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International Trade and Management of Shared Renewable Resource

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International Trade and Management of Shared Renewable Resource

Abstract

This paper examines the effects of international trade and resource management in a two-country model where each country controls domestic harvest to prevent over-exploitation of an internationally shared renewable resource (e.g., fishery resources). We show that contrary to conventional wisdom, an opening up of trade is likely to raise the steady state utility of a resource-good exporting country, even if it implements weak resource management standards, because the expansion of the resource sector which enjoys economic rent increases its total income. To maximize world welfare in a trading steady state, a resource-good importing country should implement stricter resource management after trade than under autarky but it will implement weak resource management to enjoy economic rent by mitigating the contraction of the resource sector (i.e., rent shifting). Thus, a resource-good exporting country should give some side payments to give a resource-good importing country an incentive to implement strict resource management standards.

Keywords: Gains from trade; Shared renewable resource; Resource management

JEL Classification: F11; Q27

1. Introduction

Sustainable and efficient exploitation of renewable resources can conserve an ecosystem and provide many benefits for the present and future generations. To achieve this goal, resource management is required and becomes more important when renewable resources are internationally traded and shared because the over-exploitation problem is severe in such situations. Various natural resources are highly traded in recent years (e.g., WTO, 2010).[1] Trade liberalization will expand the resource sector in a resource-good exporting country, whereas it shrinks in a resource-good importing country. As each country specializes in a comparative advantage sector, this change in production patterns will increase the world total production of resource goods, which may cause over-exploitation. Not a few renewable resources such as fishery stocks are internationally shared or transboundary due to biological conditions and national boundaries.[2] When resources are shared, they are prone to be over-exploited because of negative production externalities caused by sharing access to them. Moreover, property rights over shared resources are hard to define, which implies that we must adjust the interests of countries concerned. Thus, international coordination is important for effective resource management, which is similar to global warming prevention.

Management of renewable resources is also important from an economic viewpoint. The growth rates of renewable resources depend on their stock levels due to biological reasons.

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[1] For example, the Food and Agriculture Organization (FAO) reported that the share of fishery and aquaculture production (live weight equivalent) entering international markets as various food and feed products increased from 25 percent in 1976 to 39 percent in 2008. In 2008, world exports of fish and fishery products reached a record value of US$102.0 billion, which represented almost double the US$51.5 billion corresponding value in 1998. Net exports of fish and fish products are particularly important for developing countries and are higher than those of several other agricultural commodities such as coffee and rubber. See FAO (2010).

[2] Other examples of shared renewable resources are wildlife stocks that straddle (or migrate across) the boundaries of the territories or the exclusive economic zones (EEZs) of two or more countries, internationally shared (transboundary) aquifers and river basin resources, etc.

Moreover, the production of resource goods is usually dependent on the stock level, i.e., larger the stock level is, higher the productivity of the resource sector is. From these features, under incomplete resource management, a situation of inefficient harvesting, where more inputs than necessary are employed to produce a certain amount of resource goods, occurs when renewable resources are over-exploited (e.g., the case where the stock level is smaller than the maximum sustainable yield (MSY)).[3] Thus, we should restrict the harvest to improve efficiency of the resource sector.

The purpose of this paper is to consider international trade and resource management in a two-country, two-good model where countries share a renewable resource. Each country implements resource management to control its domestic harvest. We examine how trade liberalization affects the level of the shared resource stock, the steady state utility of each country, and resource management standards. We also investigate the optimal resource management that maximizes world welfare.

To focus on the effects of trade, we first consider the case where both countries do not change their resource management standards given exogenously even after trade. We show that contrary to conventional wisdom, an opening up of trade is likely to raise the steady state utility of a resource-good exporting country, even if it implements weaker resource management than a resource-good importing country does. As both countries face the same stock level, when trade increases (decreases) the level of the shared stock, the productivity of the resource sector improves (deteriorates) in both countries, which leads a fall (rise) of the price of the resource good. Even if the shared stock is reduced by trade, a resource-good exporting country can gain from trade because an increase in its total income, which is caused by the expansion of the resource sector that enjoys economic rent under resource management, is enough to countervail

[3] A situation of inefficient harvesting is caused by the well-known backward bending supply curve of open-access renewable resource goods. See, for example, Clark (1990) and Brander and Taylor (1997).

the negative price effect.

In the case where each country implements resource management to maximize its steady state utility, we demonstrate that a resource-good importing country may have an incentive to implement weaker resource management under trade than under autarky. This is because that country can enjoy economic rent by mitigating the contraction of the resource sector (i.e., rent-seeking behavior). However, a resource-good importing country should implement stricter resource management to maximize world welfare in a trading steady state.

The results of this paper have the following important policy implication. We observe the rent-seeking behavior caused by trade liberalization, which weakens resource management standards. Therefore, to maximize world welfare, a resource-good exporting country should give some side payments (international transfers) to give a resource-good importing country an incentive to implement strict resource management. For example, regional fisheries management organizations (RFMOs) are managed by intergovernmental entities and responsible for the conservation and management of various stocks (e.g., straddling and highly migratory fish stocks), which is mandated by the United Nations Convention on the Law of the Sea. However, some RFMOs are not working well to control over-exploitation (e.g., Worm et al., 2009; WWF, 2006).[4] We may infer that the over-exploitation problem is unsolved and becoming more severe because RFMOs do not have the international transfer mechanism as mentioned above to adjust the interests of countries concerned, although the volume of trade in fishery resources is increasing. It is worthwhile to establish such mechanism to complement the existing framework of resource management.

Most existing studies examined the welfare effects of trade liberalization in a general

[4] According to World Bank (2009), because of incomplete governance of the world marine fisheries, the lost economic benefits are estimated to be on the order of $50 billion per year, and over the past three decades, this cumulative global loss of potential economic benefits is on the order of $2 trillion.

equilibrium model when renewable resources are not internationally shared because their focus was on local resources such as forest. The seminal article by Brander and Taylor (1998) considered the case of open-access renewable resources and Brander and Taylor (1997) analyzed the effects of trade under resource management.[5] Their results suggest that the over-exploitation problem is a domestic problem particular to a resource-good exporting country which may lose from trade without resource management. In the case where countries share access to a common renewable resource stock, Bulte and Damania (2005) investigated the property of regulatory policies but did not examine the welfare effects of trade. Takarada (2009) initially considered gains from trade under the presence of an open-access shared renewable resource and showed that although the over-exploitation problem is severe, trade liberalization can be Pareto-improving. The existing literature of bioeconomics focuses on the strategic interaction between countries that share renewable resources and usually employs one good model with the assumption of a fixed price.[6] Therefore, neither the effects of price changes, factor movement, nor international trade are examined in them.

The rest of the paper is organized as follows. Section 2 sets up the model and analyzes an autarkic steady state. Section 3 examines the effects of trade under resource management. Section 4 considers the optimal resource management. Section 5 provides some discussions on the framework of the analysis and the concluding remarks will be provided in Section 6.

2. The Model

We develop a two-country general equilibrium model of trade with management of a shared renewable resource and show an autarkic steady state. We refer to the countries as “home” and

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[5] The relationship between trade and management of local renewable resources was also examined in Chichilnsky (1994), Copeland and Taylor (2009), Emami and Johnston (2000), Hotte et al. (2000), and Jinji (2007).

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

"foreign", which share the renewable resource, and use asterisks to denote foreign variables. Each country produces and consumes two goods, H and M. H is the harvest of the shared renewable resource and M is some other good which might be thought of as a manufacturing good.

2.1 Resource growth, production and consumption

We describe the basic structure of renewable resource growth. The shared resource stock at time t is denoted by $S(t)$. The natural growth rate of the resource, denoted by G, is a function of the existing stock. Suppose that in a certain population, both the birth rate and the mortality rate are proportional to the stock level. As the stock level S increases, the resource growth rate must be forced to decline by some environmental limitation. The following equation models this effect:

$$G(S) = r(S) \cdot S, \tag{1}$$

where $r(S)$ is the net proportional growth rate of the population and dependent on the stock level. We assume that $r(S) = G(S)/S$ is decreasing in S,

$$dr(S)/dS < 0. \tag{2}$$

Eq.(2) describes a process of feedback or compensation, which controls the growth of the resource stock as its level increases.[7] The environmental carrying capacity or saturation level of the stock, K, is globally asymptotically stable for positive S in the sense that $\lim_{t\to\infty} S(t) = K$, which also implies $G(K)/K = 0$. We use this pure compensation model in this paper.

As the home and foreign countries share the resource stock S, the net change of S at time t is the natural growth rate $G(S(t))$ minus the sum of the harvest rate in both countries, $H(t)$ and $H^*(t)$. Dropping the time argument for convenience, we have

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[7] The simplest and most widely used functional form of $r(S)$ that satisfies Eq.(2) is the logistic function, $r(S) = r(1 - S/K)$, where r is the intrinsic growth rate and K is the carrying capacity. See, for example, Chapter 1 of Clark (1990).

$$dS/dt = G(S) - H - H^*. \tag{3}$$

Next, we consider the production of manufacturing and resource goods. Production in both sectors is carried out by profit-maximizing firms under the condition of free entry. The production function of M is denoted by $M_P = L_M$, where L_M is the amount of labor employed in the manufacturing sector. The harvest of the shared resource is assumed to be carried out according to the Schaefer harvesting function, $H_P = qSL_H$, where H_P is the production of the resource good, L_H is the amount of labor employed in resource harvesting, and q reflects the harvesting technology. We allow a difference in the harvesting technology between the two countries, whereas the technology in producing the manufacturing good is identical between them. It is assumed that labor is freely mobile between the two sectors and fully employed, $L_H + L_M = L$, where L is the labor endowment. We choose M as the numeraire. Thus, the wage rate w must be equal to one if M is produced.

On the demand side, the utility of a country is assumed to be the Cobb-Douglas utility function, $u = H^{\beta} M^{1-\beta}$, where β is a taste parameter ($0 < \beta < 1$). We assume that preferences are identical between the two countries (i.e., $\beta = \beta^*$). Consumers in the home country maximize utility subject to the budget constraint $pH_D + M_D = I$, where p and I refer to the relative price of the resource good and the total income, respectively. The demand functions for H and M are given by

$$H_D = \beta I/p,\ M_D = (1-\beta)I, \tag{4}$$

respectively.

2.2 Resource management

We explain how the government restricts domestic exploitation. Each government imposes an ad valorem tax τ on the sales of the resource good by domestic firms to maximize its steady state utility. The government distributes tax revenue to consumers as lump-sum subsidies. We assume that enforcement of resource management is costless for simplicity.

The resource sector of the home country maximizes profit by setting the resource harvest under a given level of τ, i.e.,

$$\max_{0\leq H_P\leq qSL}\ pH_P/(1+\tau)-wH_P/qS. \qquad (5)$$

The f.o.c. for an interior solution is given by

$$p=w(1+\tau)/qS. \qquad (6)$$

Similarly, we can obtain the f.o.c. of the foreign country as $p^*=w^*(1+\tau^*)/\,q^*S$.

Eq.(6) suggests that under resource management ($\tau>0$), the resource sector enjoys economic rent. This is because production in the resource sector is restricted compared with an open-access case. The government collects the economic rent as tax revenue. Under $\tau=0$, Eq.(6) coincides with the zero-profit condition of an open-access case. In this model, we can easily know the difference in resource management standards between the two countries by comparing the value of a tax rate in each country.

Here, we do not consider the choice of the tax rate by the government and the tax rate is assumed to remain the same even after an opening up of trade. This will allow us to separate the strategic effects of resource management from the effects of trade liberalization. We will discuss an optimal tax rate that maximizes the steady state utility in Section 4.

2.3 Autarkic steady state

At autarky, both goods should be produced in each country and $w=w^*=1$ must hold. The total income of each country can be written as follows:

$$I_A=L+\tau L_{HA},\ I_A^*=L^*+\tau^*L_{HA}^*\ . \qquad (7)$$

The domestic demand for the resource good must be equal to the domestic production. Substituting Eqs.(6) and (7) into Eq.(4), the amounts of labor employed in the resource and manufacturing sectors of the home country are given by

$$L_{HA}=\beta L/(1+\tau-\beta\tau),\ L_{MA}=(1-\beta)(1+\tau)L/(1+\tau-\beta\tau), \qquad (8)$$

respectively. Similarly, we can obtain those variables in the foreign country as follows:

$$L_{HA}^{*} = \beta L^{*}/(1+\tau^{*}-\beta\tau^{*}),\ L_{MA}^{*} = (1-\beta)(1+\tau^{*})L^{*}/(1+\tau^{*}-\beta\tau^{*}). \tag{9}$$

Note that there is a one-to-one correspondence between $\tau^{(*)}$ and $L_{HA}^{(*)}$. This implies that a tax imposed on the resource good controls the amount of labor employed in the resource sector, and consequently controls the harvest of the renewable resource.

The net change of the shared resource stock S in a steady state must equal to zero. From Eq.(3), we have

$$G(S) = qSL_H + q^{*}SL_H^{*}. \tag{10}$$

Substituting Eqs.(8) and (9) into Eq.(10) yields

$$G(S)/S = \beta qL/(1+\tau-\beta\tau) + \beta q^{*}L^{*}/(1+\tau^{*}-\beta\tau^{*}). \tag{11}$$

From the compensation assumption Eq.(2), there must exist a positive autarkic stock level $S = S_A$ which satisfies Eq.(11) if and only if

$$\lim_{S\to 0_+} r(S) > \beta qL/(1+\tau-\beta\tau) + \beta q^{*}L^{*}/(1+\tau^{*}-\beta\tau^{*}). \tag{12}$$

We assume that Eq.(12) holds throughout this paper. From Eq.(11), we have $\partial S_A/\partial\tau^{(*)} > 0$. Thus, the stricter resource management is implemented, the larger the shared resource stock it will be.

We can obtain the amount of harvest and the autarkic relative price of the resource good in each country as follows:

$$H_{PA} = \beta qLS_A/(1+\tau-\beta\tau),\ H_{PA}^{*} = \beta q^{*}L^{*}S_A/(1+\tau^{*}-\beta\tau^{*}), \tag{13}$$

$$p_A = (1+\tau)/qS_A,\ p_A^{*} = (1+\tau^{*})/q^{*}S_A. \tag{14}$$

Then, the steady-state utility in each country is given by

$$u_A = L(q\beta S_A)^{\beta}\{(1-\beta)(1+\tau)\}^{1-\beta}/(1+\tau-\beta\tau), \tag{15}$$

$$u_A^{*} = L^{*}(q^{*}\beta S_A)^{\beta}\{(1-\beta)(1+\tau^{*})\}^{1-\beta}/(1+\tau^{*}-\beta\tau^{*}). \tag{16}$$

3. A Two-Country Model of International Trade

We investigate the effects of trade between the two countries that implement resource management. Both goods are freely traded but labor is immobile between countries. We focus on a trading steady state to derive clear results.

Without loss of generality, we assume that the foreign country has a comparative advantage in producing the resource good. From Eq.(14), $p_A > p_A^*$ holds if

$$(1+\tau)/q > (1+\tau^*)/q^*. \tag{17}$$

Eq.(17) is likely to hold when resource management in the home country is stricter than that in the foreign country ($\tau > \tau^*$) or the harvesting technology of the home country is inferior to that of the foreign country ($q < q^*$). Under this assumption, the home country exports M, whereas the foreign country exports H at a trading steady state.

Note that trade patterns are determined by the differences in harvesting technologies and resource management standards between the two countries. As both countries face the same stock level, a change in the stock level similarly affects each country's productivity of the resource sector. Thus, when the renewable resource is internationally shared, a country with weak resource management standards does not always have a comparative advantage in the resource sector.

In the present model, there are only three steady state patterns of production as follows (see Takarada, 2009): case (1) where the home country diversifies, while the foreign country specializes in the resource good; case (2) where the home country specializes in the manufacturing good and the foreign country specializes in the resource good; case (3) where the home country specializes in the manufacturing good, while the foreign country diversifies.[8]

We focus on case (1) because the resource good is produced in both countries even after an opening up of trade. In other cases such as case (2) and (3), because only the foreign country produces the resource good, it can manage the exploitation rate by itself. The feature of the

[8] From Eq.(18), if both countries diversify, $(1+\tau)/q = (1+\tau^*)/q^*$ must hold because $w = w^* = 1$. From Eq.(14), $p_A = p_A^*$ holds, which implies that there is no incentive for an opening up of trade.

present model is the existence of the shared stock whose level affects the productivity of the resource sector in both countries. However, in case (2) and (3), the home country only faces the indirect effect, the terms-of-trade effect caused by changes in the level of the shared stock, which is similar to the case of local resources.

3.1 Shared resource stock change

As the home country produces both goods and the foreign country specializes in H, $w = 1$ and $w^* \geq 1$ must hold. Then, the post-trade world price of H is given by

$$p_T = (1+\tau)/qS_T = w^*(1+\tau^*)/\, q^*S_T\ , \tag{18}$$

where S_T is the shared stock in the trading steady state.

The output of H in the home and foreign countries are $H_P = qS_TL_H$ and $H_P^* = q^*S_TL^*$, respectively. The total income of each country after trade can be written as $I = L + \tau L_H$ and $I^* = p_Tq^*S_TL^*$. Then, from Eq.(4), the demand for H in each country can be expressed as $H_D = \beta(L + \tau L_H)/p_T$ and $H_D^* = \beta q^*S_TL^*$. The market-clearing condition for H implies that

$$L_H = \{q\beta L - (1-\beta)(1+\tau)q^*L^*\}/q(1+\tau-\beta\tau). \tag{19}$$

From (8), we can show that $L_H < L_{HA}$, which implies that the output of M increases after trade in the home country. As the home country diversifies in the trading steady state, the condition for this steady state is $0 < L_H < L$, which yields

$$q\beta L > (1-\beta)(1+\tau)q^*L^*. \tag{20}$$

Substituting the value of L_H and L_H^* into Eq.(10), we obtain

$$G(S)/S = (\beta qL + \beta q^*L^*)/(1+\tau-\beta\tau). \tag{21}$$

There must exist a positive resource stock level $S = S_T$ that satisfies Eq.(21). As the foreign country specializes in H after trade, S_T depends on τ which restricts the amount of labor input in the home resource sector.

Comparing Eq.(21) with Eq.(11), we know that a change of the resource stock depends on the relative resource management standards of the two countries. From Eq.(2), we obtain the following results: if the home country implements stricter resource management than the foreign country ($\tau > \tau^*$), then $S_T > S_A$; if the two countries implement the same resource management standards ($\tau = \tau^*$), then $S_T = S_A$; if the home country implements weaker resource management than the foreign country ($\tau < \tau^*$), then $S_T < S_A$. Summing up, we obtain the following proposition.

Proposition 1 *Suppose that the home and foreign countries do not change their resource management standards before and after trade. Then, we obtain the following results.*

(i) An opening up of trade increases (decreases) the level of the shared resource stock in the steady state, if the home country implements stricter (weaker) resource management than the foreign country.

(ii) Trade does not change the level of the shared resource stock if the two countries implement the same resource management standards.

Note that when the home country implements strict resource management standards compared with the foreign country, trade liberalization increases the stock level even if the standards are absolutely weak in both countries. This suggests that a resource-good importing country plays an important role in recovery of the shared stock.

To understand this result intuitively, we should note that the world price of the resource good, p_T, does not always lie between the two countries' autarky prices, which is somewhat odd compared with the standard trade models. This feature is specific to this kind of model with the shared resource stock (see Takarada, 2009). From Eqs. (14) and (18), when $\tau < \tau^*$, $p_T > p_A > p_A^*$ must hold, which implies that the resource good price becomes high for both countries after trade. This high price attracts more labor into the resource sector, which has a negative effect on the resource stock. Similarly, when $\tau > \tau^*$, $p_T < p_A$ always holds. In this case, the shared stock increases by trade because the resource sector is not attractive in the home country after trade.

3.2 Welfare effects of trade

We examine gains from trade under resource management. From Eq.(4), we can obtain the steady state utility of each country after trade as follows:

$$u_T = (\beta S_T)^\beta [(1-\beta)(1+\tau)/q]^{1-\beta} [qL - (1-\beta)\tau q^* L^*]/(1+\tau-\beta\tau), \tag{22}$$

$$u_T^* = q^* L^* (\beta S_T)^\beta [(1-\beta)(1+\tau)/q]^{1-\beta}. \tag{23}$$

Comparing Eqs.(22) and (23) with Eqs.(15) and (16) and using the results of Proposition 1, we know that the welfare effects of trade depend on the difference in the two countries' resource management. Recall that Eq.(17) holds. If $\tau > \tau^*$, $u_T^* > u_A^*$ must hold, whereas the welfare effect in the home country is ambiguous. If $\tau = \tau^*$, then we obtain $u_T < u_A$ and $u_T^* > u_A^*$. If $\tau < \tau^*$, $u_T < u_A$ must be satisfied, whereas the welfare effect in the foreign country is ambiguous.

Proposition 2 *Suppose that the home and foreign countries do not change their resource management standards before and after trade. Then, we obtain the following results.*

(i) If the home country implements stricter resource management than the foreign country, trade always causes the steady state utility to rise in the foreign country, whereas trade causes the steady state utility to rise or fall in the home country.

(ii) If the two countries implement the same resource management, trade always causes the steady state utility to rise in the foreign country, whereas trade always causes the steady state utility to fall in the home country.

(iii) If the home country implements weaker resource management than the foreign country, trade always causes the steady state utility to fall in the home country, whereas trade causes the steady state utility to rise or fall in the foreign country.

The welfare effects of trade may depend on whether the steady state stock level is larger than MSY. Suppose that both stock levels under autarky and trade are greater than MSY. First, consider the case where trade decreases the resource stock (i.e., $\tau < \tau^*$). In this case, the world total output of the manufacturing good as well as that of the resource good increases (see Appendix A). Therefore, both countries cannot be made worse off by trade.

Corollary *Suppose that both steady state stock levels under autarky and trade are greater than MSY. When the home country implements weaker resource management than the foreign country, trade causes the steady state utility to rise in the foreign country.*

Second, consider the case where trade increases the stock level (i.e., $\tau > \tau^*$). In this case, the amount of harvest in a trading steady state is less than that in autarky. However, as shown, both countries can be made better off by trade. The point is that there are two goods in our model. As the stock level increases, less labor is required to produce a certain amount of the resource good. This implies that the output of the manufacturing good can increase, which could be large enough to compensate welfare losses caused by the decrease in production of the resource good.[9] We can similarly interpret other cases.

Now we focus on the transition path to the trading steady state. Right after an opening up of trade, the shared stock level remains as autarky and the demand of the resources good also remains unchanged but its production concentrates in the foreign country. As the resource sector enjoys economic rent which is equal to tax revenue, the home total income decreases after trade, whereas the foreign one increases. Therefore, the foreign utility rises and the home utility falls in the early stages of adjustment.

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[9] In this case, the output of the manufacturing good is likely to increase after trade but it might decrease. Intuitively, this is because the resource sector is attractive and the labor input in that sector does not decrease so much.

The shared resource stock will change along the transition path depending on the relative resource management standards. First, in the case where $\tau > \tau^*$, the resource stock increases during the transition path, so does the productivity of the resource sector. Then, the price of the resource good falls and utility levels rise in both countries. Hence, the foreign country benefits from trade at every point along the transition path. Although the home country loses economic rent, it may still experiences gains from trade if the price of the resource good falls enough to offset the decrease in its total income. Second, in the case where $\tau = \tau^*$, the resource stock remains the same during the transition path. Therefore, the foreign utility rises, whereas the home utility falls at the trading steady state. Third, in the case where $\tau < \tau^*$, the resource stock decreases during the transition path, so does the productivity of the resource sector. This will increase the resource price and decrease utility levels in both countries. Thus, the home utility is always lower than under autarky during the transition path. However, the foreign country can gain from trade if the increase in its total income is enough to countervail the negative price effect.

As discussed, when the price adjusts immediately after trade opens, in the second and third cases ($\tau \leq \tau^*$), the home country suffers a welfare loss at every point along the transition path. If the price does not adjust immediately, the world price of the resource good usually lies between the autarkic prices of the two countries when trade opens. In this case, overall home welfare will rise under a high discount rate when the welfare improvement from an increase in the terms of trade exceeds the present discounted value of the loss from the lower steady-state welfare. We know that the foreign country always benefits from an increase in its total income in the early stages of adjustment. Thus, both countries will have an incentive to trade under a high discount rate.

4. Optimal Resource Management

We now consider the optimal resource management standards of the shared resource stock.

In this section, we use the logistic function form for the resource growth rate, i.e., $G(S) = rS(1 - S/K)$, where r is the intrinsic growth rate and K is the carrying capacity. To obtain clear results, we assume that $r > q\beta L + q^*\beta L^*$, which is the condition for a positive autarkic resource stock in an open-access case.

Under autarky, each government chooses the optimal tax rate to maximize its own steady state utility under a given tax rate of the other country. The autarkic resource stock can be expressed as $S_A = K\{1 - q\beta L/r(1 + \tau - \beta\tau) - q^*\beta L^*/r(1 + \tau^* - \beta\tau^*)\}$. From Eq.(15), the home government's problem can be simplified as follows:

$$\max_{\tau\geq 0}\ A = \beta \ln\{1 - \beta qL/r(1 + \tau - \beta\tau) - \beta q^* L^*/r(1 + \tau^* - \beta\tau^*)\}$$
$$+(1 - \beta)\ln(1 + \tau) - \ln(1 + \tau - \beta\tau). \quad (24)$$

The f.o.c. can be written as

$$B\tau^2 + C\tau - q\beta L = 0, \quad (25)$$

where $B = (1 - \beta)\{r - q^*\beta L^*/(1 + \tau^* - \beta\tau^*)\}$ and $C = r - q^*\beta L^*/(1 + \tau^* - \beta\tau^*) - 2q\beta L$. Then, we obtain the reaction function of the home country, $\tau_A = \left(-C + \sqrt{C^2 + 4Bq\beta L}\right)/2B$. Similarly, the reaction function of the foreign country is $\tau_A^* = \left(-C' + \sqrt{(C')^2 + 4Bq^*\beta L^*}\right)/2B'$, where $B' = (1 - \beta)\{r - q\beta L/(1 + \tau - \beta\tau)\}$ and $C' = r - q\beta L/(1 + \tau - \beta\tau) - 2q^*\beta L^*$. We can show that $\partial\tau_A/\partial\tau_A^* < 0$, i.e., regulatory policies of the two countries are strategic substitutes in the autarkic steady state. We do not attempt to derive an explicit solution of the Nash equilibrium because the reaction functions of both countries are very complicated. We assume an interior solution for each country. Comparing the slopes of the two countries' reaction curves, we know that the Nash equilibrium is locally stable (see Appendix B).

Next, we investigate the optimal resource management standards at the trading steady state. From Eq.(22), the home government's problem can be simplified as follows:

$$\max_{\tau\geq 0}\ T = \beta \ln\{1 - \beta(qL + q^* L^*)/r(1 + \tau - \beta\tau)\} + (1 - \beta)\ln(1 + \tau)$$

$$+\ln\{qL-(1-\beta)q^*L^*\tau\}-\ln(1+\tau-\beta\tau). \tag{26}$$

We denote the solution for the home country's optimal resource management after trade as τ_T. In the foreign country, as it specializes in the resource good after trade, the tax imposed on the resource good cannot control the resource harvest. We assume that the foreign country implements the same resource management standards as autarky even after trade.

Finally, we consider the optimal resource management that maximizes the world welfare (i.e., the sum of the two countries' welfare) in the trading steady state. The world welfare u_W can be written as

$$\begin{aligned} u_W &= (H_D+H_D^*)^\beta (M_D+M_D^*)^{1-\beta} \\ &= (\beta S_T)^\beta [(1-\beta)(1+\tau)/q]^{1-\beta}(qL+q^*L^*)/(1+\tau-\beta\tau). \end{aligned} \tag{27}$$

As the foreign country specializes in the resource good, τ^* does not affect the world welfare. The world welfare maximization problem can be simplified as follows:

$$\begin{aligned} \max_{\tau\geq 0}\ W = \beta\ln\{1-\beta(qL+q^*L^*)/r(1+\tau-\beta\tau)\}+(1-\beta)\ln(1+\tau) \\ -\ln(1+\tau-\beta\tau). \end{aligned} \tag{28}$$

We denote the solution for the world optimal resource management after trade as τ_W.

Then, we obtain the following proposition (see Appendix C).

Proposition 3 *Suppose that in an autarkic steady state, the home and foreign countries implement the optimal resource management standards that maximize their own utility. Then, the following results are derived.*

(i) The home country may have an incentive to implement weaker resource management standards after trade than under autarky.

(ii) The world welfare in a trading steady state is maximized if the home country implements the resource management, τ_W, which is stricter than its optimal resource management under autarky and trade.

Intuition of these results is as follows. The home country will suffer income losses caused by the contraction of the resource sector which enjoys economic rent, if it does not change resource management standards after trade. Although weak resource management reduces the shared resource stock, which exacerbates the home country's terms of trade, the home country may choose income gains from the expansion of the resource sector. The world welfare can be maximized if the home country implements stricter resource management standards because the price of the resource good falls as a result of an increase in the shared resource stock.

We should note that the world welfare cannot be maximized without cooperation of the home country (a resource-good importing country). To make the home country implement strict resource management standards, the foreign country should give some side payments (international transfers) to the home country to compensate income losses from the contraction of the home resource sector. This result suggests that under trade liberalization, such mechanism is needed to control over-exploitation of shared renewable resources.

When each country has a renewable resource that is subject to open access by residents of that country only, Brander and Taylor (1998) showed that trade causes the steady state utility to fall in a resource-good exporting country because standard gains from trade are not enough to offset welfare losses caused by reduction of its local stock. If that country implements resource management, the exploitation rate is optimally controlled and it gains from trade (Brander and Taylor, 1997). On the other hand, trade increases the local stock in a resource-good importing country and it can substitute the domestically produced resource good, if the price of the imported resource good becomes too high. Thus, trade will not make a resource-good importing country worse off even without resource management. These results suggest that when renewable resources are not internationally shared, the over-exploitation problem is a domestic one particular to a resource-good exporting country. Thus, contrary to the case of the shared resource, to maximize the steady state world welfare, a resource-good importing country should give international transfers to make a resource-good exporting country implement strict resource management standards when it is myopic.

5. Discussion

In the present model, as both countries cannot diversify in a trading steady state, we focus on the case where the home country is diversified and the foreign country specializes in production of the resource good. In this case, although the foreign country will suffer welfare losses caused by weak resource management standards of the home country ($\partial u_T^*/\partial \tau > 0$), the foreign country cannot respond to it by using resource management policy because of specialization.

To consider the robustness of our results, suppose that we could develop a different model where the foreign country also diversifies in a trading steady state.[10] Even if the foreign country diversifies, we still expect rent-seeking behavior in the home country whose resource sector contracts after trade (i.e., weak resource management is a dominant strategy). The foreign country may implement strict or weak resource management after trade, depending on whether regulatory policies are strategic substitutes or complements.[11] To maximize world welfare, at least the home country should implement strict resource management, regardless of the foreign country's resource management policy. Thus, the results of Proposition 3 have relevance as long as there is economic rent from the resource sector.

The results of Propositions 1 and 2 would also remain qualitatively the same even under

[10] For example, if we assume that $M_P = L_M^{\alpha}$ $(0 < \alpha < 1)$, both countries diversify in a trading steady state. In this setting, a resource-good importing country suffers welfare losses caused by diminishing returns to scale, whereas a resource-good exporting country benefits from the contraction of the manufacturing sector. This additional effect is a disturbance for us to extract pure effects of trade liberalization. Moreover, even if we assume that $\alpha = 1/2$ as in Bulte and Damania (2005), we cannot analytically obtain most results.

[11] Bulte and Damania (2005) who studied an optimal tax on extraction effort showed that regulatory policies are strategic substitutes under autarky and also in the context of a two-country model but they become strategic complements in the small country case.

diversification in both countries. From Eq.(6), under $\tau \leq \tau^*$, $q < q^*$ is likely to hold if the wage difference is not so large between the two countries. This implies that the shared resource is prone to be reduced by trade because the production of the resource good is concentrated in the foreign country (a resource-good exporting country) which has a higher harvesting technology. In contrast, under $\tau > \tau^*$, we could have $q > q^*$, which implies that trade would increase the stock level. As we know that the welfare effects of trade depend on the terms-of-trade effect caused by a change in the stock level and economic rent, the essence of Proposition 2 would remain valid.

Although taxes are not common management tools in the real world, our analysis has relevance to consider the welfare effects of resource management. This is because the equilibrium attained by taxes and other measures such as output controls (e.g., the total allowable catch (TAC) in fisheries) are essentially the same in theoretical models. As long as the government maximizes welfare, the choice of resource management measures influences income distribution of the economy but does not affect the welfare level. Another reason for using a tax as a policy instrument is that a general equilibrium analysis is tractable.

6. Concluding Remarks

This paper examines the effects of trade when countries implement resource management of the shared resource stock. The main contribution of this paper is to consider an optimal resource management of the shared resource stock in a general equilibrium model of international trade. Shared renewable resources such as fishery resources are usually investigated in partial equilibrium models where prices are fixed. A general equilibrium analysis has an advantage to consider the effects of changes in the production patterns and terms of trade.

We show that an opening up of trade increases or decreases the level of the shared stock in the steady state, depending on the relative resource management standards of the two countries. As the resource sector enjoys economic rent under resource management, a resource-good exporting country whose resource sector expands is likely to benefit from trade, whereas trade is likely to harm a resource-good importing country. Therefore, a resource-good importing country may have an incentive to implement weak resource management after trade to mitigate the contraction of its resource sector. To prevent over-exploitation by a resource-good importing country, a resource-good exporting country should give some side payments to make that country implement strict resource management, which can make both countries better off.

Although the model of this paper is stylized, we believe that the basic insights of our analysis remain valid as long as the resource sector enjoys economic rent caused by resource management. We may extend the analysis by considering the dynamic control theoretic aspects of the over-exploitation problem of shared resource stocks to obtain more general results.

Appendix A

In a trading steady state, from Eq.(19), $L_M = (1-\beta)(1+\tau)(qL+q^*L^*)/q(1+\tau-\beta\tau)$. From Eqs.(8) and (9), we obtain that

$$L_{MA} + L_{MA}^* \leq L_M \iff (1+\tau^*)L^*/(1+\tau^*-\beta\tau^*) \leq (1+\tau)q^*L^*/q(1+\tau-\beta\tau).$$

From Eq.(17), if $\tau \leq \tau^*$, we can have

$$\frac{1+\tau^*}{1+\tau^*-\beta\tau^*}\left[\frac{(1+\tau)q^*}{q(1+\tau-\beta\tau)}\right]^{-1} < \frac{1+\tau-\beta\tau}{1+\tau^*-\beta\tau^*} \leq 1.$$

Therefore, $L_{MA} + L_{MA}^* < L_M$ holds when $\tau \leq \tau^*$.

Appendix B

From Eq.(24), the f.o.c. for the home government's problem under autarky is

$$\frac{\partial A}{\partial \tau} = \frac{\beta \dfrac{qL(1-\beta)}{(1+\tau-\beta\tau)^2}}{\dfrac{r}{\beta} - \left(\dfrac{qL}{1+\tau-\beta\tau} + \dfrac{q^*L^*}{1+\tau^*-\beta\tau^*}\right)} + \frac{1-\beta}{1+\tau} - \frac{1-\beta}{1+\tau-\beta\tau} = 0, \tag{A.1}$$

which can be simplified as follows:

$$\frac{r}{\beta}-\frac{q^*L^*}{1+\tau^*-\beta\tau^*}-\left(2+\frac{1}{\tau}\right)\frac{qL}{1+\tau-\beta\tau}=0. \tag{A.2}$$

Totally differentiating Eq.(A.2), the slope of the home country's reaction curve is given by

$$\left(\frac{d\tau}{d\tau^*}\right)_H=-\frac{\dfrac{q^*L^*(1-\beta)}{(1+\tau^*-\beta\tau^*)^2}}{\dfrac{qL}{\tau^2(1+\tau-\beta\tau)}+\left(2+\dfrac{1}{\tau}\right)\dfrac{qL(1-\beta)}{(1+\tau-\beta\tau)^2}}<0.$$

Similarly, the f.o.c. for the foreign government's problem can be written as follows:

$$\frac{r}{\beta}-\frac{qL}{1+\tau-\beta\tau}-\left(2+\frac{1}{\tau^*}\right)\frac{q^*L^*}{1+\tau^*-\beta\tau^*}=0.$$

Then, the slope of the foreign country's reaction curve is given by

$$\left(\frac{d\tau}{d\tau^*}\right)_F=-\frac{\dfrac{q^*L^*}{(\tau^*)^2(1+\tau^*-\beta\tau^*)}+\left(2+\dfrac{1}{\tau^*}\right)\dfrac{q^*L^*(1-\beta)}{(1+\tau^*-\beta\tau^*)^2}}{\dfrac{qL(1-\beta)}{(1+\tau-\beta\tau)^2}}<0.$$

Using the above results, we can show the following inequalities:

$$-\left(\frac{d\tau}{d\tau^*}\right)_H<-\left(\frac{d\tau}{d\tau^*}\right)_F \iff \frac{\tau^2(1-\beta)}{1+2\tau(1+\tau)(1-\beta)}<\frac{1+2\tau^*(1+\tau^*)(1-\beta)}{(\tau^*)^2(1-\beta)}.$$

Hence, the Nash equilibrium is locally stable at autarky.

$B>0$ holds under $\tau_A^*\geq 0$ because $r>q\beta L+q^*\beta L^*$. As the home reaction function $\tau_A=\left(-C+\sqrt{C^2+4Bq\beta L}\right)/2B$, there exists an unique positive τ_A under a given nonnegative τ_A^*. This property also holds in the case of the foreign country. As $-(d\tau/d\tau^*)_H<-(d\tau/d\tau^*)_F$, the two reaction curves intersect, which ensures that both countries' tax rates are positive in the Nash equilibrium.

Appendix C

First, we prove (ii) of Proposition 3. From Eq.(28), the f.o.c. for the world welfare maximization problem can be written as follows:

$$\frac{\partial W}{\partial \tau}=\frac{\beta\dfrac{(1-\beta)(qL+q^{*}L^{*})}{(1+\tau-\beta\tau)^{2}}}{\dfrac{r}{\beta}-\dfrac{qL+q^{*}L^{*}}{1+\tau-\beta\tau}}+\frac{1-\beta}{1+\tau}-\frac{1-\beta}{1+\tau-\beta\tau}=0. \tag{A.3}$$

Substituting this f.o.c. of τ_W into Eq.(A.1), we obtain

$$\left(\frac{\partial A}{\partial \tau}\right)_{\tau=\tau_W}=\frac{\beta\dfrac{qL(1-\beta)}{(1+\tau-\beta\tau)^{2}}}{\dfrac{r}{\beta}-\left(\dfrac{qL}{1+\tau-\beta\tau}+\dfrac{q^{*}L^{*}}{1+\tau^{*}-\beta\tau^{*}}\right)}-\frac{\beta\dfrac{(1-\beta)(qL+q^{*}L^{*})}{(1+\tau-\beta\tau)^{2}}}{\dfrac{r}{\beta}-\dfrac{qL+q^{*}L^{*}}{1+\tau-\beta\tau}}.$$

Under the assumption $r>q\beta L+q^{*}\beta L^{*}$, we know that the first term of the right hand side is smaller than the second one. Therefore, $(\partial A/\partial\tau)\,|_{\tau=\tau_W}<0$. As $(\partial A/\partial\tau)\,|_{\tau=\tau_A}=0$, we have $\tau_W>\tau_A$.

From Eq.(26), the f.o.c. for home government's maximization problem at the trading steady state can be written as follows:

$$\frac{\partial T}{\partial \tau}=\frac{\beta\dfrac{(1-\beta)(qL+q^{*}L^{*})}{(1+\tau-\beta\tau)^{2}}}{\dfrac{r}{\beta}-\dfrac{qL+q^{*}L^{*}}{1+\tau-\beta\tau}}-\frac{q^{*}L^{*}(1-\beta)}{qL-\tau q^{*}L^{*}(1-\beta)}+\frac{1-\beta}{1+\tau}-\frac{1-\beta}{1+\tau-\beta\tau}=0.$$

Substituting this f.o.c. of τ_T into Eq.(A.3) yields

$$\left(\frac{\partial W}{\partial \tau}\right)_{\tau=\tau_T}=\frac{q^{*}L^{*}(1-\beta)}{qL-\tau q^{*}L^{*}(1-\beta)}>0.$$

As $(\partial W/\partial\tau)\,|_{\tau=\tau_W}=0$, we know that $\tau_W>\tau_T$.

Next, we prove (i) of Proposition 3. To compare τ_T and τ_A, substituting the f.o.c. of τ_T into Eq.(A.1), we obtain the following expression:

$$\left(\frac{\partial A}{\partial \tau}\right)_{\tau=\tau_T}=\frac{\beta\dfrac{qL(1-\beta)}{(1+\tau-\beta\tau)^{2}}}{\dfrac{r}{\beta}-\left(\dfrac{q^{*}L^{*}}{1+\tau^{*}-\beta\tau^{*}}+\dfrac{qL}{1+\tau-\beta\tau}\right)}-\frac{\beta\dfrac{(1-\beta)(qL+q^{*}L^{*})}{(1+\tau-\beta\tau)^{2}}}{\dfrac{r}{\beta}-\dfrac{qL+q^{*}L^{*}}{1+\tau-\beta\tau}}+\frac{q^{*}L^{*}(1-\beta)}{qL-\tau q^{*}L^{*}(1-\beta)}.$$

The first and second terms of the right hand side are equal to $(\partial A/\partial\tau)\,|_{\tau=\tau_W}$ which is negative and the third term is always positive. Therefore, the sign of $(\partial A/\partial\tau)\,|_{\tau=\tau_T}$ is ambiguous.

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