Illegal Migration and Capital Mobility under the Minimum Wage Legislation of a Host Country: The Case of Different Technologies*

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In this paper, we show an international edition of Harris-Todaro Model in which illegal migration is incorporated. The framework we take is Ramaswami-Bond-Chen model where a two-country, two-factor and one-good economy is concerned. In their model we introduce the Harris-Todaro minimum wage legislation into the host country of illegal migration. Different from the previous issues where technologies are assumed to be identical between countries, we consider that they differ between countries. And then we examine how the minimum wage and the enforcement policies of the host countries affect factor prices, the amount of migrants, unemployment and economic welfare. Considering different technologies, we show two graphical examples of equilibrium, according to the factor intensity ranking between countries. An anti-intuitive result is that the intensification of enforcement by the host country would give rise to an increase in illegal migration. We found that the intensification of enforcement by increasing the penalty for fine might be a desirable policy to improve the Home welfare, and a rise in the minimum wage could make the Foreign better off.

1. Introduction

Much attention has been paid intensively in the economics of international labor movement since the studies of international capital movement were sufficiently accumulated. One of the different features between these two factor movements is that a considerable part of international labor movement is illegal while illegal capital movement seems to be rare. Concerning the economic analysis of labor migration, Ethier (1986a, b) pioneered a model of illegal migration to analyze the effects of enforcement policies designed to reduce the level of this immigration. Being inspired by Ethier's works, Bond and Chen (1987) studied the economic effects of illegal migration in Ramaswami's two-country, two-factor and one-good model under the assumption that labor movement is illegal. Bond and Chen's work was followed by Yoshida (1993 and 1996) whose attention was centered on the welfare analysis and subsequently by Hiraiwa and Tawada (2003) who examined Bond and Chen's results under the circumstances where technologies differ between countries.

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In the Ramaswami-Bond-Chen model, both the host and the source countries of illegal migration are implicitly supposed to be well-developed without any government intervention. Relaxing the full-employment assumption, Brecher and Choudhri (1987) examined factor movements by introducing a type of real-wage rigidity in the high-wage country. In Brecher and Choudri (1987), optimal policy between labor movement and capital movement is tackled, and illegal migration is also considered, however, in the circumstance where technologies are assumed to be identical between countries. In reality, technologies between countries of illegal migration turn out to be different, so we shall analyze illegal migration by using the Ramaswami-Bond-Chen framework and considering different technologies between countries.

Section 2 presents the model of illegal migration. Section 3 studies the effects of the minimum wage legislation, the enforcement policy on factor prices, employment, and capital mobility in the economy. Section 4 directs the analysis on welfare of each country, as well as the whole world. Section 5 concludes the analysis by summarizing the main results and comparing with the earlier results.

2. The Model

Considering a world where there are two countries called as Home and Foreign, respectively, and Home is assumed to be relatively capital abundant. There are two factors of capital and labor that are used to produce a single commodity in each country. The production functions are denoted by $\tilde{Y}=F(\tilde{L}, \tilde{K})$ and $\tilde{Y}^*=F^*(\tilde{L}^*, \tilde{K}^*)$, respectively, where $\tilde{Y}$, $\tilde{L}$ and $\tilde{K}$ are the output, labor input and capital input of Home, and those of asterisk are of Foreign. Capital is allowed to be mobile internationally, so an outflow of capital denoted as k must occur from Home to Foreign. Technologies are assumed to be different between countries and the commodity of each country is supposed to be numeraire.

The Home country adopts the minimum wage legislation and the wage rate is institutionally fixed as $\bar{w}$ (above the full-employment level), and exceeds that of Foreign, which gives an incentive to the Foreign workers to migrate to Home. Thereby, the model is actually an international edition of Harris-Todaro Model in which illegal migration is incorporated. Supposing that the Home government adopts an anti-immigration policy and rejects immigrants, thus any migrant from Foreign to Home, if exists, is taken as illegal. The probability for illegal migrant workers to be detected by the enforcement is an increasing function of the level of expenditure for the enforcement. The function is denoted as $p(E)$, where E is the level of the enforcement expenditure. We suppose that $p(0)$, $p\leq 1$, $dp(E)/dE\equiv p'>0$, and $d^2p(E)/dE \equiv p'' < 0$. In Home, when an illegal worker is detected, a fine is imposed on the employer Z. stands for the fine that the employer has to pay for one illegal worker. Therefore, the cost of employing an illegal worker is $w+p(E)Z$, where w is the wage paid to illegal worker. The arbitrage condition for the Home employer to employ illegal workers is

$$\bar{w}=w+p(E)Z. \tag{1}$$

In Home, since the fixed wage rate is assumed to exceed the marginal product of labor under full employment, unemployment exists in labor market and the level of unemployment is presented as U (including both illegal immigrants and natives). According to Harris-Todaro (1970), each worker in the Home country faces the same probability of being employed and that all workers are risk neutral, the arbitrage condition for the Foreign workers to emigrate to Home is

$$w(L+I-U)/(L+I)=w^*, \tag{2}$$

where the left side hand of the equation is the Home expected wage for immigrants, w^* is the Foreign wage rate, L is the labor endowment of Home, and I stands for the volume of illegal migration. In view of (1) and (2), we have

$$\bar{w}=w^*(L+I)/(L+I-U)+p(E)Z. \tag{3}$$

Under the assumption of constant returns to scale technology, the production functions of the host and source countries can be rewritten, respectively, as $F(\tilde{L}, \tilde{K})=(K-k)f((L+I-U)/(K-k))$ and

$$F^*(\tilde{L}^*, \tilde{K}^*)=(K^*+k)f^*((L^*-I)/(K^*+k)),$$

where K, L^*, K^* are the capital endowment of Home and labor and capital endowments of Foreign, and $\tilde{L}=L+I-U$, $\tilde{K}=K-k$, $\tilde{L}^*=L^*-I$, $\tilde{K}^*=K^*+k$. Then the first order condition of profit-maximization yields the following equations

$$\bar{w}=f'[(L+I-U)/(K-k)], \tag{4}$$

$$w^*=f^{*\prime}[(L^*-I)/(K^*+k)], \tag{5}$$

$$r=f((L+I-U)/(K-k))-\bar{w}(L+I-U)/(K-k), \tag{6}$$

$$r^*=f^*((L^*-I)/(K^*+k))-w^*(L^*-I)/(K^*+k), \tag{7}$$

where f', $f^{*\prime}$ and r, r^* are the first derivatives of f, f^* and capital rental of Home and Foreign, respectively.

Since capital is mobile freely between countries, in equilibrium it must hold that

$$r=r^*, \tag{8}$$

Substitution of (6) and (7) into (8) yields

$$f((L+I-U)/(K-k))-\bar{w}(L+I)/(K-k)$$
$$=f^*((L^*-I)/(K^*+k))-w^*(L^*-I)/(K^*+k). \tag{9}$$

Now the basic model construction has been finished, and four endogenous variables I, U, w^* and k can be solved by four equations of (3), (4), (5) and (9) once the exogenous variables L, K, L^*, K^*, E, Z and $\bar{w}$ are given.

3. Comparative Static Analysis

In this section, we will investigate how the policies of enforcement and the minimum wage of Home affect illegal immigration, capital flow and unemployment. Now we differentiate the equations of (3), (4), (5) and (9) and obtain the following matrix

$$\begin{bmatrix} f''/(K-k) & -f''/(K-k) & 0 & f''(L+I-U)/(K-k)^2 \\ f^{*''}/(K^*+k) & 0 & 1 & f^{*''}(L^*-I)/(K^*+k)^2 \\ -w^*U/(L+I-U)^2 & w^*(L+I)/(L+I-U)^2 & (L+I)/(L+I-U) & 0 \\ 0 & 0 & (L^*-I)/(K^*+k) & 0 \end{bmatrix}$$

$$\times\begin{bmatrix} dI \\ dU \\ dw^* \\ dk \end{bmatrix}=\begin{bmatrix} 0 \\ 0 \\ -Zp' \\ 0 \end{bmatrix}dE+\begin{bmatrix} 0 \\ 0 \\ -p \\ 0 \end{bmatrix}dZ+\begin{bmatrix} 1 \\ 0 \\ 1 \\ (L+I-U)/(K-k) \end{bmatrix}d\overline{w}$$

. (10)

where $f''\equiv d^2f/d\lambda^2<0$, $f^{*''}\equiv d^2f^*/d\lambda^{*2}<0$, $\lambda\equiv(L+I-U)/(K-k)$ and $\lambda^*\equiv(L^*-I)/(K^*+k)$.

The determinant of the square matrix of (10) is

$$\Delta=\frac{f''f^{*''}w^*(L^*-I)}{(K^*+k)^2(K-k)(L+I-U)}\left(\lambda^*-\lambda-\frac{U}{K-k}\right)<0$$

(see Appendix I), (11)

which implies two cases of equilibrium according to the factor intensity ranking between countries, i.e. $\lambda>\lambda^*$ and $\lambda<\lambda^*$ as shown in Figure 1 and Figure 2, respectively.

In order to see how the endogenous variables are influenced by the exogenous variables, we solve (10) and obtain the following comparative static results according to Cramer's rule,

$$\frac{dI}{d\overline{w}}=\frac{1}{\Delta}\left\{\frac{f''w^*(L+I)}{(K-k)^3}+\frac{w^*f^{*''}(L^*-I)^2(L+I)}{(K^*+k)^3(L+I-U)^2}+\frac{f''f^{*''}(L^*-I)}{(K^*+k)^2(K-k)}\left(\frac{L^*-I}{K^*+k}-\frac{L+I}{K-k}\right)\right\}>0,$$

(12-1)

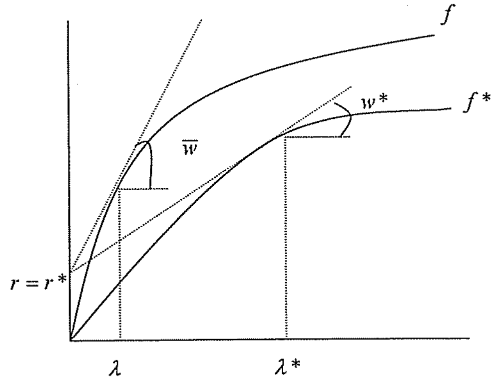

Figure 1 an equilibrium where the labor intensity of Foreign is larger

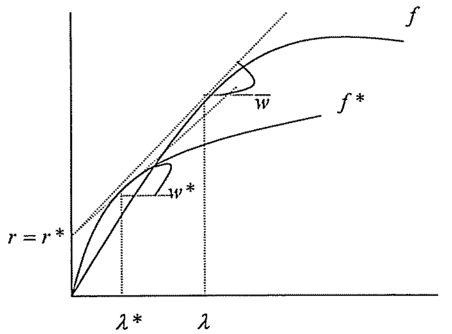

Figure 2 an equilibrium where the labor intensity of Home is larger

$$\frac{dU}{d\bar{w}}=\frac{1}{\Delta}\left\{\frac{f''w^*U}{(K-k)^3}+\frac{f^{*''}(L^*-I)^2Uw^*}{(K^*+k)^3(L+I-U)^2}\right.$$

$$\left.+\frac{f''f^{*''}(\lambda^*-\lambda)}{(K-k)(K^*+k)}\left(\frac{L^*-I}{K^*+k}-\frac{L+I}{K-k}\right)\right\}$$

$$>0 \text{ (if } \lambda<\lambda^*), \tag{12-2}$$

$$\frac{dw^*}{d\bar{w}}=\frac{f''f^{*''}w^*}{\Delta(K^*+k)(K-k)^2}\left(\frac{L^*-I}{K^*+k}-\frac{L+I}{K-k}\right)>0, \tag{12-3}$$

$$\frac{dk}{d\bar{w}}=\frac{1}{\Delta}\left\{\frac{f''f^{*''}}{(K^*+k)(K-k)}\left(\frac{L+I}{K-k}-\frac{L^*-I}{K^*+k}\right)-\frac{f^{*''}w^*(L+I)(L^*-I)}{(K^*+k)^2(L+I-U)^2}-\frac{f''w^*}{(K-k)^2}\right\}<0\,; \tag{12-4}$$

$$\frac{dI}{dE}=-\frac{Zp'(L^*-I)^2f''f^{*''}}{\Delta(K^*+k)^3(K-k)}>0 \tag{13-1}$$

$$\frac{dU}{dE}=\frac{Zp'(L^*-I)f''f^{*''}}{\Delta(K-k)(K^*+k)^2}(\lambda-\lambda^*)\gtrless 0 \quad (\text{as } \lambda\lessgtr\lambda^*), \tag{13-2}$$

$$\frac{dw^*}{dE}=0, \tag{13-3}$$

$$\frac{dk}{dE}=\frac{Zp'(L^*-I)f''f^{*''}}{\Delta(K^*+k)^2(K-k)}<0. \tag{13-4}$$

As for the effects on rental prices, according to equations of (6) and (7), we have $dr=-\lambda d\bar{w}$ and $dr^*=-\lambda^* dw^*$, which implies that $\bar{r}$ and r^* change in the opposite direction to $\bar{w}$ and w^*, respectively.

According to (12), a rise in the Home minimum wage brings about an increase in illegal immigration, and a decrease in Home capital outflow. The result is intuitive in that a rise in the Home minimum wage enlarges the wage gap between Home and Foreign thus attracts more immigrants. It should be noted that a rise in $\bar{w}$ also brings about a rise in the Foreign wage rate as (12-3) shows, for it leads to a fall in the labor intensity of Foreign (see Appendix II). Hence the Foreign rental falls and Home capital outflow decreases. As for the effect on Home unemployment, three forces should be taken into account. The first is that a rise in $\bar{w}$ decreases labor demand, the second is that an increase in illegal immigrants intensifies the competition of job vacancies, and the third is that the decrease in Home capital outflow favors for the employment in Home. Therefore, the overall effect on unemployment in Home depends on the relative magnitude of these three effects. If capital is more intensively used in Home than Foreign, i.e. $\lambda^*>\lambda$, the third force is so small that unemployment of Home will increase as the result of a rise in $\bar{w}$.

Allowing capital to be mobile internationally, the effect of the intensification of enforcement by Home is anti-intuitive. That is the intensification of enforcement by Home brings about an increase in illegal immigration as shown by (13-1). The mechanism is that an increase in E or Z decreases the wage (w) paid to illegal immigrants according to the arbitrage condition of (1), so the Foreign wage is tended to be lowered according to the arbitrage condition of (2), thus illegal migration is encouraged. As for the effect on factor prices, remembering that profit maximization implies that wage determines rental or vice versa through factor-use ratio, so it is easy to infer that the changes in exogenous variables of E or Z do not influence the factor prices as long as $\bar{w}$ is kept unchanged. Since illegal migrants increase, the outflow of Home capital must decrease so as to keep factor prices constant as shown in (13-4). Now, we shall see why the anti-intuitive result occurs when capital is allowed to move freely internationally. This can be explained in the standpoint of the source country, since capital inflow decreases, the labor demand L^*-I of the source country will be reduced, thus the amount of illegal migrants will increase as long as the labor endowment L^* is kept constant. The effect on Home unemployment is different according to the ranking of factor-use intensity between countries shown in (13-2). The intensification of enforcement increases illegal immigrants, which would intensify job competition in Home give rise to an increase in unemployment; however, it decreases Home capital outflow, which favors for the employment in Home. Considering $\frac{dI}{dk}=-\lambda^*$ (see Appendix III), when labor is more intensively used in Foreign than in Home, i.e. $\lambda^*>\lambda$, the effect of the increase in illegal immigrants is much larger, so that it brings about an increase in the Home unemployment; whereas, when capital is more intensively used in Foreign than in Home, i.e. $\lambda^*<\lambda$, the effect of the decrease in Home capital outflow is dominant, so that it gives rise to a decrease in the Home unemployment.

The effect of a change in the fine Z is qualitatively the same as that of E. In fact, dI/dZ, dU/dZ, dw^*/dZ and dk/dZ are obtained as those of dI/dE, dU/dE, dw^*/dE and dk/dE respectively, but by the replacement of $p'Z$ with p in (13-1) ~ (13-4).

4. The Welfare Analysis

Now we turn to tackle the welfare analysis of each country and the world. We assume that all consumers' preferences are the same and dependent only on the produced good. Therefore, each country's welfare is measured by its national income and the world welfare is measured by the world income.

Taking this into account, we examine how the national income of each country is affected by the minimum wage and enforcement policies. The Home and Foreign national incomes are written as

$$Y=L(L-U+I)/(L+I)\bar{w}+r(K-k)+r^*k+ZpI-E, \tag{14}$$

$$Y^*=(L^*-I)w^*+r^*K^*+Iw(L+I-U)/(L+I), \tag{15}$$

respectively. Since $r=r^*$ in equilibrium, (14) can be rewritten as

$$Y=L(L-U+I)/(L+I)\bar{w}+rK+ZpI-E, \tag{14'}$$

Through (2), (15) can be rewritten as

$$Y^* = L^* w^* + r^* K^*. \tag{15$'$}$$

First we examine the effect of an increase in the expenditure for enforcement. Differentiating (14)′ and (15)′ with respect to E and Z, we have

$$\frac{dY}{dE} = -\frac{L\overline{w}}{L+I}\frac{dU}{dE} + \left(\frac{LU\overline{w}}{(L+I)^2} + Zp\right)\frac{dI}{dE} + Zp'I - 1, \tag{16}$$

$$\frac{dY^*}{dE} = 0\,; \tag{17}$$

$$\frac{dY}{dZ} = -\frac{L\overline{w}}{L+I}\frac{dU}{dZ} + \left(\frac{LU\overline{w}}{(L+I)^2} + Zp\right)\frac{dI}{dZ} + pI > 0 \quad (\text{if } \lambda > \lambda^*), \tag{18}$$

$$\frac{dY^*}{dZ} = 0\,; \tag{19}$$

and the effect on the world welfare can be obtained, respectively, as

$$\frac{d(Y+Y^*)}{dE} = -\frac{L\overline{w}}{L+I}\frac{dU}{dE} + \left(\frac{LU\overline{w}}{(L+I)^2} + Zp\right)\frac{dI}{dE} + Zp'I - 1, \tag{20}$$

$$\frac{d(Y+Y^*)}{dZ} = -\frac{L\overline{w}}{L+I}\frac{dU}{dZ} + \left(\frac{LU\overline{w}}{(L+I)^2} + Zp\right)\frac{dI}{dZ} + pI > 0 \quad (\text{if } \lambda > \lambda^*). \tag{21}$$

The above results indicate that an increase in the penalty for Home firms that employ illegal immigrants can improve the Home welfare as well as the world welfare if labor is more intensively used in Home than in Foreign ($\lambda > \lambda^*$). In this case, since the employment of the whole world is increased, the world welfare is improved. Considering the factor prices of the Foreign are not affected, all of this increase in world income accrues to Home income. Compared with the effect of Z, the effect of E on the Home welfare and the world welfare is ambiguous for the expenditure of enforcement involves extra cost for the Home government.

Now we direct to the welfare effects of the minimum wage policy by Home. Differentiation of equations (14)′ and (15)′ yields

$$\frac{dY}{d\overline{w}} = -\frac{(L-U+I)(Lk+KI)}{(K-k)(L+I)} - \frac{\overline{w}L}{L+I}\frac{dU}{d\overline{w}} + \left(Zp + \frac{LU\overline{w}}{(L+I)^2}\right)\frac{dI}{d\overline{w}}, \tag{22}$$

$$\frac{dY^*}{d\overline{w}} = \frac{L^*k + IK^*}{K^*+k}\frac{dw^*}{d\overline{w}} > 0, \tag{23}$$

and the effect on the world welfare is obtained as

$$\frac{d(Y+Y^*)}{d\overline{w}} = -\frac{(L-U+I)(Lk+KI)}{(K-k)(L+I)} - \frac{L\overline{w}}{L+I}\frac{dU}{d\overline{w}} + \left(Zp + \frac{LU\overline{w}}{(L+I)^2}\right)\frac{dI}{d\overline{w}} + \frac{L^*k + IK^*}{K^*+k}\frac{dw^*}{d\overline{w}}. \tag{24}$$

According to the above results, a rise in the Home minimum wage makes Foreign better off, while the effect on the Home welfare, as well as the world welfare, is ambiguous. The Foreign welfare is improved in that the Foreign wage rate is raised by an increase in illegal migrants due to a rise in the Home minimum wage. Since a rise in Home minimum wage also brings about ambiguous effect on unemployment, the effect on the Home welfare and the world welfare is not decisive.

5. Conclusion

This paper has extended the analysis of illegal migration by using the Ramswami-Bond-Chen's framework under the supposition that the high-wage country (host country) adopts the minimum wage legislation. Different from the full-employment case examined by Bond and Chen, Yoshida, Hiraiwa and Tawada, we allow for unemployment and examine the effects of illegal migration on factor prices, unemployment and capital mobility. Comparing our results to those of the above literatures, we see similar effect of the enforcement by the host country on illegal immigrants when capital is specific to country. However, we obtained anti-intuitive result that the intensification of enforcement by the host country could give rise to an increase in illegal migration in the unemployment case when capital mobility between countries is allowed. We see a rise in the minimum wage would make Foreign better off.

Brecher and Choudri (1987) considered illegal migration in the case where the technology is assumed to be the same between countries, and showed that Home capital outflow could benefit the host country unambiguously. While we showed that Home capital outflow could make Home worse off in the case where the labor intensity of Home is relatively large ($\lambda > \lambda^*$); and the effect is ambiguous in the case there the labor intensity of Home is relatively small ($\lambda < \lambda^*$) (see Appendix IV). Comparative static results are shown in Table 1.

Appendix I

Now we turn to the sign of Δ in Equ. (11). This is closely related to the dynamic of the system. Under present assumption, the dynamic adjustment mechanism of the system should be specified as follows:

$$\dot{k} = a_1(r^* - r), \tag{A1}$$

$$\dot{I} = a_2\{w(L+I-U)/(L+I) - w^*\}, \tag{A2}$$

$$\dot{U} = a_3\{\overline{w} - f'(L-U+I)/(K-k)\}. \tag{A3}$$

where "." denotes differentiation with respect to time, and a_i is the positive

Table 1 Comparative Static Results (the case of the minimum wage of the host country)

	I	U	w^*	r^*	k	Y	Y^*	$Y+Y^*$
E↑	↑	↑ ($\lambda^* > \lambda$)	△	△	↓	?	△	?
		↓ ($\lambda^* < \lambda$)						
Z↑	↑	↑ ($\lambda^* > \lambda$)	△	△	↓	↑ ($\lambda^* < \lambda$)	△	↑ ($\lambda^* < \lambda$)
		↓ ($\lambda^* < \lambda$)						
$\overline{w}$↑	↑	↑ ($\lambda^* > \lambda$)	↑	↓	↓	?	↑	?

↑, ↓, and △ indicate an increase, decrease and no change in the variables, respectively.

coefficient measuring the speed of adjustment. The first two equations show that capital flows into the country with a higher rental, and that labor migrates into the country with higher wage. The third equation shows that the Home unemployment is adjusted according to the Home wage and the marginal labor productivity.

Since a fixed point of the values of the endogenous variables which satisfies $\dot{k}=\dot{I}=\dot{U}=0$ is the equilibrium point, we write the above three equations with linear approximation in equilibrium as the following

$$\begin{bmatrix} \dot{k} \\ \dot{I} \\ \dot{U} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} k^e-k \\ I^e-I \\ U^e-U \end{bmatrix}, \qquad (A4)$$

where the terms of Jacobian matrix satisfy

$$a_{11}\equiv\frac{(\lambda^*)^2 f^{*\prime\prime}}{K^*+k},\ a_{12}\equiv\frac{\lambda^* f^{*\prime\prime}}{K^*+k},\ a_{13}\equiv 0,$$

$$a_{21}\equiv\frac{\lambda^* f^{*\prime\prime}}{K^*+k},$$

$$a_{22}\equiv\frac{f^{*\prime\prime}}{K^*+k}+(\overline{w}-Zp)\frac{U}{(L+I)^2},$$

$$a_{23}\equiv -\frac{\overline{w}-Zp}{L+I},$$

$$a_{31}\equiv -\frac{\lambda f''}{K-k},\ a_{32}\equiv -\frac{f''}{K-k},\ a_{33}\equiv\frac{f''}{K-k}.$$

The determinant of the coefficient of $(A4)$ can be obtained as

$$Det(A)=\frac{-\lambda^* f^{*\prime\prime} f''(\overline{w}-Zp)}{(K^*+k)(K-k)(L+I)} \left[\frac{L+I-U}{L+I}-\frac{\lambda}{\lambda^*}\right]. \qquad (A5)$$

Since a necessary condition for local stability of equilibrium is

$Det(A)>0$,

according to $(A5)$, we can get $\frac{L+I}{K-k}-\frac{L^*-I}{K^*+k}>0$, where both $\lambda^*>\lambda$ and $\lambda^*<\lambda$ exist. So the sign of Δ is negative, i.e. $\Delta<0$.

Appendix II

In order to see the effect of a rise of $\overline{w}$ on the factor-use ratio of Foreign, we differentiate λ^* with respect to $\overline{w}$ and have the following result

$$\frac{d\lambda^*}{d\overline{w}}=-\frac{L^*-I}{(K^*+k)^2}\frac{dk}{d\overline{w}}-\frac{1}{K^*+k}\frac{dI}{d\overline{w}}, \qquad (A6)$$

Substituting (12-1) and (12-4) into $(A6)$, we obtain

$$\frac{d\lambda^*}{d\overline{w}}=\frac{f''w^*}{\Delta(K^*+k)(K-k)^2}\left(\lambda^*-\lambda+\frac{U}{K-k}\right)<0 \qquad (A7)$$

Appendix III

Let $\lambda\equiv(L+I-U)/(K-k)$ and $\lambda^*\equiv(L^*-I)/(K^*+k)$. Consider a change in E. This change does not affect any factor prices, so that λ and λ^* are kept constant. Therefore, total differentiation of λ and λ^* yields

$$d\lambda=\frac{L+I}{(K-k)^2}dk+\frac{1}{K-k}dI=0, \qquad (A8)$$

$$d\lambda^*=-\frac{L^*-I}{(K^*+k)^2}dK-\frac{1}{K^*+k}dI=0. \qquad (A9)$$

Equations $(A8)$ and $(A9)$ imply

$$dI/dk=-(K-k)/(L+I-U)=-\lambda, \qquad (A10)$$

$$dI/dk-dU/dk=-(K^*+k)/(L^*-I)=-\lambda^*.$$

$(A11)$

Appendix IV

Let us examine the effect of Home capital outflow on the Home welfare. Differentiating the national income expressed in (18)′ with respect to k, we obtain

$$\frac{dY}{dk}=-\frac{L\bar{w}}{L+I}\frac{dU}{dk}+\left[\frac{LU\bar{w}}{(L+I)^2}+Zp\right]\frac{dI}{dk}. \quad (A12)$$

In order to see the effect of capital outflow on the Home unemployment and illegal migration, we totally differentiate Equ. (4) and (5), taking $k=0$ initially, and obtain the results as the following matrix

$$\begin{bmatrix} f''/K & -f''/K \\ f^{*\prime\prime}/K^* & 0 \end{bmatrix}\begin{bmatrix} dI \\ dU \end{bmatrix}=\begin{bmatrix} -f''(L+I-U)/K^2 \\ -f^{*\prime\prime}(L^*-I)/(K^*)^2 \end{bmatrix}dk+\begin{bmatrix} 1 \\ 0 \end{bmatrix}d\bar{w}, \quad (A13)$$

of which the determinant is obtained as

$$\Delta=\frac{f''f^{*\prime\prime}}{KK^*}>0.$$

According to Cramer's Rule, we obtain the following comparative static results

$$\frac{dI}{dk}=-\frac{f''f^{*\prime\prime}(L^*-I)}{\Delta K(K^*)^2}<0, \quad (A14)$$

$$\frac{dU}{dk}=\frac{f''f^{*\prime\prime}(\lambda-\lambda^*)}{\Delta KK^*}\gtrless 0 \quad (\text{as } \lambda\gtrless\lambda^*). \quad (A15)$$

Through $(A14)$ and $(A15)$, we have

$$\frac{dY}{dk}<0 \quad (\text{if } \lambda>\lambda^*). \quad (A16)$$

which implies Home capital outflow decreases the Home welfare in the case where the labor intensity of Home is relatively large.

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