1. Program goals in converting debt via capitalization and debt swaps. This plan should include expected portions of total public and private debt to be capitalized.
2. Monetary and fiscal policies to undertake the new volumes of investments generated through the conversion programs. Such programs should ensure minimum distorsion in monetary aggregates and fiscal spending.
3. The new unified exchange rate will be a key variable to attract new investments and determine return viability.
4. Expected inflow of "new" money generated through the conversion programs. So far, Decree 2485 requires that part of the investment be made partially in cash.
5. Inclusion of new sectors into the program to cover industries with adequate risk/return parameters.

AN ADDENDUM

As expected, Venezuelan authorities laid the grounds for future investments through the debt conversion based on the new economic realities. Decree 86 was issued on March 15, 1989 with the following modifications in place:

- Incoming foreign investments will be converted at the prevailing rate under the unified market, since the former dual exchange rate system was removed.
- An auction mechanism to redeem Public Paper Debt with the Central Bank is introduced. Thus, both the investor and the Government will capture part of the discount. In these auctions, investors will bid taking as reference value an initial discount established by the Government.
- Debt conversion proceeds will only be used to finance the local component of the investment. This implies the injection of "fresh" funds to the operation.
- Local investors are now allowed to opt to the debt conversion mechanism. Dividend remmittance will be limited to 10% of capital during the first three years. Capital repatriation schedule does not vary from previous decrees.
- The creation of an investment fund will allow the investors to securely park its debt conversion proceeds, prior to effecting the capital registration and subsequent disbursement schedule. This sinking fund will be deposited with the Central Bank, allowing it to easen the monetary impact while smoothing the time lags that arise in the registration process.

Undoubtedly, there are many improvements in the new investment framework which will, should allow greater flows of funds to the country. There are, however, clear issues regarding the auction mechanism as well as the initial discounts to be established by the Government on the redeemable paper. A second issue pertains to the the fact that "new" money is required to fund the external component of investment.

Notes:

1 Decree 1200 modified Decision 24 of the Andean Pact, which regulated foreign investment for member countries.

2 In Febreary 16, 1989 the Venezuelan Government, among many other economic measures, unified the exchange rate, allowing it to fleat. The former controlled foreign exchange rate will presumably become from now on the floating parity existing at any one time. For purpose of this study, we describe the existing legislation as the Government is yet to address new foreign investment regulation based on the new economic realities.

3 As a result of the exchange rate unification, the Government's system to provide preferential dollar for imports was eliminated.

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EXCHANGE RATE DETERMINATION IN NATURAL RESOURCES–RICH ECONOMIES*

RAMON E. LOPEZ **
Country Economics Department
The World Bank
and
Department of Economics
University of Maryland

Abstract:

This paper deals with the role of natural resources in the process of determination of the real exchange rate within the context of a resource-based sector that is important within the economy and heavily integrated with other sectors. In so doing, the article tries to shed some ligth on questions like: How does the effectiveness of nominal devaluation in promoting real devaluation in a resource-rich economy compare with that in resource-poor economies? What are the implications for the responsiveness of trade flows to devaluation of explicitly considering a natural resource-based sector? Is devaluation more likely to be contractionary in a resource-rich economy rather than in a economy that does not depend on natural resources? How do changes in resource management policies (i.e., extraction taxes) affect the real exchange rate, trade balance and real income in the short run and long run? How have these results been affected by whether the resource is exploited under private property or under common property?

1. Introduction

In a large number of developing countries, natural resources constitute an important component of the economy. The performance of industries based on natural resource

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extraction and processing is a key factor in determining patterns of trade and external equilibrium. In these countries the interactions between the resource sector and the rest of the economy can be of considerable importance. Various Latin American countries exhibit quite a diversified set of resource-based industries, including fisheries, mining, forestry, and even parts of agriculture. In tropical areas, agriculture is largely based on the extraction of nutrients from the soil and natural forest, with shifting cultivation being a dominant food cultivation system. This system is oriented towards exploiting the biomass available from the natural vegetation in agriculture production, through long rotation periods, alternating one or two cultivation years with 10-15 years of fallow, where the natural vegetation growth reestablishes the required fertility and physical properties of the soil (Lopez and Niclitschek, 1988).

In many Latin American countries, including of course Chile, the value of the primary commodities extracted by the natural resource sector is estimated to reach 10-20 percent of GDP. Moreover, industries not considered as part of the resource sector, but intensive users of primary commodities produced in the resource sector, are very important from the point of view of their share in GDP, employment and exports. In fact, in most medium-income countries, the resource-based export sector has ceased to be an enclave and is substantially integrated with the rest of the economy. This implies that the resource-based industries that process and transform primary resource commodities (refining and mineral processing industries, fish processing, wood and pulp industries, etc.), compete for labor and capital with industries that are not intensive in primary commodities. Although the resource extraction activities themselves are not very intensive in labor, the industries that process primary resource commodities give employment to a sizable proportion of the labor force, thus competing with other sectors of the economy for labor and other factors of production. Even in very poor tropical economies, such as Sub-Saharan Africa, the major resource-based industry is agriculture, which is usually a large and relatively integrated sector of the economy.

Despite the importance and relatively high degree of integration of the natural resource based sector in many developing economies, a majority of the studies considering the macroeconomic implications of the resource sector concentrates on the "Dutch Disease" type of approach, which emphasizes the enclave character of the sector as a source of foreign exchange availability, with an effect on the exchange rate only via this channel (Neary and Van Wijnbergen, 1986; Svensson, 1984). Another area of research has looked at the implications of (mostly exhaustible) resources for the validity and/or adaptation of the traditional theorems of pure trade (Kemp and Long, 1979a, 1979b, 1980, and 1984; Harris, 1981; Djajic, 1986; Tawada, 1982). A concern of these studies has been the patterns of specialization in production of countries highly endowed with material resources that engage in international trade. In this view the natural resource-based sector is considered integrated into the economy with important linkages with other sectors, particularly in terms of competition for another factor of production ("labor"). An important feature of these studies is that they assume that all goods are traded and that the economy is small and open. Therefore, the focus on real exchange rate determination so prominent in the "Dutch Disease" type of studies is lost here.

Still a third line of research has been concerned with the optimal management of natural resources under the presumption that some degree of temporal and intertemporal externalities are likely to occur in their exploitation (Dasgupta and Heal, 1979; Branden and Djajic, 1983; Dasgupta, Eastwood and Heal, 1978). An important feature of these studies is their heavy microeconomic emphasis.

The analysis of the role of natural resources in the process of determination of the real exchange rate within the context of a resource-based sector that is important within the economy and heavily integrated with other sectors has not been developed. In a resource-rich economy with a high degree of integration one would expect that the process of determination of the real exchange rate and, in general, the implications of nominal devaluation are subject to peculiarities that may have important policy implications. This paper tries to fill this gap and in so doing to shed some light on questions such as: How does the effectiveness of nominal devaluation in promoting real devaluation in a resource-rich economy compare with that in resource-poor economies? What are the implications for the responsiveness of trade flows to devaluation of explicitly considering a natural resource-based sector? Is devaluation more likely to be contractionary in a resource-rich economy rather than in an economy that does not depend on natural resources? How do changes in resource management policies (i.e., extraction taxes) affect the real exchange rate, trade balance and real income in the short-run and long-run? How have these results been affected by whether the resource is exploited under private property or under common property?

In the ensuing analysis we are going to consider mostly a renewable natural resource for two reasons: first, despite the fact that renewable resources are an important component of the total resource basis in many developing countries, most analyses in the literature have concentrated on exhaustible resources. Second, for the purpose of the ensuing analysis, consideration of a renewable resource with a well defined steady state considerably facilitates the presentation, while at the same time, most of the analysis applies equally well to exhaustible resources. Throughout the analysis we will assume a small open economy that takes the world prices of tradable goods as given. We will also assume that the raw commodities just extracted are not directly tradable but rather that they are used as an input in the production of tradable (exportable) goods. The required assumption here is that transportation costs of primary resource commodities are very high and/or that regulations exist that effectively prevent the export of primary commodities with an extremely low value added. This assumption is quite realistic for most countries since the so-called "commodity" exports have been usually subject to a reasonable degree of processing before being exported. For example, even minerals such as copper are rarely exported as extracted from the earth, being subject at the very least to concentration and refinement processes and usually to further transformations before being exported.

The remainder of this paper is organized as follows: In Section 2 we present the conceptual model and specific assumptions. Section 3 is devoted to the analysis of devaluation and macro-sectoral interactions in the context of either common property and full private property of the resource. The implications of resource management policies for the real exchange rate, real income and trade flows are analyzed in Section 4. In Section 3 we provide a summary of the major findings of the study. Finally, in the appendix we present the mathematical model underlying the analysis. Readers not interested in technicalities need not look at the appendix, since the rest of the paper is, to the extent possible, self-contained with a loss only in rigor and with the need to accept certain assertions which are not readily obvious without a mathematical model.

2. Conceptual Framework

Let us consider an economy comprised of three sectors, one producing finished tradable goods, the second one producing finished non-tradable goods and the third

sector producing or extracting a primary commodity, the natural resource sector. The primary commodity is used as an input in the production of finished goods. To facilitate the exposition we assume that the production of non-tradables does not require the primary commodity while in the production of tradables the commodity is a necessary input, i.e., the tradable sector is the natural resource-based sector. The basic results are not dependent on this assumption. It is sufficient that the tradable sector be a more intensive user of the primary commodity than the non-tradable sector. Furthermore, we also assume that capital is sector specific and, hence, that only labor is fully mobile among the three sectors, with all markets being perfectly competitive.

The price of the traded good is determined by the world price times the nominal exchange rate adjusted by whatever import/export taxes exist. That is, the tradable good price is largely exogenous. The price of the non-tradable good is determined by the usual market clearing conditions and is, thus, endogenous. The real exchange rate, defined as the ratio of the tradable final good price over the non-tradable final good price, is thus the real price that clears the market for non-tradables. The supply of non-tradables is inversely related to the real exchange rate while the demand for non-tradables is increasing in the real exchange rate and in total real wealth. Real wealth, in turn, is a function of the real exchange rate and of real money Balances (thus permitting hoarding or dishoarding of money and hence positive or negative gaps between income and expenditures).

We can now define GDP conditional on a given level of availability of the primary commodity. This conditional GDP (defined as the real output of tradables plus the real output of non-tradables times one over the real exchange rate) is therefore a function of the real exchange rate, the availability of the primary commodity and of course of the total stock of labor and capital. Naturally GDP is increasing in the level of the primary commodity, V_t, and of the inverse real exchange rate $p \equiv 1/\text{real exchange rate}$. Furthermore, the marginal returns of the primary commodity (defined as the marginal contribution of the primary commodity, V, to GDP) is positive and *decreasing* in p. The reason for this lies in the assumption that the primary commodity is only used in the production of tradables (more generally, that the production of tradables is more intensive in the primary commodity than the production of non-tradables). An increase in the relative price of non-tradables (p) increases the relative profitability of the production of non-tradables vis-à-vis the profitability in the tradable sector. This causes labor to shift towards the non-tradable sector away from the tradable sector. Under the weak assumption of gross complementarity between labor and the primary commodity, the marginal product of the primary commodity in the tradable sector will fall, and thus the marginal returns of the primary commodity decreases. The same line of reasoning leads one to the conclusion that the supply of non-tradables should be decreasing in the level of the primary commodity. An increase in the primary commodity raises the marginal product of labor in the tradable sector thus absorbing labor from the non-tradables and, hence, the supply of non-tradables should fall when V increases.

The natural resource sector is assumed to be renewable and that a meaningful long-run equilibrium or steady state exists. This steady state in the resource sector is established when the extraction of the primary commodity is equal to the natural rate of growth of the resource. The natural rate of growth of the stock of resources is increasing and concave in the level of the stock. In order to extract the primary commodity firms need to incur in costs of extraction which are decreasing in the stock of the resource. That is, the more abundant is the resource the easier it is to extract it and, hence, the lower the cost of extraction per unit of the commodity. Moreover, we assume that the extraction cost function is strictly convex in the level of the resource stock. Short-run or temporary equilibrium in the resource sector requires two conditions: (i) the marginal returns of the extracted primary commodity (i.e., the marginal effect of V on GDP) net of the unitary extraction costs must be equal to the shadow value of the resource, which is the marginal increment in total wealth of society obtained by increasing the stock of the resources by one unit; (ii) the arbitrage asset market equilibrium should hold at each point in time: the opportunity cost of leaving one more unit of the resource in the ground should be equal to the expected marginal returns of doing so. The expected net marginal returns of keeping the commodity in the ground is the sum of the natural rate of growth of the resource, the expected rate of capital gains (the expected rate of growth of the shadow price of the stock) and the marginal reduction in extraction costs associated with keeping one more unit of the resource in the ground. These net marginal returns under temporary equilibrium should add up to zero.

An increase in the real exchange rate (a fall in p) will cause the marginal value product of the primary commodity to increase and, hence, will lead to greater extraction in the short-run if the resource is exploited under common property. If, however, the resource is exploited under private property, this effect will be reversed by a corresponding increase in the shadow price of the resource and extraction will decrease. That is, the induced rise in the shadow price will dominate the increase in the real exchange rate effect. The intuition behind this result is clear: real exchange rate depreciation increases the profitability of the resource stock which causes decision-makers to desire an expansion in the stock. In the non-resources context, an increased profitability of capital induces greater investment. In a natural resource context it also induces investments in the resource stock but, in contrast with normal capital, increased investment necessarily requires a curtailment in current production. This is the most common way of investing in a natural resource stock.

A permanent extraction tax, on the other hand, will cause extraction to fall in the short-run if the resource is under private property, while it may cause a *rise in extraction* in the short-run if private property of the resource is predominant! The rationale for this seemingly counter-intuitive result is similar to that for the effect of the real exchange rate. The fall in the shadow price will tend to dominate the effect of the tax increase when private resource property prevails.

In the common property case, the increased extraction associated with devaluation leads to a gradual reduction in the stock of the natural resource and to a decrease in the rate of extraction through time to finally reach a new steady state, with a lower rate of extraction than the original one. The reason for the gradual reduction in the rate of extraction after the short run expansion is due to increasing extraction costs through time, caused by the reduction in the stock of the resource. If the resource is under private property, extraction will gradually increase from the new lower levels of extraction as the resource stock increases, reaching a new steady state at a greater extraction rate. Thus, the extraction levels in the long-run at the new steady state decline in the case where the resource is mostly under common property and increase when the resource stock is predominantly under private property. Similarly, an extraction fee will cause a reduction in the rate of extraction in the short-run but an increase in the long-run in the case of common property.

3. Exchange Rate Devaluation

We analyze now the effect of nominal devaluation taking explicit consideration of the interactions between the determination of the real exchange rate and the process of extraction of the natural resource. Nominal devaluation causes excess supply of non-tradables which following the well known channels lead to a fall in the relative price of non-tradables, i.e., to a real exchange rate devaluation. This is the conventional effect which occurs for a given level of availability of primary commodities. However in the context of common property resources, devaluation also increases the rate of extraction of the primary commodity due to the fact that the marginal value product of the primary commodity increases as a consequence of devaluation. Given that marginal extraction costs are fixed in the short-run, it unambiguously follows that the extraction rate increases after devaluation. If, on the other hand, the resource is under private property the rate of extraction decreases because the shadow price of the resource stock rises.

Thus, devaluation has two initial effects, one is the usual expenditure reduction effect and the other one is a change in the availability of primary commodities. The increased availability of primary commodities, that occur when the dominant form of exploitation of the resource is common property, implies, in turn, two effects for the market for non-tradables. First, it shifts downwards the supply of non-tradables due to the fact that a greater availability of primary commodities causes the tradable sector to expand absorbing other resources from the non-tradable sector. Second, it increases real income (although not necessarily "permanent" income) and thus may increase expenditures, and in this way, at least in part off-set the initial expenditure reduction effects of devaluation. As is shown in the formal model of the appendix, stability requires that the conventional effects of devaluation dominate, thus unambiguously causing a real exchange rate depreciation or, equivalently, a fall in the real price of non-tradables. Moreover, the market stability conditions also require that the supply effect of the increased availability of primary commodities always dominate the expenditure expansion effect. The greater availability of primary commodities induced by devaluation tend, therefore, to dampen the exchange rate devaluation although it cannot reverse it. Thus, *an important result is that nominal devaluation tends to be less effective in promoting real devaluation in the short-run in an economy richly endowed in natural resources exploited under common property than in one with little endowments.* Furthermore, it is easy to see that the greater is the elasticity of resource extraction with respect to the real exchange rate, the smaller will be the effect of nominal devaluation on the real exchange rate in the short-run.

It is important to emphasize, however, that the reduced efficacy of nominal devaluation in generating real devaluation that occurs when common property is dominant does not imply that devaluation is less effective in improving the current account in resource rich countries. On the contrary, the trade flows are likely to react more rapidly to devaluation because the increased rate of extraction becomes an additional incentive to expand the production of tradables. Note that the reason for a lower effectiveness of nominal devaluation in promoting real devaluation lies on the fact that increased primary commodity availability tends to reduce further the production of non-tradables, thus releasing more resources to be used in the tradable sector.

Another important implication is that in a common property resource rich economy the effect of devaluation is less likely to be contractionary[1] at least in the short-run. *In fact, in the context of a competitive model without price rigidities and common resource property as the one considered here, the short-run effect of devaluation is always expansionary.* This is due to the increased availability of primary commodities associated with devaluation that leads to greater real income in the short-run.

If a large proportion of the resource is exploited under private property, devaluation causes the rate of extraction to fall and, thus, to the conventional effects of devaluation one needs to add the increased supply of non-tradables that the reduced extraction rate causes in the short-run. *In contrast with the case of common property, the real exchange rate now becomes more responsive to nominal devaluation while the trade account is less responsive and may even deteriorate in the short-run.*

Table 1 provides a summary of the effects of devaluation when natural resources are mostly under private and common property. The effectiveness of devaluation in generating real devaluation increases under private property and decreases under common property, while the effects on real income, rate of extraction and effectiveness in improving the trade account all decrease under private property and increase under common property of the resource.

TABLE 1

SHORT–RUN EFFECTS OF DEVALUATION

	Private Property	Common Property
1. Effectiveness on affecting the real exchange rate	+	–
2. Real income	–	+
3. Rate of extraction	–	+
4. Effectiveness on improving the trade balance	–	+

4. Resource Management and the Real Exchange Rate

Consider for example a resource extraction tax, the proceedings of which are redistributed to the private sector. The question here is what are the implications of such a tax for the real exchange rate and whether the tax is necessarily contractionary. The imposition of the tax has a direct negative effect on the rate of resource extraction and, hence, on the availability of primary commodities if the resource is under common property. This, in turn, will cause two effects that have implications for the determination of the real exchange rate. One is to cause an increase in the supply of non-tradable goods, a shift to the right of the supply curve. The other effect is a reduction in real income at least in the short-run that may reduce expenditures and, thus, decrease the demand for non-tradables. Thus, if the resource is exploited in common property the non-tradable goods' supply effects induced by the extraction tax will point towards decreasing the relative price of non-tradables (real exchange rate appreciation) by expanding output of non-tradables.

If the private sector's perception of the shadow price of the resource stock is identical to the true shadow price (i.e., if private property over the resource prevails and if contemporaneous externalities are not important) then total wealth and, hence,

permanent income will decrease in response to the extraction tax. Moreover, if the extraction tax is seen as temporary, then resource extraction will also decrease even if the resource is in private property. Thus, in this case both the supply and demand effects in the non-tradable market will point in the same direction towards a fall in the real price of non-tradables, i.e., towards a real exchange rate depreciation. It is important to mention that the real exchange rate depreciation may occur at the same time as the balance of trade deteriorates because the depreciation of the real exchange rate is generated by an expansion in the production of non-tradables.

It can be shown that in the case of common property or where contemporaneous externalities are important, the trade balance in the short-run necessarily deteriorates despite the fact that the real exchange rate may or may not appreciate. The easiest way of seeing this is using the identity of trade surplus equal to the difference between income and expenditures. Real income in the short-run always falls due to lower extraction while permanent income or wealth increase due to the improved efficiency associated with the extraction tax. If expenditures are dependent on permanent income then real expenditures will increase thus creating a gap between real income and expenditures that translates into trade deficit. Even if expenditures are related to temporary rather than permanent income the net effect on the trade balance will be negative. Given that the marginal propensity to spend out of temporary income is likely to be less than one, the fall in real income will necessarily cause a reduction in real expenditures that is less than the decline in real income. Thus the trade deficit.

In the case when the private sector uses the true shadow price of the resource stock in its decisions then effect over the short term trade balance can be ambiguous. Since permanente income falls as a consequence of the tax it is possible that the corresponding fall in real expenditures be greater than the decline in real income thus creating the possibility of an improvement of the trade account.

5. Conclusions

A major conclusion of this study is that the existence of an important natural resource sector has serious consequences for the determination of the real exchange rate and for the impact of devaluation on the trade balance and real income. Whether the resource is exploited under common or private property is an essential factor which determines the nature of the divergence between the standard analysis of devaluation and one that explicitly recognizes the existence of a resource industry.

Under common resource property nominal devaluation tends to be less effective in generating real devaluation but more effective in promoting improvements in the trade balance in the short-run. Also in this case, devaluation is largely expansionary in the short-run. However, if private resource property prevails, devaluation in a resource rich economy becomes more effective in leading to real devaluation than in a resource-poor economy, but the trade balance *deteriorates* in the short-run. Furthermore, in this case devaluation will be *necessarily contractionary* in the short-run.

The results concerning the macroeconomic implications of an extraction tax are also heavily dependent on whether private or common resource property prevails. Under common property, the tax, whether regarded as permanent or temporary, will cause the real exchange rate to depreciate, the trade balance to deteriorate and real income to fall in the short-run but permanent income or wealth to increase. If private property of the resource prevails then a permanent extraction tax will cause the rate of extraction in the

short-run to increase thus leading to a real exchange rate appreciation, an improvement in the trade balance, an increase in real income in the short-run but to a fall in permanent income. That is, to exactly the opposite effects as in the case of common property.

Note:

1 See, for example, Buffie (1984) for an analysis of devaluation in a context where perverse, contractionary effects are likely.

Appendix

The Formal Model

Define first a maximum revenue function of the tradable and non-tradable sector.

$$(1)\quad \pi(p, V) \equiv \max_{Q_T, Q_N} \left\{ Q_T + pQ_N : \tau(Q_T, Q_N, V; L, K) = 0 \right\}$$

where Q_T is output of tradable goods, Q_N is output of non-tradables, $p \equiv P_N/P_T$ is the relative price of non-tradables relative to the price of tradables (the inverse of the real exchange rate), V is the amount of primary commodities available for production of final goods and L and K are the fixed factor endowments of labor and capital. Since K and L are assumed fixed we omit them from the notation that follows. We assume, for simplicity, that labor is mobile but capital is sector specific. The price of tradables is defined as $p_T \equiv e$ where e is the nominal exchange rate and the border price is normalized to one.

The revenue function $\pi(\ )$ of course satisfies certain properties: it is increasing and convex in p with $\frac{\partial \pi}{\partial p} \equiv \pi_p = Q_N$ by Hodelling's lemma, increasing and strictly concave in V, i.e., $\pi_V > 0$ and $\pi_{VV} < 0$. It is assumed that only the tradable sector uses the primary commodity. This implies that $\pi_{pV} \equiv \frac{\partial^2 \pi}{\partial p \partial V} < 0$, that is, that the marginal revenue of the primary comodity decreases with the relative price of non-tradable. This implies that the supply of non-tradables is decreasing in the level of the primary commodity.

$$(2)\quad \pi_{pV} = \frac{\partial Q_N}{\partial V} < 0.$$

The revenue function $\pi(\ )$ fully describes the production technologies of the two final good sectors. The natural resource sector which is assumed to be of the renewable type is, under private property, described by the following intertemporal optimization problem:

$$(3)\quad J(p,R) \equiv \max_{V} \int_0^{\infty} [\pi(p,V_t) - q(R_t)V_t]\, e^{-\rho t}\, dt$$

$$\text{S.T. } \dot{R}_t = G(R_t) - V_t$$

$$R(o) = R_o,$$

where R_t is the stock of natural resources at time t, $q(R_t)$ is the extraction cost which is assumed to be decreasing and strictly convex in R_t, i.e., $q_R < 0$, $q_{RR} > 0$, ρ is the discount rate assumed given and $G(R_t)$ is the natural growth of the stock of the resource. We assume that this function is increasing and strictly concave in R_t, i.e., $G_R > 0$ and $G_{RR} < 0$. The J function of course represents the value of wealth in terms of real assets owned by the economy, including capital, labor and natural resources.

The first order conditions associated with problem (3) are the following:

(4) (i) $\pi_V(p, V) = q(R) + \psi$

(ii) $\dot{\psi} = (\rho - G_R)\,\psi + q_R\,V$

(iii) $\dot{R} = G(R) - V\,;\, R(0) = \bar{R}_o$

(iv) $\lim_{t \to \infty} \psi_t\, e^{-\rho t} = 0$

where ψ is the coestate variable corresponding to the social shadow price of the natural resource stock. We note that $\psi \equiv \frac{\partial J}{\partial R} \equiv J_R$.

From 4(i) we obtain that the rate of extraction or the availability of primary commodities at each point in time is

(5) $V = V(p, q + \psi)$

where $\frac{\partial V}{\partial p} = V_p < 0$ and $V_\psi < 0$

given the assumption that $\pi_{Vp} < o$. Since $\psi = J_R(R,p)$ is also a function of p the total effect of a change in p on the rate of extraction is

(6) $\frac{dV}{dp} = V_p + V_\psi \frac{\partial \psi}{\partial p}$

The shadow price can be shown to be decreasing in p. Consider,

(7) $J_p = \int_o^\infty \pi_p(p, V)\, e^{-\rho t}\, dt > 0$

and, hence,

(8) $\frac{\partial \psi}{\partial p} = J_{Rp} = J_{pR} = \int_o^\infty \pi_{pV} \frac{\partial V}{\partial R} e^{-\rho t}\, dt < 0$

where (7) follows from a direct application of the envelope terms to (3) and (8) is derived using the symmetry conditions.

Thus, the second right-hand side term in (6) is positive while the first is negative. It can be shown that, in fact, the total effect dV/dp is always positive, i.e., that the second positive right-hand-side term in (6) dominates. To see this we use the phase diagrams in Figures 1 and 2. In Figure 1 the steady state levels R* and ψ* are shown and NN illustrates the unique monotonic optimal path for R and ψ. Here we are using the stability conditions that require that in equilibrium the slope of the $\dot{\psi} = 0$ schedule be higher than the slope of the $\dot{R} = 0$ (in Figure 1 this is satisfied given that at the steady state point the slope of the $\dot{\psi} = 0$ schedule is positive while the slope of $\dot{R} = 0$ is negative). An increase in p shifts both schedules downwards and thus the new steady state could in principle be achieved at a lower, higher or identical level of R. If the downward shift of the $\dot{\psi} = 0$ at the original steady state is smaller than the downward shift of the $\dot{R} = 0$ then we get that the new steady state will be achieved at a lower level of R. This implies that V(t) necessarily has to increase with respect to the original steady state after p increases. This is shown in Figure 2, where AB < AC. Evaluated at the old steady state we have

(9) (i) $\left.\frac{\partial \psi}{\partial p}\right|_{\dot{\psi}=0} = -\frac{q_R V_p}{q_R V_\psi + \rho - G_R} < 0$

(ii) $\left.\frac{\partial \psi}{\partial p}\right|_{\dot{R}=0} = -\frac{V_p}{V_\psi} < 0$

FIGURE 1

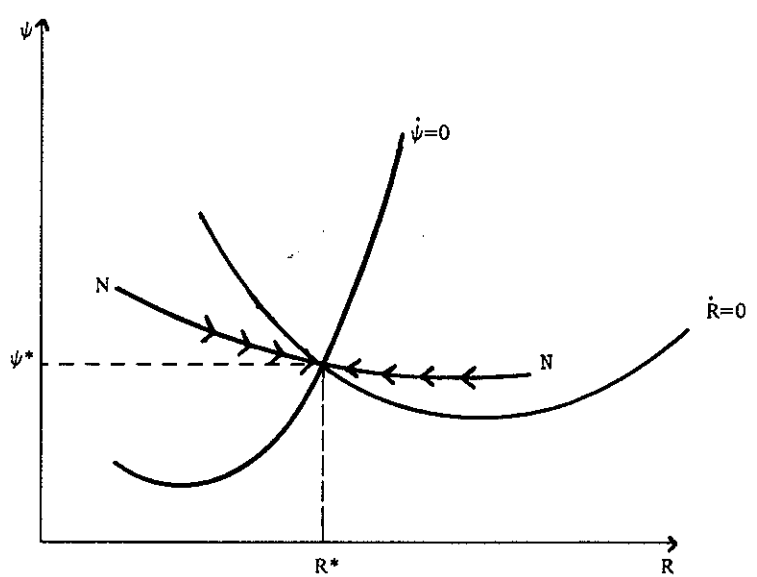
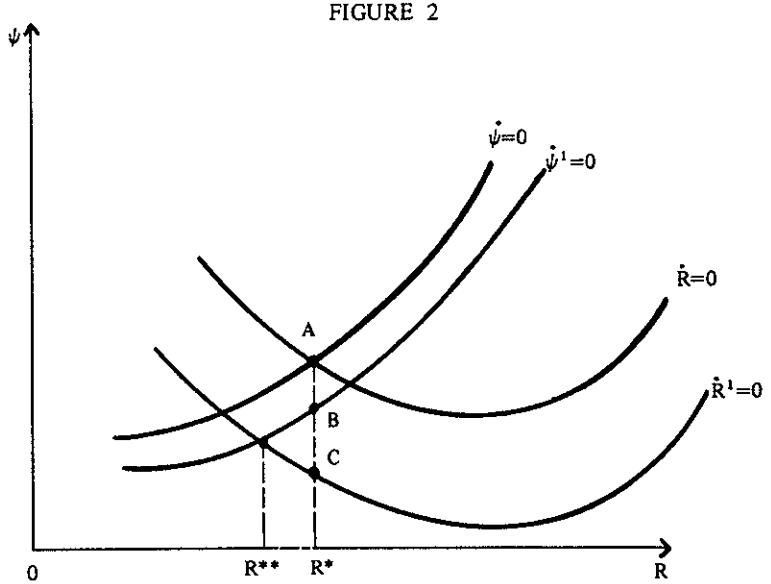


FIGURE 2



But 9(i) can be written as:

$$(10)\ \frac{\partial \psi}{\partial p}\bigg|_{\dot{\psi}=0} = -\frac{V_p}{V_\psi + \dfrac{\rho - G_R}{q_R}}$$

where the second term in the denominator is negative given that $\rho - G_R > 0$ and $q_R < 0$. Hence,

$$(11)\ \frac{\partial \psi}{\partial p}\bigg|_{\dot{\psi}=0} > \frac{\partial \psi}{\partial p}\bigg|_{\dot{R}=0}$$

which means that the absolute fall of the $\dot{\psi}=0$ schedule is *less* than the absolute fall of the $\dot{R}=0$ schedule. This is shown in Figure 2 with AB<AC. This implies that the new steady state level of R is lower at the new higher p. Since the adjustment path is monotonic, a lower steady state can only be achieved by an increase in the short-run rate of extraction. Hence $\frac{dV}{dp} > 0$.

The relative price of the non-tradables, p (i.e., the inverse real exchange rate) is determined under the assumption that the market for non-tradables clears,

$$(12)\ \pi_p(p, V) - D(p, J(p,R) + M/e) = 0$$

where $\pi_p \equiv \frac{\partial \pi}{\partial p} = Q^N$ is the supply of non-tradables with $\pi_{pp} > 0$ and $\pi_{pV} < 0$, D(•) is the domestic demand for non-tradables, M is the stock of monetary assets, e is the nominal exchange rate, and $D_p < 0$ and $D_J = D_{M/e} > 0$. We note that the inclusion of M/e in the demand function is justified because real money balances are part of the wealth.

Equations 4(i), 4(ii), 4(iii) and (12) solve for p, V, $\dot{R}$ and $\dot{\psi}$ for a given stock of money M and natural resource R. To close the system we need to consider an equation of motion for the money stock. We assume that real hoarding (H) depends upon the difference between actual and desired money stocks,

$$(13)\ H = \lambda (M^d - M/e), \quad 1 > \lambda > 0$$

where M^d is desired money balances, M is actual money balances, and λ is an adjustment coefficient. Desired money balances are assumed to be determined by the Cambridge equation.

$$(14)\ M^d = k\rho J(p,R) \quad 0 < k < 1$$

and, hence real monetary stock are subject to the following equation of motion,

$$(15)\ \dot{M}/e = \lambda [k \rho J(p,R) - M/e], \quad M(o) = \bar{M}_o.$$

Thus, equations 4(i) to 4(iii), (12) and (15) provide a solution for p, v, ψ, $\dot{R}$ and $\dot{M}$ at each pint in time given the exogenous variables R(o), M(o), ρ and e. The short-run or temporary equilibrium solution (under perfect foresight) can be directly obtained from (12) by using (6), given M(o) and R(o). The long-run or steady state solution requires to solve the five equations simultaneously using $\dot{R} = \dot{M} = 0$. This gives (under certain conditions) a unique solution for p, V, ψ, R and M/e. That is, the long-run solution is independent of the nominal exchange rate, implying that in steady state devaluation has no real effect.

Devaluation does, however, have a real effect in the short-run when R and M are given. Differentiating (12) with respect to p and e using (6) we obtain the effect of devaluation on the real exchange rate.

$$(16)\ \frac{\partial p}{\partial e} = -\frac{D_M M/e^2}{\pi_{pp} - D_p - D_j J_p + \pi_{pV}\frac{dV}{dp}} < 0$$

where dV/dp is given by (6) and is positive under private property of the resource as shown before. The denominator needs to be positive as a stability condition, and hence, since $D_M > 0$ we obtain that nominal devaluation leads to a fall in the real price of non-tradables in the short-run.

Since $\frac{dV}{dp} > 0$ and $\pi_{pV} < 0$, the value of the denominator in (16) decreases as either dV/dp or π_{pV} become greater in absolute value. Thus, as the resources sector becomes more important in the economy the responsiveness of the real exchange rate to nominal devaluation increases. This can be seen by noting that as the importance of V in the economy approaches to zero the value of π_{pV} also approaches zero while the value of

dV/dp remains finite. That is, as $V \to 0$ we obtain that $\frac{dV}{dp} \to 0$. This result holds when the resources sector is subject to private property.

If common resource property prevails then $dV/dp < 0$ because the effect of the shadow price adjustment to changes in p is not accounted for. In this case expression (6) is reduced to $V_p < 0$ since $V\psi = 0$. This implies that, the greater the importance of the resource sector, which is captured by $dV/dp > 0$, the less responsive is the real exchange rate to nominal devaluation when the resource is under common property. Of course, whether the resource is in private or common property devaluation has a negative effect on p.

Thus nominal devaluation causes the rate of extraction V to fall in the short-run if the resource is under private property and to increase if the resource is subject to common property. If we define short-run real income as $\pi(p, V) + i^* + M/e$ where i^* is the world interest rates (assuming that all money is reserves) then real income in the short-run will decrease after devaluation under private resource property because p and V both fall. That is, consideration of a variable rate of extraction of natural resources under private property provides another reason for contractionary devaluation. On the other hand, if the economy is characterized by common property of the natural resources then devaluation is likely to be expansionary even if full employment of capital and labor prevails.

What is the motion of the stock of monetary assets and of the stock of natural resources? The increase in e and fall in p causes an excess demand for money (and, hence a current account surplus) which causes $\dot{M}$ to become positive. That is, after the initial fall in the stock of real money balances, a process of gradual increase stars, the speed of which depends on the value of λ. This is of course, independent of whether private or common property on the resource prevails.

The motion of the stock of natural resources critically depends on the property rights upon the resource. If private property prevails then the short-run reduction in the rate of extraction causes the stock of natural resources to grow for a while. However, since in the new steady state the leavel of R must be equal to its level prior to devaluation, the process of increasing R after devaluation must be reverted at some point in time. That is, $\dot{R} > 0$ for a while, and then becomes negative. The initial increase in R speeds up the process of accumulation of monetary balances as the excess demand for money is exacerbated in the initial steps. However, when R starts to decrease it tends to decrease the excess demand for money. Moreover, to revert the motion of the stock of resources from $\dot{R} > 0$ to $\dot{R} < 0$ it is necessary that the rate of extraction increase at some point in the future. This will occur for two reasons: one, because the extraction costs decrease sufficiently as R has expanded and, two, because p at some point in the future needs to start increasing.

The process is exactly opposite if the resource is under common property. The rate of extraction in this case increases after devaluation thus causing $\dot{R} < 0$. Also at some point in the future the path of $\dot{R}$ is reverted to $R > 0$. This requires that starting at the turning point when $\dot{R}$ becomes positive, the rate of extraction to be lower than the one existing prior to devaluation. Since at the lower stock R prevailing at the turning point the extraction costs are higher (q is decreasing in R) than before devaluation, the only thing that can cause the path of R to become positive ($\dot{R} > 0$) is that p becomes *higher* than before devaluation. That is, although nominal devaluation always induces real devaluation in the short-run, in the intermediate run the real exchange rate will have to appreciate with respect to its level prior to devaluation.

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