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Free trade may save a renewable resource from exhaustion

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Abstract

This study considers a small open economy in which two tradable final goods are produced by using a non-tradable resource good, which has an open-access property, as an input as well as a primary factor. If the intrinsic growth rate of the resource is relatively low, there may be no non-trivial steady state or multiple steady states. This implies that, by opening international trade, the economy can escape from the risk of complete depletion of the resource.

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1 Introduction

Natural resources play an important role in economic development and improving economic well-being. Because the property rights for these resources are, in principle, incompletely defined, there may be tendencies to over-exploitation. In some cases, such an excessive use of resources may lead to an extinction even if the resources are renewable.[1]

There is also a suspicion that trade liberalization can be a cause of excessive use of natural resources. However, trade can achieve allocative efficiency compared to autarky, for natural resources as well. For example, trade might allow the economy to switch to specialize in the production of the less resource intensive good, which reduces the depletion rate of the resource. In this study, I use a simple model to show that opening of trade can save an economy from the risk of complete depletion of resources.

The model I use is an extension of Brander and Taylor (1997a, 1997b, 1998), who develop a one-factor, two-goods (a resource good and the other good), general-equilibrium model. Assuming that the resource sector is subject to open access, the authors examine trade patterns and welfare effects of trade and trade policy. The model has been re-examined or extended by, e.g., Hannesson (2000), Jinji (2006, 2007), and Takarada (2009). Contrary to these existing studies, which regard the resource good as a final consumption good, I assume that the resource is used as an input in the production of final goods rather than directly consumed.[2]

I consider a small open economy in which two final goods are produced by using labor and a resource good as inputs. As in the original Brander-Taylor model, the resource good is assumed to be subject to open access, and thus the resource sector earns no economic rents. This implies that the current resource stock determines the price ratio of inputs, and the economy normally specializes in one of the final goods. Specifically, there exists a resource stock such that the economy switches from specializing in the labor-intensive good to the resource-intensive good. The economy's total harvest level depends on the current resource stock, which changes over time depending on the harvest and the growth rate of the resource. It is shown that there can be multiple steady states,[3] including the steady state with zero resource stock (i.e., resource depletion), if the intrinsic growth rate of the resource is low.[4]

The multiplicity of long-run equilibria has an interesting implication for the effect of trade liberalization on the resource dynamics. That is, it is shown that there may exist

[1]See, e.g., Clark (1990).

[2]FAO Forestry Department (2009) states that Asian and Pacific region is becoming an important exporter of wood products, with an increasing share of high-value products such as wooden furniture. The importance of processed goods may also be found in international trade of fishery resources, see FAO Fisheries and Aquaculture Department (2009). Moreover, in a broader sense, water resources can be viewed as an example because they are used and polluted in a number of industries.

[3]Karp et al. (2001) develop a North-South trade model in which natural resources are used as an input and show the possibility of multiple steady state, which is caused by fixed-proportion technologies and an unemployment of the primary factor. Moreover, the authors assume that the countries diversify production even under free trade, and do not consider the case of resource depletion.

[4]Even in the original Brander-Taylor model, the resource depletion is possible; it is the case when the intrinsic growth rate of the resource is sufficiently low. However, because the equilibrium harvest rate in the Brander-Taylor model becomes linearly dependent on the resource stock, no other possibilities emerge in this case. In the present model, by contrast, depending on the elasticity of substitution between labor and the resource good, the equilibrium harvest rate can be a nonlinear function of the resource stock.

a situation where resource depletion is the only long-run consequence under autarky, but multiple steady states exist under free trade. In this case, if the initial stock of the resource is sufficiently large, the economy can avoid resource depletion by switching from autarky to free trade, and thereby achieve a sustainable use of the resource.

2 Model

Consider a small-open economy with two final goods, X_1 and X_2, a renewable natural resource, H, and a primary factor (labor).[5] The final goods are tradable and produced by the use of labor and the renewable resource, whereas the resource good is non-tradable and serve only as an input to produce the final goods.[6] Production in these sectors is carried out by competitive profit-maximizing firms under conditions of free entry. The labor endowment is assumed to be constant over time.

The production function of each final good is given by

$$X_j = \left\{(1-\gamma_j)L_j^{\frac{\sigma-1}{\sigma}} + \gamma_j H_j^{\frac{\sigma-1}{\sigma}}\right\}^{\frac{\sigma}{\sigma-1}}, \quad 0 < \gamma_j < 1, \tag{1}$$

where L_j and H_j are allocation of the labor and the resource good, respectively, in sector $j = 1, 2$, and $\sigma \in [0, 1)$ is equal to the elasticity of substitution between the inputs. Let $a_{Lj} \equiv L_j/X_j$ and $a_{Hj} \equiv H_j/X_j$ be the unit input coefficients, w be the wage rate, and r be the price of the resource good. The cost minimization condition for each representative firm

$$\frac{a_{Hj}}{a_{Lj}} = \left(\frac{\gamma_j}{1-\gamma_j} \cdot \frac{w}{r}\right)^{\sigma} \tag{2}$$

and the production function (1) derive the unit input coefficients as a function of the relative input price w/r: $a_{ij}(w/r)$, $i = L, H$, $j = 1, 2$. In the following analysis, I assume that sector 1 (sector 2) is resource (labor) intensive, i.e., $a_{H1}/a_{L1} > a_{H2}/a_{L2}$, or

$$\gamma_1 > \gamma_2. \tag{3}$$

The technology of harvesting is given by

$$H = qSL_H, \quad q > 0, \tag{4}$$

where L_H is the labor input allocated to resource harvesting and S is the stock of the natural resource.

The renewable resource is harvested under open access, and thus the resource harvesters earn zero profit:

$$rH = wL_H. \tag{5}$$

From (4) and (5), it follows that $qS = w/r$.

The resource stock changes according to

$$\dot{S} = G(S) - H, \tag{6}$$

[5]The trade structure in this paper is similar to Yanase and Dong (2011), but they focus on the case without resource depletion.

[6]The assumption that the resource good is non-tradable may seem odd. For example, timber is traded internationally. However, by interpreting the outputs in the resource-harvesting sector as *unprocessed* products, the traded timber products can be considered as processed products in a final-good sector.

where $G(S)$ is the natural growth function, which is specified by

$$G(S) = \alpha S\left(1 - \frac{S}{K}\right), \quad \alpha, K > 0. \tag{7}$$

The parameters K and α represent the the carrying capacity, i.e., the maximum possible size for the resource stock, and the intrinsic growth rate of the resource, respectively.

2.1 Temporary equilibrium

In a temporary equilibrium of the economy, S is exogenously given. Because the final goods are produced under constant returns, each good is produced under zero-profit conditions for the case of positive output. Let (w^d, r^d) be a pair of input prices when the economy diversifies production. Then, (w^d, r^d) satisfies both $a_{L1}(w^d/r^d)w^d + a_{H1}(w^d/r^d)r^d = p_1$ and $a_{L2}(w^d/r^d)w^d + a_{H2}(w^d/r^d)r^d = p_2$, where p_j is the price of good $j = 1, 2$. However, since $qS = w/r$ holds under the open-access harvesting, for a small-open economy where p_1 and p_2 are exogenously given, diversified production can only take place by chance, where the resource stock is happen to be equal to $S^d \equiv w^d/(qr^d)$. Otherwise, the economy specializes either final good.

Figure 1 illustrates the determination of the input prices w and r in the temporary equilibrium. If $S = S^d$, both final goods can be produced and a pair of equilibrium input prices, (w^d, r^d), is determined at the intersection of the factor-price frontiers and the $w/r = qS^d$ line. If $S > S^d$, w and r are determined at the intersection of the factor-price frontier of good 1 and the $w/r = qS$ line, and at this intersection, $a_{L2}(w/r)w + a_{H2}(w/r)r > p_2$ holds. Therefore, the economy cannot produce good 2. Analogously, the economy specializes in good 2 if $S < S^d$.

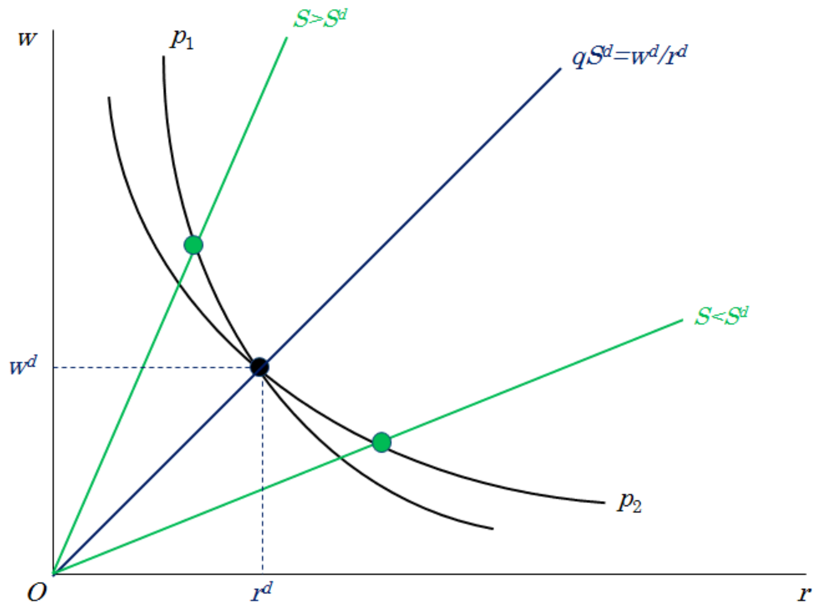

Figure 1: Factor prices in the temporary equilibrium

Proposition 1 *In the temporary equilibrium where $S < S^d$ ($S > S^d$) the small open economy specializes production in the labor-intensive (resource-intensive) good. If $S = S^d$, the economy diversifies production.*

From (2), (4), (5), and full-employment conditions $a_{Lj}(w/r)X_j = L - H/(qS)$ and $a_{Hj}(w/r)X_j = H$, the resource harvest in the temporary equilibrium when the economy specializes in good j is derived as follows:

$$H = \frac{qSL}{\left(\frac{1-\gamma_j}{\gamma_j}\right)^{\sigma}(qS)^{1-\sigma} + 1} \equiv H^j(S). \tag{8}$$

It is easily verified that for $0 \leq \sigma < 1$, $H^j(S)$ is increasing and strictly concave in S, with $\lim_{S\to 0} dH^j(S)/dS = qL$.

Given the factor-intensity assumption (3), $H^1(S) > H^2(S)$ holds. Then, in light of Proposition 1, the equilibrium level of resource harvest is derived as follows:

$$H(S) \begin{cases} = H^2(S) & \text{if} \quad S < S^d, \\ \in [H^2(S), H^1(S)] & \text{if} \quad S = S^d, \\ = H^1(S) & \text{if} \quad S > S^d. \end{cases} \tag{9}$$

Eq.(9) indicates that $H(S)$ is a correspondence of S and is upper hemicontinuous at $S = S^d$, as illustrated in the upcoming figures.

2.2 Steady state

The steady-state stock of the natural resource, S^*, satisfies $\dot{S} = G(S^*) - H(S^*) = 0$. I focus on a situation where the intrinsic growth rate of the resource is relatively low: $\alpha < qL$.[7] Then, there can be no intersection of $H(S)$– and $G(S)$–curves other than the origin, or there can be multiple steady states. In the former case, $\dot{S} = G(S) - H(S) < 0$ holds for any $S > 0$, and thus the steady state $S^* = 0$ is globally stable. That is, starting from any initial stock $S_0 > 0$, the resource is exhausted in the long run.

Next consider the case where $G(S) = H(S)$ holds at some $S > 0$. Let us define $\Delta(S) \equiv G(S) - H(S)$. Because $\Delta(0) = 0$ and $\Delta'(0) = \alpha - qL < 0$, there exists at least one $S^* \in (0, K/2)$ such that $\Delta(S^*) = 0$ if $H^2(K/2) < G(K/2)$ and $S^d > K/2$. Letting

$$\phi_j \equiv \frac{2}{\left(\frac{1-\gamma_j}{\gamma_j}\right)^{\sigma}\left(\frac{qK}{2}\right)^{1-\sigma} + 1}, \quad j = 1, 2,$$

then $H^2(K/2) < G(K/2)$ is equivalent to $\alpha > \phi_2 qL$. Let us denote the smallest stock level among these steady-state solutions by S_u^*. Because $\dot{S} < 0$ for $0 < S < S_u^*$ and $\dot{S} > 0$ for $S > S_u^*$, this steady state is unstable. Moreover, there exists the other steady-state, with the resource stock $S_s^* > S_u^*$, which is stable, as illustrated in Figure 2.[8]

[7] If $\alpha \geq qL$, it can be verified that a non-trivial steady state (i.e., steady state with a positive resource stock) uniquely exists and is globally stable. See Yanase and Dong (2011) for details.

[8] In Figure 2, it is assumed that $H^1(S) > G(S)$ for any $S > 0$. If $qL > \alpha > \phi_1 qL$, $H^1(S) = G(S)$ may hold at some $S \in (0, K)$, and thus the economy may specialize in the resource intensive good.

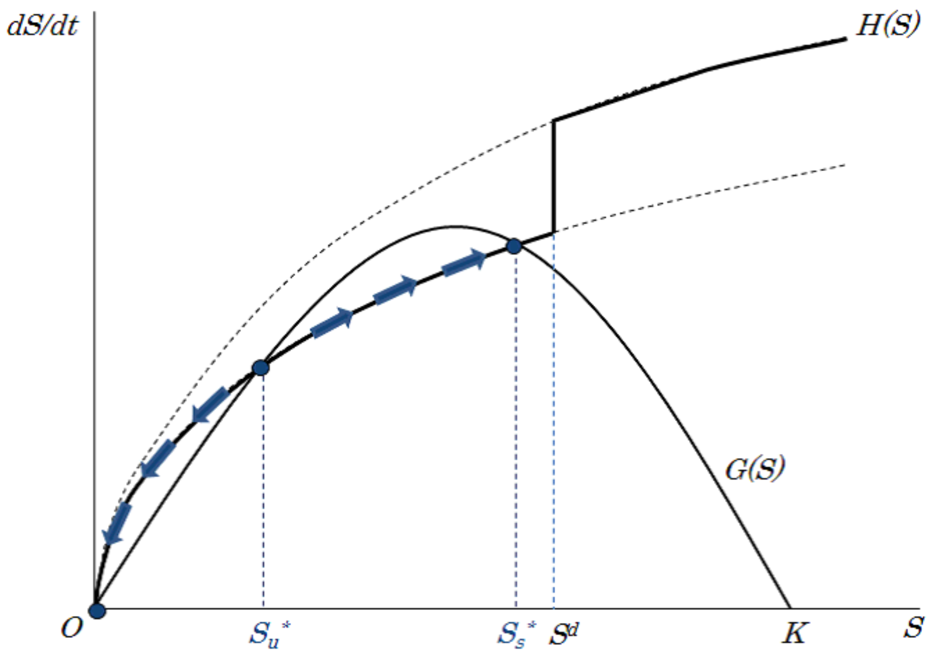

Figure 2: The case of multiple steady states

Proposition 2 *Suppose that $qL > \alpha > \phi_2 qL$ and $S^d > K/2$. Then, there exist a steady state with the resource stock $S_u^* \in (0, K/2)$ such that if $S_0 < S_u^*$, the resource is exhausted in the long run. If $S_0 \geq S_u^*$, the economy can enjoy the positive level of the resource stock in the long run.*

3 Escape from the Risk of Resource Depletion by Opening of Trade

Let us now consider the equilibrium under autarky. Assuming that the utility function of a representative consumer is given by $u(C_1, C_2) = C_1^{\beta} C_2^{1-\beta}$, $0 < \beta < 1$, where C_j is the consumption of good $j = 1, 2$ and letting $p \equiv p_1/p_2$, the first-order condition for utility maximization implies that

$$\frac{C_1}{C_2} = \frac{\beta}{p(1-\beta)}. \tag{10}$$

The temporary equilibrium of the economy under autarky is characterized by the zero-profit conditions in both sectors, full-employment conditions in which labor and the resource good are employed in both sectors, national-income identity in which producers do not earn economic rents, and the optimality condition (10) with $C_j = X_j$, $j = 1, 2$. These equilibrium conditions derive the autarkic-equilibrium resource harvest as a linear combination of $H^1(S)$ and $H^2(S)$:[9]

$$H = \beta H^1(S) + (1-\beta) H^2(S) \equiv H_a(S). \tag{11}$$

The dynamics of the resource under autarky is characterized by $\dot{S} = G(S) - H_a(S)$.

Let us denote the autarkic steady-state stock of the resource as S_a^*. If $H_a(K/2) > G(K/2)$, or equivalently, $[\beta\phi_1 + (1-\beta)\phi_2]qL > \alpha$, there may be no intersections other

[9]Details are available from the author upon request.

than the origin. That is, the natural resource will be exhausted in the long run under autarky. However, in light of Proposition 2, multiple steady states exist under free trade if $\min\{qL, [\beta\phi_1 + (1-\beta)\phi_2]qL\} > \alpha > \phi_2 qL$, as illustrated in Figure 3. Suppose that the economy's initial resource stock is larger than S_u^* and the economy is initially under autarky. If this economy switches to free-trade regime before the stock reaches S_u^* (at $S = S_t$ in the figure), the transition path of the resource harvesting moves from $H_a(S)$ to $H(S)$. The steady-state stock of the resource will be $S_s^* > 0$, and thus the economy can escape from the risk of resource depletion by switching from autarky to free trade.

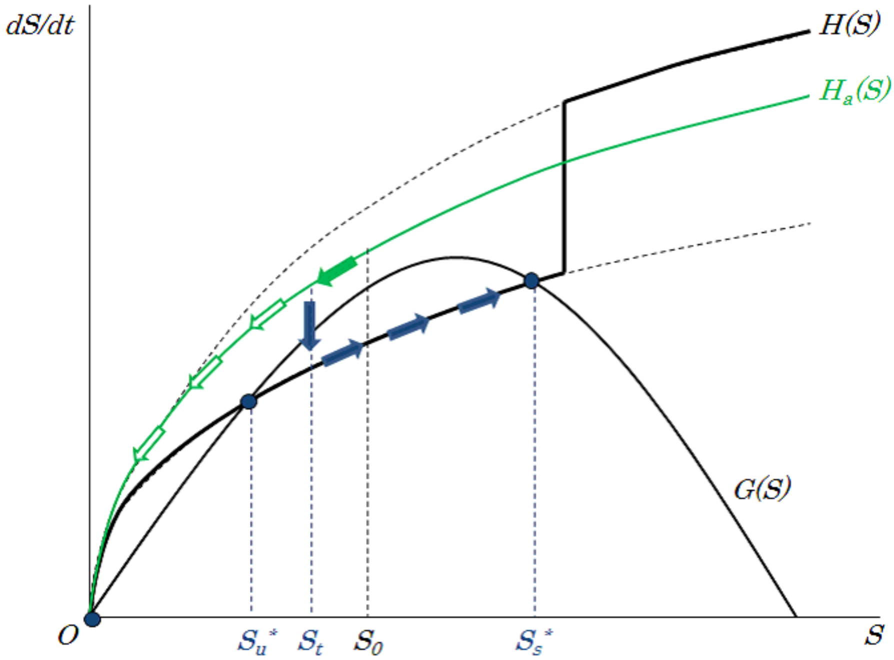

Figure 3: Trade liberalization can avoid resource depletion

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