Chukyo University Institute of Economics

Discussion Paper Series

January 2013

No. 1209

Renewable Resources, Environmental Pollution, and International Migration

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January 20, 2013

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Abstract

We develop a two-country model with two industries: the smokestack manufacturing industry, which generates pollution, and the transboundary renewable resource industry. With no trade, migration occurs from the foreign country, with lower manufacturing productivity, to the home country. If the gap in pollution abatement technology, which is superior in the home country, dominates the productivity gap, both countries gain from migration. Under a free trade equilibrium, we also show that if the marginal harvest of the resource industry is lower (higher) than marginal damage of manufacturing in the home (foreign) country, migration still causes positive effects on the stock of renewable resources, which should improve both countries' welfare.

JEL Classification Number(s): F22, Q20

Number of Figures: 0 Number of Tables: 0

Date: 04 November 2003.

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1. Introduction

To realize optimal management of transboundary renewable resources is very hard because not only is international cooperation indispensable, but several economic aspects should also be considered. In the familiar case of Japan and China, for example, East China Sea is a hot spot between the two countries. Not only is a natural gas field, which sometimes causes territorial conflicts, located just close to the border but the area is also quite rich in marine resources. As fishes are a transboundary renewable resource, international cooperation is required for its management. However, this is difficult to establish, and overfishing is common. For an optimal resource management policy between Japan and China, we need to consider two important aspects that have been ignored in previous studies. The first is environmental pollution caused by the smokestack manufacturing industry, which generates negative externalities on the stock of renewable resources. We focus on environmental pollution in the East China Sea, which comes mainly from China because of relatively poor pollution abatement technologies. Environmental pollution from industrial production has become one most serious problems of the world, which is difficult to solve because underdeveloped countries, without sufficient skills and funding, usually cannot control pollution well. Moreover, their governments often give priority to economic growth over protection of the environment. The second aspect is international factor mobility. Not only international trade strategies but also FDI and migration policies should be considered important for optimal economic management. Migration from China to Japan, which is the focus of this study, is not very large now, but the potential wage gap may cause a flood of labor mobility in the near future.

Many studies have analyzed the effects of environmental pollution resulting from international specialization and trade. The pioneering study by Copeland and Taylor (1999) extended David Ricardo's relative advantage model to examine the natural recovery of environmental resources and analyze the economic welfare effects of international specialization and trade. Suga (2002) introduced differences between two countries' pollution rates and permitted a realistic possibility of transboundary pollution. Ito and Tawada (2003) studied the effects of the transfer of pollution abatement technology from a developed to an underdeveloped country. Several studies have focused on the environmental industry. Chua (2003) examined emission tax effects on the trade pattern with a three-sector model in which one sector is the non-tradable pollution abatement service industry. Sugiyama (2003) also studied the effects of environmental policies with a two-sector model in which one sector produces pollution abatement equipment. Abe and Sugiyama (2010) analyzed the structure of comparative advantage determined by international differences in environmental policies with a model incorporating pollution abatement equipment and examined the effects of an environmental policy in an open economy.

Several studies have examined the possibilities and effects of international migration with a two-country model considering the economic value of the natural environment. Kondoh (2006) analyzed the welfare effects of international migration in the presence of transboundary pollution by using a simplified version of the Copeland and Taylor (1999) model, in which the developed country's pollution abatement technology is superior to the developing country's. In the absence of trade, workers migrate from the developing to the developed country. The developing home country surely gains, but whether the host country gains or not depends on the parameters, the abatement technology gap, and the magnitude of the transboundary pollution coefficient. Several other extension studies have been carried out. Kondoh (2007) introduced two types of workers: unskilled workers, who contribute only to production in the smokestack manufacturing industry, and skilled workers, who can contribute not only to production but also to its reduction. Kondoh (2009) introduced the pollution abatement equipment industry. Migration has positive effects on the wage rate, environment stock, and welfare of the worker in at least one country. Moreover, the possibility that both countries gain from international migration is also shown. Finally, Kondoh and Yabuuchi (2012) additionally considered the possibility of unemployment. However, note that none of these studies considers the transboundary renewable resource industry.

The literature on renewable resource economics is quite extensive. Some studies, such as Brander and Taylor (1997, 1998) Chichilnisky (1993, Francis (2005), and Jinji (2007), have investigated the effects of international trade and/or resource management. In these studies, however, each country has a renewable resource that only domestic residents are permitted to access. Bulte and Damania (2005) considered transboundary renewable resources and studied international trade and optimal resource management. The patterns of trade and gains from trade were explored in an extension study by Takarada (2009). On the other hand, as open-access renewable resources are often characterized by overexploitation, some studies such as Munro (1979), Vislie (1987), and Lindroos (2004) considered optimal resource management strategies by applying game theory models. However, it is noteworthy that these studies did not consider environmental pollution by the manufacturing industry, which damages the stock of resources. They also ignored international factor movement.

The basic model of this study is presented in Section 2. We develop a two-country model with two industries, the smokestack manufacturing industry, which generates pollution, and the transboundary renewable resource industry, which suffers from pollution. In Section 3, we present an autarkic equilibrium and show international migration from the foreign country with lower manufacturing productivity to the home country. In Section 4, we show that under international migration without trade, all workers will gain from migration if the technological gap in pollution abatement dominates the gap in production. If the technological gap in production dominates the gap in pollution abatement, domestic workers in the home country and those left behind in foreign country will lose from migration. However, whether migrants will gain or not depends on the parameters. Additionally, if their families remain in the home country, the migrants, as cross-border workers, can remit their income via a tradable good. We also consider a variety of possibilities for income remittance. In Section 5, we permit international trade. First, we specify a case in which international trade occurs. We show that international migration occurs under free trade if the home country specializes in the production of a manufactured good. If the marginal harvest of the resource industry is lower (higher) than the marginal damages of manufacturing in the home (foreign) country, migration would still cause positive effects on the stock of renewable resources, improving both countries' welfare. Section 6 presents the concluding remarks.

2. The Model

Consider a world with only two countries, the home and the foreign. Each country has two industries: the smokestack manufacturing industry and the environmentally sensitive transboundary renewable resource industry (RRI), for example, fisheries. The primary factor of production is labor.

The production functions of the manufacturing industry and RRI of the home and the foreign country are represented, respectively, as

$$M = L_M, \quad M^* = fL_M^*, \tag{1a}$$

$$A = \beta E L_A, \quad A^* = \beta E L_A^*, \tag{1b}$$

where $f < 1$ and E is the stock of resources. The output and labor input of the manufacturing industry are respectively represented by M and L_M for the home country and M^* and L_M^* for the foreign country. A and L_A are the home country's and A^* and L_A^* the foreign country's RRI output and labor input, respectively. One unit of labor input can produce one unit of output in the home country but only f units in the foreign country—because of inferior productivity in the latter. On the other hand, the RRIs of the two countries show no labor productivity differences and rely on their stock of resources. We assume that both countries confront the same lake or neighboring sea and one unit of labor input can get βE units of harvest.

Production activities of the home country's manufacturing industry generate pollution according to the following pollution function:

$$Z_M = \lambda L_M = \lambda M, \quad 0 < \lambda < 1. \tag{2a}$$

Therefore, the amount of pollution from a unit of production is a constant λ. Pollution reduces the stock of resources, and therefore the manufacturing industry's production causes negative externalities for the RRI.

The pollution function of the foreign country can also be defined similar to that of the home country,

$$Z_{M^*} = \lambda^* M^* = \lambda^* fL_M^*, \quad 0 < \lambda^* < 1, \tag{2b}$$

where we assume $\lambda < \lambda^*$, which implies that the pollution abatement technology of the home country is more advanced than that of the foreign country.

Following Copeland and Taylor (1999), we assume the resource stock follows the logistic cleansing function. We also assume one unit of the resource stock will be destroyed by one unit of pollution. Therefore, the total stock of resource, E, is

$$dE / dt = gE(\bar{E} - E) - Z, \tag{3}$$

where $Z = [\lambda L_M + \lambda^* f L_M^* + \beta E(L_A + L_A^*)]$ and $\bar{E}$ is the upper limit of the resource stock level with no pollution and $g\bar{E}^2 - 4Z > 0$ is assumed to avoid a complete destruction of resources.

3. Autarkic Equilibrium

First, we consider the case of autarky. Each sector consists of many firms operating in competitive equilibrium, and therefore the profit of each firm is zero. Let π_M and π_A be the total profits of the manufacturing industry and RRI, respectively. Then, under the assumption that both goods are produced, we obtain the following equations.

$$\pi_M = pM - wL_M = 0,\ \pi_M^* = p^* M^* - w^* L_M^* = 0 \tag{4a}$$

$$\pi_A = A - wL_A = 0,\ \pi_A^* = A^* - w^* L_A^* = 0 \tag{4b}$$

where p and p^* are the relative prices of the manufactured good and w and w^* the wage rate in the home and the foreign country, respectively. The above equations yield

$$p = w,\ p^* f = w^*, \tag{5}$$

$$\beta E = w,\ \beta E = w^*. \tag{6}$$

From (5) and (6), we have the following relations:

$$w = w^*,\ 1 = w/p > w^*/p^* = f,$$

which implies that the real wage rate is higher in the home country than in the foreign country. Therefore, international migration from the foreign to the home country should occur if permitted.

The full employment conditions of both countries are as follows:

$$L_M + L_A = L,\ L_M^* + L_A^* = L^* \tag{7}$$

where L and L^* are the labor endowments of the home and the foreign country, respectively. To specify the technology difference between the two countries, we assume the labor endowments of both countries are identical, that is, $L = L^* \equiv \bar{L}$.

Assuming no differences between the two countries' consumer preferences, on the demand side, we define the aggregate utility function as

$$U = a \log D_M + (1-a)\log D_A, \tag{8a}$$

$$U^* = a \log D_M^* + (1-a)\log D_A^*, \tag{8b}$$

where both a and $1-a$ are positive parameters, and D_M and D_A are the demands for the home country's and D_M* and D_A* the demands for the foreign country's manufactured good and resources, respectively. As the profit of each firm is zero, the GNP of the home and the foreign country should be $w\bar{L}$ and $w*\bar{L}$, respectively—the aggregate income of labor Therefore, the demands for each good are obtained by solving the utility functions, subject to the budget constraints $D_A + pD_M = w\bar{L}$ and $D_A * + pD_M * = w * \bar{L}$. Thus, we have

$$D_M = \frac{aw}{p}\bar{L},\ D_M * = \frac{aw*}{p*}\bar{L}, \quad (9a)$$

$$D_A = (1-a)w\bar{L},\ D_A * = (1-a)w * \bar{L}. \quad (9b)$$

(5) and (9a) yield

$$D_M = a\bar{L},\ D_M * = af\bar{L}. \quad (10)$$

Therefore, we conclude that the demands for both goods are independent of the relative price of the two goods, and to satisfy these demands, the manufacturing industry of each country employs $a\bar{L}$ workers while the RRI employs $(1-a)\bar{L}$ workers. From (9b) and (10), we have $M = D_M > D_M * = M*$ and $A = D_A = D_A * = A*$, which implies $U > U*$ in autarky

4. International Migration without Trade

In this section, we consider the case where international trade between the two countries is impossible because one of the two goods is non-tradable or one of the two governments prohibits trade.

In autarky, the first term in the RHS of the cleansing function (3), $gE(\bar{E}-E)$, is concave, first increasing in E from $E=0$, reaching a peak, and then decreasing. On the other hand, from (9b) and (10), the second term Z is a linearly increasing function of E. Thus, as shown in Figure 1, there are two potential steady-state equilibria in autarky: $E = E_L$ and $E = E_H$, where E_L occurs on the upward sloping portion of the cleansing function and E_H

on the downward sloping portion. The equilibrium $E = E_L$, is unstable, while $E = E_H$ is stable. Let us consider an autarky economy is at the steady state $E = E_H$.

4.1 Permanent Migrants

First, we consider the case where each immigrant intends to stay in the host country permanently. His or her migration will involve all of his or her family and property. Assume the number of permanent immigrants is $\tilde{L}$. As the population of each country changes and per capita output of manufacturing production is constant, pollution will increase in the home country and decrease in the foreign country. Thus, the total damages on the stock of resources after migration, Z', will be

$$Z' = \lambda a(\bar{L} + \tilde{L}) + \lambda^* fa(\bar{L} - \tilde{L}) + 2\beta E(1-a)L. \tag{11}$$

From (11), we can conclude $dZ'/d\tilde{L} > (<) 0$ if $\lambda > (<) \lambda^* f$ and the ZZ line in Figure 1 shifts upward (downward) to $Z'Z'[\lambda > \lambda^* f]$ ($Z'Z'[\lambda < \lambda^* f]$) after international migration. Therefore, the stock of resources will decrease (increase) in equilibrium from E_H to $E_H'[\lambda > \lambda^* f]$ ($E_H'[\lambda < \lambda^* f]$). Now, we obtain the following relationship:

$$\lambda > (<) \lambda^* f \Leftrightarrow E_H' < (>) E_H. \tag{12}$$

In other words, if the abatement technology gap between the two countries is small (large), or if the technology gap of the manufacturing industry between the countries is large (small) enough to satisfy $\lambda > (<) \lambda^* f$, then the stock of resources will increase (decrease) by the inflow of permanent migrants.

We now turn to economic welfare. As consumption of the manufactured good is constant (per capita a), by equation (10), in order to investigate the economic welfare of the initial population of the home country, we have only to compare the total resource consumption before and after immigration. The total resource consumption in autarky, A^0, is

$$A^0 = \beta E_H (1-a)L, \tag{13}$$

and that of the initial population after the inflow of permanent immigrants, A', is

$$A' = (L/L+\tilde{L})\beta E_H{}'(1-a)(L+\tilde{L}) = \beta E_H{}'(1-a)L\,. \tag{14}$$

Thus, whether economic welfare in the home country will increase or decrease after immigration depends on the stock of resources. Now, we can easily derive the following relationship:

$$\frac{dE_H}{d\tilde{L}} = \frac{-a(\lambda-\lambda^* f)}{1+2(1-a)\beta L}, \tag{15}$$

Therefore, we obtain the following relationship:

$$\lambda > (<) \lambda^* f \Leftrightarrow A' < (>) A^0\,. \tag{16}$$

Similarly, we can conclude that each of those left behind in the foreign country consumes af units of the manufactured good and $\beta E_H{}'$ units of resources. Thus, we can also conclude that one's economic welfare directly depends on the stock of resources. However, it is noteworthy that the economic welfare of immigrants may increase even though $\lambda > \lambda^* f$ is satisfied. In this situation, decreasing the stock of resources causes a negative effect, but increasing per capita consumption of the manufactured good, from af to a, causes a positive effect on economic welfare. Finally, in this model, international immigration does not reduce the wage gap between the two countries. Thus, international migration, if permitted, continues until all of the foreign workers migrate to the home country.

Proposition 1: (1) Workers migrate from the developing foreign country to the home country with advanced production technology. (2) All workers will gain from migration if the technological gap in pollution abatement dominates the gap in production. (3) If the technological gap in production dominates the gap in pollution abatement, the domestic workers in the home country and those left behind in the foreign country lose from migration. However, whether the migrants will gain or not depends on the parameters.

4.2 Cross-Border Workers Who Remit Their Income by Manufactured Goods

Next, let us consider the case where the manufactured good is tradable while the renewable resource is non-tradable because of government policy or a lack of sufficient technology[1]. In this case, as only one of the two goods is non-tradable, no international trade takes place between the two countries on the assumption that the manufactured goods are of identical quality. However, immigrants can remit some part of their income to the home country by transferring tradable manufactured goods. Here, we introduce immigrants who remit all of their income, identified as M -type cross-border workers. They commute across the border daily, and their consumption occurs mainly in the home country, where they live with their families.

Let us define the number of M -type cross-border workers who immigrate to the home country as $\hat{L}$. As the native inhabitants know that these immigrants need to exchange all of their income into tradable manufactured goods, they will choose the optimal production point on the production possibility frontier. To put it concretely, native inhabitants in the host country need to consume aL amount of manufactured goods. Therefore, considering that the income of $\hat{L}$ cross-border workers is expressed as $\hat{L}$ manufactured goods, the output of manufactured goods after immigration needs to be $aL+\hat{L}$. Similarly, the necessary amount of manufactured goods in the foreign country is afL ; therefore, considering the remittance of $\hat{L}$ manufactured goods, the output of manufactured goods in the foreign country should be $f(aL-\hat{L})$.

The effects of migration by M -type cross-border workers on the stock of renewable resources are

$$\frac{dE_H}{d\hat{L}}=\frac{-(\lambda-\lambda^* f)}{1+2(1-a)\beta L} \tag{17}$$

Thus, we can conclude that, similar to the case of permanent migration, if $\lambda>(<)\lambda^* f$ is satisfied, the stock of resources decreases (increases) after international migration of M -type cross-border workers.

However from (15) and (17), as $a<1$, we may conclude that the absolute value of the effect of the inflow of M -type cross-border workers is greater than that of permanent migrants without remittance, regardless of whether the effect is positive or negative.

4.3 Cross-Border Workers Who Remit Their Income by Renewable Resources

[1] For example, some kind of fish cannot freeze well without losing their qualities.

Finally, let us consider the case where a renewable resource like fish is tradable while the manufactured good is non-tradable because product standards differ or they embody military secrets. In this case, immigrants can remit some part of their income to the home country via a tradable resource. Here, we will again introduce immigrants who remit all of their income, referred to as A-type cross-border workers.

Again, the output of manufactured goods is aL in the home country and afL in the foreign country, equal to the pre-migration levels. Immigration does not affect manufactured good output, and the level of pollution therefore remains the same in both countries.

The total consumption of the resources in both home and foreign country after the inflow of A-type cross-border workers is $\beta E[(1-a)L+\hat{\hat{L}}]+\beta E[(1-a)L-\hat{\hat{L}}]=2\beta E(1-a)L$, which is also equal to the pre-migration level, where $\hat{\hat{L}}$ denotes the number of A-type cross-border workers.

Therefore, the economic welfare of domestic workers in the home country and those left behind in the foreign country does not change. However, migrants experience a welfare change. They gain from migration because their per capita consumption increases as regards the manufactured good, from af to a, but remains unchanged for the renewable resources.

Now we have the following proposition.

Proposition 2: (1) Compared to permanent migrants, M-type cross-border workers produce larger effects on both countries. (2) A-type cross-border workers do not cause any change in the economic welfare of domestic workers in the home country and those left behind in the foreign country, but migrants gain from migration.

5. International Trade and International Migration

Let us now examine the usual case where both goods are tradable. In general, international migration involves several difficulties, such as the need to dispose of property, acquire a visa, and raise money for the trip. On the other hand, trade can easily start arbitraging the difference between the relative prices in the two countries. Consequently, we assume that free international trade is the first step, and if a real wage gap exists between the two countries in equilibrium, international migration would occur thereafter, as the second step of market integration.

The relationship between the trade pattern and parameter a, which denotes the strength of demand for the manufactured good, has been analyzed by Copeland and Taylor (1999). Let us summarize their results as follows.

Case 1: If demand for the manufactured good is strong enough and a is sufficiently close to unity, the home country will specialize in the production of the manufactured good while the foreign country would produce both goods. Then we have

$$\beta E < w, \quad \tilde{p} = w, \tag{18a}$$

$$\beta E = w^*, \quad \tilde{p}f = w^*, \tag{18b}$$

where $\tilde{p}$ denotes the relative price of manufactured good under free trade; in this case, $w > w^*$ is satisfied. Considering that the relative price of the two goods is common to both countries after international trade, we can conclude that workers have a motivation to migrate from the foreign country to the home country.

Case 2: If demand for the manufactured good is moderate, then the foreign country will specialize in RRI and the home country in the manufactured good. Then we have

$$\beta E < w, \quad \tilde{p} = w, \tag{19a}$$

$$\beta E = w^*, \quad \tilde{p}f < w^*. \tag{19b}$$

As $w > w^*$, this case reveals a motivation to migrate from the foreign country to the home country.

Case 3: If demand for the manufactured good is weak enough and a is sufficiently close to null, the foreign country will specialize in RRI, while the home country will produce both goods. Then we have

$$\beta E = w, \quad \tilde{p} = w, \tag{20a}$$

$$\beta E = w^*, \quad \tilde{p}f < w^*. \tag{20b}$$

Here, $w = w^*$, and there is no motivation for migration between the two countries.

Now we will analyze the effects of international migration on the free trade equilibrium of the two countries in case 1. First, we consider the steady-state equilibria. From (3), the following condition should be satisfied in case 1:

$$dE / dt = gE(\bar{E} - E) - Z' = 0, \tag{3'}$$

where $Z' = [\lambda(\bar{L}+\tilde{L}) + \lambda^* f(\bar{L}-\tilde{L}-L_A^*) + \beta E L_A^*)]$. The above condition implies that if the number of migrants is exogenously given, the total stock of renewable resources is a function of the labor input of fisheries in the foreign country.

Second, we consider free trade equilibrium. In case 1, the foreign country produces both goods, and the GDP of that country should be equal to labor income under the assumption of perfect competition. Therefore, we have

$$\tilde{p}M^* + A^* = w^* \bar{L} \tag{21}$$

and, as $\beta E = w^*$ from (18b), (21) can be rewritten as

$$\tilde{p}f = \beta E . \tag{22}$$

The world price under free trade depends on the aggregate output of both the manufactured good and renewable resource; thus, $\tilde{p} = \tilde{p}(\frac{M+M^*}{A^*}) = \tilde{p}(\frac{L+\tilde{L}+f(L-\tilde{L}-L_A^*)}{\beta E L_A^*}),\ \tilde{p}' < 0$.

Totally differentiating (3') and (22), we obtain the following matrix:

$$\begin{bmatrix} fp^E - \beta & fp^{L_A^*} \\ -2gE + g\bar{E} - \beta L_A^* & -\beta E + \lambda^* f \end{bmatrix} \begin{bmatrix} dE \\ dL_A^* \end{bmatrix} = \begin{bmatrix} -fp^{\tilde{L}} \\ \lambda - \lambda^* f \end{bmatrix} d\tilde{L}, \tag{23}$$

where $p^i \equiv \partial p / \partial i,\ i = E, L_A^*, \tilde{L}$. Now, we assume $2E_H > \bar{E}$, which implies the stock of renewable resources in a steady-state equilibrium is greater than half of the upper limit (as shown in Figure 1). From the above assumption, the sign of $-2gE + g\bar{E} - \beta L_A^*$ is negative.

Additionally, from (8a) and (8b), under a free trade equilibrium, we can define the aggregate world utility function as

$$\begin{aligned} U^W &= a\log(D_M + D_M^*) + (1-a)\log(D_A + D_A^*) \\ &= a\log(M+M^*) + (1-a)\log A^*, \end{aligned} \tag{8c}$$

where U^W denotes world utility. Maximizing U^W subject to the budget constraint $p(M+M^*) + A^* = I + I^*$, where I and I^* indicate the total income of the home and foreign country, respectively, we obtain the following relation:

$$p = \frac{a}{1-a}\frac{A^*}{M+M^*}. \tag{24}$$

From (24), we obtain $\varepsilon \equiv -\frac{dp}{dQ}\frac{Q}{p} = 1$, where $Q \equiv \frac{M + M^*}{A^*}$, which implies the relative output elasticity of relative price is unity, and therefore we finally find $fp^E - \beta = 0$.

We now have the following results by simple comparative statics analysis:

$$\frac{dL_A^*}{d\tilde{L}} > 0, \tag{25}$$

$$\frac{dE}{d\tilde{L}} > 0 \quad if\ \lambda^* f > \beta E\ and\ \lambda^* f > \lambda, \tag{26a}$$

$$\frac{dE}{d\tilde{L}} < 0 \quad if\ \lambda^* f < \beta E\ and\ \lambda^* f < \lambda, \tag{26b}$$

This implies that international migration from the foreign to the home country raises the labor input of RRI in the foreign country, As the total labor endowment of the foreign country decreases, this also implies that $\frac{dA^*}{d\tilde{L}} > 0$ and $\frac{dM^*}{d\tilde{L}} < 0$. On the other hand, the total labor endowment of the home country, which specializes in the production of the manufactured good, increases. Thus, we can conclude that $\frac{dM}{d\tilde{L}} > 0$. Therefore, if the negative effects on the stock the of renewable resources resulting from the marginal increase in the foreign manufacturing industry is larger (smaller) than the negative effects in the home manufacturing industry and fisheries (i.e., conditions $\lambda^* f > (<) \beta E$ and $\lambda^* f > (<) \lambda$ hold), we can assert that the stock of fish will surely increase (decrease) by international migration. In any case, international migration will increase the output of RRI relative to the manufactured good in the foreign country, leading to perfect specialization in RRI by the country.

Now we will shift to case 2. Here, (3') should be rewritten as

$$dE/dt = gE(\bar{E} - E) - Z'' = 0, \tag{3''}$$

where $Z'' = [\lambda(L + \tilde{L}) + \beta E(L - \tilde{L})]$. As both countries specialize in one good, we obtain the international migration effects on the stock of renewable resources directly from (3"):

$$\frac{dE}{d\tilde{L}} = \frac{\lambda - \beta E}{-2gE + g\bar{E} - \beta L}, \tag{27}$$

Therefore, considering that $2E_H > \bar{E}$, we can conclude as follows:

$$\frac{dE}{d\tilde{L}} > (<) 0 \quad if\ \lambda < (>) \beta E \tag{28}$$

Summarizing the above results, we find that if $\lambda^* f > \beta E > \lambda$ is satisfied—which implies that the marginal harvest of the resource industry is lower (higher) than the marginal damage to the renewable resource from the manufacturing industry in the home (foreign) country—international migration causes positive effects on the stock of fish in both cases 1 and 2. Moreover, if the positive effect on global economic welfare from an increase in the productivity of RRI sometimes dominates the negative effect due to a rearrangement of the labor input between the industries, migration benefits both countries. On the other hand, if $\lambda^* f < \beta E < \lambda$ is satisfied, international migration reduces the stock of renewable resources.

Now we have the following proposition:

Proposition 3:

Under free trade equilibrium, international migration from the foreign country to the home country causes positive (negative) effects on the stock of renewable resources to the extent $\lambda^* f > \beta E > \lambda$ ($\lambda^* f < \beta E < \lambda$) is satisfied.

6. Concluding Remarks

Some anti-immigration groups often claim that immigrants cause environmental degradation. Our study seems to refute this assertion. In Section 4, we studied the most general case of international migration under free trade. Unlike in the transboundary pollution case demonstrated by Kondoh (2006), the world's renewable natural resources may increase under migration. This conclusion provides a theoretical basis for an open-door policy toward foreign nationals. Our results are consistent with those of Takarada (2009), where both countries gain from trade when they specialize in production. Applying a similar model, we also show the probability of gains from migration, in addition to the gains from free trade.

Several subjects still remain for future study. We focused on the production technology and pollution abatement gaps between countries, which lead to real wage differences. However, if harvesting technology differences are assumed in the renewable resource industry, similar to Takarada (2009), we may find interesting and remarkable changes in our conclusion. Furthermore, labor endowment differences, as with Japan and

China, and increasing returns to scale in either of the two industries are topics worth investigation.

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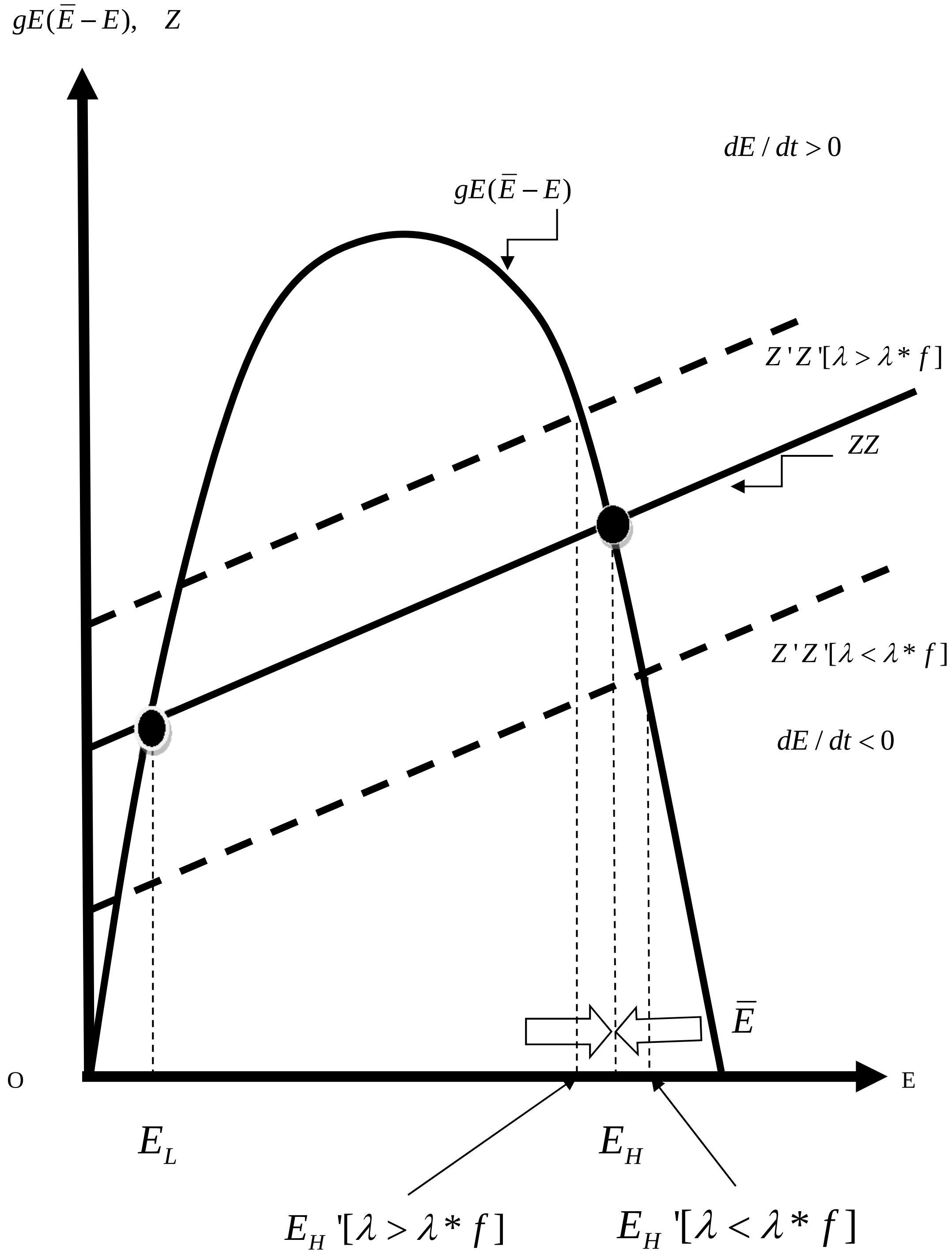
Figure 1



$gE(\bar{E}-E),\quad Z$
$dE/dt>0$
$gE(\bar{E}-E)$
$Z'Z'[\lambda>\lambda^*f]$
ZZ
$Z'Z'[\lambda<\lambda^*f]$
$dE/dt<0$
$\bar{E}$
O
E
E_L
E_H
$E_H'[\lambda>\lambda^*f]$
$E_H'[\lambda<\lambda^*f]$