Trans-boundary Pollution and International Migration

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Abstract

In this paper we analyse the welfare effect of international migration under the existence of trans-boundary pollution. We use a simplified Copeland and Taylor (1999) model a two-country, two-sector and two-factor Ricardian general equilibrium model. The developed Home country (under-developed Foreign country) is superior (inferior) in terms of the pollution abatement technology and thus it has relative advantage in the production of the environmentally sensitive agricultural good (the manufactured good which emits pollution). If there is no trade, workers will migrate from the Foreign country to the Home country. Regardless of the method of remittance, generally speaking the Foreign country gains from migration, but whether the Home country gains depends on the technology gap and the magnitude of trans-boundary pollution. If a free trade equilibrium exists, international migration occurs when the demand for the manufactured good is not large and thus the Home country specializes in the production of manufactured good. Migration will expand the production of the manufactured good as well as international trade.

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Introduction

Pollution of the environment due to industrial production has become one of the world's most serious problems. This problem is difficult to solve because in under-developed countries, which usually cannot control pollution well because they lack sufficient skills and funding, governments give priority to economic growth over the protection of the environment.

There are many studies that analyse the effects of environmental pollution resulting from international specialization and Trade. The pioneering study by Copeland and Taylor (1999) extended the relative advantage model of David Ricardo to a dynamic model considering natural recovery of environmental resources, and analysed the effects on economic welfare caused by international specialization and trade. Both Suga (2001) and Tawada (2001) introduced the difference of the scale of pollution between two countries and permitted the realistic possibility of trans-boundary pollution. Ito and Tawada (2001) studied the effects of the transfer of pollution abatement technology from a developed country to an under-developed country.

In the familiar case of Japan and China, it is the latter that mainly discharges trans-boundary pollutants. Moreover, since the wage rate in China is relatively low, international migration from China to Japan is potentially possible. Therefore, we consider that even if environmental issues are being studied, the introduction of international migration should be another optional policy that may be substituted for the

policies of maintaining autarky or permitting international trade. Our study concerns the economic effects of international migration under the assumptions of the Ricardo-Copeland-Taylor model with trans-boundary pollution. There are no existing theoretical studies about this subject.

We present the basic model in Section 2. In Section 3, we consider the case where international trade is impossible because of the existence of non-tradable goods. If immigrants intend to stay in the host country permanently, no remittance occurs. However, if immigrants' families remain in the home country as cross-border workers, then they can remit their income via the tradable good. Considering the variety of possibilities for remittance, we will study the effects of migration on the pollution level and economic welfare of the host and home countries.[1] In Section 4, on the other hand, we permit international migration. We first specify the case in which international migration occurs, and then analyse the economic effects of migration. Concluding remarks are in Section 5.

1. The Model

Consider that there are only two countries, Home and Foreign, in the world. There are two industries in each country. One is a smokestack manufacturing industry and the other is an environmentally sensitive agricultural industry. The two primary factors of production are labour and environmental capital. First we consider the Home country.

The production functions of the manufacturing and agricultural industries are represented as

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

$$A = \sqrt{E}L_A, \tag{1-2}$$

respectively, where E is the stock of environmental capital, M and L_M are, respectively, the output and labour input in the manufacturing industry, and A and L_A are those of the agricultural industry. The output in the manufacturing industry does not depend on the environmental capital stock, and one unit of output is constantly possible by inputting one unit of labour. On the other hand, the labour productivity of the agricultural industry relies on the level of the environmental capital stock, and one unit of labour input can produce $\sqrt{E}$ units of output in the agricultural industry.

The production activity in the manufacturing industry generates pollution, which is formulated as the following pollution function,

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

Therefore, the magnitude of pollution caused by unit production is constant λ. Pollution reduces the level of the environmental capital stock, and therefore the production of the manufacturing industry causes negative externalities to the agricultural industry.

Now we consider the economic model with trans-boundary pollution such as acid rain, which causes damage not only to the agricultural industry of the domestic country but also to that of the neighbouring foreign country. However, let us note that the environmental damage caused by domestic pollution is more terrible than that caused by the neighbouring foreign country. Thus, in our model we assume that the effects of trans-boundary pollution should affect only $1/b\,(1<b)$ of the same magnitude of domestic pollution.

Let M^* be the output of the Foreign country. The pollution function of the Foreign country can also be defined like that of the Home country,

$$Z^* = \lambda^* M^*, \quad 0 < \lambda^* < 1 \tag{2-2}$$

Then the total amount of pollution of the Home country, D, is

$$D = Z + Z^*/b = \lambda M + \lambda^* M^*/b. \quad (3)$$

We assume that one unit of the stock of environmental capital will be damaged by one unit of pollution. Therefore the total stock of environmental capital, E, is

$$E = \overline{E} - D \quad (4)$$

where $\overline{E}$ is the natural stock level of environmental capital with no pollution.

In each sector, competitive production is undertaken by many firms, and therefore the profit of each firm equals to null. Let π_M and π_A be the total profits of the manufacturing industry and the agricultural industry, respectively. Then, under the assumption that both goods are produced, we obtain the following two equations,

$$\pi_M = p_M M - wL_M = 0,$$

$$\pi_A = p_A A - wL_A = 0,$$

where p_M and p_A are, respectively, the price of the manufacturing and agricultural goods, and w is the wage rate. The above two equations yield

$$p_M = w, \quad (5)$$

$$p_A \sqrt{E} = w \quad (6)$$

The full employment condition of the Home country is as follows,

$$L_M + L_A = L, \quad (7)$$

where L is the labour endowment of the Home country.

On the demand side, we define the aggregate utility function as

$$U = a \log D_M + (1-a) \log D_A$$

where both a and $1-a$ are positive parameters, and D_M and D_A are, respectively, demands for the manufacturing good and the agricultural good. As the profit of each firm equals to null, the GNP of the Home country should be the aggregate income of

labour, wL. Therefore the demand for each good is obtained as a solution of the utility maximization subject to the budget constraint $p_A D_A + p_M D_M = wL$. Thus we have

$$p_M D_M = awL, \qquad p_A D_A = (1-a)wL,$$

or,

$$D_M = \frac{aw}{p_M} L, \tag{8-1}$$

$$D_A = \frac{(1-a)}{p_A} L. \tag{8-2}$$

(5) and (8-1) yield

$$D_M = aL \tag{9}$$

and therefore we can conclude that D_M is independent of the relative price of the two goods.

From equations (3) to (6), the relative price of the two goods is obtained as

$$p_M / p_A = \sqrt{E} = \sqrt{\overline{E} - \mathit{l}M - \mathit{l}^* M^* / b}. \tag{10}$$

Now we consider international migration between the two countries. For this purpose, we assume that the Foreign country is exactly the same as the Home country except for the pollution function (2). Let us assume that the pollution abatement technology of the Home country is more advanced than that of the Foreign country. Namely, we assume $L = L^*, a = a^*, \overline{E} = \overline{E}^*$ and $\mathit{l} < \mathit{l}^*$ where variables with an asterisk denote those of the Foreign country.

2. 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 good or one of the two governments prohibits trade.

In autarky, each country produces both goods and the following condition holds,

$$\sqrt{E} = p_M / p_A > p_M{}^* / p_A{}^* = \sqrt{E^*},$$

since $\overline{E} = \overline{E}^*$, $M = aL = a^* L^* = M^*$ and $l < l^*$. This means that the Home country has an advantage in the production of the environmentally sensitive agricultural goods.

BL of Figure 1 and $B^* L^*$ of Figure 2 are, respectively, the production possibility frontiers (PPF) of the Home and Foreign Countries. The former is steeper than the latter.

From equations (3) to (6), we obtain

$$\sqrt{E} = w / p_A > w^* / p_A{}^* = \sqrt{E^*} \qquad (11\text{-}1)$$

$$w / p_M = w^* / p_M{}^* = 1 \qquad (11\text{-}2)$$

and therefore the real wage rate of the Home country is larger than that of the Foreign country. Thus if international migration is permitted, workers will tend to move from the Foreign country to the Home country.

2.1 Permanent Migrants

First, let us 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 should be $\tilde{L}$. Changing the population of each country, domestic-origin pollution will increase because of increased manufacturing production in the Home country, but trans-boundary pollution will decrease because of decreased manufacturing production in the Foreign country. Thus the total level of pollution in the Home country after immigration, D', will be

$$D' = la(L + \tilde{L}) + l^* a^* (L^* - \tilde{L}) / b = D^0 + a\tilde{L}(l - l^* / b),$$

where D^0 denotes the pollution level in the case of autarky and is equal to $laL + l^* a^* L^* / b = (l + l^* / b)aL$. Now we obtain the following relationship,

$$l > (<)\, l^* / b \Leftrightarrow D' > (<) D^0.$$

In other words, if the abatement technology gap between two countries is small (large), or if the proportion of the trans-boundary pollution from the neighbouring country is small (large) enough to satisfy $l > (<) l^*/b$, then the level of pollution of the Home country will increase (decrease) by the inflow of permanent migrants.

(Figure 1 is about here)

In the case of decreasing pollution in the Home country combined with increases in the amount of labour, the total output of the Home country will strictly increase. $C_1'L'$ of Figure 1 is the PPF of the Home country after immigration where $L' = L + \tilde{L}$. E_1 (E_1') is the consumption point of all (native) inhabitants in the Home country. Total consumption of manufactured goods by natives should be constant by equation (9). Moreover, they can consume more agricultural goods than before. Thus the economic welfare of the native inhabitants in the Home country should certainly increase.

On the other hand, in the case of increasing pollution in the Home country, it is not clear whether the total output of the Home country increases after immigration. However, it is quite certain that the economic welfare of the natives should decrease. $C_2'L'$ of Figure 1 is the PPF of the Home country after immigration. E_2 (E_2') is the consumption point of all (native) inhabitants in the Home country.

Now let us consider the Foreign country. The total level of pollution in the Foreign country after immigration, $D^{*\prime}$, can be expressed as

$$D^{*\prime} = la(L + \tilde{L})/b + l^* a^* (L^* - \tilde{L}) = D^{0}{}^* + a\tilde{L}(l/b - l^*) < D^{0}{}^*,$$

where $D^{0}{}^*$ denotes the level of pollution in the case of autarky and is equal to $laL/b + l^* a^* L^* = (l/b + l^*)aL$. We may conclude that the level of pollution of the Foreign country will decrease after the outflow of permanent migrants.

The economic welfare of the Foreign country must increase. B^*L^* in Figure 2 is the PPF of the Foreign country in the case of autarky, and $C^{*'}L^{*'}$ is that after emigration, where $L^{*'} = L^* - \tilde{L}$. The consumption point of autarkic equilibrium is E^* and that of the remaining inhabitants – those left behind (TLB) – is $E_1^{*'}$. On the other hand, after migration, the consumption point of TLB is E_1^*, which shows their economy can be improved by exporting workers.

(Figure 2 is about here)

Now let us focus on the subject of how many workers will migrate if free migration is permitted. As long as the conditions (11-1) and (11-2) are satisfied, motivation for migration exists. The magnitude of effects caused by one unit of migration on the domestic and foreign stock of environmental capital is $a(\boldsymbol{l} - \boldsymbol{l}^*/b)$ and $a(\boldsymbol{l}/b - \boldsymbol{l}^*)$, respectively. By taking $|\boldsymbol{l}/b - \boldsymbol{l}^*| > |\boldsymbol{l} - \boldsymbol{l}^*/b|$ into consideration, we can conclude that the gap in the level of pollution between the two countries will be reduced regardless of the fluctuations of the Home country's pollution, and finally $E = E^*$ will be realized by international migration. The wage rates of both countries should then be the same, and the motivation for migration should disappear. But we can also assume the alternative case, that all workers in the Foreign country migrate before the establishment of $E = E^*$.

THEOREM 1:

1) Workers migrate from the developing country to the country with advanced pollution abatement technology.

2) If the abatement technology gap between two countries is small (large), or if the proportion of the trans-boundary pollution from the neighbouring country is small (large) enough to satisfy $l > (<) l^*/b$, then both the level of pollution and the economic welfare of the Home country will increase (decrease) by the inflow of permanent migrants.

3) With the outflow of permanent migrants, the level of pollution of the Foreign country will decrease and economic welfare will increase.

4) Migration will end if all the foreign workers migrate or, before that, if the stock of environmental capital of the two countries is equalized by international migration.

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

Next, let us consider the case that the manufactured good is tradable while the agricultural good is non-tradable because of government policy (as Japanese rice was formerly) or because of the difference of acceptable agricultural chemicals or genetically recombined farm products. In this case, as only one of the two goods is non-tradable, there is no international trade between the two countries under the assumption of identical quality of the manufactured good. However, now immigrants can remit some part of their income to the home country by transferring tradable manufactured goods. Here we will introduce immigrants who remit all of their income, and let us call this type of immigrant M-type cross-border workers. Cross-border workers are quite popular in EU countries. They commute across the border daily, and their consumption occurs mainly in the home country where they live with their families, not in the host country.

Now let us consider that the number of M-type cross-border workers who immigrate to the Home country is $\tilde{L}$. Native inhabitants know that those immigrants need to exchange all of their income into tradable manufactured goods and considering

that, natives will choose the optimal production point on the PPF. To put it concretely, native inhabitants in the Host country need to consume aL amount of manufactured goods, and therefore, remembering that the income of $\tilde{L}$ cross-border workers should be expressed as $\tilde{L}$ amount of manufactured goods, the output of manufactured goods after immigration needs to be $aL + \tilde{L}$. Similarly, the necessary amount of manufactured goods in the Foreign country is $a^* L^* = aL$, and therefore, taking into consideration the remittance of $\tilde{L}$ amount of manufactured goods, the output of the manufactured good in the Foreign country should be $aL - \tilde{L}$.

The level of pollution of the Home country, D'', is

$$D'' = \boldsymbol{l}(aL + \tilde{L}) + \boldsymbol{l}^*(aL - \tilde{L})/b = D^0 + (\boldsymbol{l} - \boldsymbol{l}^*/b)\tilde{L}$$

and thus we can conclude that

$$\boldsymbol{l} > (<)\, \boldsymbol{l}^*/b \Leftrightarrow D'' > (<) D^0.$$

The above relation means that if the abatement technology gap between the two countries is small (large), or if the proportion of trans-boundary pollution from the neighbouring country is small (large) enough to satisfy $\boldsymbol{l} > (<)\, \boldsymbol{l}^*/b$, then the level of pollution of the Home country will increase (decrease) by the inflow of M-type cross-border workers.

The condition under which pollution will increase or decrease is the same as with the case of permanent migrants in the former sub-section. But the effect of the inflow of $\tilde{L}$ number of workers on the environmental capital of the Home country is $(\boldsymbol{l} - \boldsymbol{l}^*/b)a\tilde{L}$ if immigrants migrate permanently without remittance, while it is $(\boldsymbol{l} - \boldsymbol{l}^*/b)\tilde{L}$ if immigrants are cross-border workers with remittances. As $a < 1$, we may conclude that the absolute value of the latter effect is larger than that of the former. Namely, if the Home country permits the inflow of some fixed number of foreign workers, the effect on the environmental capital of the Home country is larger in the

case where immigrants remit all of their income by manufactured goods than in the case where immigrants do not remit at all, regardless of whether the effect is positive or negative.

(Figure 3 is about here)

$C_1'L'$ of Figure 3 is the PPF of the Home country after the inflow of permanent immigrants. In this case the level of the pollution decreases. E_1' is the production point without remittance. On the other hand, the PPF after the inflow of M -type cross-border workers should be steeper, like $C_3'L'$. We can draw C_1L and C_3L just parallel to $C_1'L'$ and $C_3'L'$, respectively. The consumption point of the natives in the Home country in the case of permanent migrants is E_1, the intersection point of OE_1' and C_1L. While the consumption point in the case of cross-border workers is E_3, the intersection point of $M = aL$ and C_3L, and the production point should be F, just $\tilde{L}$ amount right of E_3. E_1 is below E_3, and this means that in relation to the economic welfare of the natives, cross-border workers are preferable to permanent migrants. Conversely, we can conclude by a similar approach that in the case of an increasing level of pollution, permanent migrants are preferable to the cross-border workers for the native inhabitants in the Home country.

The level of pollution of the Foreign country, $D^{*''}$, can be denoted as

$$D^{*''} = \mathit{l}(aL + \tilde{L})/b + \mathit{l}^*(aL - \tilde{L}) = D^{*0} + (\mathit{l}/b - \mathit{l}^*)\tilde{L} < D^{*0}$$

and therefore we can say that the outflow of cross-border workers will reduce the level of pollution. Similarly to the Home country case, the magnitude of effects caused by cross-border workers is larger than that caused by the same number of permanent migrants. But in this case, which type of migrants are preferable for TLB in the foreign

countries is not clear. In Figures 4-1 and 4-2, the PPF after the outflow of permanent migrants is $G_1L^{*\prime}$ and the consumption point of TLB is E_1^*. On the other hand, the PPF after the outflow of cross-border workers is $G_2L^{*\prime}$, the production point of TLB is G and the consumption point after receiving remittance is H'. Figure 4-1 (4-2) shows the case where the outflow of permanent migrants (cross-border workers) is preferable. However, in addition, the consumption point in autarkic equilibrium is $E_1^{*\prime}$ and therefore we may conclude that either type of migrants will improve economic welfare of TLB in the Foreign country.

(Figures 4-1 and 4-2 are about here)

Finally, concerning the conditions under which migration ends, similarly to the permanent migrants' case in the former sub-section, the environmental capital of the Foreign country will increase while that of the Home country may decrease or increase with a smaller magnitude. Thus the gap of the level of pollution between the two countries will be reduced by international migration. Migration will end in the case where $E = E^*$. However, we must note that if the number of cross-border workers is $a^*L^* = aL$, then remittance of manufactured goods is also $a^*L^* = aL$. Now the Foreign country will specialize in agricultural production, but in this case total demand for the manufactured good in the Foreign country will become larger than aL, and therefore the outflow of workers will not stop naturally at this stage.[2]

THEOREM 2:

1) If the abatement technology gap between the two countries is small (large), or if the proportion of the trans-boundary pollution from the neighbouring country is small (large) enough to satisfy $l > (<) l^*/b$, then both the level of pollution and the

economic welfare of the Home country will increase (decrease) by the inflow of M-type cross-border workers. The magnitude of the above effects caused by cross-border workers is larger than that caused by the same number of permanent migrants.

2) The level of pollution of the Foreign country will decrease and economic welfare will increase by the outflow of cross-border workers. However, it is not clear which type of migrants – permanent migrants or cross-border workers – are preferable for TLB in the foreign country.

3) Migration will end if the stocks of environmental capital of the two countries are equalized by international migration. However, even if the number of cross-border workers is $a^* L^* = aL$, the motivation for migration will not disappear naturally.

2.3 Cross-Border Workers Who Remit Their Income by Agricultural Goods

Finally, let us consider the opposite case where the agricultural good is tradable while the manufactured good is non-tradable, because the standards required for the products differ or military secrets exist. In this case, immigrants can remit some part of their income to the home country via tradable agricultural goods. Here we will again introduce immigrants who remit all of their income, and let us call this type of immigrants A-type cross-border workers.

Again the output of manufactured goods in the Home (Foreign) country is aL, which is equal to the demand of the native inhabitants (TLB). Immigration does not affect the output of manufactured goods, thus the level of pollution in each country does not change and is equal to that in autarkic equilibrium, D^0 and D^{*0}, respectively.

The inflow of A-type cross-border workers will expand the PPF of the Home country from LB to $L'B'$ in Figure 5, and then the production point and consumption point of the native inhabitants will be J and K, respectively. Point K is the same as

point E in Figure 1, and therefore A-type cross-border workers do not affect the economic welfare of the Home country.

(Figure 5 is about here)

Concerning the Foreign country, as shown in Figures 6-1 and 6-2, the PPF after the outflow of permanent migrants is $RL^{*\prime}$ and the consumption point of TLB is E_1^*. On the other hand, the PPF after the outflow of A-type cross-border workers will be $B^{*\prime}L^{*\prime}$ and the production and consumption points will be P and Q, respectively. The consumption point of TLB will be Q'. As the PPF of the Home country is steeper than that of the Foreign country, making use of $B^*B^{*\prime} < PQ$, we can conclude that the economic welfare of the Foreign country will increase from the outflow of A-type cross-border workers because Q' is above $E_1^{*\prime}$, the consumption point in autarkic equilibrium. However, it is not clear which type of migrants – permanent migrants or A-type cross-border workers – is preferable for TLB in the foreign country. Figure 6-1 (6-2) shows the case where the former (the latter) is preferable.

(Figure 6-1 and 6-2 are about here)

Migration will end in the case where the number of cross-border workers is $(1-a)L$ and the Foreign country specializes in the production of the manufactured good.[3]

THEOREM 3:

1) A-type cross-border workers do not affect the level of environmental capital of either country.

2) A-type cross-border workers do not affect the economic welfare of the Home country.

3) The outflow of A-type cross-border workers will increase the economic welfare of the Foreign country. However, it is not clear whether permanent migrants or cross-border workers are preferable for TLB in the foreign country.

4) Migration will end if the number of cross-border workers is $(1-a)L$.

3. International Trade and International Migration

Now let us examine the usual case where both goods are tradable. In general, there are some difficulties involved in carrying out international migration, 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 arbitrating the difference between the relative prices in the two countries. Consequently, we assume that free international trade occurs as the first step, and after that, if a real wage gap exists between two countries in equilibrium, international migration would occur as the second step.

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

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

$$p_A\sqrt{E} = w, \quad p_M = w, \tag{12-1}$$

$$p_A\sqrt{E^*} < w^*, \quad p_M = w^*, \tag{12-2}$$

and in this case, $w = w^*$ is satisfied. Remembering that the relative price of the two goods is common after international trade, we can conclude that there is no motivation for migration.

Case 2: If the demand for the manufactured good is moderate, neither strong nor weak, then the Foreign country will specialize in the production of the manufactured good and the Home country will specialize in the production of the agricultural good. Then we have

$$p_A \sqrt{E} = w, \quad p_M < w, \tag{13-1}$$

$$p_A \sqrt{E^*} < w^*, \quad p_M = w^*, \tag{13-2}$$

and in this case, as $w > w^*$, there is a motivation for migration to occur from the Foreign country to the Home country.

Case 3: If the demand for the manufactured good is weak enough and a is sufficiently close to null, then the Home country will specialize in the production of the agricultural good while the Foreign country will produce both goods. Then we have

$$p_A \sqrt{E} = w, \quad p_M < w, \tag{14-1}$$

$$p_A \sqrt{E^*} = w^*, \quad p_M = w^*, \tag{14-2}$$

and in this case we also can assert $w > w^*$. Similarly to the former case, there is a motivation for migration from the Foreign country to the Home country.

Now we will analyse the effects of international migration on the free trade equilibrium of the two countries in cases 2 and 3. In these cases, as $\sqrt{E^*} \leq p_M / p_A < \sqrt{E}$ is satisfied, as shown in equations (13) and (14), the PPF of the Home country, $B_T L$, is still steeper than that of the Foreign country, $B_T{}^* L^*$, after free trade, as shown in Figure 7. When international migration occurs in Case 3, the level of

pollution in each country will decrease. This is because firstly, in Case 3, we hold the relationship

$$D_M^* = \frac{a^* w^*}{p_M} = a^* L^*, \quad D_M = \frac{aw}{p_M} L > aL \tag{15}$$

and this means that the per-capita demand for the manufactured good in the Foreign country is $a^* = a$ while that in the Home country is larger than a. As workers migrate from the Foreign country to the Home country, the aggregate world demand for the manufactured good will directly increase by international migration. The second reason is an indirect effect. From (10), we have

$$dE / d\tilde{L} = -b^{-1} \boldsymbol{l}^* (dM^* / d\tilde{L}) d\tilde{L}$$

$$dE^* / d\tilde{L} = -\boldsymbol{l}^* (dM^* / d\tilde{L}) d\tilde{L}$$

and thus we obtain

$$d(\frac{E}{E^*}) / d\tilde{L} = \frac{E^* (dE / d\tilde{L}) - E(dE^* / d\tilde{L})}{E^{*2}} = \boldsymbol{l}^* (E - E^* / b)(dM^* / d\tilde{L}) > 0 .$$

On the other hand, from (14) we have

$$w / p_M = \sqrt{E} / \sqrt{E^*} .$$

The above equations show that international migration will enhance the real wage rate w / p_M, and (15) demonstrates it will also enhance the total demand for the manufactured good in the Home country. Because of these direct and indirect effects, the increased output of the manufactured good caused by increased demand should reduce the stock of environmental capital.

The outflow of workers will reduce the production of the agricultural good in the Foreign country, and soon the Foreign country will specialize in the production of the manufactured good. Now we will shift to Case 2. In Case 2, equation (15) still holds and so an additional outflow of workers will result in a shortage of the manufactured good

on the world market. In this situation, we will shift to the next equilibrium of Case 1 and then international migration will end.

In Figure 7-1, L' is the total amount of labour of the Home country after immigration and the PPF is $B'_T L'$. The consumption of the manufactured good in the Home country in the case of free trade is $(a+\alpha)L$, and after immigration it is $(a+\beta)L'$, where $0<\alpha<\beta$. The consumption point in the Home country is S', while that of the native inhabitants is S. As T is the consumption point before migration and the consumption of the manufactured good is not the same, we cannot obtain any clear conclusions about the effects of migration on economic welfare.

Similarly, in Figure 7-2, $L^{*'}$ is the amount of labour in the Foreign country after emigration and PPF is $B^{*'}_T L^{*'}$. The consumption point in the Foreign country after migration is U^*. The consumption point before migration is V^* while that of TLB is $V^{*'}$. We obtain two opposite cases, in which the economic welfare of TLB will increase and decrease after emigration. Figure 7-2 shows the latter case but it is easy to draw the figure of the opposite case.

(Figure 7-1 and 7-2 are about here)

However, we have two remarkable results here. First, as mentioned above, total demand for the manufactured good will increase after migration. In Figure 2, the demand changes from $2aL+\alpha L$ to $2aL+\beta L'$. Second, international trade will expand because of international migration. This is because the Foreign country exports the manufactured good, demand for this good in the Home country is increased by international migration, and the relative price of the manufactured good declines. The trade triangle of the Home country expands from $B_T T_0 T$ to $B_T' S_0' S'$ in Figure 7-1,

while that of the Foreign country also expands from $V^*X^*W^*$ to $U^*X^{*\prime}W^{*\prime}$ in Figure 7-2.

Now we have the following conclusions.

THEOREM 4:

1) In the case where both of the two goods are tradable, international migration from the Foreign country to the Home country occurs if the demand for the manufactured good is weak enough to realize the free trade equilibrium in which the Home country specializes in the production of the agricultural good.

2) The level of pollution in each country will increase because of international migration.

3) The output of the manufactured good in the Foreign country will increase after international migration.

4) International migration causes the expansion of world trade.

4. Concluding Remarks

In our paper we assumed the environmentally sensitive good to be the agricultural good, and thus the technologically developed Home country had an advantage in the production of the agricultural good. This seems to be a curious result, but it makes sense if we consider agriculture to be analogous to the highly technological industries that need relatively clean water and air, such as the computer industry or the medical instrument industry.

We simplified Copeland and Taylor (1999) and deleted the dynamic aspect relating to the natural recovery of environmental capital. A meaningful extension of our research

would be to analyse international migration adopting the original Copeland and Taylor model.

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Footnotes

1. Kondoh (1999) and Hiraiwa and Kondoh (2002) studied the effects of immigrants' remittances on the economic welfare of the host country. However, these studies are two-country two-factor models that do not consider environmental issues.

2. In the case where the Foreign country specializes in agricultural production, the following relations must be satisfied: $p_A^* \sqrt{E^*} = w^*$, $p_M^* < w^*$. This means that $D_M^* = \frac{a^* w^*}{p_M^*} > a^* L^*$ and the per-capita demand for the manufactured good is larger than a^*.

3. The relation $D_M^* = \frac{a^* w^*}{p_M^*} = a^* L^*$ still holds even in the case where the Foreign country specializes in the manufactured good. Remittance occurs only via the agricultural good, and the output of the manufactured good in the Foreign country needs to be $a^* L^*$.

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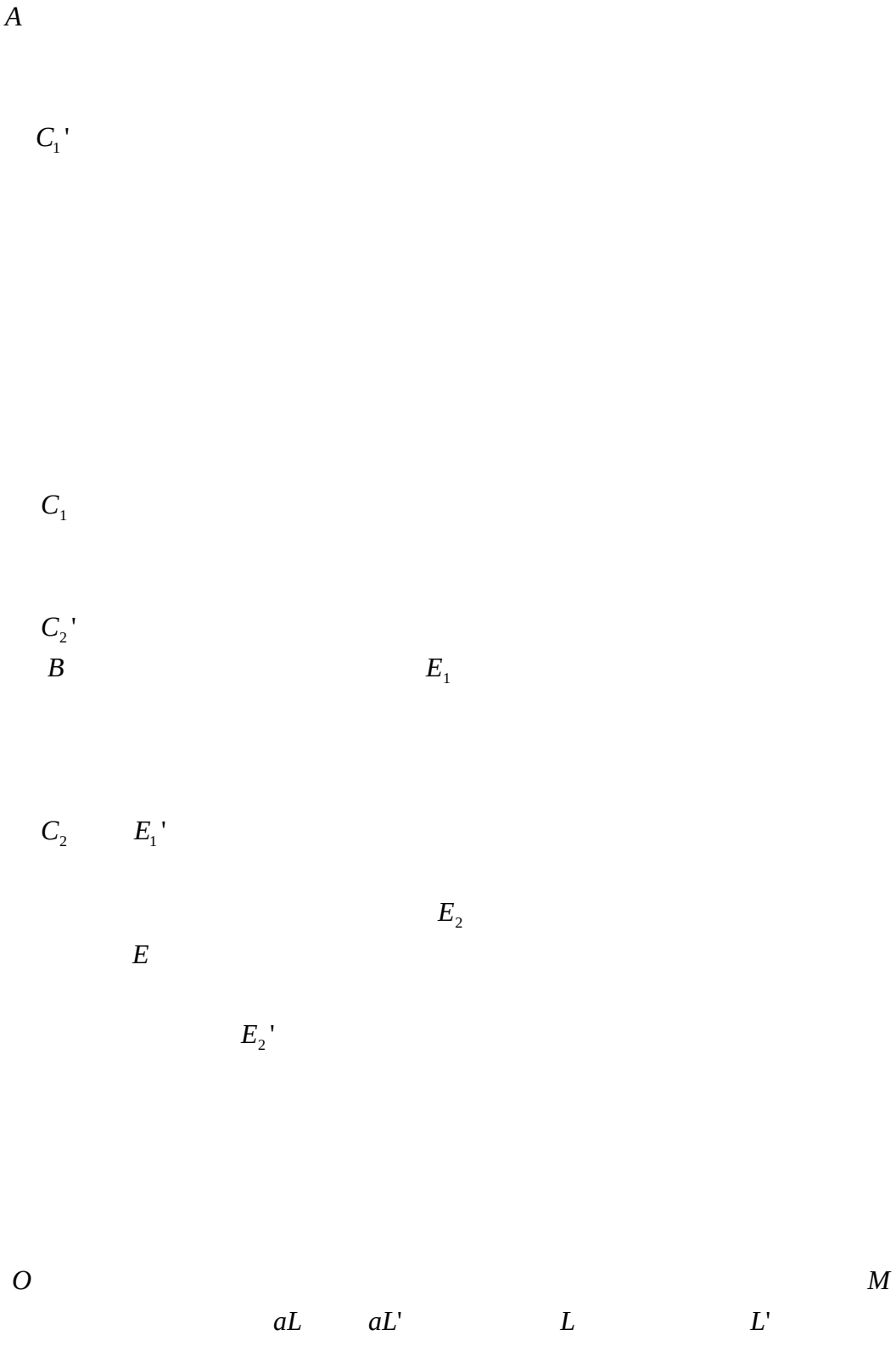

Figure 1: Home Country in case of Permanent Migrants

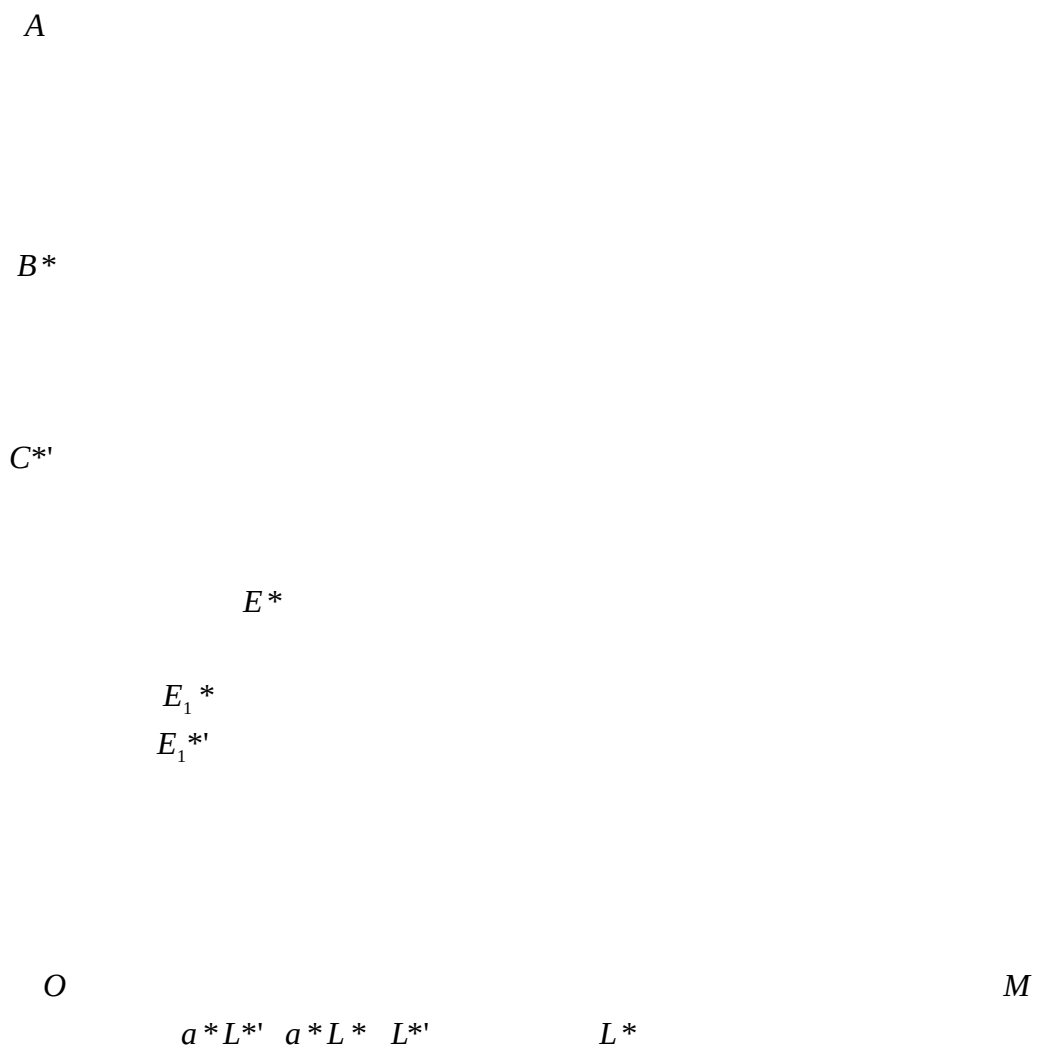

Figure 2: Foreign Country in case of Permanent Migrants

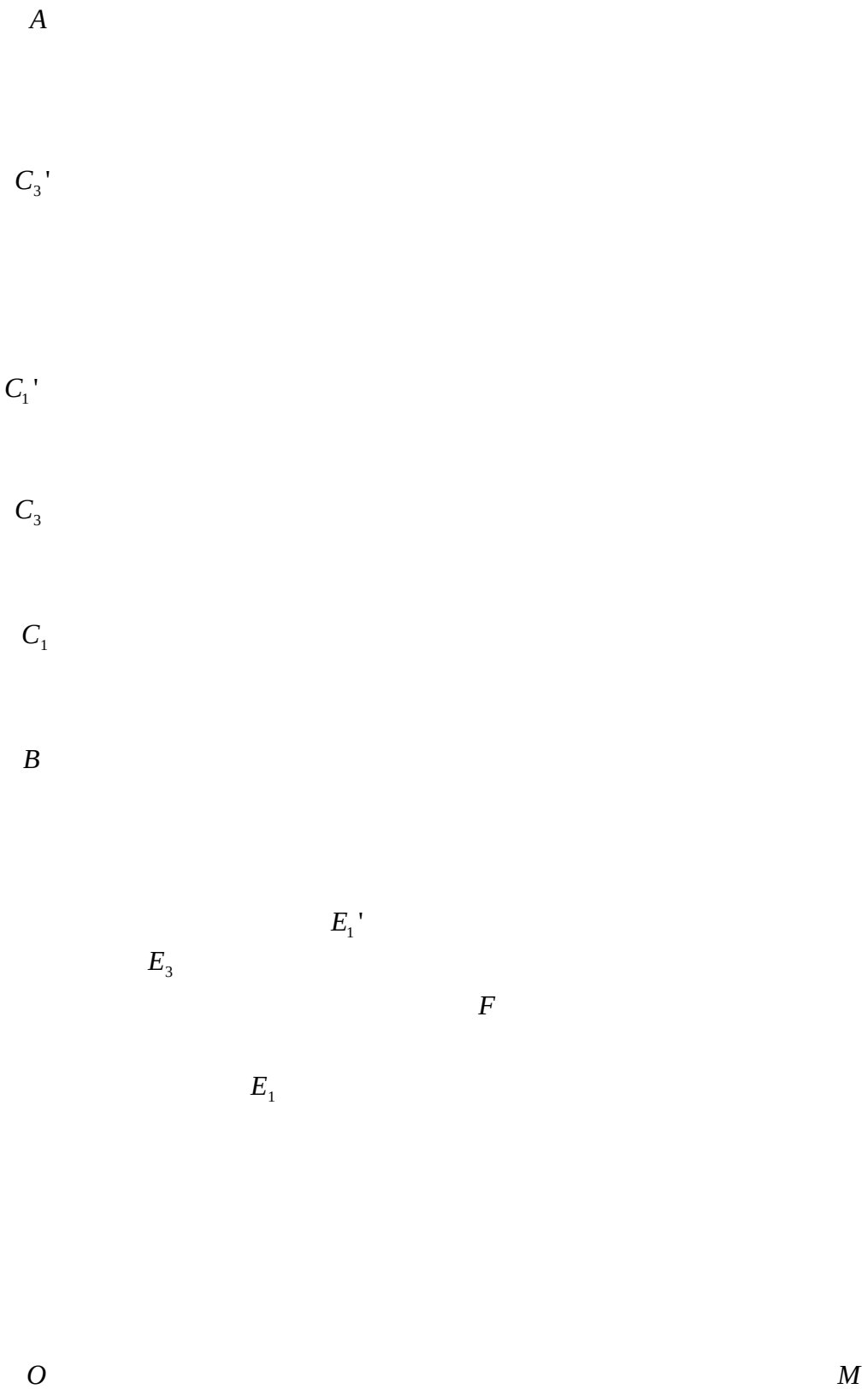

Figure 3: Home Country in case of M -type Cross-Border Workers

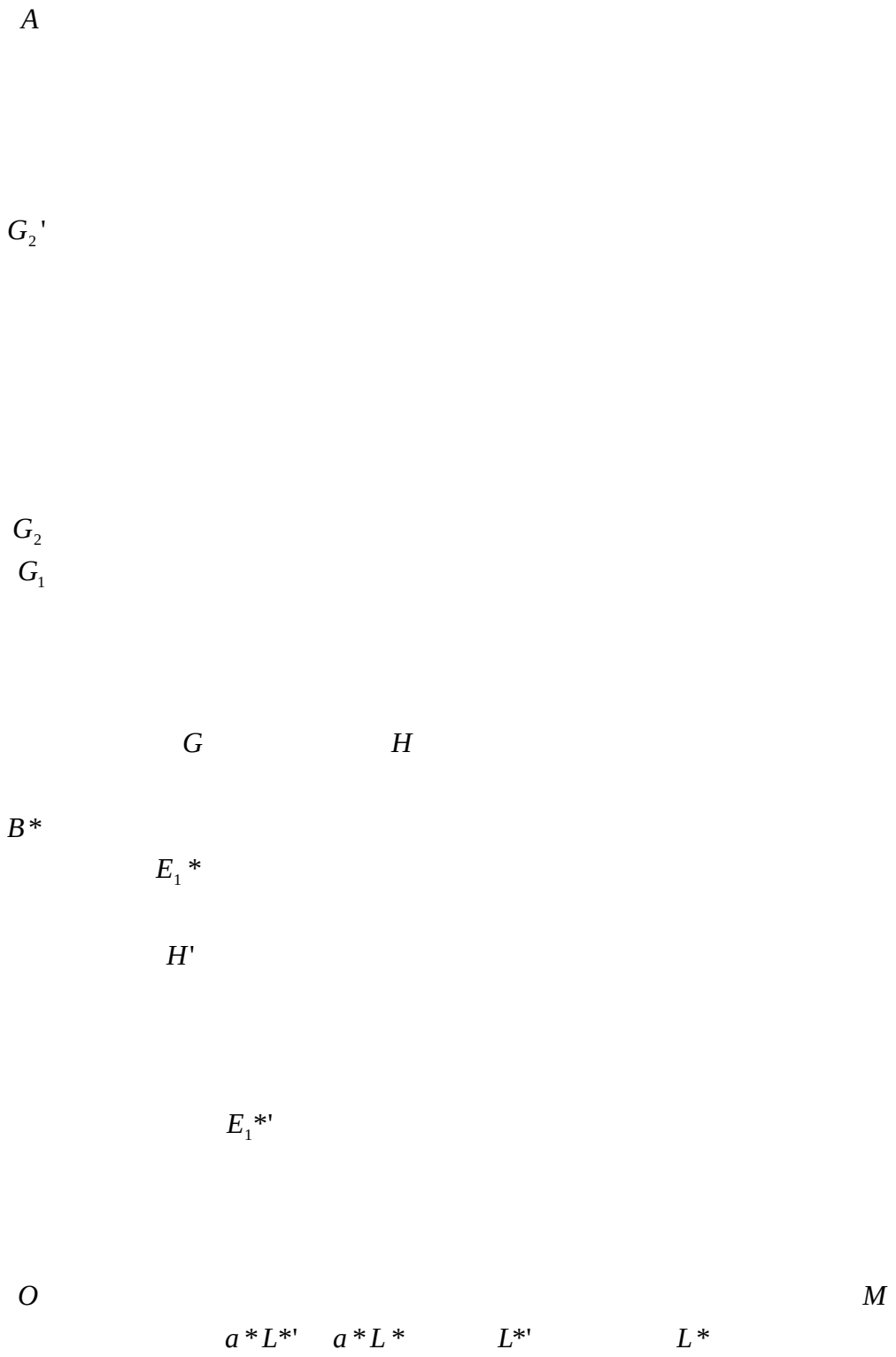

Figure 4-1: Foreign Country in case of M -type Cross-Border Workers (1)

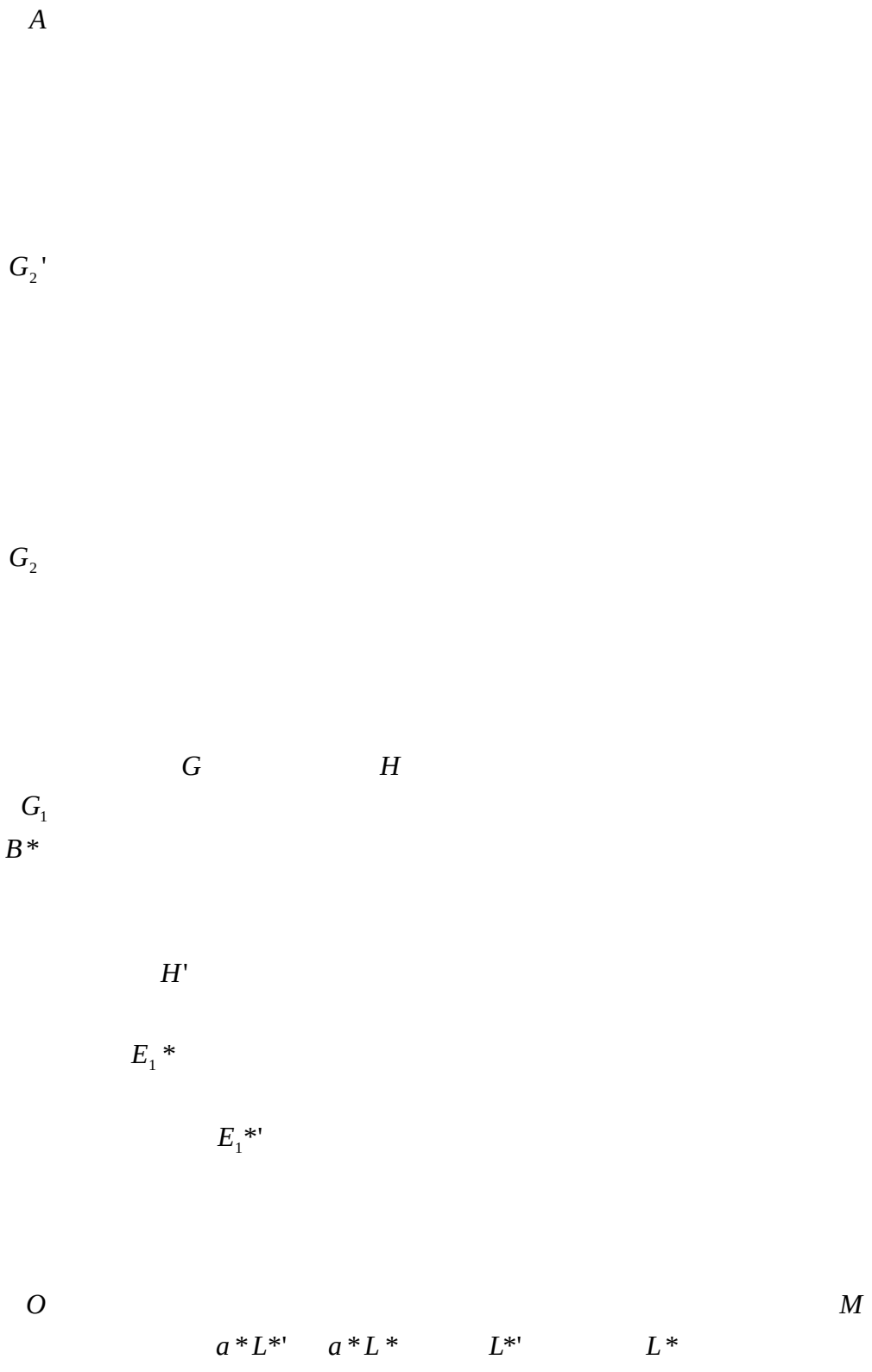

Figure 4-2: Foreign Country in case of M -type Cross-Border Workers (2)

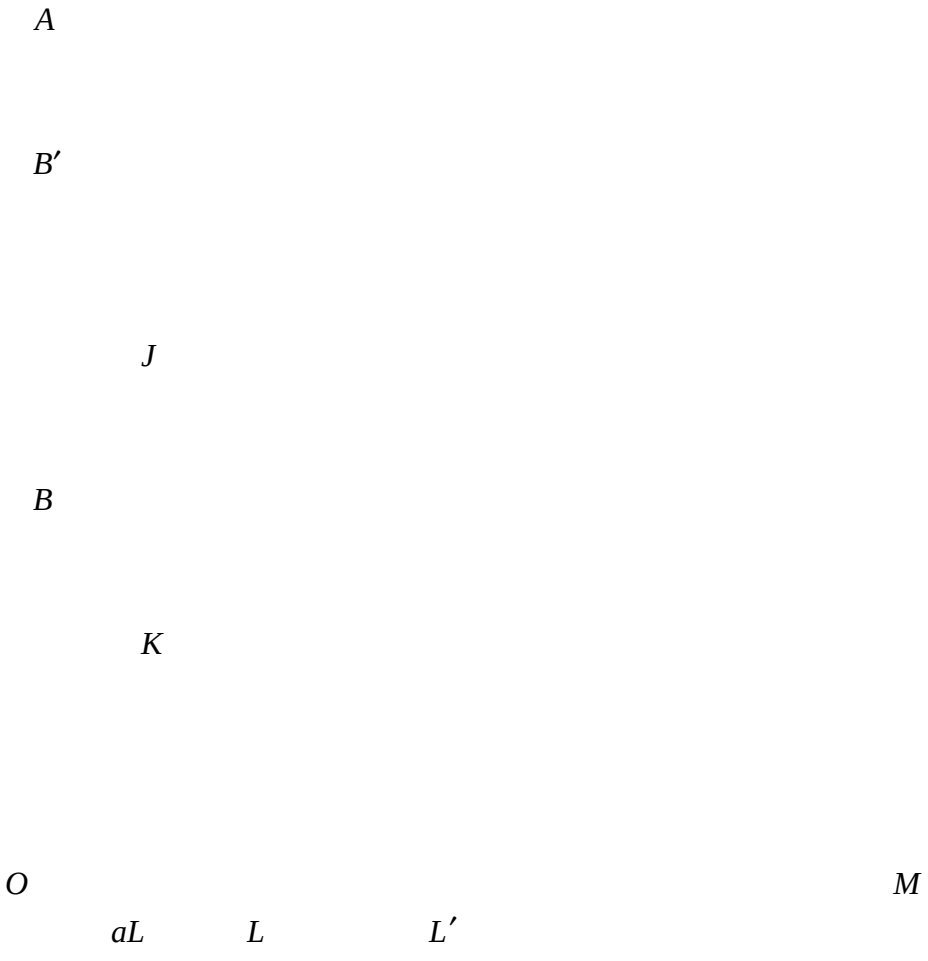

Figure 5: Home Country in case of A-type Cross-Border Workers

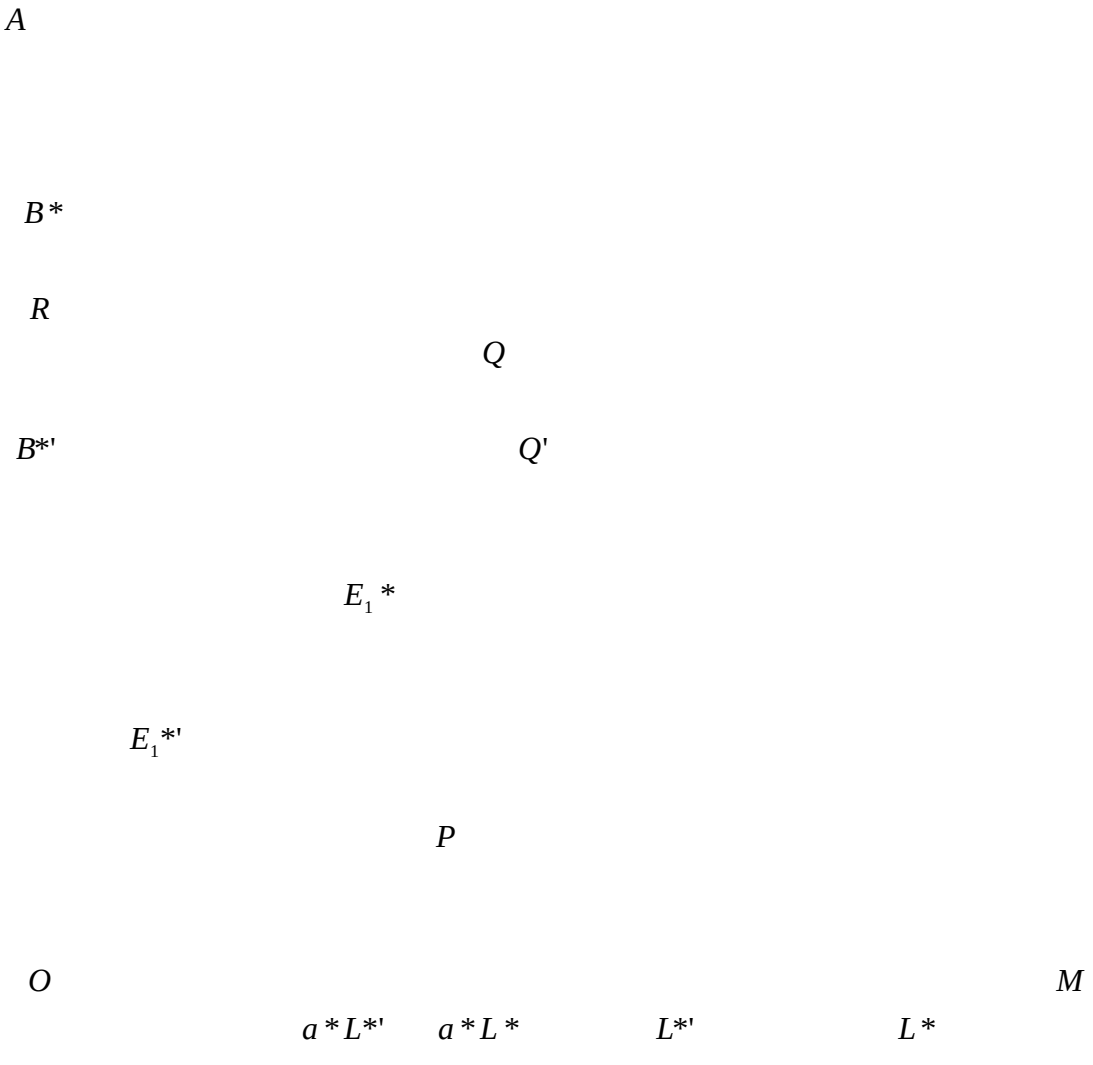

Figure 6-1: Foreign Country in case of A-type Cross-Border Workers (1)

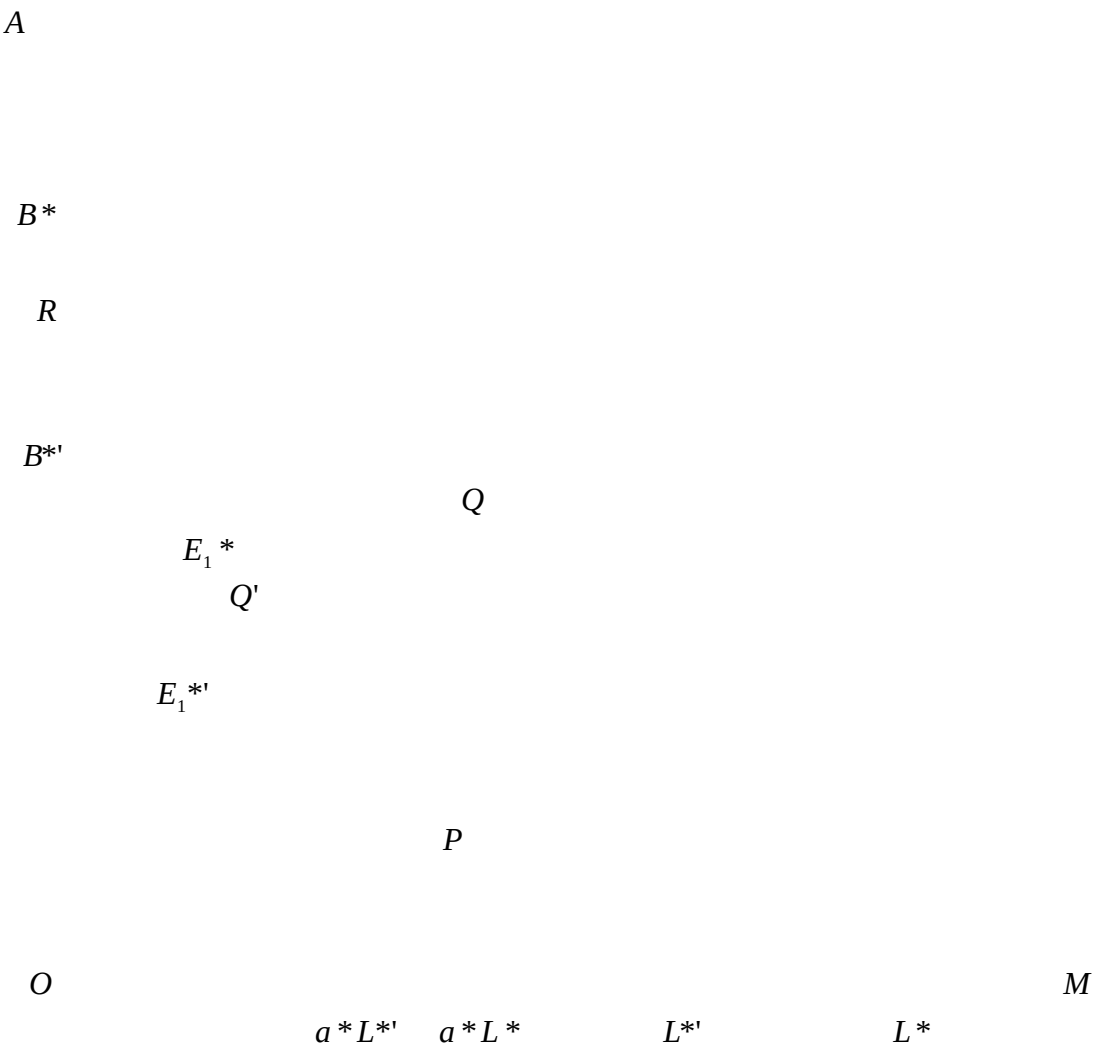

Figure 6-2: Foreign Country in case of A-type Cross-Border Workers (2)

A

B_T'

B_T S'
S_0'

T_0

T

S

O M
aL aL' L $(a+b)L'$ L'
$(a+a)L$ $(a+b)L$

Figure 7-1: Home Country with International Trade and Migration

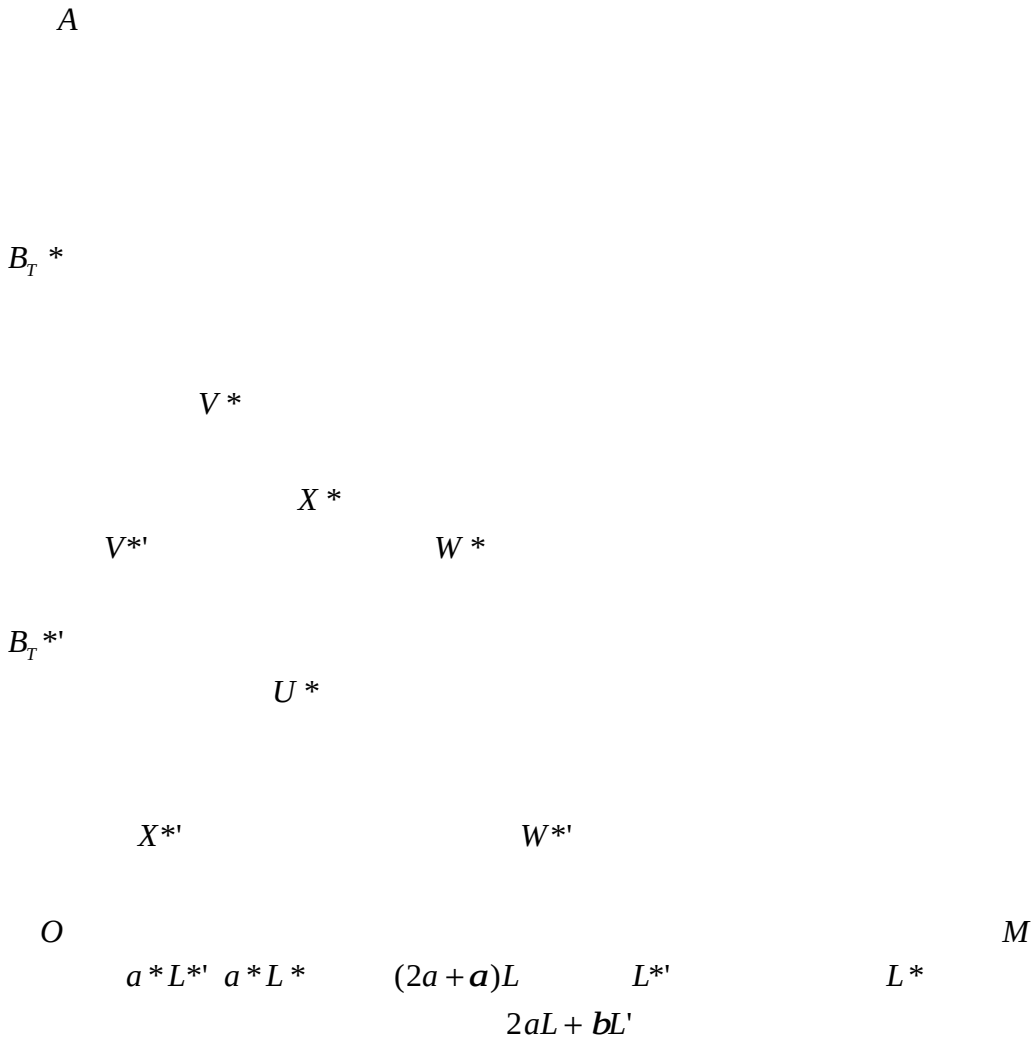

Figure 7-2: Foreign Country with International Trade and Migration