Sustainable Growth in a Two-Country Trade Model under Different Property Rights Regimes for Natural Resources*

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Abstract

We analyze the sustainability of the economic growth in a dynamic two-country trade model. The two economies are not symmetric but they differ in natural resource endowments and innovative activities. One country is a technological leader that invests in the expansion of the varieties of productive inputs. Its counterpart, is a technological follower country with no investment in innovative activities, and it is endowed with a natural resource. Technology diffuses from the leader to the follower country through the trade of the productive inputs. The renewable natural resource is used as an essential input in the productive process of the follower country. The main goal of the paper is to analyze how the distribution of the property rights for this natural resource may affect the sustainable growth rate for the two economies and the resource conservation. We analyze different property rights regimes depending on whether the property rights for the resource are

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equally distributed among consumers or the resource is in the hands of a unique manager. When the owner is a unique agent, it can be a monopoly in the leading economy or the government in the follower country, which allows us to study how the location of the property rights may affect the results.

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1 Introduction

The literature on sustainable growth developed during the nineties makes growth and environmental sustainability compatible by maintaining a steady flow of technological innovation, a conclusion that is roughly consistent with the historical experience of industrialized countries. However, only a reduced group of industrial countries accounts for the majority of the R&D expenditure (see, for example, Coe *et al.* 1997). These countries are the technological leaders and the rest of the countries in the world can be considered technological followers. In recent studies, trade between technological leader and follower countries is seen as one of the main channels for technological diffusion. The pattern of trade between developing and industrial countries is frequently characterized by the following property: developing countries export an environmentally intensive product in exchange for capital and technology intensive goods from industrial countries. Within this framework of technology diffusion through trade, in this paper we analyze the effect of different property rights regimes for the natural resource on the long-run growth rate of the two trading economies and the resource conservation.

We formulate a two-country trade model that jointly determines the long-run growth rates of two different economies. One of the trading countries is a technological leader that invests in the expansion of the varieties of productive inputs, whereas its counterpart is a technological follower country with no investment, and which is endowed with a renewable natural resource. Firstly, we study the setting of a central authority ownership for the natural resource, case in which the natural resource is in the hands of a unique owner. We distinguish two cases depending on whether this owner is the national central government (domestic government regime), or a monopolistic firm located in the leading economy (foreign monopoly regime). Secondly, we study the case where the property rights for the resource are divided among many owners who are granted an exclusive access to their individual allotment (shared-property regime). Our main goal is to analyze how the long-run sustainable growth equilibrium varies across these three different property rights regimes.

Trade relationship between different economies has rarely been taken into account by the literature on sustainable growth. Among the exceptions, in a previous work, Cabo *et al.* (2005) studies a bilateral trade between a resource-dependent economy and a technological leader country. Although there is no trade on technological innovation, the growth in the resource-dependent economy comes from the innovative country, through international trade. Another exception is Elíasson & Turnovsky (2004), whom analyze the sustainability of the economic growth for a small open economy with a renewable natural resource. This economy is defined by two sectors, the harvesting of the natural resource and the production of the final output. In the former, the harvested resource is used to purchase imports of a consumption good from abroad. Economic growth comes from capital accumulation externalities in the final output sector. Under these assumptions neither the resource conservation nor the international trade are essential to generate sustainable growth.

In Cabo *et al.* (2007a, b), the idea of the international trade as a channel for economic growth merges with the two-sector economy modeled by Elíasson & Turnovsky. In these works, the harvested resource is not traded abroad but it becomes an essential factor in the final output sector. In this last sector, economic growth comes as an expansion in the varieties of intermediate inputs imported from a technological leader country. Therefore, the technology diffusion through the trade of intermediate inputs is the transmission mechanism for growth from a technologically leading to a follower economy. While Cabo *et al.* (2007a) compares foreign investment with mutual invention, Cabo *et al.* (2007b) explores the resource curse/blessing hypothesis. The present paper inherits the main features of these models and analyzes how different ownership regimes for the property rights of the natural resource (foreign vs. domestic, single vs. multiple ownership) affect the economic growth rate and the natural resource conservation.

There is a vast literature on property rights and natural resources exploitation, although it significantly shrinks when economic growth or international trade aspects are considered. The management of open-access resources and the differences between well-defined and ill-defined property rights regimes are well studied in the literature. However, as far as we know, no attempt has been made to compare growth rates and resource exploitation levels under different well-defined property rights regimes, taking into account foreign versus domestic, and single versus multiple ownership, which is our main goal. To place our work within this stream of the literature, we comment those works more closely related.

The sustainability of the economic growth when the harvested resource is an essential input in the production of final output is also analyzed by McAusland (2005) and López *et al.* (2007). The former compares the economic growth of a closed and an open economy, under the assumption of an open-access natural resource. In contrast López *et al.* (2007) focuses on a small open economy and studies the sustainability of growth under the assumption that the property rights belong to a central authority versus the open-access exploitation regime. They consider two types of final goods depending on whether or not the natural resource has been used as a productive input. Both final goods can be invested to increase the natural resource stock. This allows the resource extraction rate to be higher than the natural regeneration indefinitely along the sustainable growth equilibrium. In contrast, our assumptions of a single resource based final good and no investment in natural capital make the environmental restriction stronger. In addition, our paper differs from López *et al.* in the concern about the property rights of the natural resource. While they compare well-defined versus ill-defined property rights, we do so for three well-defined property rights regimes, in which property rights belong to a monopolistic foreign firm, a central national authority, or they are shared by many private harvesters.

The assumption of a priori well-defined property rights within the context of international trade is reinforced by Hotte *et al.* (2000). They focus on the endogenous determination and evolution of de facto property rights regime and show how the opening of trade may transform an open-access regime into a well-defined property rights regime.

We show that, in the long-run, the stock of the resource is conserved at a lower level when the property rights are split among many owners than when the resource is exploited by a unique manager, either the domestic government or the foreign monopoly. We also show that when the trading economies have market power, and so the terms of trade are determined through supply-demand decisions, the long-run growth rate of the two economies is greater when the property rights of the resource are in the hands of a foreign monopoly firm in the leading economy. On the contrary, assuming small economies with exogenous terms of trade, what matters is not the foreign or domestic ownership of the property rights but the degree of competitiveness in the harvesting sector. That is, the foreign monopoly and the domestic government regimes lead to the same long-run growth rate that can be either higher or lower than that attained under the shared-property regime.

The rest of the paper is organized as follows. Section 2 presents the two-country trade model when the property rights for the natural resource belong to a single manager, either the monopoly firm in the leading country or the government in the follower country. Section 3 characterizes the sustainable growth path under both regimes and compares the results. Section 4 introduces the case of many harvesters of the natural resource, the so called shared-property regime, and compares the results under the three property rights regimes. Finally, section 5 concludes.

2 The model

This section develops a two-country endogenous growth model of the type described by Barro & Sala-i-Martin (1999)(Chapter 8). Upon this model we assume that one of the economies has two sectors, a final output and a natural resource sector, similar to the formulation in Elíasson & Turnovsky (2004). Technological improvements in this country are imported from a technologically leading country. Following Barro & Sala-i-Martin (1999), technological innovation carried out in the leading economy, L, flows to the follower country, F, through the trade of new varieties of productive inputs. Correspondingly, consumers in the leading country buy final goods produced in country F.

2.1 The technological follower

Two sectors coexist in this economy. The resource sector, which uses labor to harvest a renewable natural resource; and the final output sector with three productive inputs: labor, the extracted resource, and the intermediate goods invented in and traded from the leading economy.

The stock of the renewable natural resource, S, evolves according to the natural reproduction of the resource minus the rate of harvest. The reproduction function, $G(S)$, is assumed to be of the well-known logistic or Verlhust type (see, for example, Clark, 1990):

$$G(S) = \tilde{g}S\left(1 - \frac{S}{C}\right),$$

where constants $\tilde{g}$ and C denote the intrinsic growth rate of the natural resource and the carrying capacity or saturation level of the resource, respectively.

The harvesting of the natural resource, $H(v, S)$ depends upon labor and upon the abundance of the renewable resource (its stock). Thus, the harvest rate can be represented by

$$H(v, S) = B\left[(1 - v)L_F\right]^{1-\delta} S^{\theta}, \quad 0 < \delta < 1, \quad B > 0, \quad 0 \leq \theta \leq 1, \tag{1}$$

where L_F is the constant labor force, v is the portion of labor allocated to the final output sector ($1 - v$ to the resource sector). Parameter θ measures the elasticity of harvesting with respect to the stock of the resource. The decreasing marginal return to the stock of the natural resource comes as a result of the hypothesis of congestion, while the decreasing marginal return to labor is a consequence of ultimate gear saturation. One particular case is given by $\theta = 0$, which implies that harvesting is independent of the stock size (as, for example, in Elíasson & Turnovsky (2004)). Another particular case is $\theta = 1$, where the harvest rate corresponds to the well-known Schaefer pattern used in many other models. In this case, the harvest is proportional to the stock of the renewable resource.[1] To simplify notation, we shall name the harvest flow H, omitting the arguments v and S.

Thus, the dynamics of S is:[2]

$$\dot{S} = \tilde{g}S\left(1 - \frac{S}{C}\right) - B\left[(1 - v)L_F\right]^{1-\delta} S^{\theta}, \qquad S(0) = S_0. \tag{2}$$

The final good production of a representative firm presents the following functional form:

$$Y_F = A_F(vL_F)^{1-\alpha-\beta}\sum_{j=1}^{N} X_{Fj}^{\alpha} H^{\beta}, \quad A_F > 0, \quad 0 < \alpha,\, \beta,\, \alpha + \beta < 1, \tag{3}$$

[1] The hypothesis $\theta = 0$ is appropriate for forests or fish living close to the surface; whereas, $\theta = 1$ is suitable for bottom-dwelling fish (see Elíasson & Turnovsky (2004) and references therein).

[2] The time argument is eliminated when no confusion can arise.

where X_{Fj} is the amount of nondurable input of type $j \in \{1, \ldots, N\}$, traded from the leader to the follower country. The output producers pay p_j^F units of Y_F for one unit of X_{Fj} to innovators in the technological leader country. This output-production function with an expanding variety of inputs has often been used in the literature, and it is based on Dixit & Stiglitz (1977), Ethier (1982) and Spence (1976). In addition to labor and intermediate goods, we consider the natural resource as an essential factor for production. This function presents diminishing marginal productivity for each input vL_F, X_{Fj} and H, and constant returns to scale for all inputs taken together.

By perfect competition, net marginal productivities are equated to factor prices:

$$w_F = (1-\alpha-\beta)\frac{Y_F}{vL_F}, \quad p_H = \beta\frac{Y_F}{H}, \quad X_{Fj} = (vL_F)^{\frac{1-\alpha-\beta}{1-\alpha}}\left(\frac{\alpha A_F}{p_j^F}\right)^{\frac{1}{1-\alpha}} H^{\frac{\beta}{1-\alpha}}, \quad (4)$$

where w_F is the wage rate in the final output sector and p_H is the price of the natural resource.

2.2 The technological leader

The production function of a representative firm in the final output sector is:[3]

$$Y_L = A_L L_L^{1-\alpha} \sum_{j=1}^{N} X_{Lj}^{\alpha}. \quad (5)$$

By equating the marginal product to input prices, the wage rate, w_L, and the total demand of intermediate good j by producers, X_{Lj}, can be written as:

$$w_L = (1-\alpha)\frac{Y_L}{L_L}, \qquad X_{Lj} = L_L\left(\frac{\alpha A_L}{p_j}\right)^{\frac{1}{1-\alpha}}, \quad (6)$$

where p_j are the units of output payed to innovators for one unit of the intermediate input j.

As there are no innovators in the follower country, the production of intermediate goods is fully carried out in the leading country. This situation

[3]Subscript L denotes variables corresponding to the leading country. Parameters A_L and L_L may differ from their corresponding parameters for country F. Differences between A_F and A_L could reflect differences in government policies. The gap between L_F and L_L would reflect the differences in scale between the two economies.

applies as long as intellectual property rights are protected both domestically and internationally. Once the innovator has invented the new intermediate good of type j, the unitary cost of production is one unit of Y_L, while the sale price equals p_j units of Y_L. The monopolistic innovator decides the price p_j to maximize her instantaneous profits from sales to final output producers in L and F:

$$\pi_j = (p_j - 1)\left(X_{Lj} + X_{Fj}\right),$$

where X_{Lj} and X_{Fj} are given in equations (6) and (4).

The optimal price for this problem is:

$$p_j = 1/\alpha > 1.$$

The terms of trade that define commerce between these two countries can be defined as the ratio between the units of Y_L and the units of Y_F payed for the same unit of intermediate good, that is, $p_F = p_j/p_j^F$. Given this definition, once p_j is known, the units of final output of country F paid for one unit of the intermediate good j, can be written as a function of the terms of trade, that is, $p_j^F = 1/(\alpha p_F)$. Therefore, the amount of every intermediate good in each country is:

$$\begin{aligned} X_{Lj} &= X_L = L_L A_L^{\frac{1}{1-\alpha}} \alpha^{\frac{2}{1-\alpha}}, \\ X_{Fj} &= X_F = (vL_F)^{\frac{1-\alpha-\beta}{1-\alpha}} (p_F A_F)^{\frac{1}{1-\alpha}} \alpha^{\frac{2}{1-\alpha}} H^{\frac{\beta}{1-\alpha}}. \end{aligned} \tag{7}$$

Note that although X_L is constant, the quantity X_F depends on p_F, v and H (which is a function of v and S).

The cost to invent a new type of product is fixed at η units of output Y_L. Furthermore, an innovator must pay a cost to transfer and adapt her product for use in country F. This cost is fixed at ν units of output Y_L, with $0 < \nu < \eta$. We assume free entry into the business of being an inventor so that, in equilibrium, the present value of the profits for each intermediate good must equal $\eta + \nu$, that is,

$$\eta + \nu = \int_t^\infty (p_j - 1)(X_L + X_F) e^{-\bar{r}(s,t)(s-t)} ds, \tag{8}$$

where $\bar{r}(s,t) = [1/(s-t)] \int_t^s r(w)dw$ is the average interest rate between times t and s.

Differentiating (8) with respect to t and taking into account that X_F and r are time-dependent, it follows that:

$$r = \frac{(1-\alpha)(X_L + X_F)}{\alpha(\eta + \nu)}. \tag{9}$$

2.3 Property rights on the natural resource

Economic growth in the two trading economies will be driven by technological improvements made by innovators in the leading economy. The required investment is associated with the returns obtained by innovators, which depend on the demand of the intermediate goods made by final output producers in the leader and the follower countries. In country F, the adoption of new technological goods developed abroad depends on the purchase power of domestic firms. As we will show later, the location of the property rights of the natural resource (which can be either in the leader or in the follower country) influences the terms of trade between both countries.

In this section we study two different property rights regimes for the natural resource located in the follower country. First, we assume that the property rights of the natural resource are in the hands of a foreign monopoly firm located at the technologically leading country. Second, we consider that the government in the follower country nationalizes the natural resource. Either the foreign monopolistic firm (in L) or the domestic government (in F) harvests the resource and exploits its monopoly power, while selling the resource to final output producers in the follower country, to maximize the present value of her objective function.

When the natural resource is managed by a monopolistic agent, she knows the demand function of the resource made by final output producers in the follower country, given in (4). The resource's demand can be written as:

$$H^d(p_H, v) = \left[\frac{\beta A_F (vL_F)^{1-\alpha-\beta} N X_F^{\alpha}}{p_H}\right]^{\frac{1}{1-\beta}}. \tag{10}$$

Furthermore, the market clearing condition

$$B(L_F(1-v))^{1-\delta} S^{\theta} = \left[\frac{\beta A_F (vL_F)^{1-\alpha-\beta} N X_F^{\alpha}}{p_H}\right]^{\frac{1}{1-\beta}}$$

defines the price of the resource p_H as a function of v and S, for given values of N and X_F,

$$p_H(v,S) = \frac{\beta A_F (vL_F)^{1-\alpha-\beta} N X_F^{\alpha}}{[B(L_F(1-v))^{1-\delta} S^{\theta}]^{1-\beta}}. \tag{11}$$

Therefore, the monopolistic manager of the resource knows the process of price formation. With this information, when the manager decides the demand of labor, $(1-v)L_F$, she determines the amount harvested (given S), and its price (given N and X_F).

The monopoly in the leading country, given w_F chooses the demand of labor in the resource sector to maximize her stream of profits, given by

$$\Pi = p_H H - w_F(1-v)L_F,$$

through an infinite time horizon, discounted at the average interest rate between 0 and t, $\bar{r}(t,0) = 1/t \int_0^t r(w)\,dw$. This firm is concerned with the dynamics of the natural resource in (2). Thus, her maximization problem reads:

$$\max_v V = \int_0^{\infty} \Pi(v,S)\, e^{-\bar{r}(t,0)t}\, dt, \tag{12}$$
$$\text{s.t.:} \quad \dot{S} = G(S) - H(v,S), \quad S(0) = S_0,$$

where $\Pi(v,S) = p_H(v,S)H(v,S) - w_F(1-v)L_F$.

The first-order conditions for optimality are given by:

$$-\varepsilon_v^{p_H}\frac{H}{v} + (\xi_f - 1)\frac{\partial H}{\partial v} = \frac{w_F}{p_H}L_F, \tag{13}$$

$$\frac{\dot{\xi}_f}{\xi_f} = r - G'(S) + \frac{\partial H}{\partial S} - \frac{1}{\xi_f}\left\{\varepsilon_S^{p_H}\frac{H}{S} + \frac{\partial H}{\partial S}\right\} - \frac{\dot{p}_H}{p_H}, \tag{14}$$

where $\varepsilon_x^{p_H} = (\partial p_H/\partial x)(x/p_H)$ is the elasticity of p_H with respect to $x \in \{v, S\}$, λ_f is the shadow value of the renewable resource and $\xi_f = \lambda_f/p_H$ is a modified shadow value, defined as the ratio between the shadow value of the stock of the resource and the price of the harvested resource in terms of domestic output. Subscript f stands for foreign monopoly.

Considering a domestic government regime, the government in F maximizes the present value of utility for the representative consumer. A representative consumer in country F has one unit of labor per unit of time and receives a salary w_F plus the revenues from harvesting, Π, that the government transfers to consumers (voters) in form of lump-sum subsidies, at each instant. Since no innovative activity exists in country F and there is no international trade on financial assets, consumers in country F do not accumulate assets and they consume all their income. Therefore, her budget constraint is

$$c_F = w_F + \frac{\Pi}{L_F} = \frac{p_H H}{L_F} + w_F v, \tag{15}$$

where c_F is the per capita consumption. The government also determines the demand of labor in the resource sector. However, it does not maximize profits, but the present value of *per capita* utility, defined as $u(c_F) = \ln c_F$. The government dynamics problem reads:

$$\begin{aligned} \max_v V \quad &= \quad \int_0^\infty u(c_F)\, e^{-\rho t}\, dt, \\ \text{s.t.:} \qquad & \dot{S} = G(S) - H(v,S), \quad S(0) = S_0, \\ & c_F = \frac{p_H(v,S) H(v,S)}{L_F} + w_F v, \end{aligned} \tag{16}$$

where $\rho > 0$ is the social discount rate. The first order conditions for optimality are given by:

$$-\varepsilon_v^{p_H} \frac{H}{v} + (\xi_d - 1)\frac{\partial H}{\partial v} = \frac{w_F}{p_H} L_F, \tag{17}$$

$$\frac{\dot{\xi}_d}{\xi_d} = \rho - G'(S) + \frac{\partial H}{\partial S} - \frac{1}{\xi_d}\left\{\varepsilon_S^{p_H}\frac{H}{S} + \frac{\partial H}{\partial S}\right\} + \frac{\dot{c}_F}{c_F} - \frac{\dot{p}_H}{p_H}, \tag{18}$$

where λ_d is the shadow value of the resource, and $\xi_d = \lambda_d L_F/(u' p_H)$ is the modified shadow value, defined as the ratio between the shadow value of the stock of the resource and the price of the harvested resource,[4] this ratio is scaled by the population in the follower country. Subscript d stands for domestic government.

The elasticities $\varepsilon_v^{p_H}$ and $\varepsilon_S^{p_H}$ only depend on v and S. Likewise, the ratio w_F/p_H is also a function of these two variables,[5] since from (4) it follows

[4]Notice that λ_d measures utility, while λ_d/u' can be defined as the shadow value of the stock of the resource in units of output Y_F.

[5]Note that although w_F and p_H depend on N and X_F, this is not the case neither for the elasticities nor for the quotient w_F/p_H.

that:

$$\frac{w_F}{p_H} = \frac{1-\alpha-\beta}{\beta}\frac{H}{vL_F}.$$

Therefore, if the modified shadow values of the resource, ξ_f and ξ_d, equate, then from equations (13) and (17) immediately follows that, for a given stock of the resource, the foreign monopoly firm and the government in country F would demand the same amount of labor to harvest the resource. As we will see this is the case along the steady-state equilibria.

2.4 Consumers

Consumers in the leading country accumulate assets in the form of ownership claims on innovative firms. No accumulation if feasible for consumers in country F. A representative consumer in F decides on labor allocation in the final output sector or in the resource sector. Since consumers have no property rights on the resource, she decides disregarding the dynamics of the natural resource. With perfect mobility of labor, her static optimal decision equates wages in both sectors.

The budget constraints for consumers in both, the leading and the follower countries, adopt different forms, depending on the resource property rights regime.

If a foreign monopolistic firm located at country L exploits the resource, the budget constraint for a consumer in country L is:[6]

$$\dot{a}_L = ra_L + w_L + p_F\frac{\Pi}{L_L} - c_L - p_F c_{LF}, \quad a_L(0) = a_{L0}, \tag{19}$$

where a_L are the per-capita assets, r is the rate of return on assets, c_L is the per-capita consumption of the final domestic good, and c_{LF} is the per-capita consumption of the final good imported from the technological follower at a price p_F. In (19) we are assuming that consumers in country L equally share the monopolistic extractive firm and receive an equal portion of the dividends that it generates. The price of the domestic final good is defined as the numeraire, $p_L = 1$. Consequently p_F is also the price of the good imported from F. A representative consumer maximizes the utility (a

[6]The arguments of functions $H(v,S)$ and $\Pi(v,S)$ are generally skipped for notational simplicity.

logarithmic function) of the streams of domestic and imported consumptions, discounted at rate ρ:

$$\max_{c_L, c_{LF}} U = \int_0^\infty \left[\ln(c_L) + \ln(c_{LF})\right] e^{-\rho t} dt, \tag{20}$$

subject to (19). With no international asset exchange, consumers in country F cannot invest on assets, but all their earnings are consumed. Therefore, any time it holds that:

$$c_F = w_F. \tag{21}$$

If the resource is not exploited by a foreign monopoly, but by the domestic government, per capita consumption is given by (15).

Investment in assets in the leading country is independent of the monopolistic exploitation benefits, and its dynamics coincides with

$$\dot{a}_L = ra_L + w_L - c_L - p_F c_{LF}, \quad a_L(0) = a_{L0}. \tag{22}$$

A representative consumer maximizes (20) subject to (22).

The first order conditions for problems (20) subject to (19), and (20) subject to (22), lead to the same relationship between domestic and imported consumptions and their growth rates:

$$c_L = p_F c_{LF}, \quad \frac{\dot{c}_L}{c_L} = r - \rho, \quad \frac{\dot{c}_{LF}}{c_{LF}} = r - \rho - \frac{\dot{p}_F}{p_F}. \tag{23}$$

With no international exchange of assets, total households' assets in the leading economy, $a_L L_L$, are equal to the market value of the firms that produce these intermediate goods, $(\eta + \nu)N$. Therefore, households' assets run parallel to the number of varieties of intermediate inputs, N. The dynamics of the number of intermediate goods, N, can be obtained from the equality $a_L L_L = (\eta + \nu)N$, taking into account the salary in the technologically leading country, given in (6), the relationship

$$\alpha^2 Y_L = N X_L, \tag{24}$$

and the assets dynamics. Therefore, taking into account (19) and (22), the growth rate of N for a foreign monopoly and for the domestic government regimes, is given by:

$$\frac{\dot{N}}{N}=\frac{1}{\eta+\nu}\left[\frac{Y_L}{N}-\left(\frac{c_L}{N}+\frac{p_F c_{LF}}{N}\right)L_L-X_L+\frac{1-\alpha}{\alpha}X_F+\Phi_m(v,S)\right],\ N(0)=N_0, \tag{25}$$

where $m \in \{f, d\}$ stands for the foreign monopoly and the domestic government respectively, and

$$\Phi_f(v,S)=\frac{p_F\Pi(v,S)}{N}=\frac{v(1-\alpha)-(1-\alpha-\beta)}{v}p_F A_F(vL_F)^{1-\alpha-\beta}X_F^{\alpha}H(v,S)^{\beta},$$

$$\Phi_d(v,S)=0.$$

3 Sustainable growth and property rights regimes[7]

When the property rights of the resource belong to a foreign monopoly, the problem for the follower country, PF_f, is a static problem. Static demands for inputs in the final output sector in F are given by (4). Under this regime, the problem for the leading country, PL_f, is composed of two dynamic problems. Consumers choose c_L and c_{LF} to maximize (20) subject to (19). At the same time, the monopoly firm that manages the resource determines v to maximize (12) subject to (2). The salary w_L and the interest rate r are given by (6) and (9), respectively.

The main difference between the foreign monopoly and the domestic government regimes is that the management of the resource moves from the monopoly in L to the government in F, which chooses v to maximize (16) subject to (2). Thus, the problem for the follower country PF_d, becomes dynamic and the problem for the leader PL_d involves consumption decisions as the unique dynamic problem.

The economies previously described face a problem of environmental shortage when agents have to restrict the optimal harvesting to rates which are below the harvesting rate they would be chosen under a myopic management which disregard the evolution of the resource. The following proposition shows the fraction of labor that the monopolistic agents employ to harvesting in the case of a myopic management.

[7] The proofs of the propositions in this section are presented in Appendix A.

Proposition 1 *When agents do not take into account the dynamics of the natural resource, the fraction of labor allocated to output production under a myopic management either the monopoly in the leader country or the government in the follower country, v^{mm}, satisfy:*

$$0 < \frac{1+\beta}{1+\beta\phi} = v^{mm} < 1, \quad \textit{where} \quad \phi = \frac{1-\alpha-\delta\beta}{1-\alpha-\beta} > 1.$$

The assumption of a scarce natural resource leads us to concentrate on equilibria with $v > v^{mm}$, that is, equilibria with harvesting rates below $H^{mm} = B\left[(1-(1+\beta)/(1+\beta\phi))\,L_F\right]^{1-\delta}$, the myopic harvesting rate.

Depending on the market power of the trading economies, the terms of trade, p_F, can be exogenously fixed (unaffected by countries decisions) and supposed constant when economies are small, or they can be endogenously determined by the countries decisions if large open economies are considered. For simplicity, we refer to this as the large open economies (LOE) scenario, while the scenario with no market power is denoted small open economies (SOE).

For large open economies, the price, p_F, for a bilateral trade is determined by equating the value of the final good traded from F to L, to the value of the intermediate goods sold from innovators in L to producers in F:

$$L_L p_F c_{LF} = p_j N X_F. \tag{26}$$

Definition 2 *Given $N(0)$ and $S(0)$, and considering time paths for N, S, c_L, c_{LF} and v, such that problems $PL_f - PF_f$ and $PL_d - PF_d$ are solved, two types of equilibria may appear:*

- *Small open economies equilibrium: p_F is exogenously fixed in the international market and supposed constant at value $\hat{p}_F$.*
- *Large open economies equilibrium: p_F is endogenously determined from equation (26).*

In what follows, we concentrate exclusively on the steady-state equilibria. First we describe the behavior of the different variables along such steady-state equilibrium.

Proposition 3 *If a steady-state equilibrium exists, along this path:*

- *v, S, H, p_F and r remain constant;*
- *Y_L, Y_F, c_L, c_{LF}, c_F, p_H, w_L, w_F and N grow at rate $r - \rho$.*

Note that if v and S remain constant, then the harvest rate, H, and the interest rate, r, given by (9), will also be constant. Moreover, output Y_F, given by (3), will grow at the same rate as the number of intermediate goods, N. This rate will be constant if and only if $\tilde{c_L} = c_L/N$ is also constant.[8] Therefore, the steady-state equilibrium in Proposition 3, will be obtained if and only if variables v, S and $\tilde{c_L}$ remain constant. Therefore, a steady-state equilibrium corresponds with a steady state of variables v, S and $\tilde{c_L}$. Let denote these steady-state values by v_m^*, S_m^* and $\tilde{c_L}_m^*$, where the subscripts m can be f, if a foreign monopoly regime is considered, or d if a domestic government manages the resource.

The main difference between the foreign monopoly and the domestic government regimes has to do with where the revenues from harvesting are transferred. In the domestic government regime these revenues, Π, are in the hands of consumers in F. Conversely, in the foreign monopoly regime, the revenues are transferred to L and its value in units of Y_L, $p_F\Pi$, is consumed by consumers in the leading economy. These revenues determine the gap in the per capita consumption per unit of intermediate good between the foreign monopoly and the domestic government regimes.

Proposition 4 *The dynamics of the per capita consumption per unit of intermediate good in country L is:*

$$\dot{\tilde{c}}_L = \tilde{c}_L \left\{ \frac{1}{\eta+\nu} \left\{ 2\tilde{c}_L L_L - (1-\alpha) L_L A_L^{\frac{1}{1-\alpha}} \alpha^{\frac{2\alpha}{1-\alpha}} - \Phi_m(v,S) \right\} - \rho \right\}, \quad (27)$$

and the steady-state per capita consumption per unit of intermediate good reads:

$$\tilde{c_L}_m^* = \frac{\rho(\eta+\nu) + L_L A_L^{\frac{1}{1-\alpha}} \alpha^{\frac{2\alpha}{1-\alpha}} (1-\alpha) + \Phi_m(v_m^*, S_m^*)}{2L_L}. \quad (28)$$

Corollary 5 *Along the balanced path, if the foreign monopoly profits at the steady state, $\Pi(v_f^*, S_f^*)$, are positive, then the per capita consumption per unit of intermediate good in L is larger under the foreign monopoly regime than under the demestic government regime, $\tilde{c_L}_f^* > \tilde{c_L}_d^*$.*

[8] Along the steady-state equilibrium, the modified shadow price of the stock of the natural resource also remains constant under both property right regimes, ξ_d and ξ_f.

From the non-linearities in the production, harvesting and regeneration functions, a problem of multiplicity in steady-state equilibria may arise (Figure 1 illustrates an example with three balanced paths).

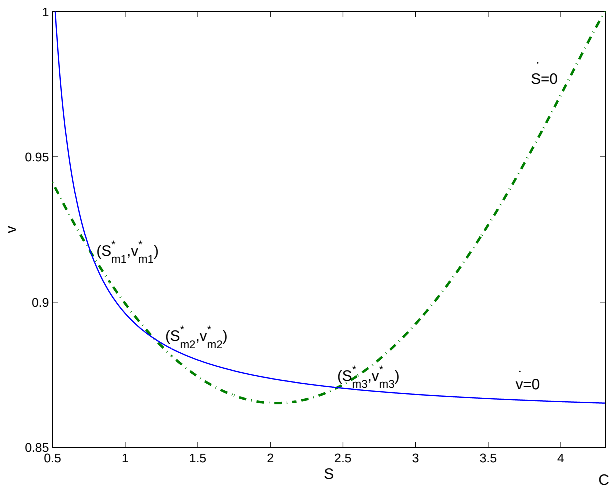

Figure 1: Monopoly regime. Example three balanced paths.

Proposition 6 *A steady-state equilibrium with $v^{mm} < v^*_m < 1$, $0 < S^*_m < C$ and $\tilde{c_L}^*_m > 0$, always exists. Furthermore, under sufficient condition:*

$$\theta \geq \frac{2\rho}{\tilde{g}+\rho}, \tag{29}$$

the equilibrium is unique.

Given the non-linearity of functions, explicit expressions of $v^*_m, S^*_m, m \in \{f,d\}$ cannot always be obtained for the two regimes. However, for the particular case when the harvesting function does not depend on the stock of the resource, $\theta = 0$, explicit expressions for these steady-state values can be easily found:

$$S^{*0}_f = S^{*0}_d = \frac{\tilde{g}-\rho}{2\tilde{g}}C < \frac{C}{2}, \quad v^{*0}_f = v^{*0}_d = 1 - \frac{1}{L_F}\left[\frac{(\tilde{g}^2-\rho^2)C}{4\tilde{g}B}\right]^{\frac{1}{1-\delta}}. \tag{30}$$

Thus, a necessary condition for the positivity of S^{*0}_m, $m \in \{f,d\}$ is $\tilde{g} > \rho$, which also guarantees that $v^{*0}_m < 1$, $m \in \{f,d\}$. That is, the intrinsic growth rate of the resource must be greater than the rate of temporal discount, in order for a feasible interior steady state to exist.

Moreover, when $\theta = 0$, the assumption of environmental shortage, that is condition $v > v^{mm}$, requires the harvesting to be below the myopic extraction, H^{mm}, which is equivalent to condition $\tilde{g} < \tilde{g}^{+}_{mm}$, where

$$\tilde{g}^{+}_{mm} = \frac{2H^{mm}}{C} + \sqrt{\left(\frac{2H^{mm}}{C}\right)^2 + \rho^2}. \tag{31}$$

Note that the steady-state values coincide when the resource is managed by a unique owner, that is, a foreign monopoly or the domestic government, $S_f^{*0} = S_d^{*0}$. As we will see later on, this result is not exclusive for $\theta = 0$, but applies for any value of $\theta \in [0, 1]$.

When $\theta \neq 0$, i.e. when the stock of the resource affects harvesting and thus it affects the production of final output in the follower country, even if S_m^* cannot be explicitly obtained, its implicit characterization allows us to compare the stocks of the natural resource at the steady state, depending on the two different property rights regimes.

At the steady state, the growth rate of the consumption of the domestic good in country F equals $r - \rho$. Therefore, the dynamics of the modified shadow prices in (14) and (18) are the same. For a given v and S, the foreign monopoly and the domestic government value the resource identically. As a consequence, equation (13) coincides with (17) and for a given S, both monopolistic managers present the same behaviour, choosing the same labor in the resource sector. Since equation (2) describes the dynamics of the resource under both regimes, the steady-state value of the labor demand in each sector and the stock of the resource are independent on the location of the property rights of the natural resource. The next proposition collects these results.

Proposition 7 *When the resource is monopoly-owned either by a foreign monopolistic firm in the leading country or by the government in the follower country, along the balanced path, the stock of the natural resource and the share of labor devoted to the final-output sector coincide under both property rights regimes. That is, $S_f^* = S_d^*$ and $v_f^* = v_d^*$.*

At the steady state, the terms of trade for large open economies are obtained taking into account the optimal consumption decisions in the leading economy and the balanced trade equation (26):

$$p^*_{Fm} = \frac{(\tilde{c}^*_{Lm} L_L)^{1-\alpha}}{(v^*_m L_F)^{1-\alpha-\beta} A_F (H(v^*_m, S^*_m))^\beta \alpha^{\alpha+1}}, \qquad m \in \{f, d\}. \tag{32}$$

Corollary 8 *Along the balanced path, the terms of trade of large open economies are larger under the foreign monopoly regime than under the domestic government regime,* $p^*_{Ff} > p^*_{Fd}$.

A straightforward consequence of Corollary 5 is that the value of the constant demand for the imported consumption good in the leading country under the monopoly regime is above that under the domestic government regime (see the first equation in (23)). However, in the follower economy, from equation (7) and Proposition 7, the demand for each imported intermediate good as a function of the terms of trade is the same upward sloping and convex function under both regimes. Thus, the balanced trade equation (26) concludes that the terms of trade are higher under foreign monopoly than under domestic government management.

The next proposition states the long-term growth rates for small and large open economies under the two property rights regimes considered.

Proposition 9 *Along a steady-state equilibrium the economies in both the technological leading and follower countries grow at the same rate given by:*

$$\gamma = \frac{1-\alpha}{\alpha(\eta+\nu)} [X_L + X_F] - \rho, \tag{33}$$

which for the different scenarios particularizes as follows:

- *Small open economies (SOE)*

$$\gamma^{soe}_m = \frac{(1-\alpha)\alpha^{\frac{2}{1-\alpha}}}{\alpha(\eta+\nu)} \left[L_L A_L^{\frac{1}{1-\alpha}} + (L_F v^*_m)^{\frac{1-\alpha-\beta}{1-\alpha}} A_F^{\frac{1}{1-\alpha}} H(v^*_m, S^*_m)^{\frac{\beta}{1-\alpha}} \hat{p}_F^{\frac{1}{1-\alpha}} \right] - \rho,$$

  $m \in \{f, d\}$.

- *Large open economies (LOE)*

$$\gamma^{loe}_m = (1+\alpha) \left[\frac{(1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}}{2(\eta+\nu)} L_L A_L^{\frac{1}{1-\alpha}} - \rho \right] + \frac{1-\alpha}{2(\eta+\nu)} \Phi_m(v^*_f, S^*_f),$$

  $m \in \{f, d\}$.

Corollary 10 *The long-run growth rates for SOE coincide under a foreign monopoly and the domestic government regimes,* $\gamma_f^{soe} = \gamma_d^{soe}$*. For LOE, if the monopoly profits at the steady state,* $\Pi(v_f^*, S_f^*)$*, are positive, then the long-run growth rate under a foreign monopoly is higher than under the domestic government regime,* $\gamma_f^{loe} > \gamma_d^{loe}$.

The rate of return on investment is positively related with the joint demand of each intermediate good made by output producers in both countries (see equation (9)). We have just seen that, for large open economies, the terms of trade are better for the follower country when a foreign monopoly manages the natural resource than under the domestic government management. This improvement in the terms of trade boosts the demand of each intermediate good made by final output producers in the follower country, which in turn pushes up the rate of return on investment and then the growth rate of the economies. In the case of small open economies, due to their lack of market power, the terms of trade are the same exogenous constant for the two regimes. Therefore, the rate of return on investment is unaffected by the different property rights regimes, and so will be the growth rate.

4 Shared property[9]

To avoid the "tragedy of the commons", the property rights of the natural resource must be clearly established. The environmental literature has frequently relied on a central authority who strictly regulates the usage of the resource (this is the case in the two property rights regimes presented above). Alternatively, well defined property rights can be in the hands of many agents. Thus, next we consider the distribution of the property rights among many equal agents who exploit their share of the resource. In the case of many managers of the resource, institutions who guarantee the exclusive access for users to their individual allotment, must be developed. There exist real examples of this last case (see, for example, Birdyshaw & Ellis (2007) and the real examples therein).

In this section we assume that each consumer in country F has an equal share of the property rights associated with the natural resource. Thus, the stock of the resource managed by the representative agent is $s = S/L_F$, and

[9]The proofs of the propositions in this section are presented in Appendix B.

from (2) it evolves as:

$$\dot{s} = \tilde{g}s\left(1 - \frac{s}{\kappa}\right) - b(1-v)^{1-\delta}s^{\theta}, \qquad s(0) = s_0, \tag{34}$$

where $\kappa = C/L_F$, $b = BL_F^{\theta-\delta}$ and $s_0 = S_0/L_F$.

The harvest rate of the representative agent reads:[10]

$$h(v,s) = b(1-v)^{1-\delta}s^{\theta}, \quad b > 0, \quad 0 < \delta < 1, \quad 0 \leq \theta \leq 1. \tag{35}$$

The total harvest rate will be $H(v,S) = L_F h(v,s)$.

Now each consumer in country F holds and manages the exploitation of an equal percentage of the natural resource. She receives a salary per unit of labor in the final output sector, and the income from the extraction of her resource. Moreover, as long as she does not accumulate assets, her budget restriction is:

$$c_F = vw_F + p_H h. \tag{36}$$

Thus, the optimization problem of the representative consumer reads:

$$\max_v \int_0^{\infty} u(c_F)e^{-\rho t}dt \tag{37}$$

$$\text{s.t.:} \qquad (36) \quad \text{and} \quad (34).$$

The first-order conditions for optimality are given by:

$$(\xi_{sp} - 1)\frac{\partial H}{\partial v} = \frac{w_F}{p_H}L_F, \tag{38}$$

$$\frac{\dot{\xi}_{sp}}{\xi_{sp}} = \rho - g'(s) + \frac{\partial h}{\partial s} - \frac{1}{\xi_{sp}}\frac{\partial h}{\partial s} + \frac{\dot{c}_F}{c_F} - \frac{\dot{p}_H}{p_H}, \tag{39}$$

where λ_{sp} is the shadow values of the resource managed by a representative consumer, and $\xi_{sp} = \lambda_{sp}/(u'p_H)$ the modified shadow value, defined as the ratio between the shadow value of the stock of the resource (in terms of final output) and its sale price.

To ensure that the resource is a real restriction on production and growth, we study first the case of an open-access resource, which may lead to the "tragedy of the commons". The following proposition shows the fraction of labor that a single agent employs to harvesting in this case of myopic management.

[10] Note that $b = BL_F^{\theta-\delta}$ means that each agent labor marginal productivity under the shared-property regime matches the global labor marginal productivity when the resource is monopoly-owned.

Proposition 11 *When agents disregard the dynamics of the natural resource, the fraction of labor allocated to output production under open access, v^{oa}, satisfies:*

$$0 < v^{oa} = \frac{1}{\phi} < \frac{1+\beta}{1+\beta\phi} = v^{mm} < 1.$$

Therefore, the assumption of a scarce natural resource made on page 15, $v > v^{mm}$, guarantees also the scarcity when the resource is managed by many owner-users.

Now, the problem in the leader country, PL_{sp}, is described by a representative consumer who has to choose c_L and c_{LF} to maximize (20) subject to (22). The salary w_L will be given by (6) and the rate of return r will be (9). In a symmetric fashion, the problem for the follower country, PF_{sp}, considers a representative consumer who has to choose v to maximize (37) subject to (34) and (36). The wage rate, w_F, and the price of the resource, p_H, will be given by (4).

When the property rights of the natural resource are located in the follower country, the revenues from harvesting do not flow to consumers in the leading economy. Therefore, consumption in this country is unaffected by harvesting revenues. This is true regardless of whether the resource belongs to the government or it is in the hands of many agents. Therefore, per capita consumption per unit of intermediate good at the steady state is equal under the shared-property and the domestic government regimes: $\tilde{c_L}^*_{sp} = \tilde{c_L}^*_d$.

When the harvesting function does not depend on the stock of the resource, $\theta = 0$, explicit expressions for these steady-state values can be easily found:

$$s^{*0}_{sp} = \frac{\tilde{g}-\rho}{2\tilde{g}}\kappa < \frac{\kappa}{2}, \quad v^{*0}_{sp} = 1 - \left[\frac{(\tilde{g}^2-\rho^2)\kappa}{4\tilde{g}b}\right]^{\frac{1}{1-\delta}}. \tag{40}$$

As for the other two regimes, a positive s^{*0}_{sp} holds under condition $\tilde{g} > \rho$, which also guarantees $v^{*0}_{sp} < 1$. Moreover, when $\theta = 0$, under the shared-property regime, condition $v > 1/\phi$ says that the harvesting is below the open-access extraction, $h^{oa} = b(1-1/\phi)^{1-\delta}$. At the steady state, this inequality is equivalent to $g(s^{*0}_{sp}) < h^{oa}$ and this condition is equivalent to $\tilde{g} < \tilde{g}^{+}_{sp}$, where

$$\tilde{g}^{+}_{sp} = \frac{2h^{oa}}{\kappa} + \sqrt{\left(\frac{2h^{oa}}{\kappa}\right)^2 + \rho^2}. \tag{41}$$

Thus, the resource is a real restriction on production if the intrinsic growth rate of the natural resource is upper bounded.

In this particular case in which harvesting is independent of the stock of the resource, $S_f^{*0} = S_d^{*0} = L_F s_{sp}^{*0}$ and $v_f^{*0} = v_d^{*0} = v_{sp}^{*0}$.

The differences in the optimal harvesting policies when the property rights of the resource belong to a unique owner (the government), and when they are in the hands of many consumers are shown by comparing systems (17)-(18) and (38)-(39). Contrary to the domestic government, the representative consumer does not know the demand function of the resource. In consequence, she does not discount the reduction in the price caused by an increment in the extraction, which increases the marginal gains of labor in the harvesting sector. Furthermore, when the manager of the resource knows the process of price formation, he acknowledges that a higher stock of the resource leads to higher harvesting and thus lower price. The time evolution of the modified shadow value of the representative consumer disregards this negative effect.

This different behaviour induces that, along the balanced path, the domestic government follows a more conservationist policy, shown by a greater stock of the resource. However, the comparison of labor demand on the resource sector is not utterly determined.

Proposition 12 *Assuming a unique*[11] *and asymptotically stable balanced path with* $v^* \in (v^{mm}, 1)$, $S^* \in (0, C)$ *and* $\tilde{c_L}^* > 0$, *then* $S_{sp}^* < S_f^* = S_d^*$, *although* v_{sp}^* *can be greater, lower or equal to* v_m^*, *with* $m \in \{f, d\}$. *However, under condition (29), then* $v_{sp}^* < v_f^* = v_d^*$.

The previous proposition states that if the natural resource is managed by a monopoly firm in L, or by the government in F, then the natural resource is better conserved (in the sense of a higher stock in the long-run), than if the resource is exploited by many owners in the follower country. Now an immediate question arises: is this higher stock of the resource necessarily linked with a slower economic growth? To answer this question in a bilateral trade framework, first we have to look at the terms of trade.

At the steady state, the terms of trade for large open economies are obtained taking into account the optimal consumption decisions in the leading

[11]Note that the steady-state equilibrium under shared property may not be unique. Sufficient condition for uniqueness under monopolistic management (29), also applies under shared property.

economy and the balanced trade equation (26) is:

$$p^*_{F\,sp} = \frac{(\tilde{c_L}^*_{sp} L_L)^{1-\alpha}}{(v^*_{sp} L_F)^{1-\alpha-\beta} A_F (L_F h(v^*_{sp}, s^*_{sp}))^{\beta} \alpha^{\alpha+1}}, \tag{42}$$

The next proposition states the long-run growth rates for small and large open economies under the shared-property regime. The proof follows the same pattern that proof of Proposition 9.

Proposition 13 *Along a steady-state equilibrium the economies in both the technological leading and follower countries grow at the same rate given by:*

- *Small open economies (SOE)*

$$\gamma^{soe}_{sp} = \frac{(1-\alpha)\alpha^{\frac{2}{1-\alpha}}}{\alpha(\eta+\nu)} \left[L_L A_L^{\frac{1}{1-\alpha}} + (L_F v^*_{sp})^{\frac{1-\alpha-\beta}{1-\alpha}} A_F^{\frac{1}{1-\alpha}} [L_F h(v^*_{sp}, s^*_{sp})]^{\frac{\beta}{1-\alpha}} \hat{p}_F^{\frac{1}{1-\alpha}} \right] - \rho.$$

- *Large open economies (LOE)*

$$\gamma^{loe}_{sp} = \gamma^{loe}_{d} = (1+\alpha) \left[\frac{(1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}}{2(\eta+\nu)} L_L A_L^{\frac{1}{1-\alpha}} - \rho \right].$$

Corollary 14 *For SOE, the long-run growth rates coincide under the foreign monopoly and the domestic government regimes, $\gamma^{soe}_f = \gamma^{soe}_d$, although they can be higher or lower than under the shared-property regime. For LOE, if the foreign monopoly profits at the steady state, $\Pi(v^*_f, S^*_f)$, are positive, then the long-run growth rate under foreign monopoly is higher than under either the shared-property or the domestic government regimes, which share the same growth rate, $\gamma^{loe}_f > \gamma^{loe}_{sp} = \gamma^{loe}_d$.*

The long-run growth rates under the foreign monopoly and the domestic government regimes are compared in Corollary 10. We add now the shared-property regime.

We first explain the results for the shared-property and the domestic government regimes, considering the case of large open economies. When the property rights of the resource are located in the follower economy the profits from resource harvesting do not reach consumers in the leading economy. In this country, the consumption of domestic good is the same constant regardless of whether the property rights are in the hands of either many owners or the government in the follower economy. The same happens with the consumption of the imported good expressed in units of output in L, $p_F c_{LF}$ (LHS of the balanced trade equation (26)). In the follower economy, the share of labor in each sector and the stock of the natural resource at the steady state do not necessarily coincide under domestic government and shared-property regimes (contrary to what happens when domestic government and foreign monopoly regimes are compared). Therefore, the final output producers in the follower economy may present a different demand function for intermediate goods, expressed as an upward slope function of the terms of trade. If the demand curve under shared property is higher (resp. lower) than under the domestic government, the terms of trade will be lower (resp. higher), so that from the balanced trade equation (26), the imported amounts coincide under both regimes. As a consequence, the rate of return on investment in new goods is the same under both regimes and so will be the growth rate of the economies.

When the two countries are small, the terms of trade are an exogenous constant. Therefore, a higher demand curve conducts to a higher imported amount and thus, a higher growth rate. The demand curve and consequently the growth rate under shared property can be higher or lower than under monopolistic management.

When comparing the shared-property and the domestic government regimes, from the two previous results it follows that the gap in the terms of trade for large open economies has opposite sign to the gap in growth rates for small open economies.

Resorting to numerical simulations, we compare the growth rates for SOE and the terms of trade for LOE, when the property rights of the resource are in the follower country either in the hands of many agents or a unique owner. This comparison can be done evaluating the following expression for the different regimes:

$$\Delta(v_k^*, S_k^*) = v_k^{*\,1-\alpha-\beta}(1-v_k^*)^{\beta(1-\delta)} S_k^{*\beta\theta}, \quad k \in \{sp, f, d\}. \tag{43}$$

For this numerical analysis we assume $\alpha = 0.3$, $\beta = 0.3$, $\delta = 0.1$, $L_F = L_L = 1$, for which $v^{oa} = 0.5970$, and $v^{mm} = 0.8652$. From the hypothesis $L_F = 1$ it follows that $B = b, C = \kappa$ and $S = s$. To establish the remainder of the parameters that define the regeneration and the harvesting functions, we

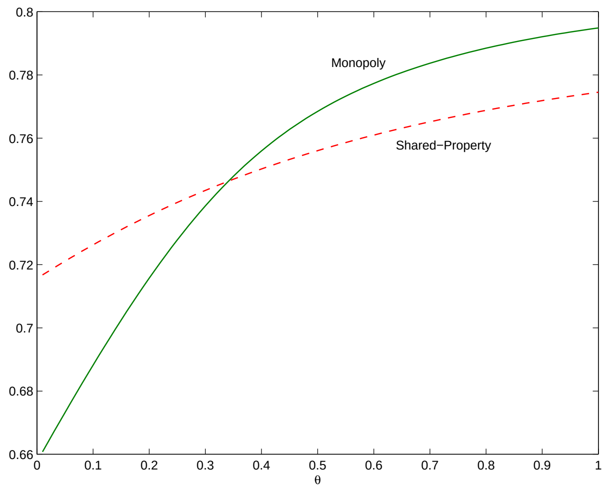

Figure 2: Comparison long-run growth rates: Monopoly vs. shared-property regimes

focus on the extreme case in which myopic management leads to exhaustion. Next lemma collects sufficient conditions for this behaviour:

Lemma 15 *The stock of the resource harvested by a unique and myopic manager is exhausted under sufficient conditions:*

$$\tilde{g} \leq B\left[\frac{\beta(\phi-1)}{1+\phi\beta}L_F\right]^{1-\delta}, \quad C \leq \frac{(2-\theta)^{\frac{2-\theta}{1-\theta}}}{1-\theta}, \tag{44}$$

where at least one inequality strictly holds.

Notice that under conditions in lemma 15, a non-myopic monopolistic manager will behave less aggressively, and hence, $v_m^* > v^{mm}$.

When conditions (44) hold in equality, they describe a situation in which the harvesting effort under myopic administration lies in the hedge of extinction. Let assume that this occurs for an intermediate value of the elasticity of harvesting with respect to the stock of the resource, $\hat{\theta} = 0.5$. Furthermore, we also assume that sufficient condition for uniqueness in (29) holds, for this value of θ. ¿From these conditions, the parameters related to the natural resource sector, $\tilde{g}$, C and B can be derived.

Figure 2 depicts the values $\Delta(v_k^*, S_k^*)$ as a function of θ, for the two monopolistic property rights regimes (a continuous line) and for the shared-property regime (a dashed line), fixed all other parameters.

¿From this figure we can conclude that the long-run growth rates for SOE under the monopoly property rights regimes, $\gamma_f^{soe} = \gamma_d^{soe}$, can be higher or lower than under the shared-property regime γ_{sp}^{soe}. Furthermore, for the given parameters' values, as θ increases "*ceteris paribus*", the more likely is that the long-run growth rate under a monopolistic regime surpasses the growth rate under the shared-property regime, and the wider is the gap between them and vice versa. The opposite behaviour arises as θ approaches 0.

The terms of trade for LOE compare inversely as function $\Delta(v_k^*, S_k^*)$ in Figure 2. In consequence, the terms of trade for small values of θ are larger under monopolistic management than under share property, and viceversa.

The differences between the growth rates for SOE (or the terms of trade for LOE) under the different property rights regimes does not reproduce differences in the shares of labor in each sector. In particular, for the chosen parameter values, numerical solutions show that $v_m^* > v_{sp}^*$ for any $\theta \in (0, 1)$. (see Figure new???)

The qualitative behaviour described in Figure 1 and new?? is robust to changes in all parameters values. Only for a very small $\hat{\theta}$ functions $\Delta(v_k^*, S_k^*)$ do not cross, but the growth rate under monopolistic management is always higher than under shared property.

5 Concluding remarks

We have studied a trade model between two asymmetric economies. One of them is a technological leader while the other, a resource dependent economy, is a technological follower. Our results have proved that the distribution of the property rights of the natural resource determines the long-run growth rates in both countries. Moreover, different property rights regimes drive to different levels of the long-run natural resource stock.

When the resource is monopoly-owned either by a monopolistic firm in the leading country or by the government in the follower country, the long-run stock of the natural resource and the share of labor devoted to the final-output sector coincide under both property rights regimes. However, when both economies are large, the terms of trade are greater under a foreign monopoly regime than under the domestic government regime. As a consequence, the long-run growth rate is also higher.

Moreover, if the natural resource is managed by a foreign monopoly firm in the technological leading country, or by the domestic government in the follower, then the natural resource is better conserved (in the sense of a higher stock in the long run), than if the resource is exploited by many owners in the follower country. However, if the economies are large, the long-run growth rate under a foreign monopoly regime is higher than under either the shared-property or the domestic government regimes, which share the same growth rate.

In the case of small open economies, numerical simulations conclude that the long-run growth rates under the foreign monopoly regime or domestic government regime can be higher or lower than under the shared-property regime.

Appendix A

Proof of Proposition 1.

Under the myopic-management regime for a single owner either if the resource is managed by a firm in the leading country or the government in the following country, the fraction of labor allocated to the final-output sector coincides. Note that if the monopoly firm in the leading country behaves myopically, he solves the maximization problem (12). Similarly, if the government in the follower country disregards the dynamics of the natural resource, he solves (16). From the necessary conditions for optimality, it is straightforward to show that the following expression must be satisfied in both single owner scenarios:

$$w_F L_F + H\frac{\partial p_H}{\partial v} + p_H\frac{\partial H}{\partial v} = 0.$$

After some simplifications we obtain: $v^{mm} = (1+\beta)/(1+\phi\beta)$. ■

Proof of Proposition 3.

Variables v and S cannot grow indefinitely at a non-zero constant rate because they are lower and upper bounded ($v \in [0,1]$ and $S \in [0,C]$). These variables must be constant on a steady-state equilibrium. Provided that H depends on v and S, which are motionless, the harvesting also must remain constant on a steady-state equilibrium.

From (25) replacing the expression of the consumption of imported goods in the technologically leading country given in (23), the production function in this country (5), and taking into account (4), we can conclude that the growth rate of N is constant along the steady-state equilibrium if the consumption of national good in the leader country, c_L, grows at the same rate as the number of intermediate goods, N, and at the same time, the amount of intermediate goods used in the follower final-output sector, $X_F(v, S)$, is also stationary. From equation (7) for X_F to be constant, since v and H are motionless, also the terms of trade, p_F, must remain constant.

Taking into account (9), provided that p_F, v and H remain constant along the steady-state equilibrium, the interest rate r is also constant and equal to:

$$r = \frac{\alpha^{\frac{2}{1-\alpha}}(1-\alpha)\left[L_L A_L^{\frac{1}{1-\alpha}} + L_F v^{\frac{1-\alpha-\beta}{1-\beta}}(p_F A_F)^{\frac{1}{1-\alpha}} H^{\frac{\beta}{1-\alpha}}\right]}{(\eta+\nu)\alpha}. \tag{45}$$

From (4) and (21) one gets that $\dot{c}_F/c_F = \dot{Y}_F/Y_F$. Taking into account (3), (7) and (1) the growth rate of consumption and final-output production of the follower country, follows:

$$\frac{\dot{c}_F}{c_F} = \frac{\dot{Y}_F}{Y_F} = \frac{\alpha}{1-\alpha}\frac{\dot{p}_F}{p_F} + \frac{(1-\alpha-\beta)(1-\phi v)}{(1-\alpha)(1-v)}\frac{\dot{v}}{v} + \frac{\dot{N}}{N} + \frac{\beta\theta}{1-\alpha}\frac{\dot{S}}{S}. \tag{46}$$

Along the steady-state equilibrium, constants v, S and p_F allow us to rewrite the growth rate of the final-output production, Y_F, and the consumption, c_F, in the follower country, in (46), equal to the growth rate of the number of intermediate goods, N (which coincides with the growth rate of the national good consumption in the leading country). Furthermore, by (23), since p_F remains constant along the steady-state equilibrium, the growth rate of the imported good, c_{LF}, equals the growth rate of the national good consumption in the leading country.

Since $\alpha^2 Y_L = N X_L$, the growth rate of the production in the leading country also equals that of N, since X_L is constant.

Finally, provided that H remains constant (4) shows that the price of the natural resource grows as the same rate as Y_F along the steady-state equilibrium. ■

Proof of Proposition 4.

From the definition of $\tilde{c}_L = c_L/N$ and its dynamics in (23):

$$\frac{\dot{\tilde{c}}_L}{\tilde{c}_L} = r - \rho - \frac{\dot{N}}{N}.$$

From this equation, the expression of r in (9), the dynamics of N in (25) and the first order condition in (23), the dynamics of the consumption per unit of intermediate good in (27) immediately follows. ■

Proof of Proposition 6.

At the steady-state equilibria, the stock of the resource has to be constant:

$$\dot{S} = G(S) - H(v, S) = 0, \tag{47}$$

which gives a definition of v as a function of S:

$$\tilde{v}(S) = 1 - \frac{1}{L_F}\left(\frac{\tilde{g}S^{1-\theta}\left(1-\frac{S}{C}\right)}{B}\right)^{\frac{1}{1-\delta}}, \tag{48}$$

that satisfies $\tilde{v}(0) = \tilde{v}(C) = 1$, $\tilde{v}(S) < 1\,\forall S \in (0, C)$, and presents a minimum in $\tilde{S} = (1-\theta)C/(2-\theta)$.

To completely determine the steady-state equilibria we must also consider the necessary conditions for optimality. Taking into account (4) and (11), after some calculus, the necessary condition (13) for the foreign monopoly (or (17) for the domestic government), can be rewritten as:

$$-\frac{1-\alpha-\beta}{v} - \frac{(1-\beta)(1-\delta)}{1-v} - (\xi_m - 1)\frac{1-\delta}{1-v} = \frac{1-\alpha-\beta}{\beta v}.$$

At the steady state, equation (14) or (18) vanishes. Furthermore, if $\theta \neq 0$, then ξ_m can be written as a function of v and S:

$$\xi_m(v, S) = \frac{\theta\beta H(v, S)}{S(\rho - G'(S)) + \theta H(v, S)}.$$

Replacing this last expression in the previous equation, and considering that $G(S) = H(v, S)$ at the steady state, then v can be written as a function of S if $\Gamma(S)(1+\beta\phi) - \theta(1+\beta) \neq 0$:

$$v_m(S) = \frac{(\Gamma(S) - \theta)(1+\beta)}{\Gamma(S)(1+\beta\phi) - \theta(1+\beta)}, \tag{49}$$

where

$$\Gamma(S) = -\frac{(\rho - G'(S))S}{G(S)} = \frac{\tilde{g}(1-2\frac{S}{C}) - \rho}{\tilde{g}(1-\frac{S}{C})}.$$

Function $v_m(S)$ is an hyperbola with an horizontal asymptote in v^{mm}. Furthermore, differentiating in (49) and simplifying, we obtain:

$$v_m'(S) = \frac{\theta(\phi-1)\beta(1+\beta)\Gamma'(S)}{[\Gamma(S)(1+\beta\phi)-\theta(1+\beta)]^2},$$

and since $\Gamma'(S) < 0\,\forall S \in (0, C)$, $v_m(S)$ is a decreasing function of S.

We are looking for steady-state equilibria with $v^* \in (v^{mm}, 1)$. Therefore, since the hyperbola presents a negative slope, we focus on the right branch. This right branch equals one at[12] $S^{*0} = (g-\rho)C/(2g)$. Since $\tilde{v}(S) < 1\,\forall S \in (0, C)$, $\tilde{v}(C) = 1$, then an equilibrium exists within the region of interest $(v^{mm}, 1) \times (S^{*0}, C)$. ¿From equation (28), the steady-state value of $\tilde{c_{Lm}}$ follows.

Condition $\tilde{S} \leq S^{*0}$ implies that $\tilde{v}(S)$ increases in the region of interest. Since $\tilde{v}(C) = v_m(S^{*0}) = 1$ and $v_m(S)$ decreases, then this condition is a sufficient condition to avoid multiple equilibria, which can be rewritten as (29). ■

Proof of Proposition 9.

The growth rate at the steady state can be obtained by the growth rate of the consumption of the national good in the technologically leading country in (23). This growth rate equals $r-\rho$, where r is given in (45). Therefore, denoting this growth rate by γ^{oe}, it can be written as follows:

$$\gamma^{oe} = \frac{1-\alpha}{\alpha(\eta+\nu)}\left[X_L + X_F\right] - \rho. \tag{50}$$

The expressions of the long-run growth rates is obtained by replacing in (50) the expressions of the amount of intermediate good used in the leader and the follower countries, X_L and X_F, given in (7).

To derive the growth rate of the economies in the SOE scenario, γ^{soe}, the price is assumed to be constant and exogenously given, $\hat{p}_F$. Conversely, in the LOE scenario, the growth rate of the economies is obtained replacing the terms of trade, p_F, by its stationary value, p^*_{Fm}, $m \in \{f, d\}$ given in (32). Substituting the value of p^*_{Fm} in (50) and simplifying, the different growth rates γ^{loe}_m in the statement of Proposition 9 follow. ■

[12] S^{*0} is the steady-state value of the stock of the resource when $\theta = 0$.

Appendix B

Proof of Proposition 11.

Under open access, consumers do not take into account the dynamics of the natural resource. They solve the maximization problem (37) subject to their budget constraint given by (36). From the necessary conditions for optimality and the definition of h in (35), it follows that $w_F(1-v) = (1-\delta)p_H h$. Taking into account expressions in (4), the fraction of labor allocated to the final-output sector, $v^{oa} = 1/\phi$, immediately follows. ■

Proof of Proposition 12.

This proof compares the steady-state values of v and S under shared-property and domestic government (as already shown, this latter matches the results under foreign monopoly).

When the natural resource is managed by a unique owner, the steady-state equilibrium is defined by equating $\tilde{v}(S)$ in (48) with $v_m(S)$ in (49), together with the expression of $\tilde{c_{Lm}}$ in (28).

When the property rights belong to many agents, following the same reasoning as for the characterization of $v_m(S)$, but considering the new necessary conditions in (38) and (39), function $v_{sp}(S)$ can be obtained:

$$v_{sp}(S) = \frac{\Gamma(S) - \theta}{\phi\Gamma(S) - \theta}, \tag{51}$$

where $\phi\Gamma(S) - \theta \neq 0$. This function behaves likewise as $v_m(S)$, i.e. it is an hyperbola with an horizontal asymptote in v^{oa}, $v'_{sp}(S) < 0$ for all $S \in (0, C)$ and $v_{sp}(S^{*0}) = 1$.

From expressions (49) and (51), and considering that $\Gamma(S) < 0 \forall S \in (S^{*0}, C)$, immediately follows that $v_{sp}(S) < v_m(S)$ for any $S \in (S^{*0}, C)$. Taking into account that within this region $v_{sp}(S)$ and $v_m(S)$ cross $\tilde{v}(S)$ from above, then $S^*_{sp} < S^*_m$.

Function $\tilde{v}(S)$ is not monotonous, therefore, v^*_m can be higher equal or lower than v^*_{sp}. However, under condition (29), $\tilde{v}(S)$ is a growing function within region (S^*_0, C), and consequently, $v^*_{sp} < v^*_m$. ■

Proof of Lemma 15.

A myopic monopolist manager devotes an extraction effort to the resource sector equal to $1-v^{mm}$. We look for the conditions that irremediablemente?? leads to extinction.

For $\theta \in (0,1)$, the steady state for the stock of the resource is given by equation:

$$H(v^{mm}, S) = G(S).$$

Note that only the right hand side of this equation is affected by parameters g and C, which increase the reproduction function. Equation above admits a trivial solution $S = 0$. Furthermore, depending on the parameters this equation may present one, two or none additional solutions. A unique interior solution would appear under tangency:

$$\frac{\partial H}{\partial S}(v^{mm}, S) = G'(S).$$

From the two equations above, a unique interior solution appears when the following condition upon g and C holds:

$$gC^{1-\theta} = B\left[\frac{\beta(\phi-1)}{1+\phi\beta}L_F\right]^{1-\delta}\frac{(2-\theta)^{2-\theta}}{(1-\theta)^{1-\theta}}. \tag{52}$$

Values of g and C, for which the LHS of (52) lies below the RHS, would imply the non-existence of an equilibrium different from $S = 0$. In consequence, the resource would be depleted.

When $\theta = 1$, harvesting is linear in the stock of the resource. A sufficient condition for extinction is to consider the slope of the extraction function greater or equal to the slope of the regeneration function at $S = 0$, that is,

$$\frac{\partial H}{\partial S}(v^{mm}, 0) \geq G'(0) \;\Leftrightarrow\; B\left[\frac{\beta(\phi-1)}{1+\phi\beta}L_F\right]^{1-\delta} \geq \tilde{g}.$$

Taking into account the RHS of the last equivalence, the sufficient condition for the carrying capacity in (44), that guarantees the depletion of the resource (i.e. the LHS below the RHS of (52)) can be easily derived.

For $\theta = 0$ if condition in lemma 15 hold (at least one in strict inequality) then immediately follows that $H(v^{mm}, S) > G(C/2)$, which means that the harvesting, independent of S, is greater than the maximum reproduction. Therefore the resource is depleted. ∎

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