Indeterminacy and Cycles
in a Cash-in-Advance Economy with Production

Gaetano BLOISE, Stefano BOSI & Francesco MAGRIS

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Abstract

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JEL Classification:
1 Introduction
of a constant rate of growth at which government injects (or withdraws) money in the economy does not affect neither the stationary solution nor the speed of convergence towards it; it follows that money is superneutral in the long-run as well as along the transitional dynamics. Another important feature concerns the determinacy of equilibrium prices and quantities, and represents the main contribution of the paper. In particular, we show that when consumption is not very intertemporally substitutable (i.e. there are sufficiently strong income effects), near the unique stationary solution there may be a continuum of convergent equilibrium trajectories indexed by the initial conditions of the variables which are not pre-determined. Therefore, although no uncertainty affects fundamentals, the particular equilibrium path which will prevail will crucially depend upon agents’ “states of expectations” and the induced coordination mechanism. Finally, in correspondence to a whole range of agents’ preferences parameters, we observe that deterministic cycles may easily arise close to the steady state.

Similar results, in terms of equilibrium determinacy and deterministic cycles, are observed when the economy, in view of the presence of aggregate externalities in capital utilization, displays long-run growth. As a matter of fact, we observe a continuum of equilibrium trajectories for the growth rate, all of them approaching asymptotically the (unique) balanced one, where quantities grow at a common constant rate, while the real and nominal interest rate as well as inflation are constant.

The mechanisms at the origin of indeterminacy and cycles in both cases is the following. When prices raise, individuals are highly liquidity constrained and investment in capital must expand. This leads to a decline in prices in the following period. When prices decline, individuals’ consumption purchases are higher and production contracts, thus generating an increase in prices in the next period. If consumption were highly intertemporally substitutable, this mechanism would lead to exploding dynamics. On the contrary, a low degree of intertemporal substitution smooths consumption oscillations.

The results we obtain provide additional support to the widely shared view that the existence of multiple equilibria and deterministic fluctuations in competitive economies is not necessarily linked either to the presence of agents maximizing on horizons of life short compared to that of the economy, as in \textit{OLG} models\footnote{See, e.g., Grandmont (1985).}.
2 The model

\[
\sum_{t=0}^{\infty} \beta^t u(c_t), \quad 0 < \beta < 1
\]

Assumption 1 The period utility function \( u : R_+ \rightarrow R \) is smooth, strictly increasing and strictly concave. Moreover \( \lim_{c \to 0^+} u'(c) = +\infty \).
\( p_t c_t \leq M_{t-1} \).

\[ \pi_t \equiv p_t / p_{t-1} \]

\[ i_t \equiv (1 - \delta + r_t) \pi_t \]

\[ u'(c_t) = \beta R_t u'(c_{t+1}) \pi_t / \pi_{t+1} \]

\[ R \equiv (1 - \delta + r) \]

\[ \lim_{t \to +\infty} \beta^t u'(c_t) [k_{t+1} + \pi_{t+1} m_{t+1}] = 0 \]

\[ m_t \equiv M_{t-1} / p_t \]

\[ F(k, l) = l f(a) \quad a \equiv k/l \]

**Assumption 2** The intensive production function \( f : R_+ \to R \) is smooth, strictly increasing and strictly concave. Moreover \( f(0) = 0 \), \( \lim_{a \to 0^+} f'(a) = +\infty \) and \( \lim_{a \to +\infty} f'(a) = 0 \).

\[ r = f'(a) \]

\[ w = f(a) - f'(a) a \]
(1 + μ)0 \hat{M}_0, \quad \mu \hat{M}_{t-1} \\
(1 + \mu)^t \hat{M}_0, \quad \hat{M}_0 \quad t \quad \hat{M} \quad \hat{M}_t = \\
\mu \hat{M}_{t-1} \\
\mu = a = k \\
π_{t+1} = m_t (1 + \mu) / m_{t+1} \\
k_{t+1} + c_t = g (k_t) \\
g (k) \equiv f (k) + (1 - \delta) k \\
\{k_t, c_t, \pi_t\}_{t=0}^\infty (k_t, c_t, \pi_t) >> 0 \quad t = 0, 1, \ldots, \\
g (k_t) - c_t = k_{t+1}, \\
(1 + \mu) c_t = \pi_{t+1} c_{t+1}, \\
u'(c_t)g'(k_t)^{-1} \pi_t^{-1} = \beta u'(c_{t+1})\pi_{t+1}^{-1} \\
k_0 > 0 \\
x \quad (k, c, \pi) \\
G_0 (x_t) = G_1 (x_{t+1}) \\
G_0 \quad G_1 \\
c_0 \\
π_0 \\
β^{-1} - (1 - \delta) \\
f' (k) = \\
\bar{k} \\
f (\bar{k}) - \delta \bar{k} \\
\bar{c} \\
\bar{m} = \bar{c} \\
\bar{π} \\
1 + \mu \\
μ < 0 \\
μ > 0 \\
1 + μ \\
β
3 Indeterminacy and cycles

\[ \{x_t\}_{t=0}^{\infty} \]
\[ k_0 \quad x \]

\[ A = [DG_1(\bar{x})]^{-1} DG_0(\bar{x}) \]

\[ A \]
\[ k_0 \quad n \]
\[ A \]

\[ s = f^{-1} f' \bar{k} \]
\[ \epsilon = -(u')^{-1} u'' \bar{c} \]

\[ \rho = -(f'')^{-1} f'' \bar{k} \]

\[ c \quad \pi \]

\[ \mu \]

\[ \mu_t = R_{t+1} m_{t+1} m_t^{-1} - 1 \]
\[ DG_i(x) \quad i = 1, 2 \]

\[ G_i \quad x \]
\[ \phi \equiv 1 - \beta (1 - \delta) > 0 \]

\[ A \]

\[ A = \begin{bmatrix} \beta^{-1} & -1 & 0 \\ \phi \rho (1 - \epsilon)^{-1} \bar{c}k^{-1} & 1 & -(1 - \epsilon)^{-1} \bar{c} \bar{\pi}^{-1} \\ -\phi \rho (1 - \epsilon)^{-1} \bar{\pi}k^{-1} & 0 & (1 - \epsilon)^{-1} \end{bmatrix}. \]

\[ \epsilon \]

\[ \epsilon \]

**Proposition 1** The linear operator \( A \) has always a real eigenvalue \( 0 < \xi_1 < 1 \). In addition:

(i) if \( 0 < \epsilon < 1 \), then there are either two real eigenvalues \( \xi_2 > 1 \), \( \xi_3 > 1 \) or two complex conjugate eigenvalues \( \xi_2, \xi_3 \) with modulus greater than one;

(ii) if \( 1 < \epsilon < \epsilon_0 \), where

\[ \epsilon_0 \equiv 2 + 2^{-1} \beta \phi \rho (1 + \beta)^{-1} (\theta s^{-1} - \delta) \]

and \( \theta \equiv \beta^{-1} - (1 - \delta) > 0 \), then there are two real eigenvalues \( \xi_2 > 1 \), \( \xi_3 < -1 \);

(iii) if \( \epsilon > \epsilon_0 \) then there are two real eigenvalue \( \xi_2 > 1 \) and \(-1 < \xi_3 < 0 \).

**Proof.**

\[ A \]

\[ P(\xi) = \xi^3 - \left[ 1 + \beta^{-1} + (1 - \epsilon)^{-1} \right] \xi^2 \]

\[ + \left\{ \beta^{-1} + (1 - \epsilon)^{-1} \right\} \left[ 1 + \beta^{-1} + \phi \rho (\theta s^{-1} - \delta) \right] \xi - \beta^{-1} (1 - \epsilon)^{-1}. \]

\[ \epsilon \neq 1 \quad \text{DG}_1 \]

\[ A \]

\[ f'(\bar{k}) = \theta, \quad \frac{\bar{\pi}}{\bar{k}} = \theta s^{-1} - \delta. \]

\[ \bar{\pi}/\bar{k} = f(\bar{k}) \bar{k}^{-1} - \delta \]
Performing simple computations, we obtain
\[
P(0) = -\beta^{-1}(1-\epsilon)^{-1},
\]
\[
P(1) = \phi \rho (1-\epsilon)^{-1} (\theta s^{-1} - \delta),
\]
\[
P(-1) = - (1-\epsilon)^{-1} \left[ (1 + \beta^{-1})(4 - 2\epsilon) + \phi \rho (\theta s^{-1} - \delta) \right].
\]

One can easily verify that
\[
P(0) < 0 \quad P(1) > 0 \quad \epsilon < 1
\]
\[
P(-1) > 0 \quad P(1) > 0 \quad 1 < \epsilon
\]
\[
P(-1) < 0 \quad \left( 1 + \beta^{-1} \right)(4 - 2\epsilon) + \phi \rho (\theta s^{-1} - \delta) < 0
\]
\[
\epsilon > \epsilon_0.
\]

\[
\lim_{\xi \to +\infty} P(\xi) = +\infty \quad \lim_{\xi \to -\infty} P(\xi) = -\infty
\]

(i) \(0 < \epsilon < 1\)
\[
P(1) > 0 \quad \xi_1 \quad \xi \leq 0
\]
\[
D = -P(0)
\]

(ii) \(1 < \epsilon < \epsilon_0\)
\[
|\xi_2| = |\bar{\xi}_2| > 1 \quad \xi_i > 1 \quad i = 1, 2
\]
\[
\xi_1 \quad P(0) > 0 \quad P(1) < 0
\]
\[
\xi_2 \quad P(-1) > 0 \quad \xi_3
\]
\[
(1, +\infty)
\]
\[
(-\infty, -1)
\]

(iii) \(\epsilon > \epsilon_0\)
\[
(\epsilon)
\]
\[
(-1, 0)
\]

Proposition 1 deserves some further comments. Since the elasticity \(\epsilon\) of the marginal utility represents the inverse of the elasticity of intertemporal substitution in consumption, inequality (11) is actually satisfied when consumption is not very substitutable across periods (i.e., when the income effect is strong enough). Indeterminacy, conversely, does not arise for any other configuration of the structural parameters which do not meet inequality (11). In fact, when intertemporal substitutability prevails, the steady state equilibrium always presents the classical saddle-path stability and, so,

\[
\lim_{\xi \to +\infty} P(\xi) = +\infty \quad \lim_{\xi \to -\infty} P(\xi) = -\infty
\]
there exists only one convergent path. Let us also observe that the elasticity 
½
of the real interest rate can be expressed as

\[(1 - s)/\sigma \quad \sigma\]

where \(\sigma\) denotes the elasticity of capital-labor substitution. It follows that the higher substi-
tutable the production inputs are (high \(\sigma\)), the more likely inequality (11) is 
satis…ed, thus indeterminacy to arise.

The change in stability which leads to indeterminacy occurs though a 
‡ip bifurcation: indeed, when \(\varepsilon\) is continuously increased and goes through
\(\varepsilon_0\), there is one characteristic root that goes through \(\chi - 1\). As it is shown,
e.g., in Grandmont (1988), this implies that when \(\varepsilon\) is close to \(\varepsilon_0\), t
h erew i l l generically emerge, according to the direction of the bifurcation, a stable 
or unstable two-period deterministic cycle, in which in‡ation and quantities 
‡uctuate perpetually.

In the next section we extend the analysis of the e¤ects of the cash-in-
advance constraint to the case in which, in view of the presence of external-
ities from physical capital, the economy exhibits long-run growth. We show 
that in close analogy to the benchmark case, equilibrium is indeterminate 
when the elasticity of the marginal utility is su¢ciently high, and that the 
change in stability occurs through a ‡ip bifurcation.

4 Cash-in-advance and growth

\[
\tilde{k} = k \\
w = \psi(k) [f(k) - kf'(k)] \\
\psi(\tilde{k}) F(k, l) \quad \psi' > 0 \\
\psi(k)f(k), \quad r = \psi(k)f'(k)
\]

\[
\frac{1}{\sigma} = \Omega + \rho \quad \Omega \equiv \omega'k/\omega \\
\omega(a)
\]
In order for balanced growth to be possible, the interest rate \( r \) must be constant, condition which requires \( \psi(k) \) to have the form \( Ak^\psi k^\alpha \), where \( A > 0 \), \( \alpha > 0 \), \( \psi > 0 \), and \( \alpha + \psi = 1 \).

\[ w_t = A (1 - \alpha) k_t \]

\[ u(c) = \begin{cases} 
  c^{1-\epsilon}/(1-\epsilon) & \text{if } \epsilon > 0, \epsilon \neq 1, \\
  \ln c & \text{if } \epsilon = 1
\end{cases} \]

\[ \epsilon \]

\[ z_t \equiv c_t/k_t \]

\[ (z, \pi) \]

\[ (1 - \delta + A) z_{t-1}^{-1} - 1 = (1 + \mu) z_{t+1}^{-1} \pi_{t+1}^{-1}, \]

\[ (1 + \mu)^{-\epsilon} \beta (1 - \delta + A \alpha) \pi_t = \pi_{t+1}^{1-\epsilon}. \]

\[ x \]

\[ (z, \pi) \]

\[ V_0(x_t) = V_1(x_{t+1}) \]

\[ V_0 \quad V_1 \]

\[ \{x_t\}_{t=0}^{\infty} \]

\[ k \quad m \quad \pi \]

\[ b \equiv \beta (1 - \delta + A \alpha) \]

\[ a \equiv 1 - \delta + A \]

\[ \bar{c} = a - b^{1/\epsilon} \quad \bar{\pi} = (1 + \mu)/b^{1/\epsilon} \]

\[ \bar{\gamma} = [\beta (1 - \delta + A \alpha)]^{1/\epsilon} - 1. \]

\[ \beta (1 - \delta + A \alpha) > 1 \]

\[ \epsilon > \ln [\beta (1 - \delta + A \alpha)] / \ln (1 - \delta + A \alpha). \]
\[
\mu > (1 - \delta + A\alpha)^{-1} - 1,
\]
\[
\epsilon > \ln \left[\beta (1 - \delta + A\alpha)\right] / \ln [(1 - \delta + A\alpha) (1 + \mu)].
\]
\[
A\alpha < A \quad \bar{z} > 0 \quad \epsilon = 1 \quad \beta < 1 + \mu.
\]
\[
(1 - \delta + A\alpha)^{-1} - 1 < \mu \leq 0.
\]

\[
B = [DV_1(\bar{x})]^{-1} DV_0(\bar{x}).
\]

\[
B = \begin{bmatrix}
\begin{array}{cc}
\frac{a}{b^{1/\epsilon}} & -b^{1/\epsilon} \left(a - b^{1/\epsilon}\right) (1 + \mu)^{-1} (1 - \epsilon)^{-1} \\
0 & (1 - \epsilon)^{-1}
\end{array}
\end{bmatrix}.
\]

\[
\zeta_2 = (1 - \epsilon)^{-1}
\]
\[
\zeta_1 = \frac{a}{b^{1/\epsilon}}
\]

\[
\begin{array}{c}
1 < \epsilon < 2 \\
0 < \epsilon < 1 \\
\epsilon > 2
\end{array}
\]

\[
\begin{array}{c}
\zeta_2
\end{array}
\]

\[
\begin{array}{c}
\zeta_1
\end{array}
\]

\[
\begin{array}{c}
(1, 0)
\end{array}
\]

\[
\begin{array}{c}
(0, -1)
\end{array}
\]

\[
\begin{array}{c}
\epsilon \neq 1.
\end{array}
\]

**Proposition 2** The linear operator \(B\) has always a real eigenvalue \(\zeta_1\) greater than one. In addition:

(i) if \(0 < \epsilon < 1\), then the other (real) eigenvalue is greater than one;

(ii) if \(1 < \epsilon < 2\), then the other eigenvalue is lower than \(-1\);

(iii) If \(\epsilon > 2\), the other eigenvalue belongs to \((-1, 0)\).
Condition $\epsilon > 2$ requires again a low substitutability in intertemporal consumption, i.e. relatively strong income effects. When $\epsilon$ goes through 2, one eigenvalue goes through $-1$ and undergoes a flip bifurcation: accordingly, for $\epsilon$ arbitrarily close to 2, at two periodic cycles will emerge in correspondence to which inflation and the consumption to capital ratio fluctuate forever. Let us finally observe that inequality (18) is perfectly consistent with its analogous in (11): indeed, the elasticity of the interest rate, comprehensive of the externalities, under the Cobb-Douglas specification of the technology here assumed, is equal to zero and so inequality (11) reduces to (18).

5 Conclusion

In this paper we have presented a cash-in-advance economy with productive capital and studied the demand of money and the determinacy of equilibrium prices, interest rates and quantities. Money is dominated by capital in terms of returns but it is held in view of the liquidity services it provides and which can be seen as implicit dividends on the basis of which it is possible to price money as whatever asset. Capital investment determines future production possibilities and thus future income which becomes therefore endogenous, in opposition to previous models à la Lucas in which quantities were given. The return on investment in capital equipment becomes also endogenous since it equalizes the marginal productivity of capital, and this improves models (Svensson (1985), Lucas and Stokey (1987)) in which assets’ yields were given exogenously. The choice among capital and money is made by comparing the opportunity cost (the nominal interest rate) of holding money with the value of its liquidity services and by taking into account that capital proceedings must be re-invested in money before being transformed in consumption.

We have focused on the stationary economy as well as on the economy displaying long-run growth. We have shown that, provided consumption is not very substitutable, the unique steady state as well as the unique balanced growth rate may be indeterminate in the sense that there exists a continuum of equilibrium trajectories converging to them and indexed by the initial conditions of the non-predetermined variables. The mechanisms at the origin of indeterminacy and cycles relies on the expanding effect on capital accumulation of a high price level followed by an opposite contracting effect induced by a successive decline in prices. If consumption were highly substitutable...
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98 - 12 De l’équilibre de sous emploi au chômage d’équilibre :
la recherche des fondements microéconomiques de la rigidité des salaires
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