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Transboundary Renewable Resource and International Trade

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Abstract

We develop a two-country, two-good model with a transboundary renewable resource. A transboundary renewable resource is an open-access resource that is shared by two countries. We characterize the autarkic steady state, then examine the patterns of trade and the post-trading steady-state utility levels. Although the resource stock is reduced by trade, both countries may still benefit from trade when they are specialized in production. We also show that the steady-state utility of a resource good importing country may be reduced by trade, even if it specializes in production of a non-resource good which we refer to as manufactures.

JEL classification: F10; Q20; Q22; Q27
Keywords: transboundary renewable resource; international trade; open access

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1. Introduction

The sustainability of renewable resource stocks has been jeopardized by various factors. It is commonly argued that the depletion of renewable resource stocks has been accelerated by a substantial increase in international trade. For example, the Food and Agriculture Organization (FAO) reported that fish and fishery products are highly traded with more than 37% (live weight equivalent) of total production entering international trade as various food and feed products. In 2006, 194 countries reported exports of fish and fishery products. World exports reached US$85.9 billion in 2006 and this represented an increase of 62.7% on 1996 (see FAO (2009)).[1] A country that has a comparative advantage in production of resource goods is likely to over-exploit its renewable resources.

Renewable resource stocks are considered to be more vulnerable when they are transboundary from a biological viewpoint. Transboundary renewable resources refer to fish and wildlife stocks that straddle (or migrate) the boundaries of the territory or the exclusive economic zones (EEZs) of two or more countries.[2] Since transboundary renewable resources are hard to manage without international cooperation, they are more likely to be over-exploited. For example, the depletion of highly migratory fish stocks such as tuna has been widely recognized in recent years.[3] The sustainability of transboundary renewable resource stocks is a significant international policy issue.

The purpose of this paper is to examine the effects of international trade when renewable

[1] Watson and Pauly (2001) pointed out that over 75% of the world marine fisheries catch (over 80 million tons per year) is sold on international markets.
[2] FAO uses the term “shared” generically to refer to transboundary, straddling, and highly migratory fish stocks (see, e.g., FAO (2004)).
[3] WWF (2006) reported that total catches of bluefin tuna on the East Atlantic and Mediterranean in 2004 and 2005 are dramatically higher than the International Commission for the Conservation of Atlantic Tunas (ICCAT) quota (a minimum illegal over-quota catch of 40% above the total quota of 32,000 tons).

resources are transboundary. Transboundary renewable resources are subject to international open access (i.e., countries share the same renewable resources). We characterize the autarkic steady state, and then examine the patterns of trade and the post-trading steady-state utility levels. We show and interpret the conditions that determine the patterns of trade, the welfare effects of opening trade, and the stock levels.

The existing studies have not examined the welfare effects of trade liberalization when renewable resources are transboundary. The seminal articles by Brander and Taylor (1997a, 1998) investigated the effects of international trade in a Ricardian type of general equilibrium model. Renewable resources have a dynamic structure of the classic Schaefer (1957) type. They assumed that each country has a renewable resource that is subject to open access by residents of that country only. The basic framework of our model is closely related to Bulte and Damania (2005) who studied trade and optimal resource management when countries share access to a common renewable resource stock. However, they did not explore the patterns of trade and gains from trade, because their focus was on the strategic interactions between harvesting countries (see also Markusen (1976)).[4] On the other hand, considerable and various papers examined shared fish stocks in game-theoretic models without taking international trade into account. These studies focused on, for example, optimal resource management strategies (e.g., Munro (1979) and Vislie (1987)), the cooperative and non-cooperative effects on harvests and stock levels (Fischer and Mirman (1992) and Levhari and Mirman (1980)), and mechanism to attain cooperation for specific fisheries (Lindroos 2004). This is because much of the concern over open-access renewable resources arises from the over-exploitation problem that has been

[4] The effects of resource management under international trade have been analyzed in various papers when renewable resources are not transboundary. See, for example, Brander and Taylor (1997b), Chichilnsky (1993, 1994), Emami and Johnston (2000), Francis (2005), Hotte et al. (2000) and Jinji (2007).

well established starting with the classic article by Gordon (1954).[5] Our analysis adds a new value to this field of research.

In this paper, we develop a two-country, two-good model with a transboundary renewable resource. The two goods are a resource good and a numeraire good which refers to manufactures. Our model is the extension of the highly stylized model established by Brander and Taylor (1997a, 1998). The present model is applicable to the analysis on renewable resources which have biological interactions between them. The basic insights of our analysis will have relevance, even if those resources are not in fact transboudary.[6]

We focus on the open-access case because transboundary renewable resources are usually hard to manage. Property rights over transboundary renewable resource stocks are hard to define because of the migratory nature.[7] Moreover, particularly in fishery, even if renewable resources have controlled access, we still observe illegal, unreported and unregulated (IUU) fishing (WWF 2006, 2008). In the Commission of the European Communities (2007), the global turnover of IUU fisheries has been estimated at in excess of €10 billion a year. In short, fishery stocks are indeed likely to be over-exploited. For example, Worm et al. (2006) projected the global collapse of all taxa currently fished by the mid-21st century (in the year 2048).[8] Major fishing countries have introduced several controls to manage domestic fishing activities: for example, input controls such as restrictions on fishing time and fishing gears, and output controls such as a total allowable annual catch (TAC) program and an individual fishing quota

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5 The literature on renewable-resource economics is too large to cite. See, for example, Clark (1990, 2006) and Munro and Scott (1985).

6 For example, productivity of agriculture and forestry may be reduced by floods, desertification and sand drifting caused by overgrazing and excessive logging in adjacent countries.

7 Caddy (1997) estimated that the number of transboundary fishery resources is the order of some 1,000 to 1,500 and shared fish stocks are ubiquitous, worldwide. He also argued that only a small percentage of such resources are subject to effective cooperative management.

8 FAO (2009) reported that while the proportion of under-exploited or moderately exploited marine fishery resources declined linearly from 40% in the mid-1970s to 20% in 2007, the proportion of fully exploited stocks remained steady at about 50%. The proportion of over-exploited, depleted or recovering stocks appears to have stabilized at between 25% and 30% since the mid-1990s.

(IFQ) system (Clark 2006). We do have international agreements on the management of migratory fish stocks such as tuna (International Commission for the Conservation of Atlantic Tunas (ICCAT)).[9] However, these controls have been hard to monitor and enforce, even if the stocks are not transboundary. Excessive use and rent dissipation is prone to be severe in international shared fisheries.[10] As long as the international management of renewable resources is incomplete, even if it is not totally absent, the basic insights of our analysis will have relevance.

We obtain the striking result that although the transboundary renewable resource stock is reduced by trade, both countries may still benefit from trade when both countries are specialized in production. The transboundary renewable resource stock is never increased by trade, because a country that has a comparative advantage in production of the resource good exploits the renewable resource. This reduction of the stock level is consistent with the empirical evidence that shared fishery stocks are indeed prone to over-exploitation (Armstrong and Sumaila 2001; McWhinnie 2009). If the reduction of the transboundary renewable resource stock is not severe, both countries are better-off because the resource good is produced by using a higher harvesting technology after trade. The transboundary renewable resource is subject to open access by two countries, which arises the international open access problem. However, our result suggests that international trade can benefit every trading country even without implementing the international management of renewable resources.

We also show that the steady-state utility of a resource good importing country may be reduced by trade, even if it specializes in production of manufactures. This result is

[9] For example, the Common Fisheries Policy (CFP) is the European Union's instrument for the management of fisheries and aquaculture.

[10] Resource stocks in some areas are in fact open access because the jurisdiction problem is unsolved (so-called "grey zone"). For example, there is a conflict between South Korea and Japan over the sovereignty of a group of islands that is called Takeshima in Japan and Usan-do in South Korea. The waters around the islands are known as an attractive fishing place.

counter-intuitive because the productivity of that country is not degraded by the depletion of the renewable resource stock. The reason is that the price of the resource good may increase when the reduction of the transboundary renewable resource stock is severe after trade. On the contrary, Brander and Taylor (1997a, 1998) demonstrated that a resource good importing country actually benefits from trade when a renewable resource is subject to open access by its residents only. If the renewable resource is not transboundary, a resource good importing country can enjoy improvement in terms of trade. Our result implies that resource goods importing countries should recognize the depletion of transboundary renewable resource stocks as a significant international problem.

The rest of the paper is organized as follows. Section 2 sets up the framework of the model. Section 3 examines the steady state patterns of trade and gains from trade. And the concluding remarks will be provided in Section 4.

2. The Model

We present the framework of the model with the transboundary renewable resource and show an autarkic steady state. The discussion will be confined to the two-country, two-good model. We refer to the countries as “domestic” and “foreign,” which share the renewable resource, and use asterisks to denote foreign variables.

2.1 Production and supply

Each country produces and consumes two goods, and we focus on the domestic country first. S represents the transboundary renewable resource stock. H is the harvest of the transboundary renewable resource, and M is some other good which might be thought of as manufactures.

Good M is treated as the numeraire whose price is normalized to 1. In addition to S, there is only one other factor of production, labor, L. Manufactures are produced with constant returns to scale using labor as the only input. One unit of labor produces one unit of good M by choice of labor. As the price of good M is 1, given competitive labor markets, the wage in manufacturing must be 1.

We assume that harvesting of the resource is carried out according to the Schaefer harvesting production function,

$$H_S = qSL_H, \tag{1}$$

where H_S is the harvest supplied by producers. L_H is the amount of labor used in resource harvesting and q, which reflects the harvesting technology, is a positive constant. Letting $a_{LH}(S)$ represent the unit labor requirement in the resource sector, Eq.(1) implies

$$a_{LH}(S) = L_H/H_S = 1/(qS). \tag{2}$$

Production in both sectors is carried out by profit-maximizing firms operating under the condition of free entry. Thus, the price of the resource good, p, must equal unit cost of production. It follows that

$$p = wa_{LH} = w/(qS), \tag{3}$$

where w is the wage. Eq.(3) incorporates the open access assumption, because it means that labor cost is the only explicit cost of production. There is no explicit rental cost for using the resource stock, S. Since labor is mobile between the two sectors, if manufactures are produced, the wage in both sectors must be 1, and Eq.(3) becomes

$$p = 1/(qS). \tag{3a}$$

Resource harvesting is carried out by profit-maximizing harvesters under conditions of free entry. In this situation, harvesting occurs until the current return to a representative entrant is just equal to the entrant's current cost. No harvester has any incentive to delay harvesting as long as positive current rents are available, because of the legitimate expectation that someone else will harvest the resource instead.

2.2 Utility, consumption and demand

A representative consumer is endowed with one unit of labor and is assumed to have instantaneous utility given by the following Cobb-Douglas utility function:

$$u = h^{\beta} m^{1-\beta}, \tag{4}$$

where h represents individual consumption of the resource good, m represents individual consumption of manufactures, and β is a taste parameter ($0 < \beta < 1$). We also assume that two countries share the same preference to the resource good (i.e., $\beta = \beta^{*}$). The representative consumer maximizes utility at each moment, subject to the instantaneous budget constraint given by

$$ph + m = w. \tag{5}$$

This maximization yields demand functions $h_D = w\beta/p$ and $m_D = w(1-\beta)$.

Total domestic demand is just L times individual demand:

$$H_D = w\beta L/p\,, \quad M_D = w(1-\beta)L. \tag{6}$$

The demand for the resource good can be rewritten in inverse form as

$$p = w\beta L/H_D. \tag{7}$$

With Cobb-Douglas preferences both goods are essential. Since good M is essential and cannot be exhausted, it will always be consumed. Therefore, in autarky, good M must be produced and the autarky wage must be 1.

2.3 Ricardian temporary equilibrium

On the production side, at a given moment the resource stock S is fixed, and the economy is Ricardian. The full employment condition defines the temporary Ricardian production possibility frontier (PPF) and is given by

$$H_S a_{LH} + M = L. \tag{8}$$

The temporary equilibrium can be solved algebraically by setting the supply price by Eq.(3) equal to the demand price given by Eq.(7). Equating the two prices and solving for H yields

$$H = q\beta LS. \tag{9}$$

Note that the temporary equilibrium harvest is an increasing linear function of the resource stock. The equilibrium output of M is $M = (1-\beta)L$, and hence a fraction β of the labor is employed in the resource sector.

2.4 An autarkic steady state

Before setting the general autarky equilibrium, it is necessary to describe the basic structure of renewable resource growth. The resource stock at time t is denoted $S(t)$. The nature growth of the resource, denoted G, is a function of the existing stock. The change of the stock at time t is the nature growth rate $G(S(t))$, minus the harvest rate $H(t)$. Dropping the time argument for convenience yields,

$$dS/dt = G(S) - H. \tag{10}$$

We use a specific functional form for G, given by

$$G(S) = rS(1 - S/K). \tag{11}$$

This functional form for $G(S)$ is the logistic function. It is widely used in the analysis of renewable resources and is perhaps the simplest empirically functional form for biological growth in a constrained environment. The variable K is the maximum possible size for the resource stock and is referred to as the "carrying capacity" of the resource. If $S = K$, further stock growth cannot occur. The variable r is the "intrinsic" growth rate. This function says that the per-capita growth rate $G(S)/S$ would be approximately equal to r if the current stock is relatively small enough compared to the carrying capacity, and that the growth rate declines linearly as S increases. The term "density-dependent growth rate" is often used to describe this situation, whether or not the relationship is linear.

Since the transboundary renewable resource is shared by two countries, the change of the stock at time t becomes

$$dS/dt = G(S) - H_S - H_S^*. \tag{12}$$

A steady state emerges when the resource growth rate $G(S)$, which is given by Eq.(11), equals the harvest of the resource both in the domestic and foreign country, which is given by Eq.(9):

$$rS(1 - S/K) = q\beta LS + q^*\beta L^*S. \tag{13}$$

The solution to Eq.(13) is $S = 0$ or $S = S_A$, as given by

$$S_A = K(1 - q\beta L/r - q^*\beta L^*/r). \tag{14}$$

Provided that S_A as given in Eq.(14) is positive, it is the unique interior autarkic steady state stock. A steady state solution with a positive stock level exists if and only if

$$r > q\beta L + q^*\beta L^*. \tag{15}$$

We assume that Eq.(15) holds throughout this paper.

Substituting the value of S_A into Eq.(3a) allows us to solve for the corresponding steady state autarky price:

$$p_A = 1/[qK(1 - q\beta L/r - q^*\beta L^*/r)], \tag{16}$$

$$w_A^* = 1/[q^*K(1 - q\beta L/r - q^*\beta L^*/r)]. \quad (17)$$

We also can obtain the utility level in each country at autarky steady state:

$$u_A = L[q\beta K(1 - q\beta L/r - q^*\beta L^*/r)]^{\beta}(1-\beta)^{1-\beta}, \quad (18)$$

$$u_A^* = L^*[q^*\beta K(1 - q\beta L/r - q^*\beta L^*/r)]^{\beta}(1-\beta)^{1-\beta}. \quad (19)$$

The resource dynamics associated with convergence to a steady state are illustrated in Figure 1. This figure illustrates a situation in which the initial stock level is S_0. The world harvest $H(S_0)+H^*(S_0)$ is in an excess of natural growth $G(S_0)$. Thus, the stock shrinks toward its autarkic steady state level S_A. It is apparent that a steady state with positive stock and harvest levels will not exist for all parameter values.

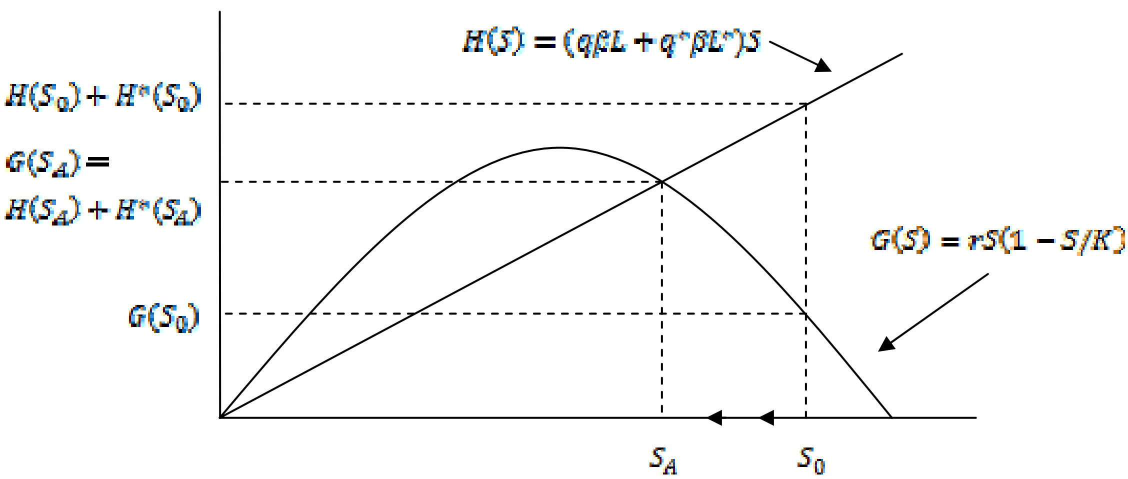


Figure 1. Transboundary renewable resource dynamics

As shown in Figure 1, if the temporary equilibrium world harvest $H + H^*$ exceeds biological growth G, then the resource stock diminishes as time proceeds. From Eq.(2), we know that the average and marginal product of labor is qS. As a result, labor productivity in the resource sector falls as S decreases. The Ricardian PPF, which has harvest intercept qLS, pivots inwards, leading to a new temporary equilibrium, as illustrated in Figure 2.

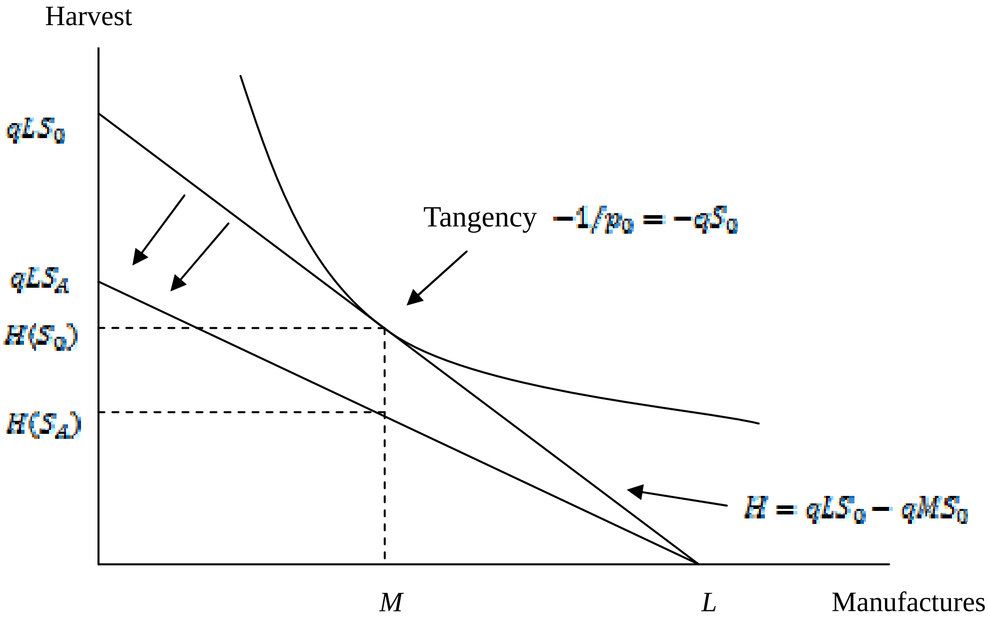


Figure 2. Temporary equilibrium dynamics in the domestic country

3. A Two-Country Model of International Trade

We consider trade between two countries when both countries share the same renewable resource. If $q^* = q$, then the autarky relative prices of the two countries are the same, and it is worth nothing to continue the discussion. That is because there is no incentive for each country to open to trade. Without the loss of any generality, we assume that the domestic country has lower harvesting technology throughout this paper, which can be expressed by[11]

[11] The parameter q and q^* can be interpreted in another way. For example, they denote spatial heterogeneity of the transboudary renewable resource that is caused by biological factors (e.g., many fishery resources move across space occasionally depending on environmental factors such as a temperature of seawater and ocean current).

$$q < q^*. \tag{20}$$

According to this assumption and Eq.(2), we can easily obtain that $a_{LM} > a^*_{LM}$. This inequality implies that the domestic country has a higher autarkic relative price of the resource good, and so a comparative disadvantage in producing it. At the trading steady state, the domestic country exports manufactures and imports the resource good, while the foreign country exports the resource good and imports manufactures.

We consider the patterns of production of the two countries at a new steady state after trade. First of all, we think about the diversified steady states at both countries. Under these circumstances, the wage in each country must be equal to 1. Because of the same post-trade relative price and the mutual transboundary renewable resource stock, $q^* = q$ must hold, which contradicts Eq.(20). Therefore, the case that both countries produce both the resource good and manufactures will not happen except $q^* = q$ holds, which is beyond our discussion.

There are only three steady state patterns of production left. One case is that the domestic country specializes in manufactures, while the foreign country diversifies. Another case is that the domestic country specializes in manufactures, while the foreign country specializes in the resource good. The third case is that the domestic country diversifies, while the foreign country specializes in the resource good. We will discuss them one by one in the rest of the paper.

3.1 Specialized steady state only for the domestic country

We now consider case (i) in which the domestic country only produces manufactures and the foreign country produces both goods at a trading steady state. Since manufactures are produced in both countries, the wage must be equal to 1 in each country ($w = w^* = 1$). Together with Eq.(6), we have the demand for manufactures in each country: $M_D = (1-\beta)L$, $M^*_D = (1-\beta)L^*$. On the other hand, the supply of manufactures in the domestic and foreign country can be expressed as follows: $M_S = L$, $M_S^* = L^* - L_H^*$. The material balance condition given by $M_D + M_D^* = M_S + M_S^*$ then implies that $L_H^* = \beta(L + L^*)$.

Since the foreign country produces both kinds of goods, the amount of labor used in the resource sector must lie between zero and the total labor force of the foreign country. This can be expressed by $0 < L_H^* < L^*$, which implies that

$$[\beta L/(1-\beta)L^*] < 1. \qquad (21)$$

If Eq.(21) holds, it can be rewritten as $(1-\beta)(L + L^*) > L$. Wage rates w and w^* cannot be less than 1, therefore,

$$(1-\beta)(wL + w^*L^*) > L. \qquad (21a)$$

It follows from Eq.(6) that the world demand for manufactures is precisely the left hand side of Eq.(21a). However, the right hand side of Eq.(21a), L, is the maximum amount of manufactures that can be produced in the domestic country, even if all domestic labor is devoted to manufactures. It follows that the foreign country must in this case produce some manufactures and have a wage equal to 1. Hence, Eq.(21) insures a diversified steady state in the foreign country.

Since diversified steady states cannot happen in both countries and the domestic country has a comparative disadvantage in producing the resource good, we can be sure that the domestic country specialized in manufactures at a trading steady-state. Therefore, we have that the necessary and sufficient condition for case (i) is Eq.(21).

Moreover, a steady state requires $G(S) = H_S^*$, because the resource good is only produced by the foreign country. Numerically solving for the post-trade transboundary renewable resource stock, denoted S_{T1}, yields

$$S_{T1} = K(1 - q^*\beta L/r - q^*\beta L^*/r), \qquad (22)$$

and the steady state solution is positive if and only if

$$r > q^*\beta L + q^*\beta L^*. \tag{23}$$

We assume that Eq.(23) holds in this subsection.[12] Since $q < q^*$, we can easily obtain that $S_{T1} < S_A$, which means that trade causes the resource stock decrease.

Since the nominal income after trade in both countries remains the same as autarky, whether the post-trade steady state utility rises or falls depends on the world price of the resource good, denoted p_{T1}. Substituting the value of S_{T1} into Eq.(3a) yields

$$p_{T1} = 1/[q^*K(1 - q^*\beta L/r - q^*\beta L^*/r)]. \tag{24}$$

Comparing Eq.(24) with Eq.(16), we have $p_{T1} > p_A$ when $r < (q + q^*)\beta L + q^*\beta L^*$, and $p_{T1} < p_A$ when $r > (q + q^*)\beta L + q^*\beta L^*$. In the domestic country, the nominal income is still L and the price of manufactures is unchanged at 1 after trade. If the price of the resource good rises, it follows immediately that welfare falls. On the other hand, if the price of the resource good falls, it follows immediately that welfare rises in the domestic country. Similarly, comparing Eq.(24) with Eq.(17), we obtain $p_{T1} > p_A^*$, which implies that the foreign country suffers steady state loss from trade. The key points of this discussion are summarized in Proposition 1.

Proposition 1. *If the trading steady state is specialized for the domestic country and diversified for the foreign country, then*

i) the necessary and sufficient condition for this case is $[\beta L/(1 - \beta)L^*] < 1$;

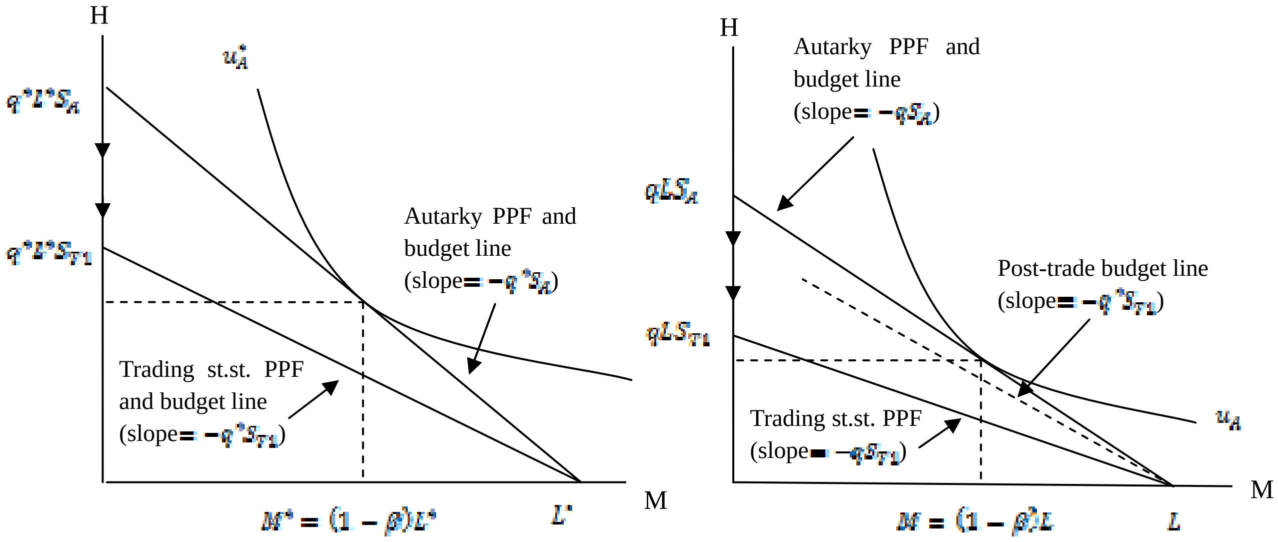
ii) the post-trade transboundary renewable resource stock is reduced by trade;

iii) if $r < (q + q^*)\beta L + q^*\beta L^*$, *then trade causes steady state utility to fall in the domestic*

12 Under Eq.(23), Eq.(15) is also satisfied because $q < q^*$.

country; while if $r > (q+q^*)\beta L + q^*\beta L^*$, then trade causes steady state utility to rise in the domestic country;

iv) trade causes steady state utility to fall in the foreign country.



3.1 The foreign country **3.2 The domestic country**

Figure 3. Transition to a steady state in case (i)

During the transition to this steady state, Eq.(21a) always holds. Thus, the foreign country must produce both kinds of goods and have a wage equal to 1 at every point on the transition pass. Right after trade opens, when the resource stock is still S_A, the relative price in the foreign country is still p_A^*. Therefore, the welfare of the foreign country is the same as autarky. The resource stock diminishes as time proceeds, and the relative price in the foreign country increases accordingly. The PPF and the budget line pivots inwards, as shown in Figure 3.1. Thus, the foreign country then converges to a diversified steady state with lower utility level than autarky. Meanwhile, the domestic country must specialize in manufactures immediately when trade opens. Right after trade, the relative price in the domestic country is lower than autarky, then the domestic country must gain from trade. As the resource stock decreases, the world price of the resource good rises. Therefore, the budget line of the domestic country may lie inside of the autarky budget line, as illustrated in Figure 3.2. Thus, the domestic country may converge to a specialized steady state with probably higher or lower utility level than autarky.

The welfare effects of trade in this case are of considerable interest. The foreign country with a higher harvesting technology suffers utility loss, because the decrease of the resource stock causes the decrease of the productivity of the resource sector, and then causes the relative price to rise in the foreign country. However, the domestic country which specializes in manufactures after trade may also suffer welfare loss. That is because when the transboundary renewable resource is over-exploited, furthermore, the instinct growth rate r is too small for the resource stock to recover, the productivity of the resource sector becomes extremely low so that the world relative price turns out to be higher than the autarky relative price in the domestic country. In short, due to the transboundary renewable resource, free trade may cause a lose-lose situation in this case.

If each country possesses its own renewable resource as in Brander and Taylor (1998), specialized production cannot be sustained when the foreign country's productivity of the resource sector becomes lower than the implicit productivity of the resource sector in the domestic country. This is the reason why the domestic country would always gain from trade during specialization when the resource stock is not shared by two countries.

3.2 Specialized steady state for each country

We examine case (ii) in which the domestic country specializes in manufactures and the foreign country specializes in the resource good at a trading steady state. A steady state requires

$G(S) = H_S^*$, because the resource good is only produced by the foreign country. Since the foreign country is specialized in the resource good, we have $H_S^* = q^* S_{T2} L^*$, where S_{T2} is the post-trade transboundary renewable resource stock in this steady state. Numerically solving for the value of S_{T2} yields

$$S_{T2} = K(1 - q^* L^*/r). \tag{25}$$

To make sure the solution to be positive, the following expression must hold:

$$r > q^* L^*. \tag{26}$$

We assume that Eq.(26) holds in this subsection.

Since the trading steady state is specialized in each country, the wage in the domestic country must be equal to 1 ($w = 1$), and the wage in the foreign country must be at least 1 ($w^* \geq 1$). The world price of the resource good, denoted p_{T2}, is therefore to be $p_{T2} = w^*/(q^* S_{T2})$, and it cannot exceed the cost of the resource good produced in the domestic country, which can be written as $1/(q S_{T2})$.

From the discussion above, we have the necessary condition for case (ii), $1 \leq w^* \leq (q^*/q)$. From Eq.(6), we have the demand for manufactures in each country: $M_D = (1-\beta)L$, $M_D^* = (1-\beta) w^* L^*$. On the other hand, the world supply of manufactures is $M_S = L$. The material balance condition given by $M_D + M_D^* = M_S$ implies $w^* = \beta L/(1-\beta)L^*$. Then, the necessary condition can be rewritten as[13]

$$1 \leq [\beta L/(1-\beta)L^*] \leq (q^*/q). \tag{27}$$

Taking the difference between S_{T2} and S_A yields

$$S_{T2} - S_A = (K/r)[q\beta L - (1-\beta) q^* L^*], \tag{28}$$

and using Eq.(27) allows us to determine the sign of Eq.(28). When the condition

13 Under Eq.(27), Eq.(15) holds because $r > q^* L^*$ by Eq.(26).

$\beta L/(1-\beta)L^* = q^*/q$ holds, then $S_{T2} = S_A$. Otherwise, it follows that $S_{T2} < S_A$.

To show sufficiency, we assume that diversification occurs. When the foreign country has a diversified steady state, as we have already discussed in Section 3.1, Eq.(21) must hold, which obviously contradicts Eq.(27). When the domestic country diversified, as we will discuss in Section 3.3, $[\beta L/(1-\beta)L^*] > (q^*/q)$ will hold, which also contradicts Eq.(27). Since there are only three patterns of production, if Eq.(27) is satisfied, specialization in each country is the only possibility.

Since manufactures are produced in the domestic country, the nominal income is still L after trade. The domestic country will gain from trade if the world price of the resource good is lower than autarky. Taking the difference between p_{T2} and p_A yields

$$p_{T2} - p_A = (r/K)(q^*L^* - q\beta L - q^*\beta L^*)(q\beta L + q^*L^* - r)$$
$$\times [qq^*L^*(1-\beta)(r - q^*L^*)(r - q\beta L - q^*\beta L^*)]^{-1}, \quad (29)$$

where the denominator is positive according to the assumptions on positive stock levels, while $(q^*L^* - q\beta L - q^*\beta L^*) \geq 0$ according to Eq.(27). When either $\beta L/(1-\beta)L^* = q^*/q$ or $r = q\beta L + q^*L^*$ holds, we can easily obtain that $p_{T2} = p_A$, which means the utility level in the domestic country is the same as autarky. On the other hand, when $1 \leq [\beta L/(1-\beta)L^*] < (q^*/q)$ is satisfied, it follows that the sign of $p_{T2} - p_A$ is the same as the sign of $q\beta L + q^*L^* - r$. If $r < q\beta L + q^*L^*$, the relative price in the domestic country rises, and then trade causes steady state utility to fall; while if $r > q\beta L + q^*L^*$, the relative price in the domestic country falls, and then trade causes steady state utility to rise in the domestic country.

The welfare effects on the foreign country, however, are more obscure. We let u^*_{T2} to be the post-trade utility level of the foreign country, it can be written as

$$u_{T2}^{*} = [q^{*}\beta L^{*}X(1 - q^{*}L^{*}/r)]^{\beta}(\beta L)^{1-\beta}. \tag{30}$$

Taking the division between u_{T2}^{*} and the autarky utility level u_{A}^{*} yields

$$u_{T2}^{*}/u_{A}^{*} = [(r - q^{*}L^{*})/(r - q\beta L - q^{*}\beta L^{*})]^{\beta}[\beta L/(1-\beta)L^{*}]^{1-\beta}. \tag{31}$$

When Eq.(31) exceeds 1, the foreign country gains from trade; while when it is less than 1, then the foreign country suffers steady state loss. Under the conditions that $\beta = 1/2$ and $L = L^{*}$, we always have $u_{T2}^{*} < u_{A}^{*}$.

Summing up, we obtain the following proposition.

Proposition 2. *If the trading steady state is specialized for both the domestic and foreign country, then*

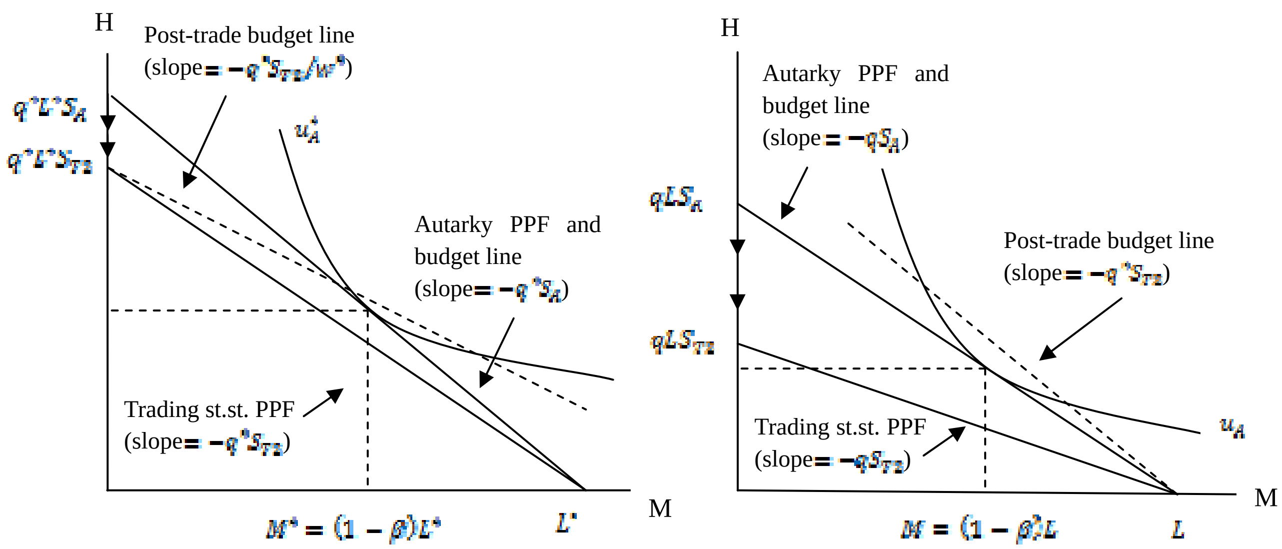
i) the necessary and sufficient condition for this case is $1 \leq [\beta L/(1-\beta)L^{*}] \leq (q^{*}/q)$*;*

ii) if $\beta L/(1-\beta)L^{*} = q^{*}/q$*, then trade does not change the post-trade transboundary renewable resource stock; otherwise the post-trade transboundary renewable resource stock is reduced by trade;*

iii) when either $\beta L/(1-\beta)L^{*} = q^{*}/q$ *or* $r = q\beta L + q^{*}L^{*}$ *holds, trade does not change the steady state utility level in the domestic country; when* $1 \leq [\beta L/(1-\beta)L^{*}] < (q^{*}/q)$ *holds, if* $r > q\beta L + q^{*}L^{*}$*, then trade causes steady state utility to rise in the domestic country, while if* $r < q\beta L + q^{*}L^{*}$*, then trade causes steady state utility to fall in the domestic country;*

iv) if $[(r - q^{*}L^{*})/(r - q\beta L - q^{*}\beta L^{*})]^{\beta}[\beta L/(1-\beta)L^{*}]^{1-\beta} > 1$*, then trade causes steady state utility to rise in the foreign country; while if the inequality runs the other way, then trade causes steady state utility to fall in the foreign country.*

Now we consider the transition to this steady state. Right after trade, the domestic country will specialize in manufactures immediately and have a wage rate which is equal to 1. Meanwhile, the foreign country will specialize in resource good right away and have a wage rate which cannot be less than 1. When the resource stock remains S_A, then the relative price in the foreign country is still the same as autarky. Since the wage rate rises, the temporary utility level of the foreign country also increases. On the other hand, the relative price in the domestic country is lower than autarky, then it follows that the utility level of the domestic country also increases temporarily.



4.1 The foreign country **4.2 The domestic country**

Figure 4. Transition to a steady state in case (ii)

As the resource stock falls, the world relative price rises accordingly, as a consequence, the utility level falls in each country. When the world price of the resource good exceeds the autarky price, the domestic country will suffer utility loss. Until then, the domestic country will gain from trade. Meanwhile, when the world price of the resource good becomes so high that the rise of the wage rate cannot cover the welfare loss which caused by the rise of the relative price, the foreign country will suffer utility loss. Until then, the foreign country will benefit from access to international markets. Hence, each country could have a convergence to a specialized steady state with probably higher or lower utility level compared to autarky. At this kind of steady state, when some conditions are satisfied, although the resource stock decreases, both countries may still gain from trade, as illustrated in Figure 4. However, unfortunately, a lose-lose situation may also occur.

3.3 Specialized steady state only for the foreign country

Finally, we consider case (iii) in which the domestic country produces both kinds of goods and the foreign country only produces the resource good. The wage in the domestic country must be equal to 1 ($w = 1$), while the wage in the foreign country cannot be less than 1 ($w^* \geq 1$). According to Eq.(3), the world price of the resource good, denoted p_{T3}, can be written as

$$p_{T3} = (w^*/q^*S_{T3}) = (1/qS_{T3}), \tag{32}$$

where S_{T3} is the post-trading transboundary renewable resource stock. From Eq.(32), it follows that

$$w^* = q^*/q. \tag{33}$$

From Eq.(20), we have $w^* > 1$. Together with Eq.(6), we have the demand for manufactures in each country: $M_D = (1-\beta)L$, $M_D^* = (1-\beta)w^*L^*$. Since manufactures are only produced in the domestic country, the world supply of manufactures can be expressed as follows: $M_S = L - L_H$. The material balance condition given by $M_D + M_D^* = M_S$ then implies that

$L_H = \beta L - (1-\beta)(q^*/q)L^*$.

Since the domestic country produces both kinds of goods, the amount of labor used in the resource sector must lie between zero and the total labor force of the domestic country. This can be expressed by $0 < L_H < L$, which implies that

$$[\beta L/(1-\beta)L^*] > (q^*/q) . \tag{34}$$

To show sufficiency, we assume that a different steady state occurs. As we have already discussed in Section 3.1 and 3.2, the inequality in Eq.(34) must run the other way. Thus, if Eq.(34) holds, a diversified steady state for the domestic country and a specialized steady state for the foreign country is the only possibility.

Moreover, this steady state requires $G(S) = H_S + H_S^*$. Numerically solving for the post-trade transboundary renewable resource stock yields

$$S_{T3} = K(1 - q\beta L/r - q^*\beta L^*/r) . \tag{35}$$

Comparing Eq.(35) to Eq.(14), we can easily obtain that $S_{T3} = S_A$. Since both countries produce the resource good after trade, the zero-profit condition must be satisfied with interior solutions. Therefore, the post-trade and autarky per-capita growth rate $G(S)/S$ must be the same, and so does the resource stock.

Since the domestic country produces both kinds of goods after trade, the nominal income is the same as autarky. The world relative price is also the same as autarky in the domestic country, therefore trade does not change the welfare of the domestic country. While the post-trade steady state utility in the foreign country, denoted u_{T3}^*, can be written as $u_{T3}^* = u_A^*(q^*/q)$, where u_A^* is the autarky utility level. As long as Eq.(20) holds, the foreign country actually gains from trade. This discussion is summarized in Proposition 3.

Proposition 3. *If the trading steady state is diversified for the domestic country and specialized for the foreign country, then*

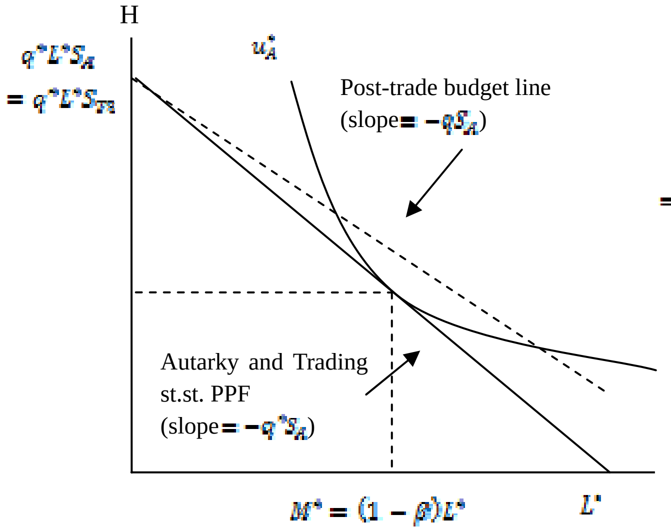
i) the necessary and sufficient condition for this case is $[\beta L/(1-\beta)L^*] > (q^*/q)$*;*

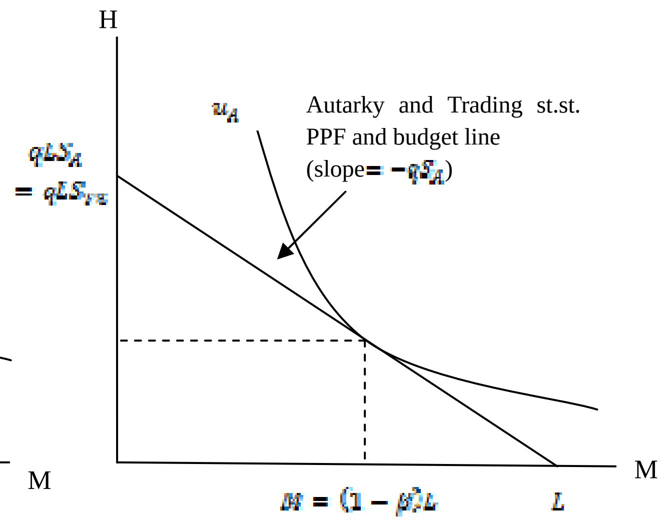
ii) the post-trade transboundary renewable resource stock is the same as autarky;

iii) trade does not change steady state utility in the domestic country;

iv) trade causes steady state utility to rise in the foreign country.

The welfare effects of trade in this case are standard. During the transition pass to this steady state, the resource stock stays the same, and so does the world price of the resource good. The production of the resource good at the trading steady state does not change. However, the production of manufactures increases because the foreign country with higher harvesting technology produces most of the resource good so that more labor can be used in producing manufactures in the domestic country. Since the PPF and the budget line stay unchanged, the domestic country, which has a diversified steady state, remains the same utility level as autarky, as shown in figure 5.2. While the foreign country, which specializes in the resource good, gains from trade because of the rise of the wage rate, as illustrated in figure 5.1.





5.1 The foreign country **5.2 The domestic country**

Figure 5. Transition to a steady state in case (iii)

4. Concluding Remarks

We developed a two-country, two-good model to examine the effects of international trade when a renewable resource is transboundary. The transboundary renewable resource is subject to international open access. Therefore, the transboundary renewable resource is likely to be reduced by trade. Then, we may expect that a resource good exporter suffers from opening trade. However, we derived the striking result that both countries may still benefit from trade when each country is specialized in production.

The main contribution of this paper is to show how the effects of trade liberalization change when countries share renewable resources. We showed that the steady-state utility of a resource good importing country may be reduced by trade, even if that country specializes in production of manufactures. This counter-intuitive result cannot be obtained when a renewable resource is subject to open access by its residents only. Our results suggest that the migratory nature of renewable resources plays an important role in evaluating gains from trade.

In this paper, we did not investigate the effects of resource management. We focused on the open-access case to clarify the basic relationship between international trade and transboundary renewable resources. However, it is important to examine how the implementation of resource management affects the steady-state utility and the stock levels. One possible extension of our model is to consider a tariff or tax on resource goods. For instance, tariffs imposed by the resource importing country may benefit the resource exporting country, and may be Pareto-improving. Another interesting topic for future research is to examine other type of resource management such as input and output controls that are commonly implemented in fishery. We expect that such resource management reinforces the results on gains from trade even under transboundary renewable resources.

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