac{1 + r_{t+1}}{1 + \theta} \frac{1 + s(v_t) + s'(v_t)\, v_t}{1 + s(v_{t+1}) + s'(v_{t+1})\, v_{t+1}}\right]^{\sigma} \tag{7}$$

The gross inflation factor depends on the velocity of money:

$$1 + \pi_{t+1} = \frac{1 + s'(v_{t+1})\, v_{t+1}^2}{1 + r_{t+1}} \tag{8}$$

In the well known Rebelo's (1991) Ak model, a world with no money, the equilibrium interest rate is pegged by the technology: $r_t = A$; and the relevant Euler condition fixes a unique endogenous growth factor:

$$\frac{c_{t+1}}{c_t} = 1 + \gamma \tag{9}$$

[5] Capital depreciation is usually parametrized by a depreciation rate δ and the budget constraint is reset as follows

$$(1 + \pi_{t+1})\, m_{t+1} + k_{t+1} + [1 + s(c_t/m_t)]\, c_t \le (1 - \delta + r_t)\, k_t + m_t + \tau_t$$

The qualitative results we shall obtain, will not depend on δ.

where

$$1+\gamma \equiv \left(\frac{1+A}{1+\theta}\right)^{\sigma} \tag{10}$$

The economy jumps on this unique growth path. There is no room for transition.

To the converse the monetary version we are considering, allows a transition. Even if at the steady state the velocity of money is constant and equation (9) still holds from (7), in the short run the growth rate, as shown by (7), may deviate from the stationary rate γ. More precisely if the velocity of money differs from its long run value (this is possible if and only if the equilibrium is indeterminate), then the velocity interferes with the consumption growth rate. Thereby the economy no longer jumps from the beginning on the balanced growth path and a transition actually arises during which the monetary imperfection is no longer neutral.

In our model if the equilibrium is determinate, agents' coordination under rational expectations selects the unique equilibrium, i.e. the stationary one and fixes the non-predetermined velocity to the steady value v. The parameter range allowing for determinacy and ruling out transition cycles is provided at the end of the paper.

The intertemporal paths for money and capital is now computed. First notice that $\tau_t = (1+\pi_{t+1})\, m_{t+1} - m_t$. Thus at equilibrium constraint (6) becomes

$$[1+s(v_t)]\, c_t + k_{t+1} = (1+r_t)\, k_t \tag{11}$$

A linear technology

$$f(k_t) \equiv Ak_t$$

as usual is enough to sustain the endogenous growth. The equilibrium of the firm implies

$$r_t = f'(k_t) = A$$

The relevant dynamics for the velocity of circulation of money with respect to consumption $v_t = c_t/m_t$ is given by the implicit function:

$$\Psi(v_t, v_{t+1}) \equiv (1+a)\frac{v_{t+1}}{v_t} - \left[1+s'(v_{t+1})\, v_{t+1}^2\right]\left[\frac{1+s(v_t)+s'(v_t)\, v_t}{1+s(v_{t+1})+s'(v_{t+1})\, v_{t+1}}\right]^{\sigma} = 0 \tag{12}$$

where a is set as follows

$$1+a \equiv \frac{(1+A)(1+\mu)}{1+\gamma} \tag{13}$$

and γ is still given by (10).

We define

$$y_t \equiv c_t/k_t \tag{14}$$

From (11) and (14) we obtain

$$k_{t+1}/k_t = 1 + A - [1 + s(v_t)]\, y_t \tag{15}$$

As

$$\frac{y_{t+1}}{y_t} = \frac{c_{t+1}/c_t}{k_{t+1}/k_t}$$

we get the following discrete time dynamic system from (7), (12) and (15)

$$\Phi(v_t; v_{t+1}) = 0 \tag{16}$$

$$y_{t+1} = (1+\gamma)\left[\frac{1 + s(v_t) + s'(v_t)\, v_t}{1 + s(v_{t+1}) + s'(v_{t+1})\, v_{t+1}}\right]^{\sigma} \frac{y_t}{1 + A - [1 + s(v_t)]\, y_t} \tag{17}$$

3 Balanced Growth

The steady state $(v; y)$ of system (16-17) is implicitly given by

$$s'(v)\, v^2 = a \tag{18}$$

$$y = \frac{A - \gamma}{1 + s(v)} \tag{19}$$

where γ is defined by (10).

As the consumption-capital ratio y must be positive, we assume

$$A > \gamma \tag{20}$$

Inequality (20) always holds if $A > \theta$ and $\sigma < 1$.

More explicitly growth is balanced as in the Rebelo's (1991) Ak model:

$$\gamma_t^m = \gamma_t^k = \gamma_t^c = \gamma$$

where $\gamma_t^m; \gamma_t^k; \gamma_t^c$ denote respectively the growth rates for real balances, capital and consumption (see equations (1), (15) and (7)).

For example the class of power functions $s(v) = v^{\alpha}$; $\alpha > 0$ provides

$$v = (a/\alpha)^{1/(1+\alpha)}$$

$$y = \frac{1 + A - [(1 + A)/(1 + \theta)]^{\sigma}}{1 + (a/\alpha)^{\alpha/(1+\alpha)}}$$

Under the Assumption 1 the impact of money growth ¹ on velocity v is positive, because it raises the in‡ation rate and the nominal interest rate, i.e. the opportunity cost of holding money. Notice that under Assumption 1 we observed counter-cyclical e¤ects of money velocity. More generally dv=da > 0: In particular all the parameters raising a; raise v and increase the transaction costs. Furthermore more impatient consumer is, bigger turns out to be the stationary velocity v; because @a=@µ > 0; as intuition suggests: the greater the current consumption need, the faster the circulation of money. The impact of the intertemporal substitution ¾ on a; and thereby on v; is negative, provided that A > µ; i.e. the long term velocity decreases under higher substitution of the present consumption by future purchases. A has a positive impact on a and v; if and only if ¾ < 1; i.e. higher the productivity, higher the current consumption and money velocity, under su¢ciently low intertemporal substitution. Otherwise for ¾ > 1; saving prevails on consumption, and v slows down in our restrictive interpretation of the quantity theory that focuses on consumption transactions.

The Euler condition (7) directly provides the stationary consumption growth which is exactly that of the non-monetary version (Rebelo, 1991) in equation (9). Growth is balanced: the growth rate is the same for real balances and capital. Even if money turns out to be superneutral at the steady state, it a¤ects the transition. As above, the transversality condition restricts the set of plausible parameters. At the steady state $\lim_{t ! 1} ¸_t k_t = 0$: More explicitly

$$1 + µ > (1 + °)^{1 i 1=¾}$$

See the appendix for details.

4 Local Real Indeterminacy

The variables $v_t = c_t=m_t$ and $y_t = c_t=k_t$ are independently non-predetermined because c_t and m_t (i.e. p_t) are independently non predetermined. Local indeterminacy arises if and only if the dimension of the stable manifold is strictly greater than the number of pre-determined variables. In our case this number is zero and hence we require a con…guration of either saddle or sink for our stationary state to observe indeterminacy[6].

[6] A stable manifold is the union of all the convergent trajectories. A variable, which has been determined prior to time t; is said to be predetermined at time t: For instance in

The Jacobian matrix of system (16-17) evaluated at the steady state (18-19) is given by

$$J = \begin{bmatrix} \lambda_1 & 0 \\ \psi & \lambda_2 \end{bmatrix}$$

where

$$\lambda_1 = -\frac{\partial \Phi / \partial v_t}{\partial \Phi / \partial v_{t+1}} \tag{21}$$

$$\lambda_2 = \frac{1 + A}{1 + \gamma} > 1 \tag{22}$$

are the eigenvalues of J and

$$\psi \equiv y \left[\frac{y s'(v)}{1 + \gamma} + \sigma \left(1 + \frac{\partial \Phi / \partial v_t}{\partial \Phi / \partial v_{t+1}} \right) \frac{2 s'(v) + v s''(v)}{1 + s(v) + v s'(v)} \right] \tag{23}$$

The sink configuration is ruled out by $\lambda_2 > 1$; that is the required condition for the consumption to be positive. Therefore local indeterminacy occurs, if and only if the stationary state is a saddle:

$$\left| -\frac{\partial \Phi / \partial v_t}{\partial \Phi / \partial v_{t+1}} \right|_v < 1 \tag{24}$$

Inequality (24) holds if and only if

$$\left| 1 - \frac{v^2 / (1 + a)}{1 / (2 s' + s'' v) + \sigma v / (1 + s + s' v)} \right| > 1 \tag{25}$$

that is a necessary and sufficient condition for local indeterminacy.

In the $(v_t; y_t)$-plane the saddle path we obtain under (25) and (5) is downward-sloped. The linearized saddle path is computed:

$$y_t = m v_t + n \tag{26}$$

standard macroeconomic dynamics the stock of capital k_t plays as a predetermined variable, because it depends on the investment decisions, which has been taken in the previous period $t - 1$: In our model as consumption and real balances are not predetermined, neither is the velocity of circulation of money with respect to consumption. Indeterminacy occurs when the dimension of the stable manifold is greater than the number of predetermined variables.

where

$$m \equiv \frac{j}{\lambda_1 - \lambda_2} < 0$$
$$n \equiv y - \frac{j}{\lambda_1 - \lambda_2} v > 0$$

$v; y; \lambda_1; \lambda_2; j$ are respectively provided by (18), (19), (21), (22), (23) (see the appendix for details).

Assume now that (25) is satisfied, i.e. there is local indeterminacy. Rational agents coordinate their initial behavior to stay on the saddle path which is compatible with a long-run equilibrium: $(v_0; y_0)$ must belong to the saddle path. As there is local indeterminacy the agents freely implement v_0; but they are forced to satisfy approximately (26) in a neighborhood of the steady state, i.e. to select the convergent equilibrium path:

$$y_0 \approx m v_0 + n$$

In other words the choice of y_0 is no longer free. As $y_0 = c_0/k_0$ and k_0 is a predetermined variable, the agents choose the right consumption c_0 to stay on the saddle path from the beginning on and to converge to the steady state. As the saddle path is locally downward-sloped, a lower initial velocity ($v_0 < v$) will entail lower transaction costs and then a higher initial consumption c_0 and a lower initial consumption growth rate $\gamma_1^c = c_1/c_0 - 1 < \gamma$ (see also the Euler equation (7)).

Moreover we notice that under (25) and (5)

$$-1 < \lambda_1 < 0 \tag{27}$$

Thereby the transition sequence $\{v_t; y_t\}_{t=0}^{\infty}$ converges to the steady state $(v; y)$ displaying contracting oscillations of period 2 around $(v; y)$ along the saddle path.

The currency velocity displays counter-cyclical effects for consumption dynamics in a neighborhood of the steady growth. From (7) we observe that under the Assumption 1 $v_{t+1} > v_t$ entails $c_{t+1}/c_t < 1 + \gamma$: The consumption growth rate falls under its balanced long run value. In less formal terms the reduction of real balances, raising the velocity of money and transaction costs, temporarily slows down the consumption growth.

More precisely an increase in money velocity due to a contraction of real balances, is associated to a raise of the opportunity cost of holding money, which is represented by the nominal interest rate $i_t = (1 + \pi_t)(1 + r_t) - 1$. The opportunity cost of real balances (and consumption) is interpreted as the relative "price" of the consumption good with respect to capital[7].

We notice that the real interest rate, $r_t = A$, is constant over the time and the nominal interest rate dynamics are due only to inflation movement.

In the very short term there exists a negative relation between the inflation and consumption growth. We observe according to equation (8) and Assumption 1 that $\pi_{t+1} > \pi_t$ if and only if $v_{t+1} > v_t$. Thereby an increasing inflation across the time pulls the consumption growth rate below its long run value and conversely a decreasing inflation pushes this growth rate above the balanced growth rate.

The increase of the opportunity cost of consumption depresses the consumption growth rate below the long run value, but makes the capital relatively cheaper. Thereby capital accumulation is boosted as well as the consumption growth rate of the following period, which will exceed the balanced growth rate.

This is the rationale for the oscillations of period two we have formally obtained in (27).

In general the literature is not unanimous about the inflation impact on growth and theoretical models are often powerless to emphasize a strong negative relation, basically because of money superneutrality[8]. In the empirical

[7] Capital and consumption good have the same nominal price p_t. However the real balances and consumption have the same real opportunity cost i_t with respect to the productive capital, because of the cash-in-advance.

[8] By definition the exogenous growth models are not adapted to capture the interplay between monetary growth, inflation and real growth. One prediction from Tobin's model (1965) is that an inflationary money growth positively affects the capital stock. Sidrauski (1967), using a model with money in the utility function, develops long run neutrality results. A negative relationship between money growth and capital is shown in Brock (1975) when the supply of labor is endogenous. In Stockman (1981) a cash-in-advance constraint is applied to consumption and investment. In Cooley and Hansen (1989) money is introduced through a cash-in-advance constraint on consumption. In both of these articles higher inflation rates affect steady-capital/output ratios but not growth rates. In the Real Business Cycle theory as advanced by Kydland and Prescott (1982) and Long and Plosser (1983), money typically plays no role. In Matsuyama (1991) endogenous price fluctuations are associated to a higher money supply growth.

By construction the endogenous growth models are better to explain the inflation impact on growth. In Jones and Manuelli (1993) the effects of inflation are still evaluated in a model of endogenous growth with increasing returns. Inflation is recognized to induce small growth rate effects and moderate welfare costs. In Van der Ploeg and Alogoskoufis models low in‡ation are sometime recognized to stimulate growth. Higher in‡ation rates by confounding relative price signals, make resource allocation ine¢cient and slow down the growth[9].

If the equilibria are indeterminate, the agents may individually saturate this degree of freedom by relating their choices to exogenous random signals (sunspots), which do not a¤ect the fundamentals (technology, preferences and endowments). The probability distribution of a sunspot is assumed to be common knowledge and it is inferred from past realizations. In other words the sunspot shocks the believes instead of the fundamentals. If the way of relating the economic future to this distribution is the same for all the agents, the believes are shared. If the choices of the agents and shared believes satisfy the stochastic version of dynamic system (12), the shared believes become self-ful…lling prophecies (Azariadis, 1981). Local indeterminacy is the necessary condition to observe stochastic (sunspot) equilibria, i.e. endogenous ‡uctuations (among the others Grandmont, 1991). According to a Woodford's conjecture (1986b), it turns out to be also su¢cient. Under higher transaction costs ® and a low elasticity of intertemporal substitution ¾ the economy displays local indeterminacy and possible stochastic (sunspot) equilibria of endogenous growth. A higher absolute value of the elasticity of marginal utility is equivalent to either a lower intertemporal substitution or a higher risk aversion across the states of nature. Thus the behavior of a risk averse consumer subject to strong monetary constraints may be a source of endogenous ‡uctuations.

We stress the possibility of ‡uctuations of the currency velocity due to shocks on the beliefs. With a standard binding cash-in-advance velocity ‡uctuations are ruled out ($v_t = 1$) : The possibility of exogenous ‡uctuations with shocks on the fundamentals has already been shown in exogenous growth by Lucas and Stokey (1987). However the authors need two goods (cash and credit good) and ‡uctuations end up being strictly exogenous. As seen above, in our model the impact of velocity on the transitional consumption growth rate is recognized to be counter-cyclical.

Eventually we notice that the choice of a discrete time setting to study

(1994) monetary growth is no longer neutral. It boots real growth and in‡ation therefore rises by less than the monetary growth.

[9] A large evidence points out that 10% increase in the in‡ation rate is associated with a decrease in the growth rate of between about 0:2 and 0:7% (among the others Fischer (1993), Chari et al. (1995)). However authors disagree about the e¤ects of moderate in‡ation (Ghosh and Phillips, 1998).

monetary imperfections is not neutral for indeterminacy. Transactions are not continuous in time and usually the consumer does not dispose of liquid amount prior to some instant of cashing. A discrete timing better captures momentary exchanges. Thereby a continuous time approach is a less precise language to describe a sequence of isolated payments. In particular local indeterminacy disappears in the continuous time version of the model and there is no longer room for endogenous fluctuations[10].

4.1 A Numerical Example

If $s(v) = v^{\alpha}$; $\alpha > 0$; the condition for local indeterminacy (25) becomes

$$\frac{1+a}{a(1+\alpha)} + \frac{\alpha\sigma(1+a)}{\alpha v + a(1+\alpha)} < \frac{1}{2}$$

Local indeterminacy arises for instance if α is sufficiently high (higher transaction costs) and σ is sufficiently low (difficulty to substitute consumption intertemporally).

We notice that for $\alpha = +\infty$ we obtain the cash-in-advance:

$$\lim_{\alpha \to +\infty} v = \lim_{\alpha \to +\infty} (c/m) = 1$$

[10] The consumer maximizes the functional $\int_0^{\infty} u(c_t)e^{-\theta t}dt$ under the law of motion $\dot{a}_t = -\pi_t m_t + r_t k_t + \tau_t - [1 + s(c_t/m_t)]c_t$. The utility function is still isoelastic, the real wealth a_t is constituted by m_t and k_t; and the remaining symbols are usual. The inflationary tax is given by $-\pi_t m_t$: A constant monetary growth is assumed: $\mu = \dot{M}_t/M_t$: Standard computations provide the reduced form for dynamics in terms of velocity:

$$\begin{aligned}\dot{v}_t &= \varphi(v_t) \\ &\equiv v_t\left[s'(v_t)v_t^2 + \sigma(A-\theta) - (A+\mu)\right]\left\{1 + \sigma\frac{v_t[2s'(v_t) + s''(v_t)v_t]}{1 + s(v_t) + s'(v_t)v_t}\right\}^{-1}\end{aligned}$$

The stationary velocity solves the equation $s'(v)v^2 = A + \mu - \sigma(A-\theta)$ and the stationary balanced growth rate is $\gamma = \sigma(A-\theta)$ as in Rebelo (1991). The transversality condition takes the form $\theta > \gamma(1 - 1/\sigma)$: In this dynamics local determinacy prevails if, and only if, the steady state is unstable: $\varphi'(v) > 0$: A sufficient condition for instability is $2s'(v) + s''(v)v > 0$: Only one money velocity is compatible with the rational equilibrium: economy directly jumps to the stationary growth rate γ; by adjusting its initial consumption to $c_0 = k_0(A-\gamma)/[1+s(v)]$: There is no transition and money is superneutral. Hence the continuous time version of the model displays no real indeterminacy at all and no self-fulfilling fluctuations. For more details see Bosi (1999).

and the local indeterminacy condition becomes

$$\sigma = \lim_{\alpha \to +\infty} \frac{1+a}{a(1+\alpha)} + \frac{\alpha\sigma(1+a)}{\alpha v + a(1+\alpha)} < \frac{1}{2}$$

which is exactly the condition we require in the class of endogenous growth models with cash-in-advance (see Bosi (2000) and Bloise, Bosi and Magris (2001)).

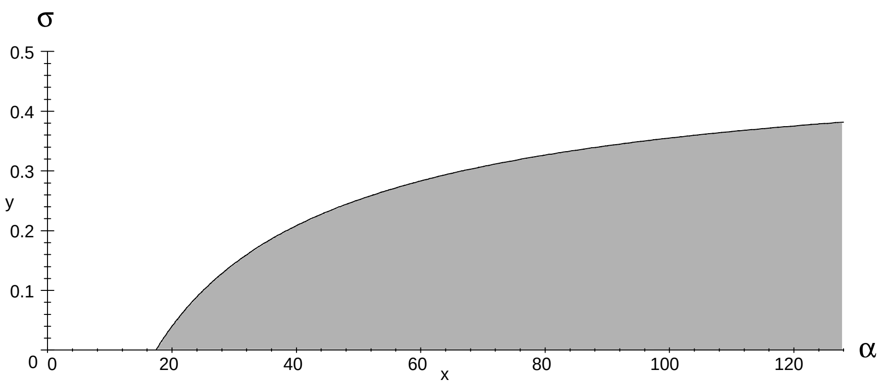

Figure 1. Local indeterminacy region.

In the picture the shaded area represents the set of local indeterminacy parameter pairs $(\alpha; \sigma)$. The bifurcation frontier captures the trade-off between the monetary constraint and intertemporal substitution. Productivity, time preference and monetary rule are respectively fixed to $A = 10\%$; $\theta = 1\%$; $\mu = 2\%$.

4.2 Interest pegging

Let the monetary authority follow an alternative monetary policy which consists in pegging the interest rate $(i_t = i)$. The velocity of money turns out to be fixed as well: $1 + s'(v_{t+1})\, v_{t+1}^2 = (1 + \pi_{t+1})(1 + A) = 1 + i$. There is no longer transition. According to equation (7) the economy jumps on its long run growth rate defined by (10).

5 Fiscal Policy and Price Level Determination

Under a constant money supply growth, there is room for local real indeterminacy, i.e. a continuum of paths for the equilibrium growth rates. The real determinacy arises only under specific parameter configurations if money growth is constant, and always occurs under a nominal interest pegging.

However the initial budget constraint (6) evaluated along the stationary growth path provides no information at all about the initial price level p_0: In other terms even if the inflation path of a determinate equilibrium is known, the starting point for the price path is indeterminate as well as the nominal variables. To rule out this nominal indeterminacy and for instance the related risk of hyperinflation, the monetary policy must be completed by a specific fiscal policy.

The basic framework we have presented in the first section can be easily augmented to take into account the government's objective and budget constraint. In particular taxes, public debt and public spending can be introduced.

Without entering the analytical details, we highlight that, under the interest rate rule $i_t = i$; the nominal determinacy prevails if and only if the fiscal policy is non-Ricardian[11].

Barro's Ricardian equivalence simply means the irrelevance of government debt for real quantities (1974). According to Woodford (1995) a fiscal regime is said to be Ricardian if the present discounted value of government liabilities converges to zero irrespective of the price path. More precisely the limiting condition (a no-Ponzi game) holds for the government intertemporal budget constraint regardless of the evolution of the other endogenous variables. If the fiscal solvency holds only for particular price paths, the fiscal regime is said to be non-Ricardian.

In the pure quantity-theoretic reasoning the control of money supply determines the prices. A shared conviction by monetary theorists is that pure interest rate pegging will leave the price level indeterminate (Wicksell (1965), Sargent and Wallace (1975)). In the last two decades the generality of indeterminacy conclusions has been contested.

The general question is whether the government can use some other policy tools, such as taxes or debt policy, in conjunction with monetary policy to

[11] See among others Bosi and Guillard (1999).

…x the initial price level and thereby, as seen above, the entire price path.

In contrast with Sargent and Wallace (1975) the initial price level is no longer determined by money supply. The initial price is pinned down by the …scal budget constraint and more precisely by the needs of …scal solvency.

Now the …scal budget constraint becomes the equilibrium condition (Woodford, 1995) that rules out the nominal indeterminacy obtained in Sargent and Wallace (1975) under an interest peg.

Woodford (1995) assumes that the agents believe in …scal solvency, i.e. in the respect of the government's intertemporal budget constraint. Thereby this solvency condition becomes an additional equilibrium condition, which removes the residual degree of freedom for nominal indeterminacy and …xes the initial price. They coordinate themselves on the unique initial price and then on the unique price path, which is jointly determined by this starting point and the in‡ation path. The in‡ation path is a real path already …xed by the interest pegging[12].

According to Woodford (1995) a Ricardian …scal policy plays no role at all in price-level determination, while the path of the money supply clearly does. This is the validity domain for the quantity theory. In a non-Ricardian regime the interest rate pegging delivers a unique price level, while a constant money supply growth yields a multiplicity of solutions.

6 Conclusion

Policy makers dislike economic ‡uctuations. Shocks on technology spread in form of real business cycle, while shocks on beliefs turn into endogenous business cycle. A good policy mix minimizes the amplitude of ‡uctuations due to shocks on fundamentals and rules out the necessary condition for endogenous ‡uctuations, i.e. the equilibrium indeterminacy.

Our paper focused on this second point and provided an answer to a relevant question: what mix of monetary and …scal policy is required to avoid quantity and price indeterminacy?

In presence of costly purchasing transaction a constant money growth is a bad tool against ‡uctuations. In particular under higher transaction costs and lower intertemporal substitution indeterminate transition equilibria arise around a long run growth path. In other words the intertemporal substitution

[12]Cushing (1999) contests the solvency condition and Woodford's conclusions. The government may cheat even if private agents are rational.

represents the consumer's freedom against the monetary imperfection viewed as a behavioral constraint and a major cause of indeterminacy.

Conversely in our simple setup the interest pegging is a good monetary rule, fixing the currency velocity and forcing the agents over a unique growth trajectory. As usual we assume that they have common knowledge of fundamentals and rational expectations and thereby are able to self-coordinate on the determinate balanced path.

However this monetary policy remains powerless to anchor the prices without the complement of a non-Ricardian fiscal policy.

7 Appendix

The transversality condition in endogenous growth.

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

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

$$1+\theta > (1+\gamma)^{1-1/\sigma}$$

Saddle path. We want to prove equation (26). Let v_1 and v_2 be the eigenvectors respectively associated to the eigenvalues λ_1 and λ_2; and V be the eigenvector matrix. In our case (triangular Jacobian) we get

$$V \equiv [v_1; v_2] = \begin{bmatrix} (\lambda_1 - \lambda_2)/j & 0 \\ 1 & 1 \end{bmatrix} \tag{28}$$

We have normalized the second component of each eigenvector to one.

In the linearized dynamics the starting point $(v_0; y_0)$ belongs to the convergent path if and only if

$$\lim_{t\to\infty} \begin{bmatrix} v_t - v \\ y_t - y \end{bmatrix} = \lim_{t\to\infty} \left(J^t \begin{bmatrix} v_0 - v \\ y_0 - y \end{bmatrix} \right) = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

where $(v; y)$ is the stationary state. Let

$$\Lambda \equiv \begin{bmatrix} \lambda_1 & 0 \\ 0 & \lambda_2 \end{bmatrix}$$

be the Jordan canonical form. We obtain

$$\lim_{t \to \infty} \left(V \Lambda^t V^{-1} \begin{bmatrix} v_0 - v \\ y_0 - y \end{bmatrix} \right) = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

This is possible if and only if the explosive eigenvalue ($\lambda_2 > 1$) is ruled out, i.e. if and only if

$$V^{-1} \begin{bmatrix} v_0 - v \\ y_0 - y \end{bmatrix} = \begin{bmatrix} c \\ 0 \end{bmatrix} \qquad (29)$$

where c is a constant. From (28) we compute the second row of the vector equation (29):

$$-j (v_0 - v) + (\lambda_1 - \lambda_2)(y_0 - y) = 0$$

i.e. the equation (26) of the tangent line to the stable manifold.

Under (25) we obtain $\lambda_1 < \lambda_2$; while under (25) and (5) we get $j > 0$ (see (23). Hence

$$\frac{j}{\lambda_1 - \lambda_2} < 0$$

and the saddle path is downward-sloped in a neighborhood of $(v; y)$:

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