A Generalization on the Analysis of Trade and Environmental Pollution

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Abstract

This paper treats a comprehensive analysis of welfare in an open economy where there are two countries, two goods, one factor and the transboundary pollution which is generated by the production activity in the manufacturing sector and gives a damage to the productivity of the agricultural sector. One of our main findings is that both countries can gain from trade irrespective of their production patterns after trade if the transboundary rate of pollution from an agricultural good exporting country is sufficiently large and the nontransboundary rate of pollution in a manufacturing good exporting country is sufficiently small. This result has not been pointed out in the existing analyses with this type of models so far.

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1. Introduction

With increased concerns for the effects of trade liberalization on global environment, there have been appearing a large number of theoretical studies focusing on the interaction between international trade and the environment. Among them, Copeland and Taylor (1999) examined patterns of trade and welfare effects of trade using a generalized Ricardian model in which a manufacturing industry generates pollution and lowers the productivity of an agricultural industry through a deterioration of the local environment by pollution. They showed that an agricultural good exporting country necessarily gains from trade while a manufacturing good exporting country may suffer a welfare loss caused by trade. Their analysis succeeded in shedding light on the influence of the environment to international trade in a fairly simple general equilibrium framework[1].

But Copeland and Taylor (1999) confined their analysis to the case of local pollution. Thus, Benarroch and Thille (2001) and Unteroberdoerster (2001) focused on transboundary pollution under the assumption that the amount of pollution generated by a unit production differs between countries and showed that an agricultural good exporting country may also lose from trade if the transboundary rate of pollution is sufficiently high. Benarroch and Thille (2001) also dealt with a case in which each country differs in its size or alternatively in the transboudary rate of pollution.

The purpose of this paper is to extend Benarroch and Thille's analysis by accommodating the differences in country size, the amount of pollution generated by a unit production and the transboundary rate of pollution altogether into one model. Then

we examine how these differences affect the trade gains in each country. One of our findings is that there is a case where both countries gain from trade irrespective of their production patterns after trade, which has not emerged in Benarroch and Thille (2001) and Unteroberdoerster (2001). Actually, we can show that both countries can always enjoy the gains from trade if the transboundary rate of pollution in an agricultural good exporting country is large and the nontransboundary rate of pollution in a manufacturing good exporting country is small enough.

The structure of the paper is as follows. In the next section, we set up a model and give a brief explanation on autarky. In Section 3, we investigate the pattern of production in the trading equilibrium. In Sections 4 and 5, we study how the differences between the two countries affect the environmental quality and welfare in each country, respectively. Section 6 is devoted to a summary of the results.

2. Model

The economy consists of two countries called as Home and Foreign, two tradable goods called as manufacturing and agricultural goods, and one primary factor supposed to be labor. Both goods are produced by the use of labor. In this economy, we assume a state of the natural environment to be affected by the production of the manufacturing good and to affect the production of the agricultural good. We suppose that the production technologies of the manufacturing and agricultural goods in Home are described as

$$M = L_M, \tag{1}$$

$$A = E^{\theta} L_A, \quad 0 < \theta \leq 1, \tag{2}$$

respectively, where M and A are the outputs of the manufacturing and agricultural

goods, respectively, L_M and L_A are the labor inputs in the production of the manufacturing and agricultural goods, respectively, and E represents the level of the natural environment in Home. In the formulation (2), the productivity of labor in the agricultural sector depends on E, so that, if the Home natural environment improves (E increases), the productivity of labor in agricultural sector rises. We assume that these production aspects are adopted to Foreign, too. Throughout this paper, superscript "$*$" is used to represent Foreign variables and we suppose that the external economies of the natural environment to the agricultural production is the same between countries, i.e. $\theta = \theta^*$.

The production of the manufacturing good in each country generates pollution that deteriorates environmental quality in both countries. Let us define β as the fraction of pollution generated by one unit production of the manufacturing good in Home that remains in the country, and γ as the fraction of pollution generated by one unit production of the manufacturing good in Home that crosses the border and goes to the other country. β^* and γ^* of Foreign are also defined similarly to β and γ, respectively. Then, the total amounts of pollution in Home and Foreign can be formulated as

$$D = \beta M + \gamma^* M^*, \qquad D^* = \beta^* M^* + \gamma M, \tag{3}$$

respectively, where D (D^*) is the amounts of pollution received by Home (Foreign).

We assume that the state of the natural environment is damaged by the amount of existing pollution. Therefore, the levels of the natural environment in Home and Foreign are expressed as

$$E = \overline{E} - D, \qquad E^* = \overline{E} - D^*, \tag{4}$$

where E (E^*) is the level of the natural environment of Home (Foreign) and $\overline{E}$ is the highest level of the environment attained when no pollution exists. $\overline{E}$ is assumed to be

common to both countries.

Let D_M and D_A denote the demands for the manufacturing and agricultural goods in Home, respectively. We assume that Home preferences are represented by the following utility function,

$$u = a \ln D_M + (1-a) \ln D_A, \qquad 0 < a < 1, \tag{5}$$

where a is the share of income spent on the manufacturing good. Under the assumption of perfect competition in both industries, the zero profit condition is satisfied in both industries. So Home's demand for manufacturing and agricultural goods can be written as

$$D_M = awL / P_M, \qquad D_A = (1-a)wL / P_A, \tag{6}$$

respectively, where w is the wage rate, L is the amount of labor endowed with Home, and p_M and p_A are the prices of the two goods. Assuming that preferences of Foreign are completely the same to those of Home, (6) hold with asterisk for Foreign but with $a = a^*$.

As the autarkic equilibrium price of the manufacturing good must be equal to the wage rate in each country, Home's autarkic equilibrium amount of the manufacturing good is aL and that of Foreign is aL^*. Thus the amounts of pollution in Home and Foreign in the autarkic equilibrium are expressed as

$$D = a(\beta L + \gamma^* L^*), \qquad D^* = a(\beta^* L^* + \gamma L), \tag{7}$$

respectively.

We impose the following assumptions.

Assumption 1 $\quad \overline{E} > \beta L + \gamma^* L^* > \beta^* L^* + \gamma L$.

Assumption 2 $\quad \beta > \gamma, \qquad \beta^* > \gamma^*$.

Assumption 1 ensures that, in the autarky, the level of the natural environment of

each country is positive in sign and the amount of pollution received in Home is greater than that of Foreign[2]. Assumption 2 implies that, in each country, the transboundary rate of pollution is smaller than the nontransboundary rate of pollution[3].

3. Trade between Two Countries

The pattern of production in the trading equilibrium depends on the relative size of the two countries, the comparative advantage in production determined by the relative level of the natural environment between countries, and the share of the world income spent on the manufacturing good. The following proposition shows how the pattern of production is determined.

Proposition 1.

Under Assumptions 1 and 2, the following holds for the trading equilibrium.

(i) Home is specialized in the manufacturing good and Foreign is diversified if and only if $L/(L+L^*) < a < 1$.

(ii) Home is specialized in the manufacturing good and Foreign is specialized in the agricultural good if and only if $\hat{a} \le a \le L/(L+L^*)$, *where*

$$\hat{a} = (\overline{E} - \beta L)^{\theta} L / [(\overline{E} - \beta L)^{\theta} L + (\overline{E} - \gamma L)^{\theta} L^*].$$

(iii) Home is diversified and Foreign is specialized in the agricultural good if and only if $0 < a < \hat{a}$.

Proof. See Appendix A.

The implications of this proposition are as follows. In Case (i), there are strong tastes for the manufacturing good. So the world demand for the manufacturing good in the trading equilibrium exceeds its maximum level that Home can supply under its

specialization. Hence both countries have to produce the manufacturing good in order to clear the market. The demand degrees for two goods are about half and half in Case (ii), so that both countries specializes in production, Home having an advantage in the production of the manufacturing good specializes in the manufacturing good and the other specializes in the agricultural good. Case (iii) is that the tastes for the manufacturing good are weak relative to the agricultural good. In this case, Home should produce both goods, while Foreign specializes in the agricultural good.

4. The Effects of Trade on the Environment

Although our final purpose is to see the welfare level of each country after opening trade, it is heavily dependent on the level of the natural environments after trade. Thus, in this section, we examine how the parameters, β, β^*, γ, γ^*, L, L^* and $a(=a^*)$ affect the level of the natural environment of each country in the trading equilibrium. Hereafter, we denote variables of the trading equilibrium with superscript "T" and those for autarky with superscript "A".

4.1 Home

We treat two alternative cases separately. One case is that the transboundary rate of pollution in Foreign is smaller than the nontransboundary rate of pollution in Home, i.e. $\gamma^* < \beta$. In this case, the shift of one unit of production of the manufacturing good from Foreign to Home raises the level of pollution experienced in Home by $\beta - \gamma^* (> 0)$. Therefore, a shift of the manufacturing production from Foreign to Home deteriorates the Home environment. The other case is that $\beta < \gamma^*$. In this case, a shift of the manufacturing production from Foreign to Home conversely improves the Home environment. Bearing this into our mind we can establish the following.

Proposition 2.

Under Assumptions 1 and 2, the following holds for the level of the Home environment.

(i) The case where $\gamma^* < \beta$.

The Home environment deteriorates by trade irrespective of the value of a.

(ii) The case where $\beta < \gamma^*$.

(ii-1) If $\beta < \gamma^* < \beta[(\overline{E} - \gamma L)/(\overline{E} - \beta L)]^{\theta}$, *the Home environment improves by trade for any* a *such that* $0 < a < V(\gamma^*)$ *or* $W(\gamma^*) < a < 1$ *and it deteriorates by trade for any* a *such that* $V(\gamma^*) < a < W(\gamma^*)$, *where* $V(\gamma^*)$ *is a positive scalar depending on* γ^* *and satisfying* $0 < V(\gamma^*) < \hat{a}$, *and* $W(\gamma^*)$ *is equal to* $\beta L/(\beta L + \gamma^* L^*)$ *and satisfying* $\hat{a} < W(\gamma^*) < L/(L + L^*)$.

(ii-2) If $\beta[(\overline{E} - \gamma L)/(\overline{E} - \beta L)]^{\theta} < \gamma^*$, *the Home environment improves by trade irrespective of the value of* a.

Proof. See Appendix B.

Proposition 2 can be seen diagrammatically. In Figure 1, the schedule HUH' represents the combinations of γ^* and a that equate the level of the Home environment in autarky to that of the trading equilibrium. On any point below (above) the schedule, $E^T < E^A$ ($E^T > E^A$).

(Figure1)

An intuitive explanation of Proposition 2 (i) can be provided as follows: Because of Proposition 1, Home produces the manufacturing good more in the trading equilibrium than in autarky and Foreign produces less in the trading equilibrium than in autarky. Moreover, the world demand for the manufacturing good does not fall by opening trade.

Thus the Home environment always gets worse by trade whenever $\gamma^* < \beta$.

Next we will explain Proposition 2 (ii) intuitively. In general there is a tendency to expand the world production of any good by opening of trade because the production of one good shifts to a country having an advantage in that good and becomes more efficient in the world economy. In particular, the production expansion in the manufacturing good deteriorates the natural environments. We call this negative effect as the production expansion effect. After opening trade, the production of the manufacturing good tends to shift to Home from Foreign, which implies that the natural environments improve under the assumption $\beta < \gamma^*$. We call this positive effect as the production shifting effect. The total effect, which determines whether the Home natural environment improves or not, consists of these two effects.

Now consider the case (ii-1). If the world preferences in the manufacturing good are weak enough, i.e. $0 < a < V(\gamma^*)$, the production expansion effect is small in the absolute amount. Hence, the production shifting effect dominates and thus the Home natural environment improves. If the world preferences in the manufacturing good are strong enough, i.e. $W(\gamma^*) < a < 1$, the production expansion itself is small[4]. Therefore the Home natural environment improves. In the case of $V(\gamma^*) < a < W(\gamma^*)$, the production expansion effect is large enough to dominate the production shifting effect and thus the Home natural environment deteriorates.

Finally consider the case (ii-2). In this case the gap between β and γ^* is so large that the production shifting effect always dominates the production expansion effect. Hence the Home natural environment improves.

4.2 Foreign

In Foreign case, we also treat the cases of $\beta^* < \gamma$ and of $\gamma < \beta^*$ independently.

Proposition 3.

Under Assumptions 1 and 2, the following holds for the level of the Foreign environment.

(i) The case where $\beta^* < \gamma$.

The foreign environment deteriorates by trade irrespective of the value of a .

(ii) The case where $\gamma < \beta^*$.

(ii-1) If $\gamma < \beta^* < \gamma[(\overline{E} - \gamma L)/(\overline{E} - \beta L)]^{\theta}$, *the Foreign environment improves by trade for any* a *such that* $0 < a < V^*(\beta^*)$ *or* $W^*(\beta^*) < a < 1$ *and it deteriorates by trade for any* a *such that* $V^*(\beta^*) < a < W^*(\beta^*)$, *where* $V^*(\beta^*)$ *is a positive scalar depending on* β^* *and satisfying* $0 < V^*(\beta^*) < \hat{a}$, *and* $W^*(\beta^*)$ *is equal to* $\gamma L/(\gamma L + \beta^* L^*)$ *and satisfies* $\hat{a} < W^*(\beta^*) < L/(L + L^*)$.

(ii-2) If $\gamma[(\overline{E} - \gamma L)/(\overline{E} - \beta L)]^{\theta} < \beta^*$, *the Foreign environment improves by trade irrespective of the value of* a .

Proof. The Proof can be provided in a similar manner to that of the case of Home.

Q.E.D.

In the case of Foreign, we can provide Figure 2 similar to that of Home. In the figure, the schedule FF'F" represents the combinations of β^* and a that equate the level of the Foreign environment in autarky to that of the trading equilibrium. On any point below (above) the schedule, $E^{*T} < E^{*A}$ ($E^{*T} > E^{*A}$).

(Figure 2)

An intuitive explanation for Proposition 3 can be explored in a similar manner to that of Proposition 2, so that we omit it here.

5. The Welfare Effects of Trade

Now we are in a position to investigate how the parameters, β, β^*, γ, γ^*, L, L^* and $a(=a^*)$, affects the welfare of each country by trade.

5.1 Home

Whenever trade improves the environment in Home, the Home welfare rises after trade. This is because of the expansion of the Home production possibilities as well as the improvement of the terms of trade. In the case where trade gives a damage to the environment in Home, whether the Home welfare rises or falls depends on the production pattern. If Home incompletely specializes, the home production possibilities contract and so does the budget constraint. Thus the Home welfare falls. However Home specializes in the manufacturing good, whether the Home welfare rises or not relies on whether the improvement of the terms of trade dominates the contraction of the production possibilities. We prove this precisely.

Proposition 4

Suppose that Assumptions 1 and 2 hold. Then, if the Home environment improves by the opening of trade, Home becomes better off after trade. If the Home environment deteriorates by the opening of trade, Home becomes better off after trade provided that $a > \overline{a}(\gamma^*)$, *and it becomes worse off after trade provided that* $a < \overline{a}(\gamma^*)$, *where* $\overline{a}(\gamma^*)$ *is a positive scalar depending on* γ^* *and satisfying* $\hat{a} < \overline{a}(\gamma^*) < 1$.

Proof. See Appendix C.

All cases in proposition 4 are illustrated in Figure 1. In the diagram, the schedule

UU' represents the curve of $\bar{a}(\gamma^*)$ on which the terms of trade effect balances with the environmental deterioration effect. The shadowed area is where the Home utility level after trade, i.e. u^T, is lower than that of autarky, i.e. u^A. The other area shows that $u^T > u^A$. We find in Figure 1 that the larger is γ^* relative to β, the more likely is the Home welfare improvement by trade. This is because a production shift of the manufacturing good from Foreign to Home tends to work favorably to the environments of both countries as γ^* becomes larger relative to β. Then it makes easy for Home to gain from trade by a rise in productivity in the agricultural sector and the improvement of the terms of trade.

5.2 Foreign

Whenever trade improves the environment in Foreign, Foreign welfare rises after trade. However, if trade degrades the Foreign environmental quality, the effect of trade to the Foreign welfare depends on the production pattern. The reason for this can be explained in a similar manner to that in the case of Home. We provide the following proposition as a counterpart of Proposition 4.

Proposition 5.

Suppose that Assumptions 1 and 2 hold. Then, if the Foreign environment improves by the opening of trade, Foreign becomes better off after trade. If the Foreign environment deteriorates by the opening of trade, Foreign becomes worse off after trade provided that $L/(L+L^*) < a < 1$.

Proof. If the Foreign environment improves, the Foreign production possibility frontier shifts outward. Thus the autarkic consumption point necessarily satisfies the

budget constraint after trade, so that the Foreign welfare rises after trade. Next suppose that the Foreign environment deteriorates. If $L/(L+L^*) < a < 1$, Foreign is diversified. The environmental deterioration contracts the production frontier and so does the budget line. This implies that the Foreign welfare falls after trade.

Q.E.D.

Proposition 5 is shown in Figure 2 where the line FF'F" is a borderline concerning whether the environmental quality rises or not. This borderline is drawn due to Proposition 3. The foreign environment improves (deteriorates) after trade in the area above (below) the borderline. In the shadowed area, the Foreign environment becomes worse in quality after trade but whether the welfare rises or not is ambiguous.

6. Conclusion

This paper extended Benarroch and Thille's analysis by accommodating the differences in country size, the transboundary and nontransboundary rates of pollution altogether into one model. Then we showed the following results. That is, the environment and the welfare tend to improve by trade in the manufacturing good exporting country when its nontransboundary rate of pollution is relatively small to the transboundary rate of pollution in the other country. On the other hand, in the agricultural good exporting country, its environment and welfare tend to improve when its nontransboundary rate of pollution is relatively large to the transboundary rate of pollution in the other country.

Remarkably, we found an interesting case where the both environments are improved by trade. So far any theoretical analyses were limited by imposing the restriction on exogenous parameters and hence failed to find this case exactly. Therefore the existing studies concluded that it is necessary for at least one country to receive an

environmental damage by trade. Hence there were no discussions about the possibility that trade is gainful to both countries irrespective of their production patterns after trade. In Propositions 4 and 5, we have revealed the relationship between a quality change in the each country's environment and the welfare change in the corresponding country by trade, from which we have found the possibility that the environmental quality improves in both countries, hence both countries become better off.

Footnotes

1 Okuno and Konishi (1993) examine the optimal pollution tax by using a Rcardian model with consumption externalities in the form of transboundary pollution. Itoh and Tawada (2001) analyze how the international transfer of technology for reducing pollution influences the welfare levels in each country by using Copeland and Taylor's model.

2 Under Assumption 1, Home's agricultural industry is less productive than Foreign's in the autarkic equilibrium. This suggests that Home exports the manufacturing good and Foreign exports the agricultural good after opening trade.

3 Assumption 2 ensures that Home and Foreign always have a comparative advantage in the manufacturing and agricultural good, respectively.

4 Actually we can see that, if $a > L/(L + L^*)$, there is no expansion of the world production in the manufacturing good by the opening of trade.

Appendix A: Proof of Proposition 1

When Home exports the manufacturing good and Foreign exports the agricultural good, world demand for the manufacturing good (hereafter WD_M) is

$$WD_M = a[L + (E^*)^\theta L^* / p], \tag{A.1}$$

where $p = p_M / p_A$.

First, suppose that Home is specialized in the manufacturing good and Foreign is diversified. In this case, p is equal to $(E^*)^\theta$, so that $WD_M = a(L + L^*)$. Furthermore, WD_M must be larger than L when this pattern of production is realized in the trading equilibrium. Therefore we obtain the following:

(I) It holds that $L/(L + L^*) < a < 1$ if Home is specialized in the manufacturing good and Foreign is diversified.

Next, suppose that Home is specialized in the manufacturing good and Foreign is specialized in the agricultural good. In this case, the levels of the natural environment of Home and Foreign are given by

$$E = \overline{E} - \beta L, \qquad E^* = \overline{E} - \gamma L, \tag{A.2}$$

respectively. Furthermore, WD_M must be equal to L and p must satisfy $E^\theta \le p \le (E^*)^\theta$ when this pattern of production is realized in the trading equilibrium. Therefore we obtain the following:

(II) It holds that $\hat{a} \le a \le L/(L + L^*)$ if Home is specialized in the manufacturing good and Foreign is specialized in the agricultural good.

Finally, suppose that Home is diversified and Foreign is specialized in the agricultural good. In this case, the levels of the natural environment of Home and Foreign are, respectively, given by

$$E = \overline{E} - \beta M^T, \qquad E^* = \overline{E} - \gamma M^T, \tag{A.3}$$

where M^T is the amount of the manufacturing good that Home supplies in the trading equilibrium. Then, the market clearing condition that $WD_M = M^T$ can be reduced to $a = F(M^T)$, where

$$F(M^T) = (\overline{E} - \beta M^T)^\theta M^T / [(\overline{E} - \beta M^T)^\theta L + (\overline{E} - \gamma M^T)^\theta L^*]. \quad \text{(A.4)}$$

Our inspection of (A4) yields the fact that the function $F(M^T)$ has the following property:

$$M^T > (<) \overline{M} \quad \Leftrightarrow \quad F'(M^T) < (>) 0, \quad \text{(A.5)}$$

where $\overline{M}$ is a positive scalar satisfying $0 < \overline{M} < \overline{E} / \lambda$. That is, the function $F(M^T)$ has a positive (negative) slope to the LHS (RHS) of $\overline{M}$, so that $\overline{M}$ is a unique maximum point of $F(M^T)$. In order to eliminate the possibility of multiple equilibria, we assume that $L < \overline{M}$. Reminding that $\hat{a}$ equals $F(L)$ and M^T is smaller than L, we obtain the following:

(III) It holds that $0 < a < \hat{a}$ if Home is diversified and Foreign is specialized in the agricultural good.

The inverse of (I), (II) and (III) can be easily shown by the use of the contradictory proposition. Hence (i), (ii) and (iii) of Proposition 1 hold.

Q.E.D.

Appendix B: Proof of Proposition 2

First, let us prove Case (i). If $\gamma^* < \beta$, the Home environment deteriorates by a shift of the manufacturing production from Foreign to Home. Actually, trade shifts the manufacturing production from Foreign to Home without reducing the world demand for the manufacturing good, so that the Home environment deteriorates by trade

irrespective of the value of a under the assumption that $\gamma^* < \beta$.

Second, let us prove Case (ii). In the case where $\beta < \gamma^*$, the Home environment improves by a production shift of the manufacturing good from Foreign to Home. If Foreign is diversified in the trading equilibrium, i.e. $L/(L+L^*) < a < 1$, then world demand for the manufacturing good remains unchanged after trade, so that the Home environment improves by opening trade. If both countries are specialized in their exported goods, i.e. $\hat{a} \le a \le L/(L+L^*)$, then the amount of pollution incurred in Home after trade is βL. Reminding that the autarkic pollution levels in Home is equal to $a(\beta L + \gamma^* L^*)$, we obtain the following:

$$a > (<) W(\gamma^*) \Leftrightarrow E^T > (<) E^A \quad \text{if} \quad \hat{a} \le a \le L/(L+L^*), \tag{B.1}$$

where $W(\gamma^*) = \beta L/(\beta L + \gamma^* L^*)$ and E^T (E^A) is the level of the natural environment of Home in the trading equilibrium (autarky). If Home is diversified in the trading equilibrium, i.e. $0 < a \le \hat{a}$, then the amount of pollution incurred in Home after trade is $a\beta[L + (\overline{E} - \gamma M^T)^\theta L^* / (\overline{E} - \beta M^T)^\theta]$. Thus the following holds:

$$\gamma^* > (<) G(M^T) \Leftrightarrow E^T > (<) E^A \quad \text{if} \quad 0 < a \le \hat{a}, \tag{B.2}$$

where $G(M^T) = \beta[(\overline{E} - \gamma M^T)/(\overline{E} - \beta M^T)]^\theta$. Now, suppose that $\beta < \gamma^* < \beta[(\overline{E} - \gamma L)/(\overline{E} - \beta L)]^\theta$. Then, there exists a unique value of $a \in (0, \hat{a})$ such that $\gamma^* = G(M^T)$. (Note that $G(M^T)$ is strictly increasing over $[0, L]$ and M^T is strictly increasing with respect to a over $[0, \hat{a}]$.) By the use of this fact, we can rewrite (B.2) as follow:

$$V(\gamma^*) > (<) a \Leftrightarrow E^T > (<) E^A \quad \text{if} \quad 0 < a < \hat{a}, \tag{B.3}$$

where $V(\gamma^*)$ is the value of a such that $\gamma^* = G(M^T)$ and satisfying $0 < V(\gamma^*) < \hat{a}$. Moreover, it holds that $\hat{a} < W(\gamma^*) < L/(L+L^*)$ under the present assumption. Form this fact, (B.1) and (B.3) it is shown that Case (ii-1) of Proposition 4 holds. Next, suppose that $\beta[(\overline{E} - \gamma L)/(\overline{E} - \beta L)]^\theta < \gamma^*$. In this case, γ^* is larger than $G(M^T)$ for any

$a \in (0, \hat{a})$ and a is larger than $W(\gamma^*)$ over $[\hat{a}, L/(L+L^*)]$. From these facts, (B.1) and (B.2), we find that Case (ii-2) of Proposition 4 holds.

Q.E.D.

Appendix C: Proof of Proposition 4

We have already explained the reason why Home becomes better off after trade when trade improves the Home environment and the reason why Home becomes worse off after trade when trade gives a damage to the diversified Home environment. Thus, we focus on the case where trade is harmful to the Home environment and Home is specialized in the manufacturing good. In this case, it is sufficient to see a change of the relative price of the manufacturing good by trade in order to examine whether the Home utility rises or not after trade.

First, let us consider the case where Foreign is diversified in the trading equilibrium, i.e. $L/(L+L^*) < a < 1$. In this case, the relative price of the manufacturing good after trade, say, p^T is equal to the relative productivity of the agricultural good to the manufacturing good in Foreign, namely, $\{\overline{E} - \beta^*[a(L+L^*) - L] - \gamma L\}^\theta$. Reminding that the autarkic relative price, say, p^A is equal to $[\overline{E} - a(\beta L + \gamma^* L^*)]^\theta$, we obtain the following:

$$a[(\beta - \beta^*)L - (\beta^* - \gamma^*)L^*] > (<)(\gamma - \beta^*)L \;\Leftrightarrow\; u^T > (<)u^A. \tag{C.1}$$

Now suppose that $\gamma - (\beta - \gamma)L/L^* > \gamma^*$. Then, under Assumption 1, we have $\gamma > \beta^*$, which implies that $(\beta - \beta^*)L - (\beta^* - \gamma^*)L^* > 0$. Thus, we can rewrite (C.1) as follow:

$$a > (<)Y(\gamma^*) \;\Leftrightarrow\; u^T > (<)u^A, \tag{C.2}$$

where $Y(\gamma^*) = (\gamma - \beta^*)L/[(\beta - \beta^*)L - (\beta^* - \gamma^*)L^*]$ and $L/(L+L^*) < Y(\gamma^*) < 1$.

Next, suppose that $\gamma - (\beta - \gamma)L/L^* < \gamma^*$. In this case, if $\gamma > \beta^*$, then we can obtain (C.2) in a similar manner to that of the case of $\gamma - (\beta - \gamma)L/L^* > \gamma^*$. However, under

the present supposition, we obtain $Y(\gamma^*) < L/(L+L^*)$, so that the Home utility level rises after trade for any $a \in (L/(L+L^*),1)$. If $\gamma \leq \beta^*$, then the Foreign environment remains unchanged or rises by trade due to Proposition 3, so that the Home utility level rises after trade for any $a \in (L/(L+L^*),1)$.

Second, let us consider the case where Foreign is specialized in the agricultural good after trade, i.e. $\hat{a} \leq a \leq L/(L+L^*)$. In this case, p^T is equal to the relative productivity of the agricultural good to the manufacturing good in Home, i.e. $(\overline{E}-\gamma L)^{\theta}[aL^*/(1-a)L]$. Moreover, p^T (p^A) is shown to be strictly increasing (decreasing) with respect to a over $[\hat{a}, L/(L+L^*)]$. Under the supposition that $\beta[(\overline{E}-\gamma L)/(\overline{E}-\beta L)]^{\theta} < \gamma^*$, it holds that $p^T > p^A$ at $a=\hat{a}$ because p^T is equal to $(\overline{E}-\beta L)^{\theta}$ at that point. Thus the Home utility level rises after trade for any $a \in [\hat{a}, L/(L+L^*)]$. Under the supposition that $\gamma-(\beta-\gamma)L/L^* > \gamma^*$, we obtain $p^T < p^A$ at $a = L/(L+L^*)$, so that the Home utility level falls after trade for any $a \in [\hat{a}, L/(L+L^*)]$. Finally, under the supposition that $\gamma-(\beta-\gamma)L/L^* < \gamma^* < \beta[(\overline{E}-\gamma L)/(\overline{E}-\beta L)]^{\theta}$, it holds that $p^T < p^A$ at $a=\hat{a}$ and $p^T > p^A$ at $a = L/(L+L^*)$. Therefore we can obtain

$$a > (<) Z(\gamma^*) \;\Leftrightarrow\; u^T > (<) u^A, \tag{C.3}$$

where $Z(\gamma^*)$ is the value of a such that $p^T = p^A$ and thus it satisfies that $\hat{a} < Z(\gamma^*) < L/(L+L^*)$.

Defining $\bar{a}(\gamma^*)$ as $Y(\gamma^*)$ if $\gamma-(\beta-\gamma)L/L^* > \gamma^*$ and $Z(\gamma^*)$ if $\gamma-(\beta-\gamma)L/L^* < \gamma^* < \beta[(\overline{E}-\gamma L)/(\overline{E}-\beta L)]^{\theta}$, then we obtain Proposition 4.

Q.E.D.

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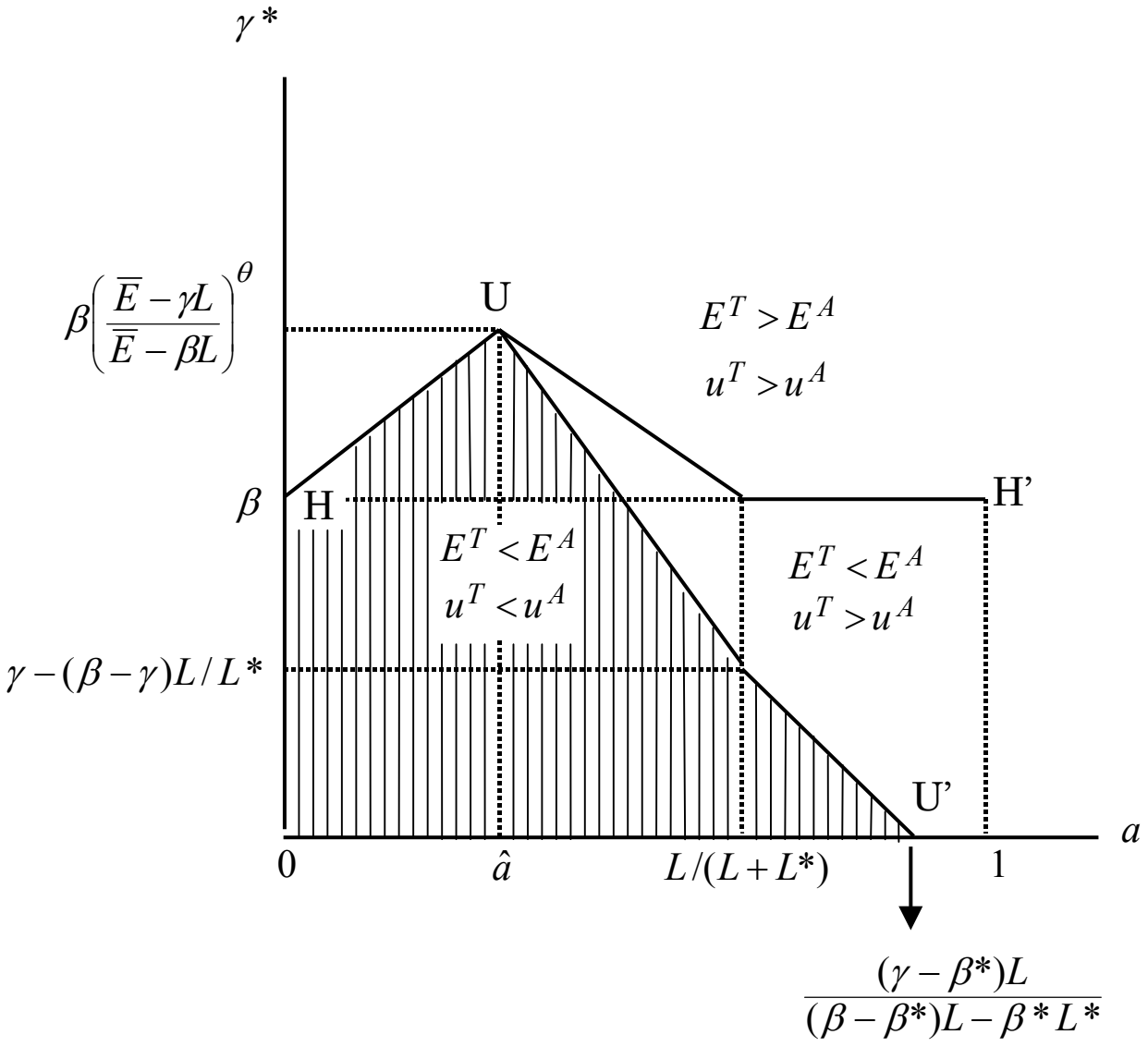
γ^*
$\beta\left(\frac{\overline{E}-\gamma L}{\overline{E}-\beta L}\right)^{\theta}$
U
$E^T > E^A$
$u^T > u^A$
β
H
H'
$E^T < E^A$
$u^T < u^A$
$E^T < E^A$
$u^T > u^A$
$\gamma-(\beta-\gamma)L/L^*$
U'
a
0
$\hat{a}$
$L/(L+L^*)$
1
$\frac{(\gamma-\beta^*)L}{(\beta-\beta^*)L-\beta^* L^*}$

Figure 1

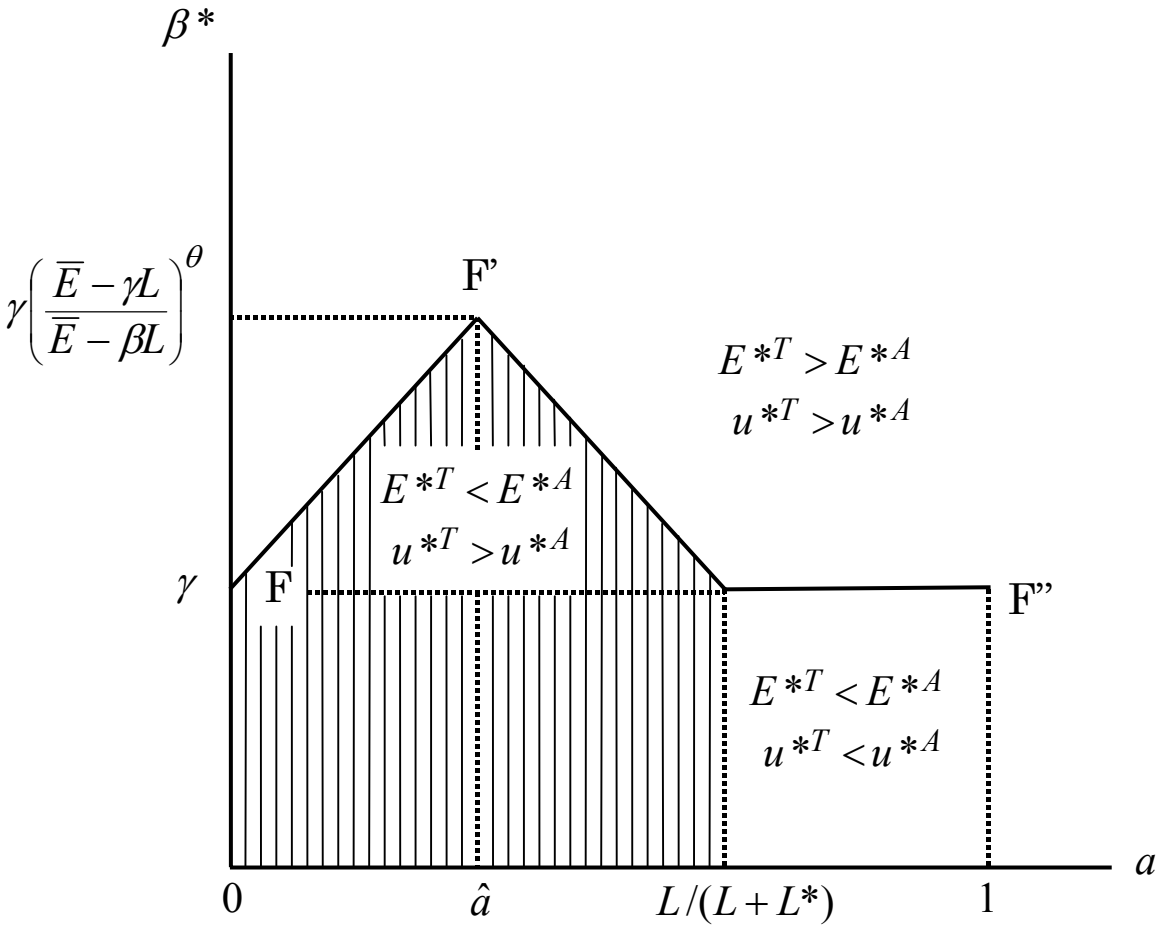
$\beta*$
$\gamma\left(\frac{\overline{E}-\gamma L}{\overline{E}-\beta L}\right)^{\theta}$
F'
$E*^T > E*^A$
$u*^T > u*^A$
$E*^T < E*^A$
$u*^T > u*^A$
γ
F
F"
$E*^T < E*^A$
$u*^T < u*^A$
a
0
$\hat{a}$
$L/(L+L*)$
1

Figure 2