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ENVIRONMENTAL RESOURCES, PUBLIC INPUTS AND FISCAL CONSTRAINTS

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Abstract:

We study the consequences of a binding constraint on the level of public expenditures directed at sustaining an environmental resource, which enters as a public input (alongside capital) into the economy-wide production function. As expected, the long run stock of that resource is reduced; however, we also find that the long run capital stock is reduced in a larger proportion. Also, the capital-environmental resource ratio becomes sensitive to changes in the rate of interest.

1. Introduction

Environmental resources are crucial regenerating assets of any ecönomy[1]; they are normally involved in the most serious intertemporal misallocation problems in both industrialized and developing countries. One standard presentation is the so called problem of the control of pollution[2] where the output coming from a given production process raises the rate of depletion of a renewable resource, having a direct impact on the welfare (consumption) of economic agents. This effect competes against expenditures on "clean-up" activities that are usually financed by the public sector due to the common property nature of the resource in question. Thus, this paradigm-example emphasizes two crucial dimensions in the control of these resources: the level of production inducing a reduction of the stock *vis-à-vis* the (level or) rate of expenditures and other activities that help at regenerating resources. This allows some speculation on the relationship between growth and environmental resources; in particular, it is accepted that the latter are in danger of being misused in contexts characterized by fast growth and very low efforts directed at controlling resources. Perhaps a too direct extension of this reasoning to most Latin American countries could lead some to believe that we should not worry too much about environmental hazards given the stagnation and de-industrialization process that has taken place during the eighties: only a modest policing on the evolution of those resources would be enough to guarantee the absence of overuse; later in the future, when growth resumes, we could calibrate this policy according to the situation.

There are, however, good reasons to be skeptical about the previous argument (see Dasgupta (1982, pp. 169)). Among the possible lines of qualification, in this paper we have chosen to stress the role of public expenditures in the maintenance of a sustainable rate of use of environmental resources. We are led to this view given the fiscal nature of the adjustment process of most Latin American economies to the debt crises, which involves a drastic across the board reduction of public sector activities. Under severe fiscal constraints the economy may be "spending" too little in the maintenance of resources inducing a too fast use of them even in a stagnated economy; more generally, a binding fiscal constraint may have important allocative implications.

We address these issues in a simple model specified, for our purposes, with some different features from the one mentioned above. First, we see environmental resources as public *inputs* affecting (alongside capital) production (instead of consumption)[3]. In turn, we maintain the fact that the level of output reduces the available stock of environmental resources over time and that this can be attenuated by some public spending directed at the regeneration of the stock. We first address the nature of the stationary solution of the model deriving the rules for optimal allocation and some dynamics. Then, we proceed to examine a regime where public spending meets a constraint and the economy has to adjust to this situation. We are able to obtain results concerning the way both capital and the environmental resource long run stocks are affected by this constraint; more precisely we show that both long run stocks are reduced to accommodate a lower output level compatible with the sustainability of the environmental resource; moreover, the steady state capital-environmental resource ratio decreases. In addition, changes in the rate of interest are no longer neutral concerning that long run ratio.

2. Environmental Resources and Public Inputs

We start with a simple model of an economy which seeks the maximization of the present value of utility U(C), where C is consumption. All variables are defined in per-capita terms and, to simplify computations, we further assume that the population is not growing. We will consider time as a continuous variable and, for simplicity, all time subscripts will be suppressed. Time separability of U(•) allows us to write

$$\int_0^{\infty} U(C).e^{-rt}\ dt \tag{1}$$

The economy operates with a production function

$$Y = F(K,S) \tag{2}$$

where K is capital and S the stock of a renewable resource[4]. This resource is used in the production process but its rate of depletion is, in turn, affected by the level of output. We can think of S as an environmental resource like a river, lake, a forest or the atmosphere. Thus, we have that S evolves in time according to

$$\dot{S} = -\delta.F(K,S) + G \tag{3}$$

where $\dot{S}$ = dS/dt (all time derivatives are denoted by the dot), $\delta \in (0,1)$ is a constant, and G is the level of public expenditure directed at S. Finally, we take the aggregate macro-identity

$$Y = C + \dot{K} + G \tag{4}$$

The problem is then formally to maximize (1) subject to (3) and (4)[5]. The optimal plan is obtained from the following Hamiltonian

$$H = U(C).e^{-rt} + \lambda_1\ [F(K,S) - C - G] + \lambda_2\ [-\delta.F(K,S) + G] \tag{5}$$

which gives the standard conditions

$$U'(C).e^{-rt} - \lambda_1 = 0 \tag{6}$$

$$\lambda_1.F_S - \lambda_2.\delta.F_S = -\dot{\lambda}_2 \tag{7}$$

$$\lambda_1.F_K - \lambda_2.\delta.F_K = -\dot{\lambda}_1 \tag{8}$$

$$-\lambda_1 + \lambda_2 = 0 \tag{9}$$

where $F_s = \partial F/\partial S$ and $F_k = \partial F/\partial K$[6]. From expression (6) we obtain the time derivative

$$\dot{\lambda}_1 = (-r.U' + U''.\dot{C})e^{-rt} \tag{10}$$

where $U' = \partial U/\partial C>0$; $U'' = \partial^2 U/\partial C^2<0$. Taking into account (8) and (9) we have

$$-\dot{\lambda}_1 = \lambda_1(1-\delta)F_K \tag{11}$$

Substituting (10) into (11) and arranging terms we get

$$\dot{C} = [(1-\delta)F_K - r]/v \tag{12}$$

where v is the absolute degree of aversion to consumption variability $-U''/U'$.

Let us first characterize the steady state solution. From (12) we have

$$r = (1-\delta).F_K^* \tag{13}$$

that is, the rate of time preference (interest) is equated to the physical marginal productivity of capital *net* of its effect (through output) on the stock of the environmental resource.

Moreover, we also know that consumption is stabilized at a level C* which, using (3) and (4) with $\dot{S} = \dot{K} = 0$ is

$$C^* = (1-\delta).F(K^*,S^*) \tag{14}$$

The steady state level of S is found by first noting that (9) implies $\dot{\lambda}_1 = \dot{\lambda}_2$ and therefore

$$F^*_K = F^*_S \quad (15)$$

Both marginal productivities must be the same and, moreover, given the structure of the model, this result is valid even outside the steady state. This last condition results from the feasibility of continuous arbitrage between both "types" of capital, K and S. Precisely, the role of public expenditure is to allow this process.

Assuming, for example, a Cobb Douglas specification for F(•) we further obtain that both K and S should evolve in a complementary way, i.e. if $F = K^{\alpha}.S^{\beta}$ we should observe[7].

$$\alpha.S = \beta.K \quad (16)$$

Thus, with (16) we can study the dynamic process of the model forming a system in $\dot{C}$ and $\dot{K}$. From (12) we can write

$$\dot{C} = [1-\delta).F_K(K, \beta.K/\alpha) - r]/v \quad (17)$$

And substituting (3) into (4), solving for $\dot{K} + \dot{S} = \dot{K}(1+\beta/\alpha)$ we get

$$\dot{K} = [(1-\delta).F(K, \beta K/\alpha) - C].\alpha/(\alpha+\beta) \quad (18)$$

The Jacobian for system (17) - (18) can be shown to have positive trace and negative determinant and so the system has a locally stable saddle point (see the Appendix).

To sum up, in this simple model public expenditure is adjusted so that the marginal productivity of the environmental resource equates that of physical capital (see condition (9)) and in turn both are equal to the net rate of interest $r/(1-\delta)$. In the following section we study a regime where $\dot{G}$ cannot be freely adjusted.

3. Implications of a Fiscal Constraint

One crucial feature of the previous model is that public expenditure in the environmental resource can be adjusted without restriction and the precise level of G is endogenously determined. In the steady state G is stabilized at.

$$F(K^*,S^*) - C^* = \delta.F(K^*,S^*) = G^* > 0 \quad (19)$$

Suppose instead that there exists a permanent constraint in the level of public expenditure $\bar{G} < G^*$. This means that we lose expression (9) of the previous section and that the equality between marginal productivities (expression (15)) is no longer guaranteed –as shown below–. From (6) we obtain again (10); taking $\dot{C} = 0$ to examine the steady state and substituting into (8) we obtain

$$\lambda_2 = (F_K - r).U'(C).e^{-rt}/\delta.F_K \quad (20)$$

Using this expression we can write (7) as

$$\left\{U'(C) - \delta\ [(F_K - r).U.(C)/\delta.F_K]\right\} F_S e^{-rt} = r.e^{-rt}.U'(C)\ (F_K - r)/\delta.F_K \quad (21)$$

and solving this expression we obtain

$$r = F_K - \delta.F_S \quad (22)$$

The presence of a constraint in the level of public spending in the resource has implications for the optimal rule that determines the stocks K and S. A reduction in G below (19) means that the product has to adjust downwards, so that

$$\delta.F(\bar{K},\bar{S}) = \bar{G} \quad (23)$$

is satisfied. Differentiating (22 - (23) with respect to the constraint $\bar{G}$ and to the rate of interest r we obtain:

$$dK/d\bar{G} > 0 \qquad dS/d\bar{G} > 0 \qquad d(K/S)/d\bar{G} > 0^{8}$$
$$dK/dr < 0 \qquad dS/dr > 0 \qquad d(K/S)/dr < 0 \quad (24)$$

Both K and S have to be reduced to achieve the lower output level $\bar{G}/\alpha$, but the reduction of capital K must be higher than that of the environmental resource S; in other words, the fiscal constraint induces a lower capital-environmental resource ratio, even in a case where the assumed technology (Cobb-Douglas) dictated before a unique K/S ratio equal to α/β (see expression (16)). Furthermore, the second part of (24) shows the non neutrality of the rate of interest to this ratio; in particular the long-run complementarity between K and S for all rates of interest is no longer valid: an increase in r still reduces the optimal K but now increases the optimal stock of the environmental resource.

The fact that the K/S ratio is lower with $\bar{G} < G^*$ implies that $\bar{F}_K > \bar{F}_S$ and so expression (15) no longer holds[9]; thus the optimal rule (22) cannot be expressed as (13). Rather, the evaluation of the optimal K and S should now take into account expression (23), which fixes the level of output.

4. Concluding Remarks

The main formal result of this paper, stated in the previous section, is that the presence of a binding constraint on the level of public expenditures directed at sustaining an environmental resource has noticeable implications in the allocation of both capital and that resource. First, binding fiscal restrictions tend, as expected, to reduce the long run stock of the environmental asset. Less obviously, the stock of capital in the long run is also reduced, in a larger proportion, implying a lower long run capital-environmental asset ratio. Finally, an increase in the rate of interest has a negative impact upon that steady state ratio.

These effects may go in the same direction in the case of highly indebted Latin American economies: rationing in international credit markets and very high domestic interest rates have gone together with a hard fiscal constraint, due to the high proportion of the external debt held by governments. This implies that, according to our previous results, these economies will be facing a lower capital/environmental resource ratio than in the absence of those constraints. In other terms, the presumption derived from our analysis is that if "initial conditions" of actual economies show that capital is scarce relative to environmental resources (a low K/S ratio), and a low expenditure-high interest rate regime prevails, development plans should pay attention to possible inconsistencies created by sharp reductions in S or by policies inducing a relatively fast capital growth. An important corollary of our analysis is that myopic policies oriented to lower public expenditures may not only lead to a depletion of environmental resources, but also affect the long-run capital stock through the reduction of the availability of those natural resources.

The significance of public sector adjustment to low expenditures in the discussion of environmental control is a topic that cannot be neglected. That even a stagnated economy can be negatively affected by this policy has been one of the motivations of this paper. For a stagnated output only means a relatively smaller rate of depletion of the resource; but that is only one dimension of the problem. From equation (3) it is clear that a sustainable stock of the environmental asset implies an expenditure/output ratio equal to δ. It is reductions from this threshold which put the economy in conflict with the maintenance of resources and, eventually, of output levels. Stagnation does not seem a promising way out of this conflict, in particular if it aggravates the fiscal gap.

Appendix

First of all, it will be shown that the differential system (17)-(18) exhibits a saddle path solution in a neighborhood of the steady state. The determinant of the Jacobian matrix is

$$\det(J) = (1-\delta)[F_{KK} + \beta F_{KS}/\alpha]\,(\alpha/\alpha+\beta) \qquad \text{A.1)}$$

In the particular case of the production function $F = K^{\alpha}S^{\beta}$ this expression becomes

$$\det(J) = (\beta\alpha/\alpha+\beta)\,(1-\delta)\,K^{\alpha-1}\,S^{\beta-1}\,(\alpha+\beta-1) \qquad \text{(A.2)}$$

which is negative under our assumption $\alpha + \beta < 1$.

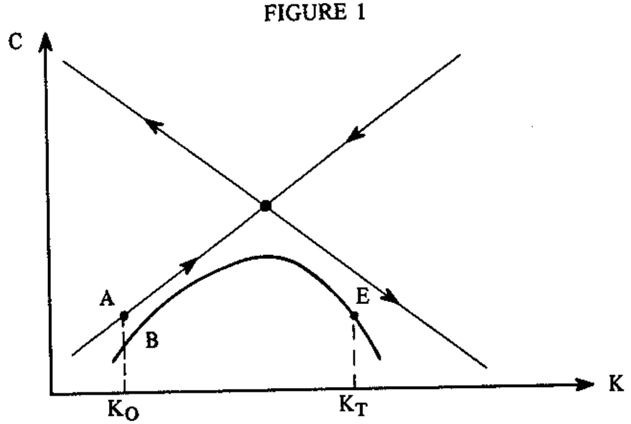
Therefore, we have a saddle point and, moreover, it can be shown that the path slopes upwards. This result is obtained computing

$$(1-\delta)[F_{KK} + \beta F_{KS}/\alpha]/\mu_1 > 0$$

where μ_1 is the negative eigenvalue associated to the Jacobian matrix.

Figure 1 depicts the main dynamics properties of our system.

FIGURE 1



Given the initial levels K_0 and S_0, private consumption and government expenditure are accommodated to reach the path at A through instantaneous changes in $\dot{K}$ and $\dot{S}$.

Notice also the interesting features of a trajectory that moves the economy from B to E. This could be the case of an optimal accumulation process with fixed time and capital end values. Recall that on the optimal path $K/S = \alpha/\beta$ and assume that K_0 is too low compared to S_0 to meet that condition –as would be the case of a typical LDC. Therefore, the optimal solution will involve an initial reduction of S by increasing C and lowering G but, from that moment on, S will be growing at the same rate as K. However, this program will fail if a constraint on G is exogenously imposed and, sooner or later, K will have to be reduced accordingly.

Regarding our second model (with $G = \overline{G}$), its dynamics are much more difficult to study since we have lost equation (15). From equations (3), (4), (6), (7) and (8) the following system of equations can be constructed:

$$\begin{aligned}
\dot{\sigma}_1 &= (r - F_K)\sigma_1 + F_K\sigma_2,\\
\dot{\sigma}_2 &= -F_S\sigma_1 + (r + \delta F_S)\sigma_2,\\
\dot{K} &= F(K,S) - w(\sigma_1) - \overline{G},\\
\dot{S} &= -\delta F(K,S) + \overline{G},
\end{aligned}$$

where σ_i is the current value of λ_i and $w(\sigma_1)$ is the inverse of $u'(c) = e^{rt}\lambda_1$.

Assume $r = 0$ (the traditional Ramsey problem); then it can be shown that the eigenvalues of the Jacobian matrix are:

$$\mu_1 = F_K,\ \mu_2 = -\delta F_S,\ \mu_3 = \mu_4 = 0$$

Recalling that from the necessary conditions (at the steady state): $F_K = \delta F_S$, we get $\mu_1 = -\mu_2$. This is the Samuelson-Kurz result (see Kurz (1968)).

When there is discounting we can show that negative as well as positive roots exist.

The characteristic equation is:

$$\begin{aligned}
H(\sigma) = {} & \sigma^4 - 2r\sigma^3 - (\delta F_S F_K - r^2 - rw' F_{KK}/F_K)\sigma^2 - \\
& - (-\delta F_S F_K + rF_{KK}w'/F_K)\,r\sigma - \delta rw'[\delta F_K F_{SS} - \\
& - (F_K + F_S)F_{KS} + F_S F_{KK}] = 0,
\end{aligned}$$

and it can be seen that $H(0) < 0$ and $H > 0$ when $\sigma \to \pm\infty$ Therefore, at least a negative a positive root exist. Following Levhari and Liviatan (1972), if σ_i is a root also is $r - \sigma_i$, and consequently, all roots are real numbers. Notice also that the trace of the Jacobian matrix is $2r > 0$. To summarize, global asymptotic stability does not exist, we do not have complex roots (oscillatory trajectories) and it is possible to converge to the steady state since at least a negative root will be present.

Notes:

1 For a clear up to date exposition of the economics of environmental resources, se Mahler (1989).

2 See Dasgupta (1982, ch.8). Of course this is only one among the many dimensions of the control of environmental resources, as lucidly presented in that book.

3 We do not deny the importance of a "pollution like" effect in actual situations; rather, we are aware of reports that suggest that the most immediate environmental hazards, in some stagnated Latin American economies, may come from deteriorated living conditions of low-income groups (see, for example, CEPAL (1990)). Still, we prefer to concentrate in this, to our knowledge, less studied case. Even so, incorporating that effect would not change too much our point although it complicates the formal analysis.

4 If all variables except S were defined in per-capita terms; the form of F(•) in (2) would be equivalent to assuming that the production function is characterized by constant returns to scale in capital and labour *only* (the "primary" inputs). The introduction of S means that, by Euler's theorem, since the economy product is exhausted after payments to labour and capital are made, "Lindahl pricing" (i.e. a set of user chargés for S) is unfeasible as a way to finance S (see Feehan (1989)). Nevertheless, we do not make explicit the public finance (i.e. distorionary taxation) problem behind the model.

5 From this formulation, it is clear that we are abstracting from dynamic fiscal policy considerations by not allowing the government to issue debt instruments. Nevertheless, in this section, we assume that G can be financed, at any level, period by period with current taxes; in the next section we add a further constraint to this scheme so G will be exogenously given. A similar analysis, replacing traditional government iso-perimetric by instantaneous constraints is used by Chisari and Fanelli (1990) to discuss optimal growth trajectories in fiscally constrained regimes.

6 In addition, we have the transversality conditions

$$\lim_{t\to\infty} \lambda_1 K = \lim_{t\to\infty} \lambda_2 S = 0$$

7 In the appendix, we futher assume that $\alpha + \beta < 1$ in order to have a dynamically stable model. In terms of the assumption discussed in footnote 4, F would be homogeneous of degree $1 + \beta$ in all factors of production.

8 For our case, we have that

$F_K - \delta . F_S = r$ can be writen as

$\alpha . K^{\alpha-1} . S^{\beta} - \delta . \beta . K^{\alpha} . K^{\beta-1} = r$ and

taking $K^{\alpha-1} . S^{\beta-1}$ as common factor, multiplying both sides by K.S and using $F = G/\delta$ we obtain

$(\alpha/K) - \delta . (\beta/S) = r . \delta/G$

Thus an increase in G must be accommodated with an increase in K/S.

9 For our Cobb-Douglas case, we have

$F_K/F_S = \alpha . S/\beta . K > \alpha . S^*/\beta . K^* = F^*_K/F^*_S = 1.$

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A MODEL OF RESOURCE CONSERVATION FOR RURAL SUBSISTENCE HOUSEHOLDS

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Abstract:

This paper presents a dynamic model of a rural household that is economically dependent on the exploitation of a renewable natural resource. A special feature of the model is that resource utilization decisions are interrelated with consumption and work. It is shown that the existence of an income effect in resource stock and price changes is important to understand household behavior. Resource usage, for example, can decline as a result of a larger resource stock. It is also shown that under binding subsistence constraints taxation of the rural sector not only negatively affects rural household economic welfare, but also environmental resources.

Introduction

Apart from the traditional concerns expressed by ecologists and biologists, degradation of the natural environment has recently come to be thought as an important economic problem facing developing countries. There exists a growing concern by international agencies and policy makers about the management of environmental resources in the less prosperous and ecological more sensitive areas of the world. Over exploitation of the natural base has been specially critical in poor communities, which depends on the usage of the resource to reach minimun levels of subsistence.

Most of the theoretical work on optimal patterns of resource exploitation assumes a perfect capital market. In these models the production decisions of the household are independent of consumption and work. Examples of important contributions that follows this assumption are Dasgupta and Heal (1979), Clark (1985), and Baumol and Oates (1988). This approach is specially inappropiate in explaining conservation practices by small farmers in developing countries. Small landholders are subject to severe financial constraints, and consumption and work decisions are clearly interrelated to the level of