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# Trade and Labor Market Integration with Heterogeneous Labor

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**Keywords:** diversity; labor market integration; pattern of trade; income distribution

**JEL classification:** F15; F22

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# Trade and Labor Market Integration with Heterogeneous Labor


## Abstract

This paper explores the impact of labor market integration between an advanced country (North) and backward country (South) on income distribution and pattern of trade by making use of a two-sector, competitive trade model with heterogeneous labor. We prove that, for the North, after the labor market integration, none of the workers is worse off; instead some people earn higher wages than before. And, for the South, some workers are worse off. In addition, we find that the pattern of trade for the integrated economy might reverse.



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## 1. Introduction

In this paper, we set up a two-sector, general equilibrium model to explain why labor market integration between an advanced country (North) and backward country (South) would benefit the high ability workers and hurt the low ability workers and hence worsen the distribution of income.

In the traditional Heckscher-Ohlin-Samuelson model, if the countries are in the same diversification cone, free trade in goods would result in factor price equalization, which implies that trade and factor movements are substitutes. In fact, factor price equalization is not ensured under labor market integration. Casual observation suggests that wages in the more-developed country (or region) are higher than those in the less-developed country (or region) in the prominent examples of labor market integration, for example, West versus East Germany, the United States versus Puerto Rico, Northern versus Southern Italy and the European Union versus Spain. In this scenario, Spilimbergo (1999) ascribes the difference in wage between North and South to the availability of fixed factors (e.g., capital, and the physical infrastructure). Namely, these fixed factors provide workers in the North (South) with more (less) labor productivity, which then lead to higher (lower) wages in the North (South). However, the difference in ability of workers between North and South might be one important reason why the wages in the North are higher than those in the South. Therefore, our model will stress the character of heterogeneous labor.

Whether labor market integration should raise income inequality in an integrated bloc or not is an important issue. Most studies suggest that economic integration should exacerbate income inequality in the European Union, for example, Morris et al. (1994), Kosonen (1995), Western (1997), Alderson (2004), Alderson et al. (2005) and Beckfield (2006). But Ruffin (1988) develops a “missing link” Ricardian model with heterogeneous labor. To proceed further, by using the feature of “corner solution”, we

can easily extend the Ruffin's model to show not only that labor market integration leads to factor price equalization but also that it doesn't affect income distribution. In the recent literature, Grossman and Maggi (2000) construct a competitive model of trade between the more-developed countries. They observe that the working population in a country like Germany is less heterogeneous compared to the United States, and then derive the impact of trade on income distribution. They argue that trade benefits the low-talent workers who work in the export sector and harms the middle-talent workers who work in the import sector before and after the opening of trade. On the contrary, whether the workers who switch occupation from the importable sector to the exportable sector gain or lose from trade must depend on consumption shares. In other words, trade decreases income inequality. On the other hand, Grossman (2004) specifies an analytical framework involving the feature of imperfect labor contracts to explore the effect of trade between two similar countries on income distribution. Contrary results, that trade benefits the high-talent workers and damages the low-talent workers, are obtained. Namely, trade causes a deterioration of income distribution. In addition, Grossman and Helpman (1991) develop a two-country model of endogenous innovation and imitation to prove that wages of the North are higher than those of the South after integration, i.e., the income inequality between countries rises after integration.

Whether labor market integration should influence the pattern of trade (POT) for an integrated economy or not is also an interesting issue. In some pioneering work, Grossman and Maggi (2000) and Grossman (2004) prove that a country like Germany with a less diverse population will export passenger cars, industrial equipment and chemicals, produced by a supermodular technology. In contrast, a country like the United States with a more diverse population will export software produced by a submodular technology. They argue that diversity of workers' talent plays an important role in determining POT.

The question posed in this paper is: How does the labor market integration between advanced and backward countries (say, North and South) affect income distribution and POT of the integrated bloc? In order to address these topics, we construct a two-sector, competitive trade model with heterogeneous labor, as derived by Grossman and Maggi (2000). Assume that the talent of workers has a uniform distribution. We shall show that, after the integration between the advanced country (North) and backward country (South), the POT for the integrated economy might reverse, from import good *S*, produced by a submodular technology, and export good *C*, produced by a supermodular technology, to export *S* and import *C*. In addition, we also prove that, for the advanced country, after the labor market integration, none of the workers is worse off; instead some people earn higher wages than before. And, for the backward country, some workers are worse off.

The remainder of this paper is organized as follow. Section 2 establishes the theoretical model with heterogeneous labor, and solves for the equilibrium. Section 3 shows that the POT for the integrated economy might reverse due to labor market integration. The relationship between integration and income redistribution is considered in Section 4. Section 5 concludes the paper.

## 2. The model

In this section we set out the main assumptions underlying the analysis and introduce the basic nature of the production technologies. The supermodular and submodular technologies, as derived by Grossman and Maggi (2000), state that workers of different skill levels interact. There are some production activities in which workers perform different tasks which are highly complementary (e.g., complicated manufacturing processes). If performing one better increases the marginal product of better performance in the other, the two tasks could be viewed as complementary tasks. In short, the supermodular technology means that the property of the production

incorporates the aforementioned viewpoint of complementarity. On the other hand, the notion opposite to supermodularity is submodularity. Generally speaking, submodular production technology could characterize some production processes including those requiring creativity or problem solving. In these situations, we could argue that the marginal value of a more talented inventor rises when the abilities of other workers on the same project are less (see Milgrom and Roberts (1990), Kremer (1993) and Grossman and Maggi (2000)).

Now consider that the economy comprises two small countries, *A* and *B*, each with a continuum of workers. Let $L^j$ be the measure of labor forces in country $j$ ($j \in \{A, B\}$). Every worker's talent $t$ is heterogeneous and perfectly observable, both to himself and to all potential employers. Hence, talent $t$ could represent a worker's endowment and years of schooling. Assume that talent's distribution is the uniform distribution and has probability density function $\phi^j(t)$ as shown below:

$$\phi^j(t) = \begin{cases} \dfrac{1}{b^j}, & \text{if } t \in [t^j_{\min}, t^j_{\max}], \\ 0, & \text{otherwise}, \end{cases}$$

where

$$t^j_{\min} = \bar{t}^{\,j} - \frac{b^j}{2}, \quad t^j_{\max} = \bar{t}^{\,j} + \frac{b^j}{2}.$$

The variable $b^j$ represents the diversity of talent. The larger the variable $b^j$ is, the more diverse the distribution of talent will be. We assume that $t^j_{\min}$ and $t^j_{\max}$ are the minimum and maximum talent levels respectively and $\bar{t}^{\,j}$ is the average talent level.

Suppose that there are two sectors in each country and that both countries are similar in their production technologies. The production process involves two tasks including task *x* and task *v* in each sector. The tasks are indivisible and each task is performed by exactly one worker. In one sector which we denote the *C* sector, a pair of workers performs complementary tasks. Let $F^j_C(t_x, t_v)$ be the supermodular

production function in the *C* sector when the first task (task *x*) is performed by a worker with talent $t_x$ and the second (task *v*) by a worker with talent $t_v$. For simplicity, we assume that the complementarity is extreme. Hence, the production function of *C* sector can be specified as:

$$F_C^j(t_x, t_v) = \min\{t_x, t_v\}.$$

In the other sector which we denote the *S* sector, the talent of the superior worker fully dominates the effective output. The workers toil on substitutable tasks. Let $F_S^j(t_x, t_v)$ be the submodular production function in the *S* sector. For simplicity, we also assume that the substitutability is extreme. Thus, the production function of *S* sector can be specified as:

$$F_S^j(t_x, t_v) = \max\{t_x, t_v\}.$$

Grossman and Maggi (2000) prove that the *C* sector employs workers with similar abilities and the *S* sector attracts the most-talented and least-talented workers in equilibrium. We define that the variable $\hat{t}^j$ represents the least-talented worker and $m^j(\hat{t}^j) = 2\bar{t}^j - \hat{t}^j$ represents the most-talented worker in the *C* sector. Consequently, total output of good *C* (denoted by $Y_C^j$) is

$$Y_C^j = L^j \int_{\hat{t}^j}^{m^j(\hat{t}^j)} F_C^j(t,t)\phi^j(t)dt = \frac{L^j \bar{t}^j}{b^j}(\bar{t}^j - \hat{t}^j). \quad (1)$$

And total output of good *S* (denoted by $Y_S^j$) is

$$Y_S^j = L^j \int_{t_{\min}^j}^{\hat{t}^j} F_S^j[t, m^j(t)]\phi^j(t)dt = \frac{L^j}{2b^j}(\frac{b^j}{2} - \bar{t}^j + \hat{t}^j)(\frac{b^j}{2} + 3\bar{t}^j - \hat{t}^j). \quad (2)$$

Next, we will describe the production possibility frontier. By combining equation (1) with equation (2) and eliminating the variable $\hat{t}^j$ we can derive the $PPF^j$ which represents the production possibility frontier of country *j* as shown below:

$$Y_S^j = \frac{L^j}{2}(\frac{1}{2} - \frac{1}{L^j \bar{t}^j} Y_C^j)(\frac{b^j}{2} + 2\bar{t}^j + \frac{b^j}{L^j \bar{t}^j} Y_C^j). \quad (3)$$

Meanwhile, the marginal rate of transformation ($MRT^j$) can be calculated as follows:

$$\text{MRT}^j = 1 + \frac{b^j}{L^j \bar{t}^{j^2}} Y_C^j . \tag{4}$$

Assume that preferences in the countries *A* and *B* are identical and homothetic. Therefore, we can characterize a competitive, free-trade equilibrium. That is to say, the competitive equilibrium maximizes the national aggregate output at a given relative price, *p*, which represents the relative price of good *C*.

### 3. Labor market integration

Labor market integration means that workers can move freely between countries (regions). In our paper, assume that countries *A* and *B* join together to integrate a larger economic unit. Hence, we allow that workers are freely mobile between countries *A* and *B* after labor market integration. With that, we will analyze the impact of the labor market integration on POT and welfare.

After integration, the free movement of workers between countries *A* and *B* would lead to the changes of the labor forces and talent distribution. We make use of the superscript "*I*" to denote the variables after integration. Therefore, $L^I$ is the measure of labor forces ($L^I = L^A + L^B$) and $\phi^I(t)$ represents the probability density function of talent. At the same time, we assume that $t^I_{\min}$ and $t^I_{\max}$ are the minimum and maximum talent levels respectively, and $\bar{t}^I$ is the average talent level. Let $Y_C^I$ ($Y_S^I$) represent the aggregate output of good *C* (*S*) of countries *A* and *B* after integration. Under certain situations as will be considered in this paper, the $\phi^I(t)$ will also be a uniform distribution. Therefore, by using the analytical method of Section 2, we can derive the $\text{PPF}^I$ representing the production possibility frontier after integration as shown below:

$$Y_S^I = \frac{L^I}{2}\left(\frac{1}{2} - \frac{1}{L^I \bar{t}^I} Y_C^I\right)\left(\frac{b^I}{2} + 2\bar{t}^I + \frac{b^I}{L^I \bar{t}^I} Y_C^I\right), \tag{5}$$

where the variable $b^I$ denotes the diversity of talent after integration. Meanwhile, the marginal rate of transformation after integration ($\text{MRT}^I$) can be calculated as follows:

$$\text{MRT}^I = 1 + \frac{b^I}{L^I \bar{t}^{I^2}} Y_C^I . \quad (6)$$

For simplicity and without losing generality, suppose that the diversities of talent and the measures of labor forces in countries *A* and *B* are identical, i.e., $b^A=b^B=b$ and $L^A=L^B=L$. Therefore, the average talent levels in countries *A* and *B* will play an important role. Next, Sections 3.1 and 3.2 will analyze the impact of the labor market integration on POT and welfare under identical and different average talent levels respectively.

3.1 Integration of identical countries

Suppose that countries *A* and *B* are identical before labor market integration. In other words, the average talent levels in countries *A* and *B* are identical, i.e., $\bar{t}^A = \bar{t}^B = \bar{t}$. After integration, the probability density function $\phi^I(t)$ would be:

$$\phi^I(t) = \begin{cases} \frac{1}{b}, & if \ \ t \in [t_{\min}^I, t_{\max}^I], \\ 0, & otherwise, \end{cases}$$

where

$$t_{\min}^I = \bar{t} - \frac{b}{2}, \ \ t_{\max}^I = \bar{t} + \frac{b}{2}.$$

Note that the probability density functions of talent are identical before and after the integration when countries *A* and *B* are identical, i.e., $\phi^I(t) = \phi^A(t) = \phi^B(t) = 1/b$. We only observe that the aggregate labor forces become double after integration. By substituting the relationships of $L^I=2L$, $b^I=b$ and $\bar{t}^I = \bar{t}$ into equation (5), we can obtain the $\text{PPF}^I$ when countries *A* and *B* are identical as following:

$$Y_S^I = \frac{L}{2}(1 - \frac{1}{L\bar{t}} Y_C^I)(\frac{b}{2} + 2\bar{t} + \frac{b}{2L\bar{t}} Y_C^I). \quad (7a)$$

By using equations (3) and (7a), Figure 1 shows the production possibility frontiers before and after integration (see Appendix 1 for the mathematical derivation). Before integration, because these two countries have the same labor forces and

probability density functions of talent, we can describe their production possibility frontiers as the curve $PPF^A$, which is also equal to $PPF^B$. The relative price of good *C* on the world market is represented by the slope of a straight line labeled *p*, tangent to $PPF^A$ ($PPF^B$) at a point, $Q_0$. After integration, we find that the probability density function of talent is unaltered but the aggregate labor forces become double. Therefore, the production possibility frontier, as the curve $PPF^I$, is identical in shape to $PPF^A$ and tangent at a point, $Q_1$, with the same relative outputs as $Q_0$.

Obviously, with identical and homothetic preferences in the countries *A* and *B*, we may postulate that the individual country's POT and welfare are unchanged after labor market integration between two identical countries.

*** Figure 1 ***

3.2 Integration of advanced and backward countries

Suppose that countries *A* and *B* are different before integration. In this subsection, country *A* is an advanced country with larger average talent levels, and country *B* is a backward country with smaller average talent levels. Assume that $t_{\min}^{A} = t_{\max}^{B}$. Thus, the difference of the average talent levels of countries *A* and *B* is the diversity of talent, i.e., $\bar{t}^{A} = \bar{t} + b$, and $\bar{t}^{B} = \bar{t}$. Therefore, after integration, the probability density function $\phi^{I}(t)$ would be:

$$\phi^{I}(t) = \begin{cases} \dfrac{1}{2b}, & \text{if } t \in [t_{\min}^{I}, t_{\max}^{I}], \\ 0, & \text{otherwise,} \end{cases}$$

where

$$t_{\min}^{I} = t_{\min}^{B} = \bar{t} - \frac{b}{2}, \quad t_{\max}^{I} = t_{\max}^{A} = \bar{t} + \frac{3b}{2}.$$

Note that integration of advanced and backward countries would lead to the changes of the probability density functions of talent and the average talent levels, i.e.,

$\phi^I(t) = 1/2b$, and $\bar{t}^I = \bar{t} + b/2$. Similarly, the aggregate labor forces also double. Again, by substituting the relationships of $L^I$=2$L$, $b^I$=2$b$ and $\bar{t}^I = \bar{t} + b/2$ into equation (5), we can obtain the PPF$^I$ when countries *A* and *B* represent advanced and backward countries respectively as follows:

$$Y_S^I = \frac{L}{2}[1 - \frac{1}{L(\bar{t} + b/2)} Y_C^I][2b + 2\bar{t} + \frac{b}{L(\bar{t} + b/2)} Y_C^I]. \quad (7b)$$

By making use of equations (3) and (7b), we can describe the production possibility frontiers before and after integration in Figure 2 (see Appendix 2 for the mathematical derivation).

Some interesting results can be drawn from Figure 2.

(1) Before integration, the output ratios between *S* and *C* under the given world price *p*, are $Y_S^A / Y_C^A$ for country *A* and $Y_S^B / Y_C^B$ for country *B*. And, $Y_S^B / Y_C^B > Y_S^A / Y_C^A$. Because country *A* has a larger average talent level than country *B*, we can find that country *A* compares advantage at good *C* and country *B* compares advantage at good *S*.

(2) After integration, at the same price level *p*, the equilibrium output ratio is $Y_S^I / Y_C^I$, as reflected by the point $Q_2$, and $Y_S^I / Y_C^I > Y_S^B / Y_C^B > Y_S^A / Y_C^A$ (see Appendix 2 for the mathematical proof). That is, compared to the initial output ratio, the post-integration output level of *S* with respect to *C* increases, larger than either country *A* or country *B*.

*** Figure 2 ***

We observe that labor market integration would lead to the change of the probability density function of talent; that is, the distribution of talent becomes more diverse. Thus, the production possibility frontier, as the curve PPF$^I$, shifts out more toward good *S* than toward good *C* and is tangent at a point, $Q_2$. In fact, an economy with a more diverse distribution of talent has an advantage in producing good *S*.

Therefore, the maximum potential output of good *S* after integration is larger than the aggregate maximum potential output of good *S* of countries *A* and *B*.

Since $Y_S^I / Y_C^I > Y_S^B / Y_C^B > Y_S^A / Y_C^A$, that is a higher $Y_S / Y_C$ ratio after integration, clearly, POT for the integrated economy would be more likely to export *S* and import *C*, as compared with the initial POT for each country. For example, suppose that the preference refers to the equilibrium demand at points $D^B$, $D^A$ and $D^I$ at the given *p*, in Figure 2 (note that the identical and homothetic preferences will ensure a straight income consumption curve, i.e., $D^B$, $D^A$ and $D^I$ are on the same straight line through the origin O). As can be seen clearly, in this case, we observe that the POT for both countries will reverse, from import *S* and export *C* to export *S* and import *C*.

It will not be difficult to find other POT change patterns for different initial demand positions. If the income consumption curve lies between $\overrightarrow{OQ_0}$ and $\overrightarrow{OQ_1}$, then country *A* will encounter a POT reverse after integration, while country *B* will not.

**4. Income redistribution**

In this section, we will explore the effect of labor market integration on income distribution. To analyze these, it is necessary to indicate the determinants of the equilibrium wages of workers with different talent. Because a pair of workers with similar ability with talent between $\hat{t}^j$ and $m^j(\hat{t}^j)$ perform complementary tasks in the *C* sector of country *j*, each worker of a matched pair contributes equally to the value of the product in a competitive equilibrium. Therefore, the equilibrium wages in the *C* sector of country *j* can be described as follows:

$$w^j(t) = \frac{p^j t}{2}, \qquad t \in [\hat{t}^j,\ m^j(\hat{t}^j)]. \tag{8}$$

Firms in the *S* sector of country *j* also earn zero profits. Therefore,

$$w^j(t) + w^j[m^j(t)] = F_S^j[t, m^j(t)], \qquad t \in [t_{\min}^j, \hat{t}^j). \tag{9}$$

Generally speaking, workers' talents are substitutable when they contribute in parallel to finishing a target outcome in the *S* sector. Grossman and Maggi (2000) prove that the *S* sector attracts the most-talented and least-talented workers. In these situations, we can argue that the marginal value of a most-talented worker rises when the contribution of a least-talented worker is less. Moreover, equation (8) offers the equilibrium wage for the marginal worker in the *S* sector of country *j* with talent $\hat{t}^j$. Therefore, the equilibrium wages for workers with less talent than $\hat{t}^j$ can be described as follows:

$$w^j(t) = \frac{p^j \hat{t}^j}{2} - (\hat{t}^j - t) = (\frac{p^j}{2} - 1)\hat{t}^j + t, \qquad t \in [t_{\min}^j, \hat{t}^j). \tag{10}$$

By combining equations (9) and (10), we can derive the equilibrium wages for workers with more talent than $m^j(\hat{t}^j)$ as follows (see Appendix 3 for the mathematical derivation):

$$w^j(t) = 2t - \frac{p^j \hat{t}^j}{2} - m^j(\hat{t}^j), \qquad t \in (m^j(\hat{t}^j), t_{\max}^j]. \tag{11}$$

Obviously, linearity follows directly from equations (10), (8), and (11), and the slopes are 1, $p^j/2$, and 2, respectively. By making use of equations (10), (8), and (11), we can describe the wage distribution of workers with different talent under a given relative price in Figure 3.

*** Figure 3 ***

It is now easy to derive the equilibrium wages after integration. Again, by using the aforementioned analytical method, we can derive the equilibrium wages in the *C* sector after the integration as follows:

$$w^I(t) = \frac{p^I t}{2}, \qquad t \in [\hat{t}^I, m^I(\hat{t}^I)]. \tag{12}$$

We also can find the equilibrium wages for workers with less talent than $\hat{t}^I$ as

follows:

$$w^I(t) = (\frac{p^I}{2} - 1)\hat{t}^I + t, \qquad t \in [t^I_{\min}, \hat{t}^I), \tag{13}$$

and for workers with more talent than $m^I(\hat{t}^I)$ as follows:

$$w^I(t) = 2t - \frac{p^I \hat{t}^I}{2} - m^I(\hat{t}^I), \qquad t \in (m^I(\hat{t}^I), t^I_{\max}]. \tag{14}$$

Obviously, linearity follows directly from equations (13), (12), and (14), and the slopes are 1, $p^I/2$, and 2, respectively. In summary, the wage distribution of workers with different talent under a given relative price after integration can be described by equations (13), (12), and (14).

Next, Section 4.1 will analyze the impact of labor market integration on income distribution under a constant world price *p*. However, as shown earlier, the integration may lead the relative supply of *S* over *C* to change, which in turn may result in a change in the world price *p*, if the integrated economy unit is large enough. Therefore, Section 4.2 will discuss the relationship between the relative world price and income distribution before and after integration.

4.1 Income redistribution with constant terms of trade

First, consider that countries *A* and *B* are identical before integration. Under the situation, after the labor market integration, the probability density function of talent remains the same but the aggregate labor forces become double. Therefore, it is obvious that income distributions are also unaltered after the integration.

Next, consider country *A* as the advanced country and country *B* as the backward country, as discussed in Section 3.2. Naturally, the wage distributions for countries *A* and *B*, represented by equations (10), (8) and (11), can be depicted as Line-*GHIJ* and Line-*CDEF* respectively in Figure 4. Again, by making use of equations (13), (12) and (14), the wage distribution after integration can be described straightforwardly as Line-*KLMN*. Figure 4 depicts the wage distributions associated

with a given relative price. We have drawn the schedule as overlapping in the ranges of $[\hat{t}^I,\ m^B(\hat{t}^B)]$ and $[\hat{t}^A,\ m^I(\hat{t}^I)]$, following directly from equations (8) and (12). By Figure 4, it is now easy to identify the effects of the labor market integration on the various workers' wages in countries *A* and *B*.

*** Figure 4 ***

For the advanced *A*-country, none of the workers is worse off; instead some people earn higher wages than before. More specifically, people with ability above $m^I(\hat{t}^I)$, and those below $\hat{t}^A$, earn higher wage income after the integration, while others with $\hat{t}^A \le t \le m^I(\hat{t}^I)$ face the same wage level as before. For the backward *B*-country, some are worse off. Specifically, workers with $t \le \hat{t}^I$ and $t \ge m^B(\hat{t}^B)$ will receive lower wages after the integration, while all others earn the same wage income.

In addition, we can also observe from Figure 4 a clear pattern of occupation change for some people within each country. (i) Workers that switch from *S*-sector to *C*-sector are those with ability between $[m^B(\hat{t}^B), \hat{t}^A]$, which includes two groups: one comprises the high ability workers in country *B*, that is, $t \in [m^B(\hat{t}^B),\ t^B_{\max}]$; the other is the low ability workers in country *A*, i.e. $t \in [t^A_{\min},\ \hat{t}^A]$. Obviously, workers in the former group are losers in terms of wage decrease due to the integration, while workers in the other group are winners. (ii) On the other hand, there is an occupation change from *C*-sector to *S*-sector. This type is composed of two groups of workers: group one is the workers with $t \in [\hat{t}^B,\ \hat{t}^I]$ in country *B*, the other $t \in [m^I(\hat{t}^I),\ m^A(\hat{t}^A)]$ in country *A*. And clearly, the former group has lower income than before, while the other has higher wages after the integration.

4.2 Income redistribution with terms of trade change

Suppose that the integration of countries *A* and *B* creates an economic unit that is large enough to alter the world price. In the case where countries *A* and *B* are identical,

the integration does not change the relative output, thus the world relative price is also unaltered. Therefore, the effect on income distributions will be absent, the same as the case of constant *p* as discussed in Section 4.1.

In the case where country *A* is an advanced country while country *B* is a backward country, obviously, the wage distributions for countries *A* and *B* before integration can be duplicated from Figure 4 as Line-*GHIJ* and Line-*CDEF* respectively in Figure 5. As analyzed before, the integration leads to a more diverse distribution of talent, which in turn makes the relative output of good *S* rise. As a result, for the integrated economy, the world relative price of good *C* will increase. Thus, by making use of equations (13), (12) and (14), we can describe the wage distribution with this relative price change as Line-$K'L'M'N'$ in Figure 5. By comparing equations (8) with (12), we know that the locus of equilibrium wages in the *C* sector after integration, i.e. Line-$L'M'$, is linear and steeper than the individual country's locus before integration, Line-*DE* for *B*-country and Line-*HI* for *A*-country.

*** Figure 5 ***

We are now ready to discuss the income redistribution and the corresponding welfare effect due to the integration. Obviously, the labor market integration will benefit all the workers of country *A* and hurt the high-talent workers who begin in the *S* sector and move to the *C* sector in country *B*. Meanwhile, for workers who remain in the same sector before and after integration, their wages would increase.

## 5. Conclusion

We set up a two-sector, competitive trade model with heterogeneous labor to explore the impact of labor market integration between North and South on income distribution and POT.

Spilimbergo (1999) indicates that the welfare level would increase in the North

and decrease in the South due to the labor market integration. We further prove that, for the advanced country (North), after the labor market integration, none of the workers is worse off; instead some people earn higher wages than before. And, for the backward country (South), some workers are worse off. In addition, we show that if the integrated economy is large enough to alter the world price, the labor market integration will benefit all the workers of an advanced country and hurt the high-talent workers who begin in the *S* sector and move to the *C* sector in a backward country.

The lumpiness referring to various differences among regions within a country, as discussed in Courant and Deardorff (1992), can be a determinant of POT. A sufficiently uneven allocation of production factors between regions can lead the country as a whole to export the good that intensively uses the lumpier factor. On the contrary, after labor market integration, we find that the POT for the integrated-economy might reverse.

**Appendix 1** Derivations of the equilibriums before and after labor market integration under identical countries

Since countries *A* and *B* are identical, i.e., $L^A$=$L^B$=$L$, $\bar{t}^A = \bar{t}^B = \bar{t}$, $b^A$=$b^B$=$b$, and $\phi^A(t) = \phi^B(t) = 1/b$, we have PPF$^A$=PPF$^B$. Now consider the equilibrium relative outputs before and after integration under a given relative price. Let $p$ represent the relative price of good *C*. In equilibrium, the equilibrium condition ($p$=MRT$^j$, $j \in \{A, B\}$) holds and by substituting equation (4) into the equilibrium condition, we get:

$$Y_C^j = \frac{L\bar{t}^2}{b}(p-1). \tag{A.1}$$

By substituting equation (*A*.1) into equation (3), we obtain:

$$Y_S^j = \frac{L\bar{t}^2}{2b}[(1+\frac{b}{2\bar{t}})^2 - p^2]. \tag{A.2}$$

From equations (*A*.1) and (*A*.2), we can find the relative output of country *j* as shown below:

$$\frac{Y_S^j}{Y_C^j} = \frac{(1+\frac{b}{2\bar{t}})^2 - p^2}{2(p-1)}. \tag{A.3}$$

After the integration, the relationships of $L^I$=2$L$, $\bar{t}^I = \bar{t}$, $b^I$=$b$ and $\phi^I(t) = 1/b$ hold. Similarly, by substituting equation (6) into the equilibrium condition ($p$=MRT$^I$), we get:

$$Y_C^I = \frac{2L\bar{t}^2}{b}(p-1). \tag{A.4}$$

By substituting equation (*A*.4) into equation (7a), we obtain:

$$Y_S^I = \frac{L\bar{t}^2}{b}[(1+\frac{b}{2\bar{t}})^2 - p^2]. \tag{A.5}$$

From equations (*A*.4) and (*A*.5), we also can find the relative output after integration as shown below:

$$\frac{Y_S^I}{Y_C^I} = \frac{(1+\frac{b}{2\bar{t}})^2 - p^2}{2(p-1)}. \qquad (A.6)$$

Obviously, equations (*A*.3) and (*A*.6) indicate that the ratios of outputs before and after integration are identical under any given relative price, as shown in Figure 1.

Finally, from equations (*A*.1), (*A*.2), (*A*.4), and (*A*.5), we find that the relationships of $Y_C^I = Y_C^A + Y_C^B$ and $Y_S^I = Y_S^A + Y_S^B$ hold. Namely, we prove that total output after integration must be equal to aggregate outputs of countries *A* and *B* before integration under any given relative price.

**Appendix 2** Derivations of the equilibriums before and after labor market integration under different countries

Countries *A* and *B* represent advanced and backward countries respectively. Assume that they are different only in their average talent levels i.e., $L^A$=$L^B$=$L$, $\bar{t}^A = \bar{t} + b$, $\bar{t}^B = \bar{t}$, and $b^A$=$b^B$=$b$. By using equation (3), the PPF$^A$ can be derived as follows:

$$Y_S^A = \frac{L}{2}[\frac{1}{2} - \frac{1}{L(\bar{t}+b)}Y_C^A][\frac{5b}{2} + 2\bar{t} + \frac{b}{L(\bar{t}+b)}Y_C^A]. \qquad (A.7)$$

Meanwhile, the PPF$^B$ can be also derived as follows:

$$Y_S^B = \frac{L}{2}[\frac{1}{2} - \frac{1}{L\bar{t}}Y_C^B][\frac{b}{2} + 2\bar{t} + \frac{b}{L\bar{t}}Y_C^B]. \qquad (A.8)$$

From equation (4), we can find the MRT$^A$ and MRT$^B$ as follows:

$$\text{MRT}^A = 1 + \frac{b}{L(\bar{t}+b)^2}Y_C^A, \qquad (A.9)$$

$$\text{MRT}^B = 1 + \frac{b}{L\bar{t}^2}Y_C^B. \qquad (A.10)$$

Next, we will derive the ratios of outputs before and after integration under given relative price *p*. By substituting equations (*A*.9) and (*A*.10) into the equilibrium conditions ($p$=MRT$^A$, and $p$=MRT$^B$), we get:

$$Y_C^A = \frac{L(\bar{t}+b)^2}{b}(p-1), \qquad (A.11)$$

$$Y_C^B = \frac{L\bar{t}^2}{b}(p-1). \qquad (A.12)$$

By substituting equations (*A*.11) and (*A*.12) into equations (*A*.7) and (*A*.8) respectively, we obtain:

$$Y_S^A = \frac{L(\bar{t}+b)^2}{2b}\{[1+\frac{b}{2(\bar{t}+b)}]^2 - p^2\}, \qquad (A.13)$$

$$Y_S^B = \frac{L\bar{t}^2}{2b}[(1+\frac{b}{2\bar{t}})^2 - p^2]. \qquad (A.14)$$

From equations (*A*.11) and (*A*.13), we can find the relative output of country *A* as shown below:

$$\frac{Y_S^A}{Y_C^A} = \frac{[1+\frac{b}{2(\bar{t}+b)}]^2 - p^2}{2(p-1)}. \qquad (A.15)$$

Similarly, from equations (*A*.12) and (*A*.14), we find the relative output of country *B* as shown below:

$$\frac{Y_S^B}{Y_C^B} = \frac{(1+\frac{b}{2\bar{t}})^2 - p^2}{2(p-1)}. \qquad (A.16)$$

After the integration, the relationships of $L^I$=2$L$, $\bar{t}^I = \bar{t} + b/2$, $b^I$=2$b$ and $\phi^I(t) = 1/2b$ hold. Similarly, by substituting equation (6) into the equilibrium condition ($p$=MRT$^I$), we get:

$$Y_C^I = \frac{L(\bar{t}+b/2)^2}{b}(p-1). \qquad (A.17)$$

By substituting equation (*A*.17) into equation (7b), we obtain:

$$Y_S^I = \frac{L(\bar{t}+b/2)^2}{2b}[(1+\frac{b}{\bar{t}+b/2})^2 - p^2]. \qquad (A.18)$$

From equations (*A*.17) and (*A*.18), we also find the relative output after integration as shown below:

$$\frac{Y_S^I}{Y_C^I} = \frac{(1+\frac{b}{\bar{t}+b/2})^2 - p^2}{2(p-1)}. \qquad (A.19)$$

Generally speaking, we believe that every worker's talent is positive, i.e., $t_{\min}^{I} = \bar{t} - b/2 > 0$. By making use of $\bar{t} > b/2$, we obtain:

$$\bar{t} + \frac{b}{2} < 2\bar{t} < 2(\bar{t} + b) . \qquad (A.20)$$

By using equations (*A*.15), (*A*.16), (*A*.19), and (*A*.20), we can find:

$$\frac{Y_S^I}{Y_C^I} > \frac{Y_S^B}{Y_C^B} > \frac{Y_S^A}{Y_C^A} . \qquad (A.21)$$

Obviously, equation (*A*.21) indicates the order of the equilibrium relative outputs before and after integration under any given relative price, as shown in Figure 2.

**Appendix 3** Derivations of the equilibrium wages for workers with talents at the upper end of the distribution

By substituting equation (10) into (9), we have:

$$w^j[m^j(t)] = m^j(t) - (\frac{p^j}{2} - 1)\hat{t}^j - t , \qquad t \in [t_{\min}^j, \hat{t}^j) . \qquad (A.22)$$

Again, by substituting the relationship of $m^j(t) = 2\bar{t}^j - t$ into equation (*A*.22), we have:

$$w^j[m^j(t)] = 2m^j(t) - \frac{p^j\hat{t}^j}{2} - m^j(\hat{t}^j) , \qquad t \in [t_{\min}^j, \hat{t}^j) . \qquad (A.23)$$

Finally, we can rewrite equation (*A*.23) as equation (11).

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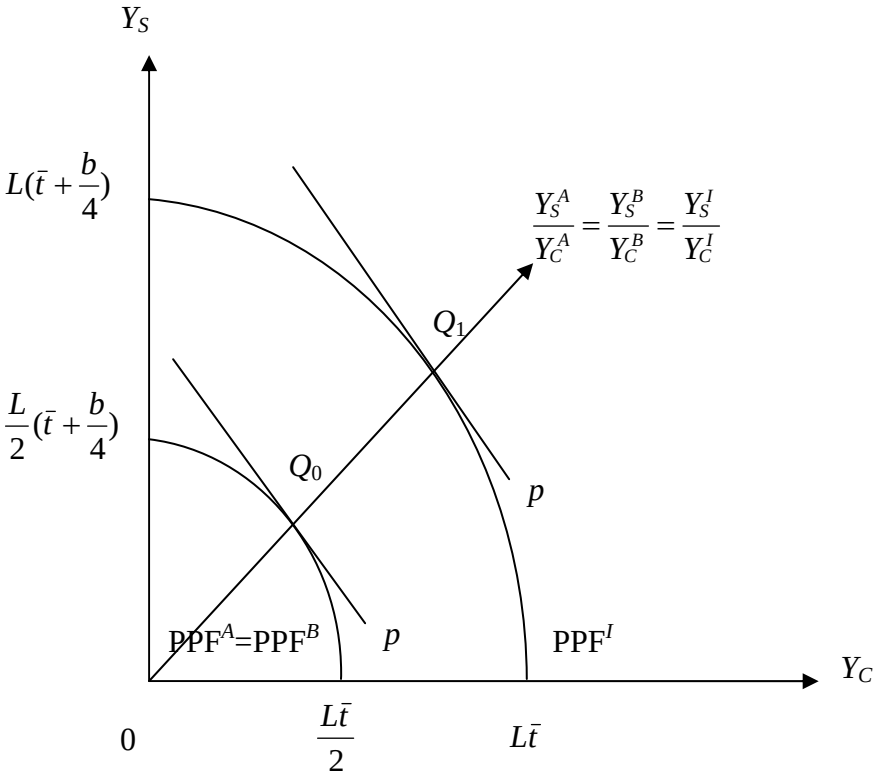


Figure 1 Integration of identical countries

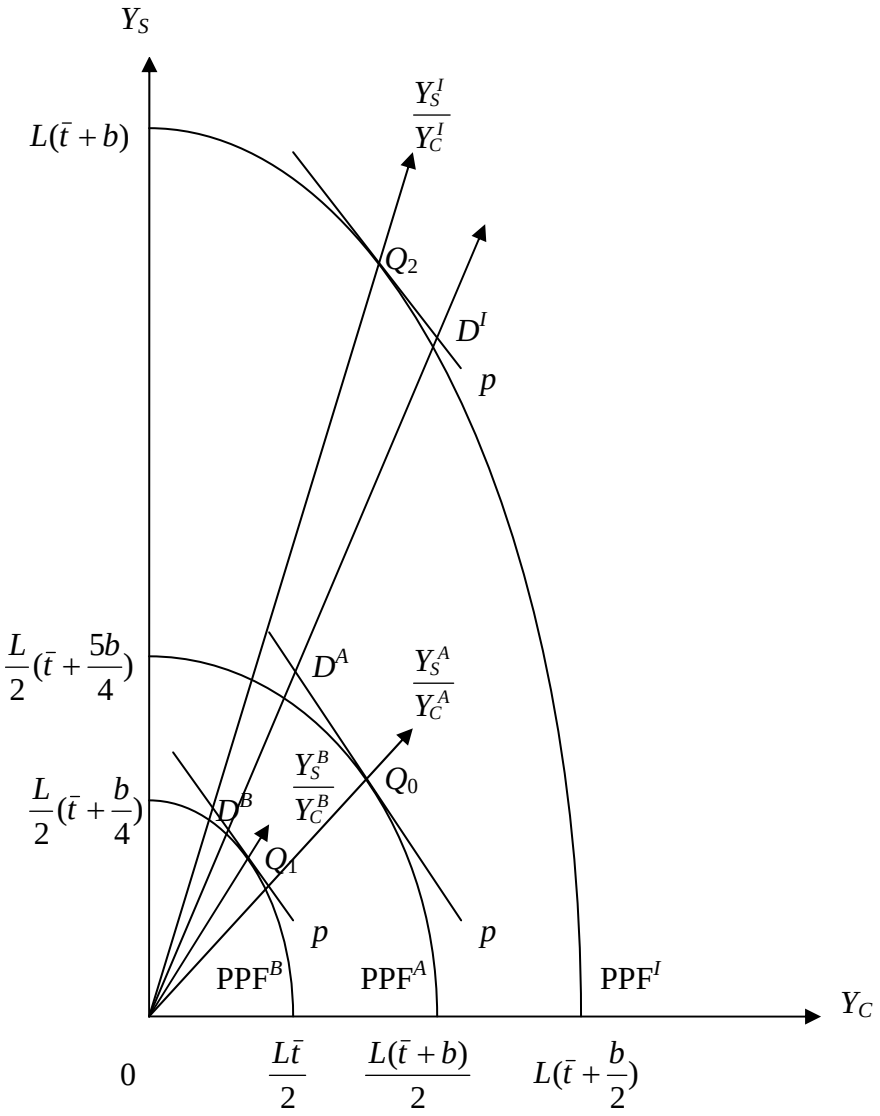


Figure 2 Integration of advanced and backward countries

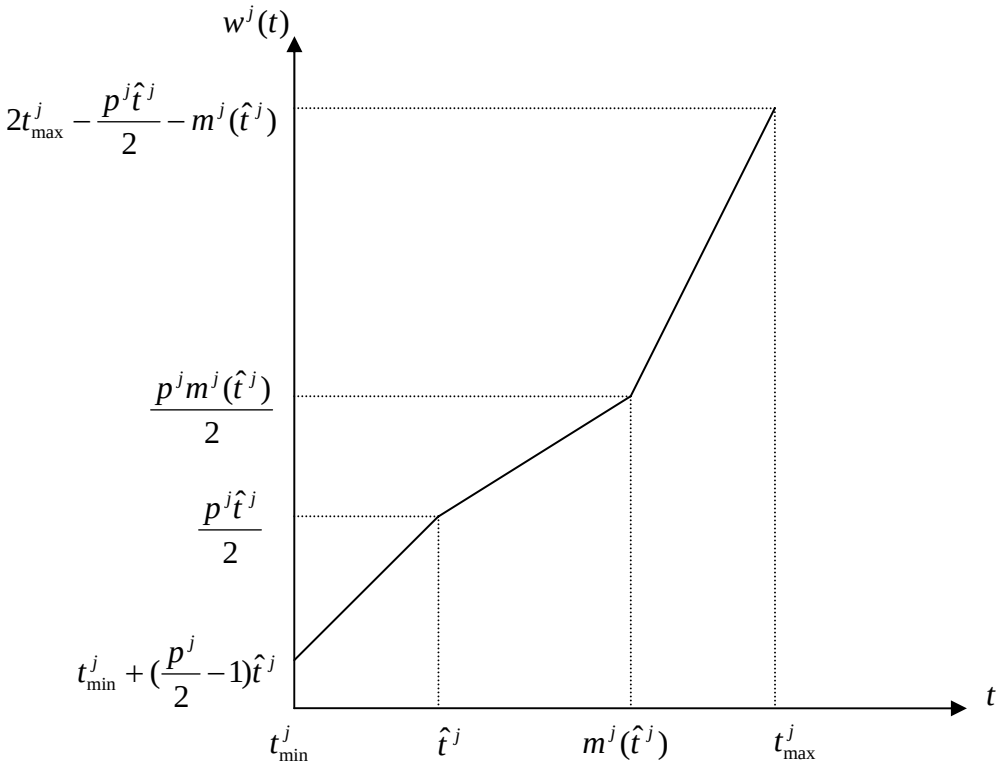


Figure 3 Wage distribution of country *j*

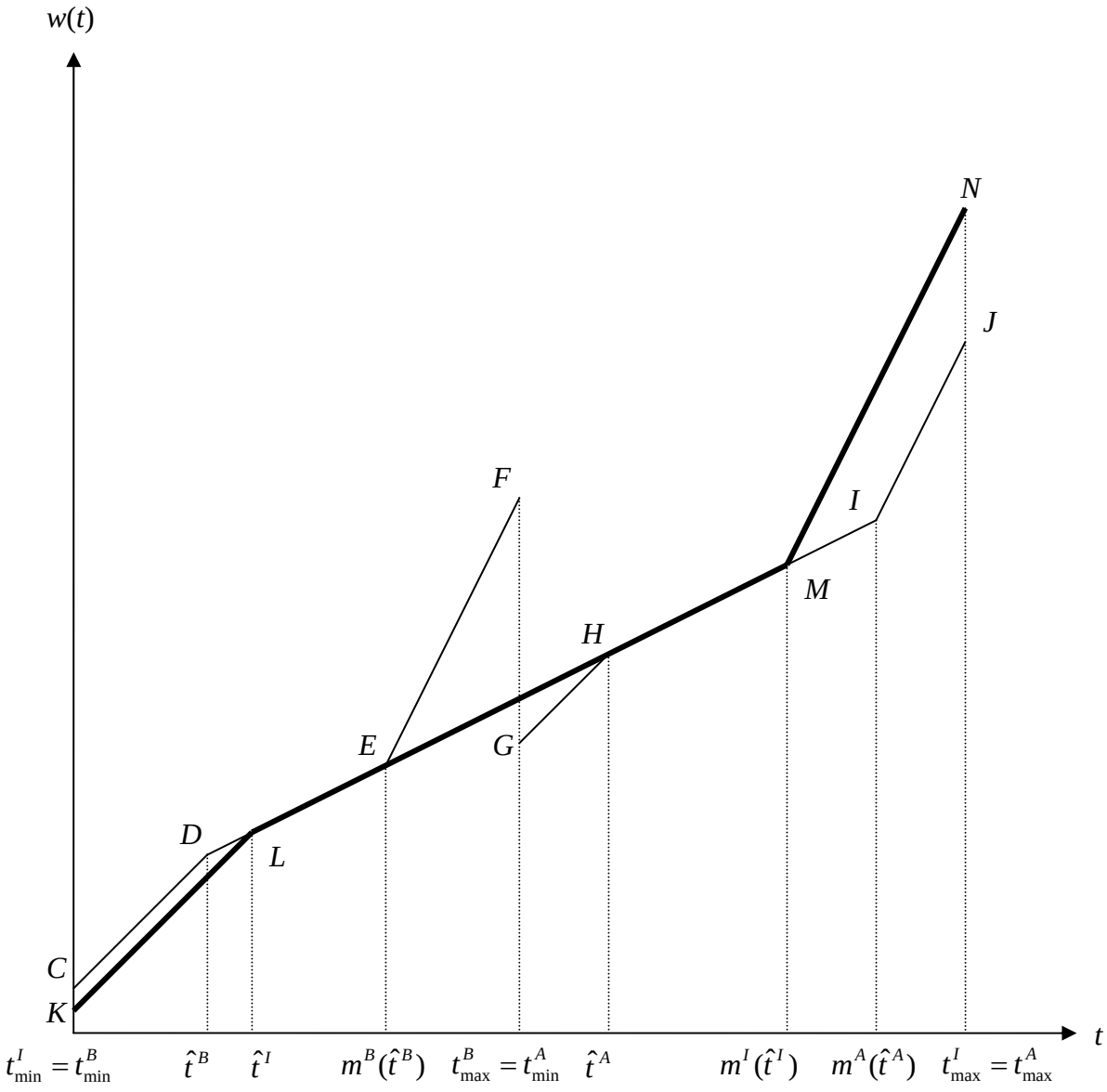


Figure 4 Effects of labor market integration on wage: given the relative price

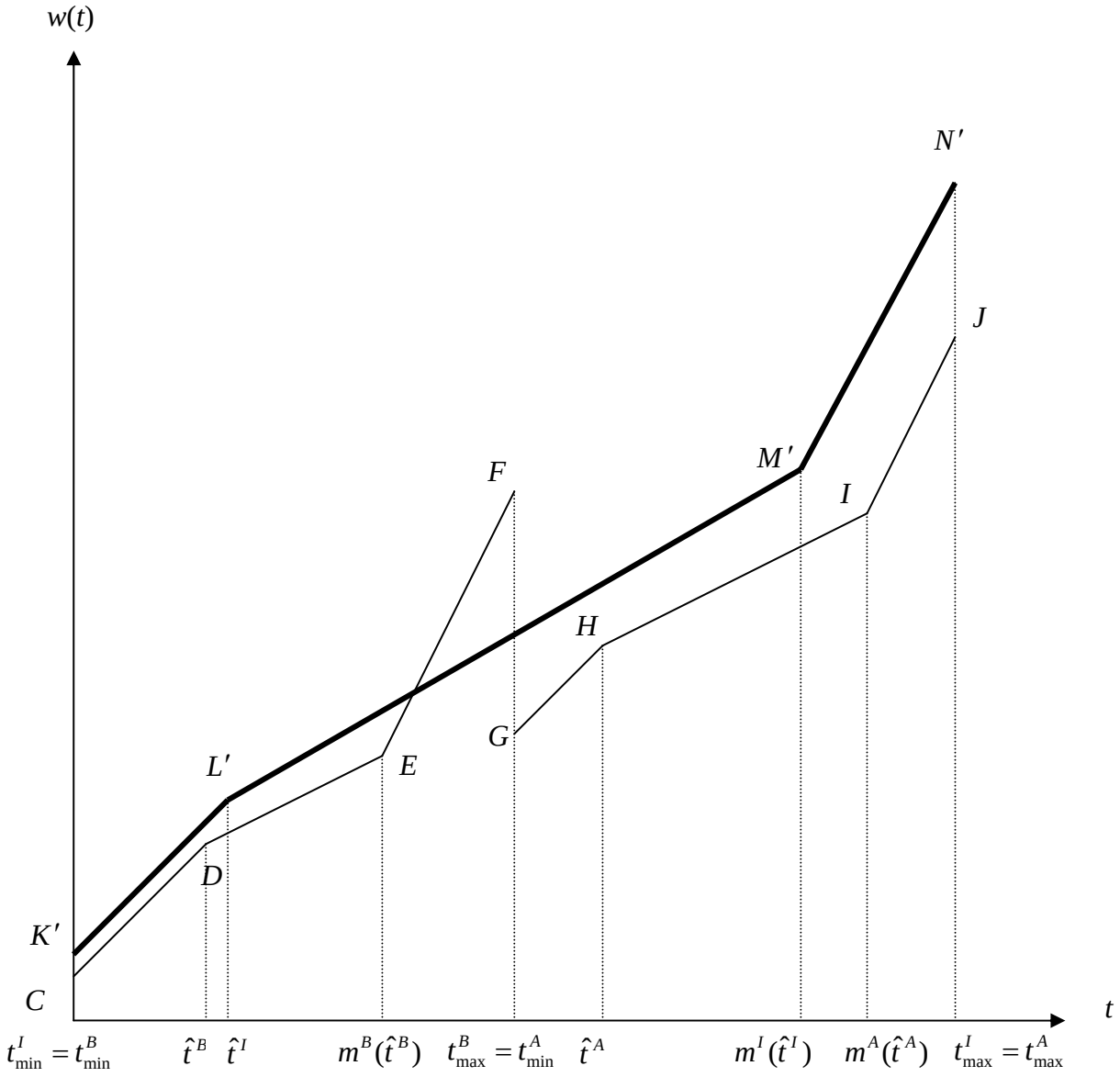


Figure 5 Effects of labor market integration on wage: a rise in the relative price

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