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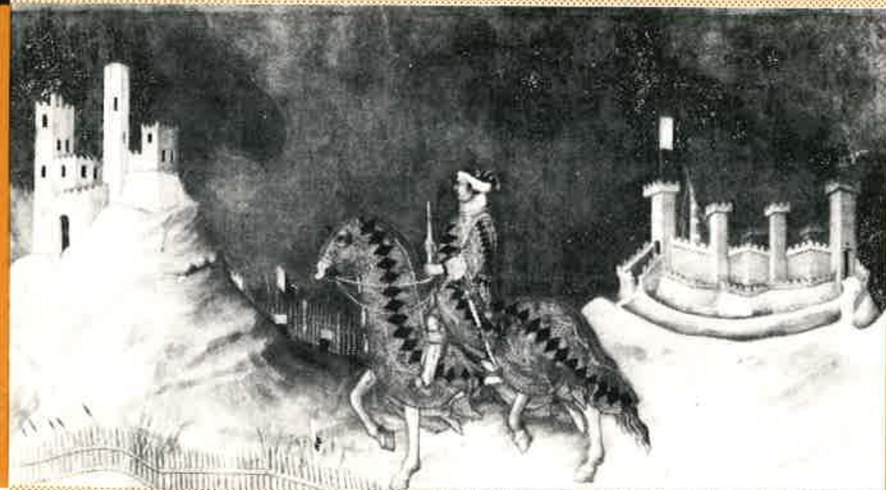
**QUADERNI DEL DIPARTIMENTO
DI ECONOMIA POLITICA**

Giovanni Ferri

PREFERENCES AND TECHNOLOGY IN THE REAL BUSINESS CYCLE



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Giovanni Ferri

PREFERENCES AND TECHNOLOGY IN THE REAL BUSINESS CYCLE

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Giovanni Ferri, Servizio Studi Banca d'Italia - Roma

Introduction

In the recent revival experienced by business cycle theory we have witnessed the acknowledged success of some real equilibrium business cycle (RBC) models[1].

The goodness of fit they have achieved in mimicking U.S. post-war data is noticeable. One might be led to think that now we have a better grasp on the how and why of economic ups and downs -especially if one belives equilibrium theories are capable of rationalizing the phenomenon, as argued by Lucas (1977).

The policy corollary implied by the whole class of equilibrium models of the business cycle is that no counter-cyclical policy is desirable since the observed fluctuations are consistent with agents' optimality. In the originary monetary-misperception equilibrium business cycle model (Lucas 1975) policy actions are feasible though welfare diminishing. In RBC models -implicitly embodying the reverse causation hypothesis proposed after Sims' findings (Sims 1980, 1982)- outside money and the institutions in charge of issueing it are completely disregarded. Such a disruption of traditional policy analysis, I think, is an additional if not a primary reason for inquiring into the robustness of RBC models.

It is certainly reassuring to know that someone, by simulating a micro-consistent optimizing model, has come close to actual macro time series data. However, these papers assume very special features of preferences and technology over time.

I was puzzled in this connection: what is the role of these assumptions in the workings of those models and, isn't

1. The two most interesting contributions we considered in this track of analysis are Kydland and Prescott (1982) and Long and Plosser (1983).

it their introduction that gains us the new grasp on economic fluctuations?

A common presumption maintains that the peculiar time features of preferences and technology embodied in RBC models give no substantial contribution in generating the cycle. The source of the cycling in these models is instead thought to be the existence of exogenous stochastic shocks to technology: "... in the study of Kydland and Prescott (1982) ... the only source of cyclical fluctuations is a technology shock" (McCallum 1986; p. 399). The purpose of the other non-standard assumptions would be just that of "... obtaining a good quantitative match between RBC model implications and actual business cycle fluctuations" (McCallum 1989; p. 13). In other words, it is the stochastic shock to technology that determines the qualitative properties of the model. Only a quantitative role is reserved for the outlined features of preferences and technology.

It is difficult to rigorously draw any conclusion on this respect on the basis of RBC models. Indeed, given their complexity, these models do not lend themselves to easy analytic solutions. Yet, one may try to shed some light on this issue by focusing on a simplified version of the model that embodies analogous features. Accordingly I tried to determine the impact of the referred assumptions on the dynamic properties of a standard model.

In particular, focusing on Kydland and Prescott (1982), I describe the dynamic implications for the model when one superimposes:

(i) a time-to-build technology for capital;
(ii) a form of time-dependence in preference over leisure.

One would like to assess what role each of these assumptions plays in determining the dynamic properties of the model. However, this task is overwhelming because assumptions on preferences and technology are inextricably

tied. Nevertheless, a viable avenue which may be followed is to single out each assumption and measure its impact on the motion of an otherwise standard model. This is the approach taken here.

The first part of this paper establishes global conditions under which introducing a "time-to-build" technology for production of capital goods will have a substantial impact on the dynamic properties of a one-sector growth model. Unless the economy is already at a steady state both consumption and the capital stock will in general exhibit a cyclical behavior.

In the second part I analyze the impact on the dynamics of a standard model associated with embedding in it the hypothesis of time-non-separability for preference over leisure.

In order to keep the problem manageable I was forced to introduce two simplifying assumptions. In the first part capital stocks are determined endogenously, but no intertemporal substitution in labor is allowed -i.e. labor is an exogenous constant. In contrast, in the second part labor is completely endogenous -i.e. there may be intertemporal substitution- whereas the amount of capital is exogenously given. The relevance of my results would be somehow lessened by these exogeneity assumptions if one were to consider the two parts separately. On the other hand, the two results would be strengthening each other when considered together.

In fact, both (i) and (ii) prove to be causes of a fluctuating pattern for the variable they directly affect, when the other factor of production is kept exogenously fixed. An optimal pattern of capital accumulation is likely to be monotonic only if labor supply grows along with capital. On the other hand, if both consumption and leisure are normal goods, labor supply cannot keep growing for ever; rather, at a certain point the agent will increase his leisure. Then, the optimal capital path will necessarily become an oscillatory path. In other words, a shrinking -as opposed to a constant- amount of labor fortifies the case for fluctuations.

Indeed, one should not be astonished by this result. Barro and King (1984) point out that non-time-separable preferences (and also some "richer specifications of intertemporal production opportunities") should be embedded in EBC models to build in autocorrelation over consumption and leisure choices and also Kydland and Prescott (1982) admit that this is the scope for time-to-build and substitution over labor-leisure across time.

My result proves, via a global dynamic analysis, that non-time-separability of preferences over leisure (time-to-build capital is a sufficient condition for generating such an autocorrelation among the flow and stock variables of this simplified model.

Barro and King (1984) justify such a time structure of preferences (and likewise for a non-time-separable technology for capital accumulation) on the grounds of the economic behavior they hypothesize for the rapresentative agent (and for available production techniques). Whereas these assumptions may be accepted or refused on a theoretical level, it is apparent that the only avenue to evaluate how realistic they are lies with little known empirical evidence.

Indeed, even the policy conclusions implied by RBC models that no effective welfare increasing counter-cyclical policy can be performed because there is simply no need for it seem to be weakened by my results. If the simulations of the model gain a good fit to the actual data on the basis of assumptions that are not supported by clearcut evidence, then the associated model is also jeopardized.

Doubts are also cast on the exclusive role commonly assigned to the stochastic shock to productivity in generating the cycle. According to my results, it is clear that the outlined assumptions on preferences and technology do play a part in shaping the qualitative (and not only the quantitative) dynamics of RBC model solutions.

1. Statement of Problem I.

I consider a neoclassical one-sector growth model with a representative agent maximizing utility over an infinite horizon. The agent derives his utility from consumption of the only good in the economy and also form leisure. He has perfect foresight. The single commodity is produced by a concave production function $f(k_{t-2},k_{t-1},l_t)$ which is twice differentiable and increasing in its arguments; where l_t is labor supplied at t, k_{t-2} and k_{t-1} are the capital goods operating at t whose production was originally initiated at t-2 and t-1 respectively. At each point in time the individual has to decide how much to consume out of current output. Saving is identically equal to investment. Unlike the standard one-sector growth model, I assume that a multiperiod technology is used in producing capital goods. s time periods are required to transform the original inputs into new finished capital. Without loss of generality, I set the time-to-build s=2, in order to preserve analytical manageability. Investment projects initiated at t deliver finished capital only at t+2.

The last paragraph can be condensed into the following equation

$$(1.1) \qquad k_t = f(k_{t-2},k_{t-1},l_t) - c_t + (1-g)k_{t-1}$$

where $k_t-(1-g)k_{t-1}$ is gross investment today and g is the rate of depreciation. The same vintage of capital enters production in heterogeneous forms for two periods in a row. First it enters as young (unfinished) capital one time period after its own production started. At this stage it carries out production jointly with the old capital. It contributes to production to a lesser extent than the old capital, but its contribution is nevertheless non-negligible.

Next period (i.e. two periods after they started building it) it will be a fully productive (old) capital, and only then will it pay depreciation at a rate g.[2] The time subscripts attached to each capital stock refer to the time period when its production is undertaken.

The representative agent faces the following intertemporal optimization problem

$$(1.2) \quad \underset{\{k_t, l_t\}}{\text{Max}} \quad \Sigma^{\infty}_{t=1} \; [\; U(c_t) + R(l^{\#} - l_t) \;] \; \beta^{t-1}$$

subject to:

$$(1.1);$$
$$k_t > (1-g)k_{t-1};$$
$$0 < l_t < l^{\#};$$
$$k_0, \; k_1 \text{ given.}$$

$R(.)$ is strictly concave, whereas I take $U(.)$ to be a linear function for the sake of clarity. $l^{\#}$ is the maximum amount of per period work. The discount factor is constrained in the range $0 < \beta < 1$.

The above may be stated as a dynamic programming problem

$$(1.3) \quad W(k_1,k_2) = \underset{\{k_3,l_3\}}{\text{Max}} \; \{f(k_1,k_2,l_3)+(1-g)k_2+R(l^{\#}-l_3)+\beta W(k_2,k_3)\}$$

The value function $W(k_1,k_2)$ is strictly concave since $R(.)$ is strictly concave, and $U(.)$ is concave. Hence, the values k_3 and l_3 in the optimal solution are unique. They only dpend on the set of initial conditions (k_1,k_2) and it is possible to express then as continuous functions

$$k_3(k_1,k_2) \quad \text{and} \quad l_3(k_1,k_2).$$

2. The time-to-build technology assumed in Kydland and Prescott (1982) does not allow for unfinished capital to be productive at all. That would be a limiting case of the model we analyze here.

Accordingly, since at optimum $l_3=l_3(k_1,k_2,k_3)$, (1.3) may be represented as

$$(1.4) \quad W(k_1,k_2) = \underset{\{k_3\}}{\text{Max}} \; \{\; V(k_1,k_2,k_3) + \beta W(k_2,k_3) \;\}$$

or, alternatively,[3]

$$(1.4') \quad W(k_1,k_2) = \underset{\{k_3\}}{\text{Max}} \; \{V(k_1,k_2,k_3)+\beta V(k_2,k_3,k_4)+\beta^2 W(k_3,k_4)\}$$

2. A General Dynamic Property of the Model

Since the capital good is the only stock variable in this economy, the dynamics of the model is characterized by the pattern for accumulation. By using the optimality requirement for the accumulation path it is possible to derive sufficient conditions for the system to obey an oscillatory (monotonic) law of motion through time. These conditions hinge on the properties of the return function $V(k_t,k_{t+1},k_{t+2})$. More specifically, they depend on a particular configuration for the signs of V_{12}, V_{13}, and V_{23} -where V_{ij} represents a second cross-partial derivative of $V(k_t,k_{t+1},k_{t+2})$:[4]

<u>Proposition 1</u>: Consider problem (1.2):

(i) If V_{12}, V_{13}, $V_{23} < 0$, for all $(k_t,k_{t+1},k_{t+2}) > 0$ then an interior optimal trajectory $\{k_t\}$ cannot be strictly monotonic;

(ii) If $[V_{23} + bV_{12}] < 0 \;\; (>0)$ and $V_{13}=0$ for all $(k_t,k_{t+1},k_{t+2}) > 0$ then an interior optimal

3. Henceforth we drop the $\underset{\{k_3\}}{\text{Max}}$ symbol. It is assumed to hold.

4. The type of global analysis used here is related to the one in Benhabib and Nishimura (1985).

trajectory $\{k_t\}$ is strictly oscillatory (monotonic):
$[(k_{t+2} - k_{t+1})(k_{t+1} - k_t)] < 0 \quad (>0) \quad \text{for } k_t \neq k_{t+1}.$

Proof: see appendix.

3. The Impact of the Time-to-build Technology

Here I am going to assume that the representative agent supplies inelastically a fixed amount of labor for each and every period. This is done in order to insulate the impact of the time-to-build technology, while ruling out any possible effect from substitution in leisure.

If we keep labor exogenous, problem (1.2) becomes

(3.1) $\max_{k_t} \Sigma^{\infty}_{t=0}\, c_t\, \beta^t$

subject to:

(3.2) $k_t = h(k_{t-2}, k_{t-1}) - c_t + (1-g)k_{t-1};$

$k_t > (1-g)k_{t-1};$

$k_0,\ k_1$ given.[5]

(3.1) and (3.2) are expressed in per capita variables. l_t is an exogenously given constant which I set equal to one for each and every t. Accordingly, the originary production function $f(k_t, k_{t+1}, l_{t+2})$ collapses to $h(k_t, k_{t+1})$.

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5. When we drop leisure choices from the agent's optimal prob one might think that interiority of solutions is lost. On the contrary, we must point out that although the agent's utility function is linear, consumption itself is strictly concave with respect to past investment decisions due to strict concavity of the production function. Hence, concavity of the problem is always guaranteed as long as we restrict our analysis to strictly concave branches of the production function.

(3.1) may be recast as the dynamic programming problem in (1.4)

(3.3) $W(k_1,k_2) = \max\ \{\ V(k_1,k_2,k_3) + \beta W(k_2,k_3)\ \}$

where $V(k_t,k_{t+1},k_{t+2}) = h(k_t,k_{t-1}) + (1-g)k_{t+1} - k_{t+2}.$

The associated cross-partial derivatives V_{12}, V_{13}, and V_{23} are easily computed:[6]

$V_{13} = V_{23} = 0;$

$V_{12} = h_{12}(k_t,k_{t-1}).$

It turns out that part (ii) of proposition 1 applies to this problem, as long as $h_{12}(k_t,k_{t+1}) \neq 0$.

Let us consider a Cobb-Douglas production function

(3.4) $f(K_t,K_{t+1},l_{t+2}) = K_t^{a_1}\ K_{t+1}^{a_2}\ l_{t+2}^{a_3} \qquad (a_1+a_2+a_3)>0.$

and in my case, assuming constant returns to scale, let it

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6. If we were to let the agent determine labor endogenously as in (1.2) the resulting cross-partials would be:
$V_{13} = V_{23} = 0$ and
$V_{12} = \{f_{12}(k_t,k_{t+1},l_{t+2}) + $
$+[f_{33}(°)+R''(l^{\#}-l_{t+2})]\,\partial l_{t+2}/\partial k_{t+1}\}\,\partial l_{t+2}/\partial k_t.$
where
$\partial l_{t+2}/\partial k_t = -f_{31}/[f_{33}+R''(°)];$
$\partial l_{t+2}/\partial k_{t+1} = -f_{32}/[f_{33}+R''(°)].$
Accordingly, the trajectory for capital will be oscillatory if any of the two following conditions is satisfied:
(I) $f_{13}(°) < 0$ and $f_{12}(°) > f_{23}(°) > 0.$
(II) $f_{13}(°) > 0$ and $f_{12}(°) < f_{23}(°) < 0.$
Both conditions (I) and (II) are compatible with constant returns to scale. We will limit the discussion to the exogenous labor model because the complementarity and substitutability relations among the three factors of production would require a deeper analysis in order for us to draw precise conclusions from (I) and (II).

collapse to[7]

(3.5) $h(k_t,k_{t+1}) = [k_t + bk_{t+1}]^{(a_1+a_2)}$ $b < 1$.

Here I am assuming $b < 1$ in order to be consistent with a time-to-build technology in giving account of the fact that young capitals are unfinished, and do contribute to production to a limited extent. An alternative way of looking at my model would be to interpret it as a vintage growth model. Capital goods would enter production for two consecutive time periods, but would pay a depreciation only in the second period. Young capitals would be more productive than the old ones as the former would supposedly embody a technological progress. The higher productivity of the young capital goods would then be reflected in a $b > 1$, in the above expression (3.5). However, I must point out that my results are robust to this change, and would carry over to the case of b greater than unity.

In general h_{12} is negative, but this result depends on the returns to scale that obtain. If there are constant or decreasing returns to scale, $h_{12}<0$. On the other hand, although necessary, increasing returns to scale are not a sufficient condition for non-negativity of the cross-partial of $h(°)$.

7. Indeed, suppose that if we assume CRS the production function that applies is

$$f(K_t,K_{t+1},l_{t+2})=h(K_t,K_{t+1})l_{t+2}=[K_t+bK_{t+1}]^{(a_1+a_2)}l_{t+2}^{-(a_1+a_2)}$$

and finally,

$$h(k_t,k_{t+1})l_{t+2} = [k_t + bk_{t+1}]^{(a_1+a_2)}$$

this kind of production function takes into account the fact that the contribution to production by the young capital is not the same as the one by the old capital, as $b\neq1$.

Here the cross-partial of $h(°)$ is clearly negative since $(a_1 + a_2) <1$:

$$h_{12}(k_t,k_{t+1}) = b(a_1+a_2)(a_1+a_2-1)[k_t+ bk_{t+1}]^{(a_1+a_2-2)}.$$

The rationale for this result lays with the fact that when I raise the amount of young capital (k_{t+1}) this will have an impact on the marginal product of the old capital via the change in the quantity of the fixed labor factor which joins it for production. The increment in per-capita old capital engenders a tendency for its marginal contribution to production to decrease.

Why is the oscillatory accumulation path optimal for the agent? This may be easily tracked from the first order condition of the problem via a heuristic proof. The agent's choice for any k_t must satisfy the condition

(3.6) $V_3(k_{t-2},k_{t-1},k_t)+\beta V_2(k_{t-1},k_t,k_{t+1})+\beta^2V_1(k_t,k_{t+1},k_{t+2})=0$

Suppose he were to raise k_{t-1}. Since $V_{32}=0$, there would be no impact on $V_3(k_{t-2},k_{t-1},k_t)$ and the only change, as far as k_t is concerned, would be in the marginal benefit of k_t when it enters production as young capital, $\beta V_2(k_{t-1},k_t,k_{t+1})$, which would decline, because $V_{21} < 0$. But then condition (3.6) could only hold if the agent were to lower k_t, whereby increasing its marginal benefit in each one of the three periods. Furthermore, updating (3.6) one period ahead requires

(3.7) $V_3(k_{t-1},k_t,k_{t+1}) +$
$+ \beta V_2(k_t,k_{t+1},k_{t+2}) + \beta^2V_1(k_{t+1},k_{t+2},k_{t+3}) = 0.$

The increase in k_{t-1} would have no impact here since $V_{31} = 0$, but the decline in k_t would raise $\beta V_2(k_t,k_{t+1},k_{t+2})$ as $V_{21} < 0$. Accordingly, k_{t+1} would have to increase in order to preserve the equality in (3.7). In other words, considering that

$$V_3(k_{t-2},k_{t-1},k_t) = V_3(k_{t-1},k_t,k_{t+1}) = -1;$$

$$V_2(k_{t-1},k_t,k_{t+1}) = h_2(k_{t-1},k_t) + (1-g);$$

$$V_2(k_t,k_{t+1},k_{t+2}) = h_2(k_t,k_{t+1}) + (1-g);$$

$$V_1(k_t,k_{t+1},k_{t+2}) = h_1(k_t,k_{t+1});$$

$$V_1(k_{t+1},k_{t+2},k_{t+3}) = h_1(k_{t+1},k_{t+2}),$$

(3.6) becomes

$$(3.6') \quad -1 + \beta[h_2(k_{t-1},k_t) + (1-g)] + \beta^2[h_1(k_t,k_{t+1})] = 0.$$

Raising k_{t-1} lowers the marginal benefit from k_t as a young capital since the marginal product of k_t at time t+1 is decreased as $h_{12} < 0$. Then the only way to satisfy (3.6') is via reducing k_t which will engender higher marginal returns for it both at t+1 and at t+2. By the same token, optimality of the agent's plan requires that also the following be true

$$(3.7') \quad -1 + \beta[h_2(k_t,k_{t+1}) + (1-g)] + \beta^2[h_1(k_{t+1},k_{t+2})] = 0.$$

In other words, having decreased k_t, the agent has an incentive to consume less and invest more at time t+1.

I may conclude that, unless the agent is already at a steady state, both consumption and the capital stock will follow a two-period cycling path. I must then remark that the nature of these fluctuations is solely technological. If it were possible to obtain fully productive capital goods available tomorrow out of investment projects initiated today the optimal accumulation path for the agent would be

monotonic.

It is the presence of the time-to-build technology which, by raising the cost of hedging across time, makes the cycling path for capital optimal to the agent. Therefore, it is evident that introducing such an assumption in the process for building capital is likely to have an impact on the mechanics of the model in which it is embodied.

4. Statement of Problem II.

I consider an economy where an infinitely lived representative agent optimizes his utility across time. At each moment in time the individual enjoys consumption and leisure. There is only one commodity in this economy which is produced according to a concave production function that employs no capital, $f(l_t)$ -alternatively one may think of capital being exogenously given and fixed. The commodity is perishable and no technology is available for carrying it to the future. At each point in time the utility function ios separable and additive in consumption and leisure.

For my specific purposes, I assume that the individual holds time-separable preferences on consumption. This is not the case for leisure. Indeed, the agent's ability to gain utility out of any given amount of leisure today depends on the whole stream of his labor choices during the past n-1 periods. This assumption may be justified on the grounds of being more in line with the prediction of consumer theory[8], although, as I argue, it should be supported also by empirical evidence. Without loss of generality, I set $n = 3$. The agent's objective is to maximize the following

8. See Barro and King (1984) who present a detailed case on this respect.

$$(4.1) \qquad \max_{\{l_t\}} \Sigma^{\infty}_{t=0} \{U(c_t) + \hat{R}[l^{\#} - \Gamma(l_{t-2},l_{t-1},l_t)]\}\beta^t$$

subject to:

$$(4.2) \qquad c_t < f(l_t);$$

$$0 < \Gamma(l_{t-2},l_{t-1},l_t) < l^{\#}; \qquad \Gamma(0) = 0^{9}$$

$$(4.3) \qquad \Gamma_1(°),\Gamma_2(°),\Gamma_3(°) > 0; \quad \Gamma_{12}(°),\Gamma_{13}(°),\Gamma_{23}(°) > 0;$$

$$0 < l_t < l^{\#} \quad \text{(all the above holding for each t);}$$

$$l_{-2},\ l_{-1} \text{ given.}$$

Under usual circumstances[10], the infinite horizon optimization in (4.1) may be formulated as a dynamic programming problem:

$$(4.4) \qquad Z(l_{-2},l_{-1}) = \sup_{\{l_0\}>0} \{Y(l_{-2},l_{-1},l_0) + \beta Z(l_{-1},l_0)\}$$

where $Z(l_{i-1},l_i)$ is the value function of the optimal problem at time i+1, and the return function

$$(4.5) \qquad Y(l_{t-2},l_{t-1},l_t) = \{U[f(l_t)] + R(l_{t-2},l_{t-1},l_t)\}$$

where $R(l_{t-2},l_{t-1},l_t) = \hat{R}[l^{\#} - \Gamma(l_{t-2},l_{t-1},l_t)]$.

In order to characterize the dynamic pattern for consumption, output and employment in this simple economy I am allowed to focus on labor only. In the implicit assumption of a constant intensity of his effort, the agent, in optimizing (4.1), is solely concerned with his flow of dated labors to be supplied. Given his preferences over leisure and consumption, the value of the problem is completely determined by the pattern for his labor supply.

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9. The simplest case I can imagine for function $\Gamma(°)$ is a quadratic time-dependence such as $G(l_{t-2},l_{t-1},l_t) = [al_{t-2} + bl_{t-1} + dl_t]l_t$ for some proper weights a,b,d>0.

10. Boundedness of the utility function, continuity and stric concavity of both utility and production functions.

5. The Impact of Non-time-separable Preferences

I am interested in characterizing how this economy will behave after, for any reason, it is taken away from its rest point. In particular, I am going to ask the following: after a shock occurs, will the agent converge monotonically to the stationary level or will there be fluctuations in his labor supply about its rest point?

In order to answer this question I shall use part (i) of Proposition 1 stated above that provides me sufficient conditions for an oscillatory (monotonic) labor supply pattern after the shock occurs.

In my case, considering (4.5), I obtain:

$$Y_1(l_{t-2},l_{t-1},l_t) = R_1(l_{t-2},l_{t-1},l_t);$$

$$Y_2(l_{t-2},l_{t-1},l_t) = R_2(l_{t-2},l_{t-1},l_t).$$

Hence, I get the following cross-partials:

$$Y_{12} = R_{12}(l_{t-2},l_{t-1},l_t)$$

$$Y_{13} = R_{13}(l_{t-2},l_{t-1},l_t)$$

$$Y_{23} = R_{23}(l_{t-2},l_{t-1},l_t).$$

This result matches with the hypothesis in the proposition above. In fact, Y_{12}, Y_{13} and Y_{23} are all negative[11].

R_{13} and R_{23} measure the impact at the margin of supplying an extra unit of labor today and tomorrow, respectively, on the marginal disutility of working the day after tomorrow, as the agent will perceive it the day after tomorrow. The more he works today -or tomorrow- the higher the marginal utility of leisure, for any given amount, the day after tomorrow.

It is now clear that if I let the agent supply an amount of labor away from its rest point, consumption, output and employment will fluctuate in this simple model. This behavior is optimal for the agent since when $l_t \neq l^*$ it is also the case that $c_t \neq c^*$ (where * labels steady state values).

Because of the autocorrelation in his preferences over leisure, in the near future he will face a higher (lower) negative impact of l_t onto his marginal utility out of leisure, for any given level of l_{t+1} and l_{t+2}. Then, he will have to lower (increase) his supply of labor in order to make up for having "overworked" ("underworked") in the past. Output and consumption will also move in the same direction.

There is no asset available which enables the individual to transfer his wealth across time, whereas his

11. Recall that $R(l_{t-2},l_{t-1},l_t) = \hat{R}[l^\# - G(l_{t-2},l_{t-1},l_t)]$.
Therefore, in the extended form:

$$Y_{12}=R_{12}(l_{t-2},l_{t-1},l_t)=$$
$$=d/dl_{t-1}\{-\Gamma_1(l_{t-2},l_{t-1},l_t)\hat{R}'[l^\#-\Gamma(l_{t-2},l_{t-1},l_t)]\}$$
$$= \Gamma_{12}(°)\hat{R}'[°] + \Gamma_1(°)\Gamma_2(°)\hat{R}''[°];$$
$$Y_{13}= d/dl_t\{-\Gamma_1(°)\hat{R}'[°]\} =-\Gamma_{13}(°)\hat{R}'[°]+\Gamma_1(°)\Gamma_3(°)\hat{R}''[°];$$
$$Y_{23}= d/dl_t\{-\Gamma_2(°)\hat{R}'[°]\} =-\Gamma_{23}(°)\hat{R}'[°]+\Gamma_2(°)\Gamma_3(°)\hat{R}''[°].$$

Provided conditions (4.3) are satisfied and $\hat{R}[l^\#-\Gamma(°)]$ is concave, Y_{12}, Y_{13}, Y_{23} < 0.

preferences are correlated over time. As a result, whenever he starts out supplying an amount of labor other than the one associated with a stationary behavior the only impact onto his future lies with the associated change in tomorrow's problem state variable, l_t. On its turn this change will modify the terms of substitution between consumption and leisure in the near future.

6. Concluding Remarks.

In the light of my results I may conclude that, in general, assuming a time-to-build technology for capital and non-time-separability in preferences over leisure engenders fluctuations in the model. Therefore, unless conclusive evidence is supplied, introducing these assumptions seems improper. Otherwise, we might just be dealing with an interesting exercise but one unable to enhance our understanding of business cycles.

Indeed, even the policy conclusions implied by RBC models that no effective welfare increasing counter-cyclical policy can be performed seem to be weakened by my results. If the simulations of the model gain a good fit to the actual data on the basis of assumptions that are not supported by clearcut evidence, then the associated model is also jeopardized.

It is my hope that the results described will provide an additional stimulus for a thorough micro-empirical research on the time structures of technology in the capital goods sector and of consumers' preferences over time.

Doubts are also cast on the exclusive role commonly assigned to the stochastic shock to productivity in generating the cycle. According to my results, it is clear that the outlined assumptions on preferences and technology do play a part in shaping the qualitative (and not only the quantitative) dynamics of RBC model solutions.

APPENDIX

Consider the problem,

$$W(k_{-1},k_0) = \underset{\{k_t\}>0}{\text{Max}}\ \Sigma^{\infty}_{t=0}\ \beta^t V(k_{t-1},k_t,k_{t+1})$$

$$= \underset{\{k_1\}>0}{\text{Max}}\ \{V(k_{-1},k_0,k_1) + \beta W(k_0,k_1)\}$$

$$= \underset{\{k_1,k_2\}>0}{\text{Max}}\ \{V(k_{-1},k_0,k_1) + \beta V(k_0,k_1,k_2) + \beta^2 W(k_1,k_2)\}$$

I introduce two different sets of initial conditions: $\{k_{-1},k_0\}$ and $\{k'_{-1},k'_0\}$. Let k_1 and k_2 be the optimal choices from $\{k_{-1},k_0\}$ and k'_1 and k'_2 be the optimal choices from $\{k'_{-1},k'_0\}$.

If $k_{-1} \neq k'_{-1}$ or $k_0 \neq k'_0$ the following two inequalities must hold

$$\text{(A1)}\quad \{V(k_{-1},k_0,k_1) + \beta V(k_0,k_1,k_2) + \beta^2 W(k_1,k_2)\} \geq$$
$$\geq \{V(k_{-1},k_0,k'_1) + \beta V(k_0,k'_1,k'_2) + \beta^2 W(k'_1,k'_2)\};$$

$$\text{(A2)}\quad \{V(k'_{-1},k'_0,k'_1) + V(k'_0,k'_1,k'_2) + \beta^2 W(k'_1,k'_2)\} \geq$$
$$\geq \{V(k'_{-1},k'_0,k_1) + \beta V(k'_0,k_1,k_2) + \beta^2 W(k_1,k_2)\}.$$

Summing up (A1) and (A2) yields, after simplification and regrouping,

$$\text{(A3)}\,[V(k_{-1},k_0,k_1)-V(k_{-1},k_0,k'_1)]+[V(k'_{-1},k'_0,k'_1)-V(k'_{-1},k'_0,k_1)]$$
$$+\beta\{[V(k'_0,k'_1,k'_2)-V(k'_0,k_1,k_2)]+[V(k_0,k_1,k_2)-V(k_0,k'_1,k'_2)]\}\geq 0.$$

Condition (A3) may be restated in integral notation as

$$\text{(A4)}\quad \{ \int_{k'_1}^{k_1} [V_3(k_{-1},k_0,s_1)-V_3(k'_{-1},k'_0,s_1)]ds_1 +$$
$$+ \beta \int_{k'_0}^{k_0} [V_1(s_0,k_1,k_2)-V_1(s_0,k'_1,k'_2)]ds_0 \} > 0.$$

By adding and subtracting:

(i) $\int_3(k_{-1},k'_0,s_1)$ in the first integral;

(ii) $\int_1(s_0,k'_1,k_2)$ in the second integral,

I obtain

$$\int_{k'_1}^{k_1} \{V_3(k_{-1},k_0,s_1)-V_3(k_{-1},k'_0,s_1)+V_3(k_{-1},k'_0,s_1)-V_3(k'_{-1},k'_0,s_1)\}ds_1+$$
$$\text{(A5)}$$
$$+\beta\int_{k'_0}^{k_0} \{V_1(s_0,k_1,k_2)-V_1(s_0,k'_1,k_2)+V_1(s_0,k'_1,k_2)-V_1(s_0,k'_1,k'_2)\}ds_0 \geq 0.$$

Finally, condition (A5) may be restated in a more convenient form as

$$\{ \int_{k'_1}^{k_1}\int_{k'_0}^{k_0} V_{32}(k_{-1},s_0,s_1)ds_0 ds_1 + \int_{k'_1}^{k_1}\int_{k'_{-1}}^{k_{-1}} V_{31}(s_{-1},k'_0,s_1)ds_{-1}ds_1 +$$
$$\text{(A6)}$$
$$+ \beta\{ \int_{k'_0}^{k_0}\int_{k'_1}^{k_1} V_{21}(s_0,s_1,k_2)ds_0 ds_1 + \int_{k'_0}^{k_0}\int_{k'_2}^{k_2} V_{31}(s_0,k'_1,s_2)ds_0 ds_2\} \geq 0.$$

(A6) must be satisfied if the path $\{k_t\}$ is to be optimal. By using condition (A3) I can infer some important restrictions on the shape of the trajectory for capital accumulation. These restrictions depend on the particular configuration of the cross-partials V_{12}, V_{13}, and V_{23} of the return function.

Part (i): If, as in part (i) of the proposition, I have

$$\text{(A7)}\qquad V_{12} < 0, \qquad V_{13} < 0 \quad \text{and} \quad V_{23} < 0$$

I proceed as follows.

Consider the two different sets of initial conditions $\{k_{-1},k_0\}$ and $\{k'_{-1},k'_0\}$ such that $k_{-1}<k_0$ and $k'_{-1}<k'_0$. Then, without loss of generality, I may set $k_{i+1}=k'_i$. Hence, the two paths, if monotonicity holds, will yield

(A8) $k_{-1}<k'_{-1}; k_0<k'_0; k_1<k'_1; k_2<k'_2$ (or $k_{-1}<k_0<k_1<k_2<k_3$).

If (A6) holds, not all inequalities in (A8) can be satisfied at the same time, otherwise condition (A6) would be violated. Therefore, the optimal trajectory cannot be strictly monotonic, as in (A8).

Part (ii): If $V_{13} = 0$, $V_{12} \leq 0$ and $V_{23} \leq 0$ (not being both zero), then (A6) becomes

(A9) $\int_{k'_1}^{k_1}\int_{k'_0}^{k_0} \{V_{32}(s_0,s_1) + \beta V_{21}(s_0,s_1)\}ds_0\, ds_1 > 0.$

Thus, if $[V_{23} + \beta V_{12}] < 0$, $k'_0 > k_0$ implies $k'_1 > k_1$. (An argument -just identical to the heuristic proof of the two-period cycling in the text- involving the first order conditions shows that the equality cannot hold if $[V_{23} + \beta V_{12}] \neq 0$). Now if I set $k'_0=k_1$, it follows that $k_2=k'_1$ and $k_1>k_0$ implies $k_2<k_1$.

The proof for the monotonic case with $[V_{23} + \beta V_{12}] > 0$ is identical.

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