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 <u>only</u> (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 charges 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

$$\text{lím}_{t\to\infty} \lambda_1 K = \text{lím}_{t\to\infty} \lambda_2 S = 0$$

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 usage of environmental resources. An indication of this interaction is the considerable diversity in resouce conservation practices existing in rural areas of developing countries.

The integration of consumption, work, and resource explotation decisions is also important to explain the positive relationship between resource degradation and work effort, emphasized in influential studies on the consequences of population growth. Pingali and Binswanger (1985), for example, found that degradation of natural forests and natural fertility of the soils as a result of population growth, is followed by higher level of labor effort used in fuelwood gathering and food crop production. Boserup (1965, 1980) suggested that this effect and the economies of scale asociated with higher population densities, are an important determinant of agricultural intensification and modernization.

This paper is an extension of the farm-household model, developed by Sen (1974), and specially Lopez and Chambers (1983), to analyze the decisions of a rural household highly dependent on the usage of renewable natural resources. In the first part of the paper the model and the conditions for optimality are presented. Comparative dynamic experiments are then used to examine the effect of several gevernment policies on output and labor supply, and resource conservation. Finally, the effects of subsistence level of consumption and leisure on resource exploitation practices are discussed.

The Model

Rural households are considered to maximize intertemporal utility subject to the technology available, exogenous and constant input and output prices, the initial stock and the capacity of natural growth of the resource. The rural household is assumed to be isolated in the sense that there are no capital and resource markets. Formally this maximization problem can be represented as follows:

$$(1)\quad \underset{s,l}{\text{Max}} \int_0^\infty e^{-\delta t}\, u\,(c(t),\, H-l(t))\, dt$$

subject to

(i) $c(t) = \pi\,(p, w, s(t), x(t)) + y + wl\,(t)$

(ii) $x(t) = k\,(x(t)) - s\,(t)$

(iii) $c(t) \geqslant \bar{c},\ H-l\,(t) \geqslant \bar{L}$

(iv) $x(0) = x_o$

where u(•) is a twice differentiable, strictly concave instantaneous utility function; c(t) is consumption at time t; l(t) includes both on-farm and off-farm work and δ is the rate of time preference. Assuming pure compensation the natural growth of the resource increase with the stock level at a decreasing rate i.e., $k_{xx} < 0$, and $k(0) = K(\bar{x}) = 0$ where $\bar{x}$ is the saturation level. The usage of the resource is represented by s(t) and the subsistence level of consumption and leisure by $\bar{c}$ and $\bar{L}$ respectively.

The net farm income given the resource stock level and rate of exploitation is given by the restricted profit function defined as:

$$(2)\quad \pi(p, w, s, x) = \text{Max}\,(pq - wx\colon (q, t)\ \epsilon\, \tau(q, l, s, x))$$

τ (•) represents the production possibilities for given levels of the stock and usage of the resource. It can be shown that given certain general properties of τ (•) the function π(•) is twice differentiable, convex in p and w, non-decreasing in output prices and non-increasing in input prices (Diewert, 1974). The π(•) function is also non-decreasing in the stock and usage of the resource, reflecting their positive contribution to the net income generated by the household. Another natural assumption is that stock and resource usage are complementary, i.e., $\pi_{xs} > 0$. For a forest resource this implies that the value of a cubic meter of timber increases with tree size. Besides, the solution of the intertemporal problem requires that π(•) must be strictly concave in s and x.

The constrained current value Hamiltonian associated with 1 is:

$$(3)\quad H = u\,(\pi\,(p, w, s, x)) + y + wl, H-l) + \mu\,(k(x) - s) \\ + \lambda\,(\pi(p, w, s, x) + y + w(H-l) - \bar{c}) + \theta\,(H-l-\bar{L})$$

where μ is the current value costate variable, and λ and θ are Lagrangian multipliers. Necessary and sufficient conditions for an optimun are:

(4) (i) $\dfrac{\partial u}{\partial s} = u_c\,\pi_s - \mu + \lambda\pi_s = 0$

(ii) $\dfrac{\partial u}{\partial l} = u_c w + u_l - \theta = 0$

(iii) $\dfrac{\delta u}{\delta \lambda} = \pi(p, w, s, x) + y + w(w-l) - \bar{c} \geqslant 0$

$(\Pi\,(p, w, s, x) + w(H-l))\lambda = 0 \qquad \lambda \geqslant 0$

(iv) $\dfrac{\partial u}{\partial \theta} = H - l - \bar{L} \geqslant 0 \quad (H - l - \bar{L})\ \theta = 0;\ \theta > 0$

(v) $\dot{\mu} = \delta\mu - u_c\pi_x - \mu k_x - \lambda\pi_x$

(vi) $\dot{x} = k(x) - s$

(vii) $\lim\limits_{t \to o} e^{-\delta t}\,\mu(t)x\,(t) = 0$

Let consider first the case in which the minimun leisure and consumption constraints are not binding, that is when $\lambda = \theta = 0$. After few manipulations one obtains the following system of differential equations:

(5) (i) $u_c\pi_s = \mu$

(ii) $-u_l / u_c = w$

(iii) $\dot{\mu} = \mu(\delta - k_x - \pi_x/\pi_s)$

(iv) $\dot{x} = k(x) - s$

(v) $\lim\limits_{t \to \infty} e^{-\delta t}\,\mu(t)\,x(t) = 0$

The first equation indicates that a reduction of the stock is tolerated until the marginal unit value of the resource lost equals the foregone income due to the decreasing productivity that will be suffered by the household in the future. Equation 5 (ii) is he neoclassical condition that determines the supply of labor. That is, the marginal rate of substitution between leisure and consumption must be equal to the wage rate.

Equations 5 (iii) and (iv) describe the motion of the system. The co-state variable or the shadow price of the resource must grow at the rate of time preference less the stock contribution to current income and the value of the change in the resource growth that results. The term π_X/π_S is the ratio of the marginal value product of resource stock with respect to resource usage. A smaller contribution of the stock with respect to consumption requires a lower discount rate to sustain the same optimal program. Expression 5 (v) is the transversality condition associated with an infinite horizon problem.

An alternative and more intuitive form to charaterize the solution of the intertemporal maximization problem facing the rural household is first, to maximize with respect to the controllers for given values of μ and x. The interior solution to this static problem must satisfy equations 5 (i) and 5 (ii). The resulting optimal controls are function of μ, x and the other parameters of the static problem. Thus, one can write

(6) (i) $s = s(p, w, y, x, \mu)$

(ii) $l = l(p, w, y, x, \mu)$

These equations determines the temporary equilibrium of the system. At each moment the household chooses the hours of work (1) and the resource usage (s) given the price of labor (w), the inputed price of the resource (μ) an the stock level (x). If the land value depends only on the resource productivity and if the land market is perfect, the μ of a representative household should be equal to the market price of land.

The appendix presents the comparative statics for the temporary equilibrium. An increase in the shadow price of the resource reduces its usage causing a reduction in household consumption. This effect on the consumption level is partially compensated by an increased in the number of hours worked. As in the standard case, exogenous income affects negatively labor supply resulting in an ambiguous effect on the level of the resource utilization. The initial lower pressure on the resource as a result of the lump-sum transfer might be offset by the reduction in the labor effort. As one would expect the short run effect of an increase of the relative price of the outputs on resource usage is positive. A more surprising result is the negative effect of labor supply that results from higher output prices. This is explained because the household is willing to trade part of the greater income for a higher level of leisure. The effects of input prices are ambiguous depending on the substitutability or complementarity that exists between resouce use, labor and another purchased input.

The next step requires the characterization of the long run or steady-state equilibrium of the dynamic system described by the motion equations 5 (iii) and 5 (iv). In the steady state $\dot{\mu} = \dot{x} = 0$. By implicit differentation and from the adjoint equation the slope of the $\dot{\mu} = 0$ schedule is

(7) $$\left.\frac{d\mu}{dx}\right|_{\dot{\mu}=0} = -\frac{(\pi_X/\pi_S)_X + k_{XX}}{(\pi_X/\pi_S)_S \quad su} < 0$$

where $(\pi x/\pi s)x$ and $(\pi x/\pi s)s$ denotes partial derivatives. From the concavity of $\pi(\cdot)$ in x and s one obtains that their signs are negative and positive respectively. Therefore, both the numerator and the denominator are negative and the $\dot{\mu} = 0$ schedule is downward sloping.

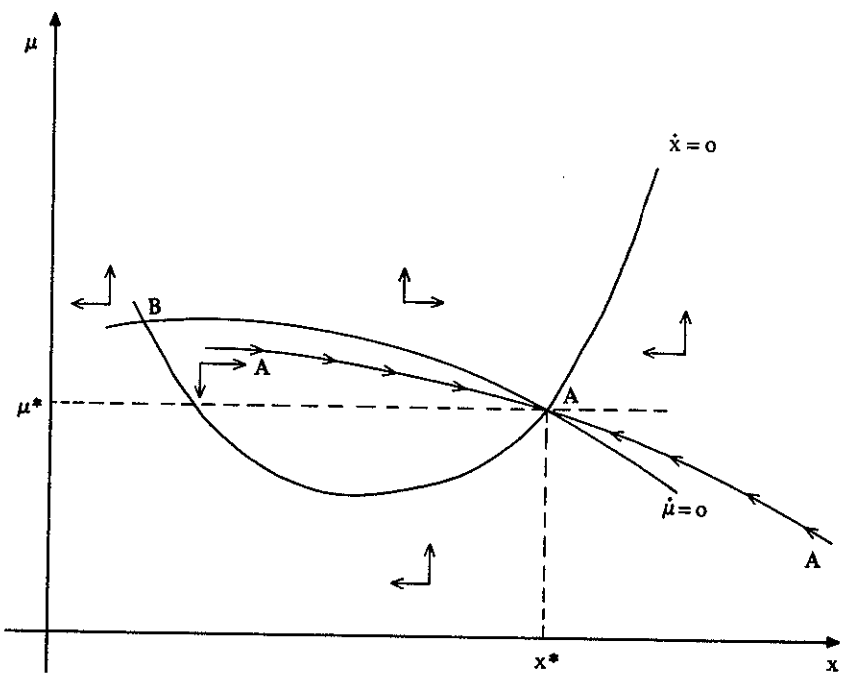
The slope of the $\dot{x} = 0$ schedule is obtained substituting equation 6 (i) into the motion equation for the stock, 4 (v), and by implicit differentiation one obtains

(8) $$\left.\frac{d\mu}{dx}\right|_{\dot{x}=o} = \frac{kx - sx}{su} \gtrless 0$$

From the results obtained in the appendix resource utilization decreases with the shadow price of the resource and is likely to increase with the stock level. The inverted U shape of the k(•) function implies that the $\dot{x} = 0$ schedule is downward sloping for low values of x and upward sloping for high values of x.

Figure 1 depicts both schedules and the dynamics of the system. The couple $(\overset{*}{\mu}, \overset{*}{x})$ represents a saddlepoint equilibrium and AA indicates the unique stable path. If x_o is sufficiently large, the household can move away from the unstable area on the unique path to the saddlepoint equilibrium.

FIGURE 1

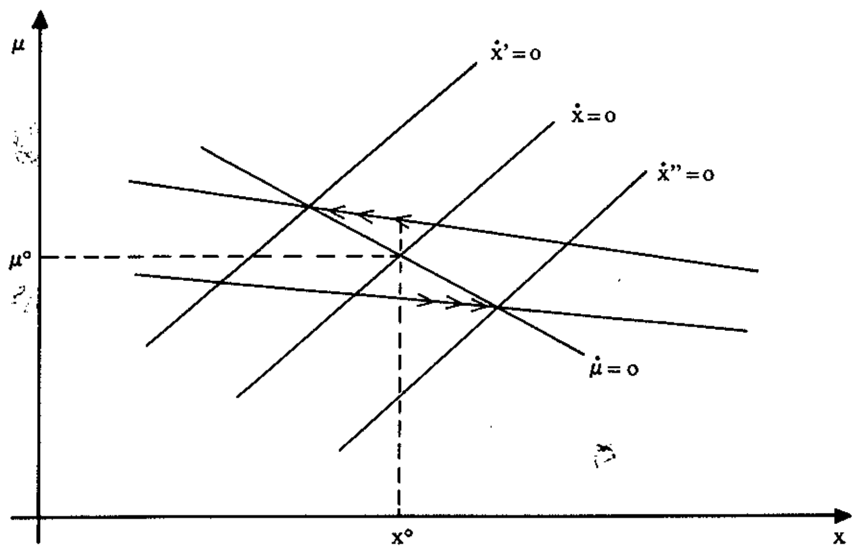


Assuming stability one can analyze the comparative dynamic of the different exogenous variables. An increase in the rate of preference produces a downward shift in the $\dot{\mu} = 0$ schedule as indicated in figure 1. In the new steady-state both the stock of the resource and the shadow price are lower. A lower price of the resource implies a reduction in labor supply and an increase in resource consumption. The shadow price in the very short run overshoots the long run equilibrium leading to temporary over depletion of the resource and reduction in the labor supply. Comparing different steady-states corresponding to different levels of δ, one gets the expected result that a household with a lower rate of preference is more conservationist and works harder.

The Household Response to an Ouput Price Increase and a Lump-sum Grant

Figure 2 shows the linearized system that corresponds to an area close to the saddlepoint equilibrium. An increase in the output price shifts the $\dot{x} = 0$ schedule to the left, since s is increasing in p assuming that resource usage is a normal input. The $\dot{\mu} = 0$ schedule also shifts and the direction depens on the scale of production on the relative contribution of stock level and usage. Assuming homothetic technology for a sub-function of these two inputs $(\partial\pi x/\partial\pi s)/\partial p = 0$ and the $\dot{\mu} = 0$ remains unchanged.

FIGURE 2



The impact effect of a rise in the output price is characterized by an increase in the shadow price of the resource, although insufficient to compensate the shift in the resource demand curve. Hence, the natural growth rate is lower than resource utilization reducing the stock level to reach a new stady-state with lower stock level and higher shadow price.

An interesting result of the model is with respect to the dynamic of output price response. Using Hotelling's lemma one can derive from (2).

$$(9)\quad q = \frac{\partial\pi}{\partial p}(p, w, s, x)$$

the conditional short-run output supply function. The output response in the short run is given by π_{pp}. In the intermediate run, allowing for adjustment of the resource stock, the output response is

$$(10)\quad \frac{\partial q^i}{\partial p} = \pi_{pp} + \frac{\partial q}{\partial x}\frac{\partial x}{\partial s}\frac{\partial s}{\partial p} = \pi_{pp} - \frac{\partial q}{\partial x}\frac{\partial s}{\partial p}$$

and thus the magnitude of the price effect diminishes over time due to the reduction of the resource stock during the period of adjustment. This is opposite to the well known result of investment theory. Internal or external adjustment cost to the firm produces an optimal slow adjustment of the stock of capital and larger output response in the intermediate and long run. The model can explain temporary booms in production for those activities strongly based in natural resource exploitation.

A permanent lump-sum grant can be represented by an increase in y. A rise in y does not have any effect on the $\dot{\mu} = 0$ schedule. The $\dot{x} = 0$ curve might shift to the right because the income effect on resource utilization is negative as indicated in the appendix. The lump sum subsidy policy can also be discussed using figure 2 by shifting the $\dot{x} = 0$ curve to the right. Inmediately after the new program is annunciated the price of the resource falls, undershooting the long-run equilibrium. During the adjustment process the natural reposition of the stock is larger than the resource usage leading to higher stock levels in the long-run.

The Effect of Subsistence Levels of Leisure and Consumption

The discussion until now has assumed the existence of a stable path that allows the system to reach the steady-state. A case in which the long-run equilibrium might be unstable is when minimum levels of consumption and leisure are considered.

If the subsistence constraint is binding $\lambda > 0$ and $\theta > 0$ in conditions 4 (iv) and 4 (v). By substituting the time restriction in the consumption constraint one obtains

$$(11)\quad \pi(p, w, s, x) + y + w(H - \bar{l}) = \bar{c}$$

This equation indicates the minimun resource usage necessary to reach the minimun level of leisure and consumption given the stock of the resource and parameters of the model. By implicit differenciation of equation (11) one get that $ds/dx = -\pi x/\pi s < 0$, which is the marginal rate of technical substitution between the stock level and resource usage given other input and output prices. In the space of x and s the subsistence condition can be represented by and isoprofit curve which is decreasing and convex. The area above this curve represents the feasible set of resource explitation.

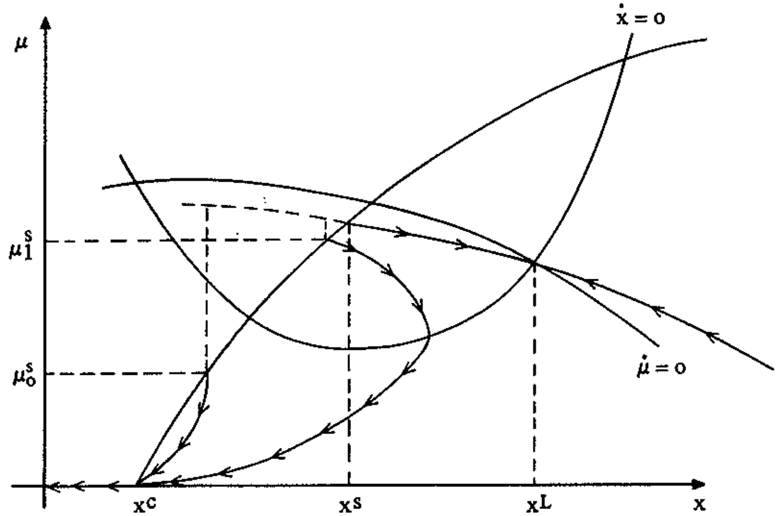
A diagram in the μ–x space can be obtained by substituting equation 6 (i) into equation (11). The resource shadow price consistent with a minimun level of consumption and leisure is given by $\mu = \mu(\bar{l}, \bar{c}, x, p, w, y)$. By differentiation of equation (11) after substituting by equation (6) (i), one can show that the shadow price (μ) is likely to increase with the level of the stock, and it increases with a rise in output prices, wages and a lump-sum grant. As one would expect a rise in the level of the subsistence requirements produces a decline in the shadow price of the resource. Note that this is consistent with the Kuhn-Tucker conditions in equations (4). When the subistence constraint is binding λ and θ are positive which is equivalent to a reduction in μ in equation (4) (i).

Figure 3 illustrates how the stability of the system is affected by subsistence levels of consumption and leisure. The area on the right side of the curve $\mu = \mu(x, \bullet)$ contains the path of resource utilization that satisfies the subsistence requirement. If the initial resource stock is smaller than x^S the rural household can not follow the stable path to the long-run equilibrium. The "adjusted" shadow price of the resource is lower than in the equilibrium path, inducing greater levels of resource usage and lower levels of stock growth. If the initial stock is between x^I and x^S the net growth of the resource is initially positive and after a period the natural growth is not enough to sustain the exploitation levels and the stock starts declining. For stock levels lower than x^I the path to the extinction of the resource is shorter since the stock starts inmediately diminishing. Figure 3 also illustrate that minimum subsistence at a sufficiently low level of the stock (x^C) induces the rural household to behave as if the shadow price would be zero, which would be the same behaviour under the existence of open access to the resource.

The effect of price policies that negatively affect the rural sector can now be analyzed using this framework. A reduction in the output price shifts both the $\dot{x} = 0$ schedule and the curve indicating subsistence requirements to the right (Figure 3). If the household has initially a stock x^S and is moving towards the long run equilibrium, then the lower output price induces a greater resource utilization to reach minimun subsistence. The shadow price moves downward producing a deterioration of the resource in the long-run.

Lower output prices produce more intensive exploitation by households suffering subsistence constrains which also results in an increase in production. Hence, a cheap

FIGURE 3



food policy for resource based goods appears attractive to the naive policy maker. Subsistence households keep producing levels of output above the levels that existed before the implementation of the policy. However, the rural household is eating-up the resource and eventually will have to abandon the land.

Conclusions

The objective of this paper has been to develop a conceptual framework of a rural household useful for incorporating the environmental dimension in the evaluation of sectoral policies. An important feature of the model, that departs from the literature on optimal exploitation of renewable resources, is that it allows for the interaction of decisions on consumption, work and resource utilization.

An important result is the existence of an income effect associated with resource stock changes, which reduces and can even change the direction of the standard effect on resource usage. A lower stock level causes a fall in available income increasing the relative valuation of consumption with respect to leisure. This results in an increase in the household labor supply and might induce a greater use of the resource.

Similarly, the income effect associated with a rise in the output price might produce a decline in resource consumption. However, the more likely result implies greater production and resource utilization in the short run. The household response induces a consumption of the resource that is greater than the natural growth, producing a decline of the resource stock over time and a smaller output supply response in the long run. On the other hand, a lump-sum transfer is clearly beneficial for the environmental resource. The household reacts to a higher exogenous income increasing consumption and reducing hours of work. Although this causes a negative effect on the resource usage, it has to be smaller than the direct positive effect related to the lower income that needs to be self-produced.

The last results are related to the implications of binding subsistence constraints. It is shown that minimun levels of consumption and leisure are a source of unstability for initial low levels of the resource stock. In this case a reduction in the output price diminishes available income inducing an increase in the only free variable, resource utilization. Therefore under subsistence constraints the effects of price policies that discriminates againts the rural sector are clearly negative for resource conservation. This framework also provides implications for policies that affect labor migration and resource markets. Restrictions on the transaction of land, to avoid migration from rural areas and the concentration of land ownnership, forces the household to continue on a path of degradation of their natural environment.

Appendix

Comparative Static of the Temporary Equilibrium

Writing out the arguments of equations (5) (i) and (ii) one has

A.1) (i) $u_C\,[\pi(p, w, s, x) + y + wl, H-l]\ \pi_S(p, w, s, x) - \mu = 0$

(ii) $w + \overline{u}_l[\overline{\pi}(p, w, s, x) + y + wl,\ H-l] = 0$

where $\overline{u}_l = u_l/u_C$. Total differentiation yields

A.2) (i) $[u_{cc}(\pi_p dp + (\pi_w + 1)dw + \pi_s ds + \pi_x dx + dy + wdl) + u_{c\ell} dl]\pi_s + u_c(\pi_{sp}dp + \pi_{sw}dw + \pi_{ss}ds + \pi_{sx}dx) - d\mu = 0$

(ii) $dw + \bar{u}_{\ell c}(\pi_p dp + (\pi_w + 1)dw + \pi_s ds + \pi_x dx + dy + wdl) + \bar{u}_{\ell\ell} dl = 0$

Reordering terms and writing in matrix form

$$\text{A.3)} \quad H\begin{bmatrix} ds \\ dl \end{bmatrix} = \begin{bmatrix} d\mu - \beta^p dp - \beta^w dw - \beta^x dx - u_{cc}\pi_s dy \\ -\bar{u}_{\ell c}(\pi_p dp + \pi_x dx + dy) - (1 + \bar{u}_{\ell c}(\pi_w + 1)dw \end{bmatrix}$$

where $\beta^i = (u_{cc}\pi_s\pi^i + u_c\pi_s^i)$ for $i = p, x$, $\beta^w = (u_{cc}(\pi_w + 1)\pi_s + u_c\pi_{sw}$ and H is the Jacobian matrix given by:

$$H = \begin{bmatrix} u_{cc}\pi_s^2 + u_c\pi_{ss} & u_{cc}\pi_s w + u_{c\ell}\pi_s \\ \bar{u}_{\ell c}\pi_s & \bar{u}_{\ell\ell} + \bar{u}_{\ell c} w \end{bmatrix}$$

The matrix H is negative definite by strict concavity of function u(•) in s and l and function π(•) in s. This is also the second order sufficient condition associated with the maximization of the Hamiltonian function with respect to the controllers. This implies that the implicit function theorem allows us to solve s and l as functions of the parameters of the static problem as in equation (7) in the text. Negative semidefiteness of H implies that the diagonal elements are negative and $H > 0$.

Using Cramer rule the effect of μ on resource utilization is

$$\text{A.4)} \quad \frac{\partial s}{\partial \mu} = \frac{\bar{u}_{\ell\ell} + \bar{u}_{\ell c} w}{|H|} < 0$$

which says that the resource demand is downward sloping. Decreasing marginal rate of substitution between leisure and consumption implies that both $\bar{u}_{\ell\ell}$ and $\bar{u}_{\ell c}$ are negative. To obtain this result one must note that the partial derivatives are expressed in term of hours of work instead of leisure.

Similarly the effect of μ on the labor supply can be determined as follows:

$$\text{A.5)} \quad \frac{\partial l}{\partial \mu} = -\frac{\bar{u}_{\ell c}\ \pi_s}{|H|} > 0$$

A higher μ reduces resource usage and current consumption, decreasing the marginal rate of substitution between leisure and consumption ($\bar{u}_\ell$) which induces an increase in hours worked.

The effect of a lump-sum grant (increase in y) after some manipulations is

$$\text{A.6)} \quad \frac{\partial s}{\partial y} = -\frac{\pi_s}{u_c|H|}\,[u_{cc}u_{\ell\ell} - u_{\ell c}^2] < 0$$

There exists two opposite effects. For a given level of labor supply, a greater income increase consumption decreasing its marginal utility which causes a reduction in output production and s. The hours worked also decreases, however, producing a greater consumption of the resource to sustain a given consumption level. The concavity assumption of the utility function assures that the former and direct effect is larger than the latter and indirect effect. It is verified that a lump-sum subsidy affects negatively labor supply since

$$\text{A.7)} \quad \frac{\partial l}{\partial y} = -\frac{1}{|H|}(u_{cc}\,\pi_{ss}\,\bar{u}_{\ell c}) < 0$$

The effect of the stock level on resource utilization can be determined from the expression:

$$\text{A.8)} \quad \frac{\partial s}{\partial x} = -\frac{1}{|H|}[u_c\,\pi_{sx}\,(\bar{u}_{\ell\ell} + \bar{u}_{\ell c}w)] + \pi_x\frac{\partial s}{\partial y} \gtrless 0$$

The first term is positive reflecting the standard effect of the stock level on resource utilization. The second negative term comes from the interaction of exploitation and consumption decisions recognized in the model.

The effect of the resource stock on labor supply can be determine unambiguosly. The expression after some transformations is

$$\text{A.9)} \quad \frac{\partial l}{\partial x} = \frac{u_c\ \bar{u}_{\ell c}}{|H|}\,[\pi_{sx}\pi_s + \pi_{ss}\pi_x] < 0$$

Note that l represents total labor supply which is different to the labor demanded by the household production. Assuming that labor and the stock are complementary factors of production, labor demanded increases with the stock level.

A rise in one output price yields expressions analogous to A.8 and A.9 and the effects on s and l can be obtained substituting x by p in both expressions. It is resonable to assume that resource use is a normal input, i.e., $\pi_{sp} > 0$, and we get that the expected positive effect on s can be conpensated by the income effect given by the second term resulting in an ambiguous sign. Similarly to a stock change, it is obtained that higher prices reduces labor supply.

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