Economic integration with regional knowledge spillover: a theoretical approach

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1. Introduction

This paper aims to analyze the consequences of integration of two economies, each economy composed by two sectors – innovation and consumer good. The model assumes four fundamental hypotheses: (i) all individuals can choose to be an engineer or an innovator; (ii) in the production of knowledge, the marginal productivity of innovators is increasing and (iii) the productivity of workers (engineers and innovators) is a function of formal and unformal education, and the latter is positively related to the proportion of innovators to the total population.

From these hypotheses, the model obtains three main results: (1) economic integration may not be desirable to the smaller economy, (2) there is always a tax system imposed by the government of smaller economy that is able to prevent integration, and (3) depending on parameters, this tax system can be either welfare improving or even more harmful for the small economy than economic integration. The latter case becomes more likely as two aspects are combined: (a) unformal education is important and (b) size difference between economies is significant.

After presenting the main equations of the model, possible equilibria are shown in three steps: first step analyzes a single economy in autarky, considering labor productivity as a constant; then, two economies are integrated, but without considering government's interventions yet; and, finally, the third part brings the complete model.

2. The model

The model analyzes the integration of two economies – North and South. In each economy, there are N individuals who decide between being an engineer or an innovator. The number of engineers and innovators are, respectively, Z and X. Thus:

$$N_j = X_j + Z_j \qquad where\ j \in \{South; North\}\ \mathrm{j} \tag{1}$$

All workers have the same productivity level, which depends on both exogenous parameters and the proportion of innovators to the total population:

$$l_j = min\left\{1 + \delta\left({X_j}/{N_j}\right); 1 + \delta\alpha\right\} \tag{2}$$

δ measures the importance of an innovative environment to the productivity of workers. As can be seen in equation (2), the maximum productivity of workers of the economy j is reached when $X_j\ /\ N_j = \alpha$.

In this model, the innovators are also the entrepreneurs of the economy. They not only innovate but also transform their innovations into physical capital to produce consumer good. Each innovator works in her laboratory by herself and produces physical capital as final product. The production of a specific lab i is:

$$K_{j,i} = \left(X_j l_j\right)^{(\theta-1)} \tag{3}$$

The production function of innovation sector is defined as follows:

$$K_j = K_{j,i} X_j = (X_j l_j)^{(\theta-1)} X_j \text{ where } \theta > 1 \tag{4}$$

The innovator i contracts $Zj,_i$ engineers from economy j to producing the final good, obeying equation 5:

$$Y_{g,i} = ((X_g l_g)^{(\theta-1)})^{\alpha}(Z_{j,i} l_{j,i})^{1-\alpha} \qquad where\ g \in \{South; North\} \tag{5}$$

If firm i is a multinational, $g \neq j$, otherwise $g = j$.

Considering a competitive labor market, engineers earn the value of their marginal productivity. As there is only one final good, its price can be set equal to one dollar. Thus, engineers' wage can be defined as follows:

$$w_{j,Z} = (1-\alpha)(X_g l_g)^{(\theta-1)\alpha} Z_{j,i}^{-\alpha} l_j^{1-\alpha} \tag{6}$$

Innovators earn the capital remuneration, which can be defined as

$$w_{j,X} = \alpha(X_g l_g)^{(\theta-1)\alpha}(Z_{j,i} l_j)^{1-\alpha} \tag{7}$$

Finally, let W be a measurement for welfare, which includes wage (w), transfers/taxes (t), migration cost (m), and capital mobility cost (c). Then, we will have for both engineers and innovators:

$$W_{j,Z} = w_{j,Z} + t_{j,Z} - m \tag{8}$$

$$W_{j,X} = w_{j,X} + t_{j,X} - m - c \tag{9}$$

Migration cost will be zero for individuals who work where they were born and positive otherwise, whereas capital mobility cost will be zero if innovator produces physical capital and final good at the same place, and positive otherwise.

3. Equilibria

3.1. Closed Economy

In a closed economy, $m = c = 0$. Besides, as mentioned in the introduction, in this subsection, the productivity of workers will be a constant. Let l be equal to one.

The condition for equilibrium is that wages after taxes and transfers are equals.

$$W_X = W_Z \tag{10}$$

Without government, this economy reaches the equilibrium when marginal productivity of engineers equals the capital remuneration. From equations (6) and (7):

$$(1-\alpha)X^{(\theta-1)\alpha}Z_i^{-\alpha} = \alpha X^{(\theta-1)\alpha}Z_i^{1-\alpha} \tag{11}$$

Which gives:

$$Z_i = \frac{1-\alpha}{\alpha} \tag{12}$$

Equation (12) determines the number of engineers per firm (and per innovator). It is assumed that $\alpha \leq 0.5$. This restriction means that each innovator needs at least one engineer.

Note that this equilibrium is stable: if wage of engineers becomes slightly higher, some innovators will become engineers, reducing the marginal productivity of engineers and increasing capital remuneration.

An interesting aspect of this result is that competitive market does not take into account positive externality generated by innovators. In other words, the proportion between engineers and innovators does not depend on θ.

Introducing a central planner who desires to maximize welfare, the number of engineers per firm turns out to be different from equation (12). In this case, central planner should divide population into engineers and innovators so that they have the same marginal productivity. As result, optimum number of engineers (Z_i^{cp}) by firm will be smaller than before and decreasing in θ:

$$Z_i^{cp} = \frac{1-\alpha}{\theta\alpha} \tag{13}$$

This distribution can be obtained by creating an income-transfer mechanism between both occupations, through which each innovator receives the amount of tax paid by all the engineers that work for her.

$$t_x = \frac{1-\alpha}{\theta\alpha}(-t_z) \tag{14}$$

In the next subsections, taxation strategy (under economic integration) will be investigated in more details.

3.2.Two economies.

As long as two economies (North and South) have the same parameters, wages will be the same and there will be no reasons for integration. Nevertheless, a small change in any parameter may drive both economies to a complete integration.

As starting change, it is assumed in our analysis that $N > N^*$, being N^* the total population of South.

Given an initial change, it is hard to know whether economic integration will occur through migration or capital flow. Capital and labor mobility are substitute to each other and will be analyzed separately[1].

Allowing labor mobility, the result is straightforward. When N becomes greater than N^*, firms of North will have more capital and, as consequence, wages of North increase. Then,

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[1] It might be the case that geographic or cultural distance would impose more uncertainty and costs to labor mobility; in this case, one should expect relatively more migration flow between Portugal and Germany and more capital flow between Brazil and Germany.

all people from South migrate to North (as the first person moves, the difference between North and South becomes bigger). In the end of the day, nobody will live in the South. In the North, income per capita will be higher than before integration, and everybody will earn the same amount.

Note that the increase of wages comes from the amount of capital per firm. There is no change in worker productivity, since Z_i remains the same (equation 12) and the proportion of *X* to the total population is the same as well.

Using superscript *n*, *s* and *I* to denote, respectively, North, South, and 'integrated', we can represent the gains of integration by the following relation:

$$\frac{w^I}{w^j} = \left[\frac{(N^n+N^s)}{N^j}\right]^\alpha \text{ where } j = n, s \tag{15}$$

The analysis under free capital mobility is a bit more complicated. Considering the simplicity of explanation - and without loss of generality - it will be assumed that $K = (Xl)X = X^2l$. Thus, the total capital per firm (capital production per innovator) will be determined by

$$K_i = Xl = Xmin\left\{\left(1+\delta\frac{X}{N}\right); (1+\delta\alpha)\right\} \tag{16}$$

Since the initial increase in N, wages in North become higher. Then, innovators of North can open firms in South and contract engineers paying less than the wage in North. Because innovators become better off, some engineers at North become innovators. This movement goes on until all people from South work as engineers for innovators from North. In the equilibrium, there will be only innovators in the North ($X^* = 0$), and ${}^X\!/_N > \alpha$. Therefore

$$l = \min\left\{1+\gamma\frac{X}{N}; 1+\gamma\alpha\right\} = 1+\gamma\alpha \tag{17}$$

$$l^* = \min\left\{1 + \gamma\frac{X^*}{N^*}; 1 + \gamma\alpha\right\} = 1 \tag{18}$$

$$X = \alpha\frac{[N(1 + \delta\alpha) + N^*]}{1 + \delta\alpha} \tag{19}$$

It is interesting to note that given the higher wage offered by firms from North, the education and innovation systems in South are eliminated, which will reduce the productivity of workers of South.

As we will show shortly, in the South, the final wage of engineers after complete integration may be lower than the wage before integration. This undesirable transition happens because, for any productivity level of South workers, multinationals from North can offer higher wage – they have more capital per firm. Then, as a person from South starts working for a firm of North, the number of innovators in South reduces. This reduction decreases, in turn, the productivity of all workers of South. In other words, the individual decision of working for a multinational generates a negative externality to the rest of the South economy, since it reduces the innovation sector.

Comparing wages before (subscript b) and after (subscript a) integration, we will have for both regions:

$$\frac{w_a}{w_b} = \frac{N(1 + \delta\alpha) + N^*}{(1 + \delta\alpha)N} \tag{20}$$

$$\frac{w_a^*}{w_b^*} = \left(\frac{N(1 + \delta\alpha) + N^*}{N^*}\right)^{\alpha}\frac{1}{(1 + \delta\alpha)^{1+\alpha}} \tag{21}$$

It is easier to analyze the relationship between wages before and after integration, if it is assumed that

$$N^* = \beta N \text{ for } \beta < 1 \tag{22}$$

Then, equations (23) and (24) become:

$$\frac{w_a}{w_b} = \frac{(1 + \delta\alpha + \beta)}{(1 + \delta\alpha)} \tag{23}$$

$$\frac{w_a^*}{w_b^*} = \left(\frac{1 + \delta\alpha + \beta}{\beta}\right)^{\alpha} \frac{1}{(1 + \delta\alpha)^{1+\alpha}} \tag{24}$$

In the North, wages clearly increase, reaching its maximum value when β is close to 1 (or $N \cong N^*$). Given a value of β, the wage difference is negatively related to δ (importance of X for worker productivity). This result is quite intuitive: under economic integration ($X^* = 0$), the economy of South will be relatively less significant as δ is higher.

In the South, wages may have reduced with the economic integration. The economic integration means (1) more capital per firm, which increases marginal productivity of engineers and (2) lower individual productivity of workers of South, which is a function of number of innovator in South.

From equation (24), it is possible to define the maximum $\beta$for economic integration to be enhancing.

$$\beta < \frac{(1 + \delta\alpha)}{(1 + \delta\alpha)^{\frac{1+\alpha}{\alpha}} - 1} \tag{25}$$

If β is small enough - which means the difference between $N$and N^* is big enough – the economic integration will be desirable: North is much bigger than South and the gain in terms of capital per firm will be extremely significant for South. Note that, for $\delta = 0$, economic integration is always desirable.

As conclusion of the second case – with capital mobility -, it is possible to say that economic integration may represent a threat for the smaller economy. The concentration of innovation in the North increases the global production of innovation, but reduces the individual productivity in the South (given capital per firm), since the innovation sector of South disappears.

3.3. Government intervention

In this subsection, the focus will be the smaller economy that can lose with integration. More specifically, the aim is to analyze how (if so) and to what extent can government' actions prevent the small economy from losses of economic integration.

To do that, government of the smaller economy creates an income transfer mechanism from engineers to innovators. This mechanism not only increases both the number of innovators and the amount of capital per firm, but also reduces the number of engineers in each firm. It is worth emphasizing that all those changes increase the wage of engineers (before paying taxes). The income transfer should be enough so that the wage of engineers (before paying taxes) equals the amount paid by firms from North. In this case, there is no incentive for engineers of South to work for a firm of North.

The first part - how many new innovators a given percentage of income tax (*t*) generates - can be defined as follows:

$$(1-t)(1-\alpha)(1+\delta\alpha)X^{\alpha}\left(\frac{N-X}{X}\right)^{-\alpha} = \alpha(1+\delta\alpha)X^{\alpha}\left(\frac{N-X}{X}\right)^{1-\alpha} + t\left(\frac{N-X}{X}\right)(1-\alpha)(1+\delta\alpha)X^{\alpha}\left(\frac{N-X}{X}\right)^{-\alpha} \tag{26}$$

The left hand side corresponds to the wage of an engineer after taxes, and the right hand side represents the wage of an innovator plus income transfer from the government. In other words, equation 26 is the condition for equilibrium in the labor market of South.

Despite the complexity of equation (26), t can be shown as a function of X and Z in a very simple relation:

$$t = \frac{\Delta X}{Z} \tag{27}$$

ΔX represents the number of new innovators and Z is the number of engineers before taxes. Therefore, the percentage of income tax paid by engineers is equivalent to the percentage of engineers that become innovators. Numerically, if there were 100 engineers before tax creation, an income tax corresponding to 25% of total income would make 25 engineers become innovators.

The second part – pinning down the number of innovators in South so that the wage of engineers before taxes in South becomes equal to the wage offered by firms from North – requires the reintroduction of two economies into the analysis (as before, South is the smaller economy and its variables bring an asterisk subscript).

The task is to find X^* (number of engineers in the South) that equalizes wages of engineers in both regions.

$$(1-\alpha)(1+\delta\alpha)X^{*\alpha}\left(\frac{N^* - X^*}{X^*}\right)^{-\alpha} = (1-\alpha)(1+\delta\alpha)\alpha^{\alpha}N^{\alpha}\left(\frac{1-\alpha}{\alpha}\right)^{-\alpha} \tag{28}$$

It is possible to simplify equation (30) assuming that $N^* = \beta N$ and $X^* = xN^*$. Thus, we have

$$\frac{x}{\alpha} = \frac{(1-\alpha)}{\alpha}\frac{x}{(1-x)}\beta \tag{29}$$

Which turns out to be:

$$\frac{X^*}{X} = \frac{Z_i^*}{Z_i} \tag{30}$$

Before integration, $Z_i^* = Z_i$ and $X^* < X$. Then, income transfer in South increases $X^*$and, as results, reduces Z_i^* (number of engineers per firm) until the point where equation (28) becomes true. Therefore, even though X^* has to increase, it remains smaller than X, since the difference is compensated by fewer engineers per firm in South ($Z_i^* < Z_i$).

4. Possible scenarios

The results of the complete model come from the interaction of five wages in South whose notations are defined as follows: w_{aut}(wage under autarky), w_{fI} (wage offered by the first multinational coming from North), w_{eI} (equilibrium wage under complete economic integration), w_{aT} (wage after taxes – or wage minus taxes), and w_{bT} (equilibrium wage in case Government imposes taxes, but before discounting taxes).

So, it is true that

$$w_{aT} = (1-t)w_{bT} \tag{31}$$

$$w_{fI} > w_{eI} \tag{32}$$

When $N > N^*$, a firm comes from North and offers w_{fI} to the workers of South. Because $N > N^*$, we know that $w_{fI} > w_{aut}$. Economic integration starts unless the government of South imposes an income tax to all engineers – including those who work for multinationals – so that:

$$w_{fI} \le w_{bT} \tag{33}$$

Therefore, w_{bT} is crucial to prevent integration. However, in case it does prevent, the welfare of workers of South will is represented by w_{aT}. Then, before intervening, South

Government should check if taxes preventing economic integration are welfare improving, i.e., if

$$w_{eI} < w_{aT} \tag{34}$$

Government intervention avoids integration as long as condition 33 is satisfied, and it is desirable as long as condition 34 is satisfied.

Graphs 1 and 2 relate wages and tax levels and both assume $N = 100$ and $\alpha = 0.5$. Graph 1 represents situation in which taxes are welfare improving. In contrast, Graph 2 shows the case where government cannot do anything to avoid losses from economic integration.

Point where blue and green lines cross each other identifies the minimum percentage of income taxes, say t_{min}, that satisfies condition 33. Preventing will be desirable only if there exist t', so that

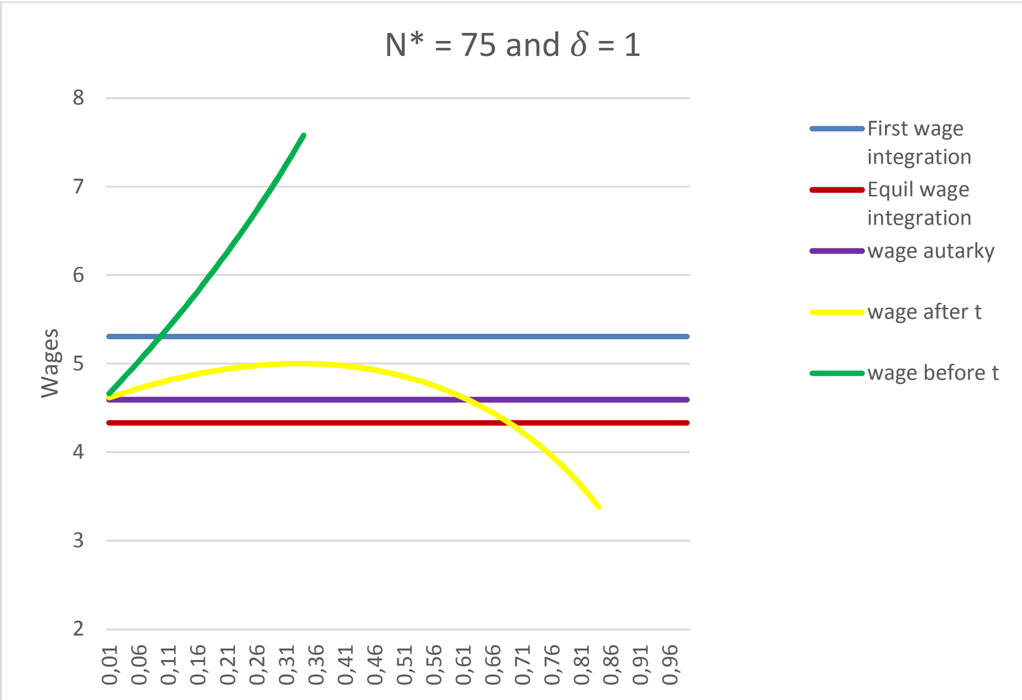
$$t' \geq t_{min} \tag{35}$$

And

$$w_{aT}(t') \geq w_{eI}(t') \tag{36}$$

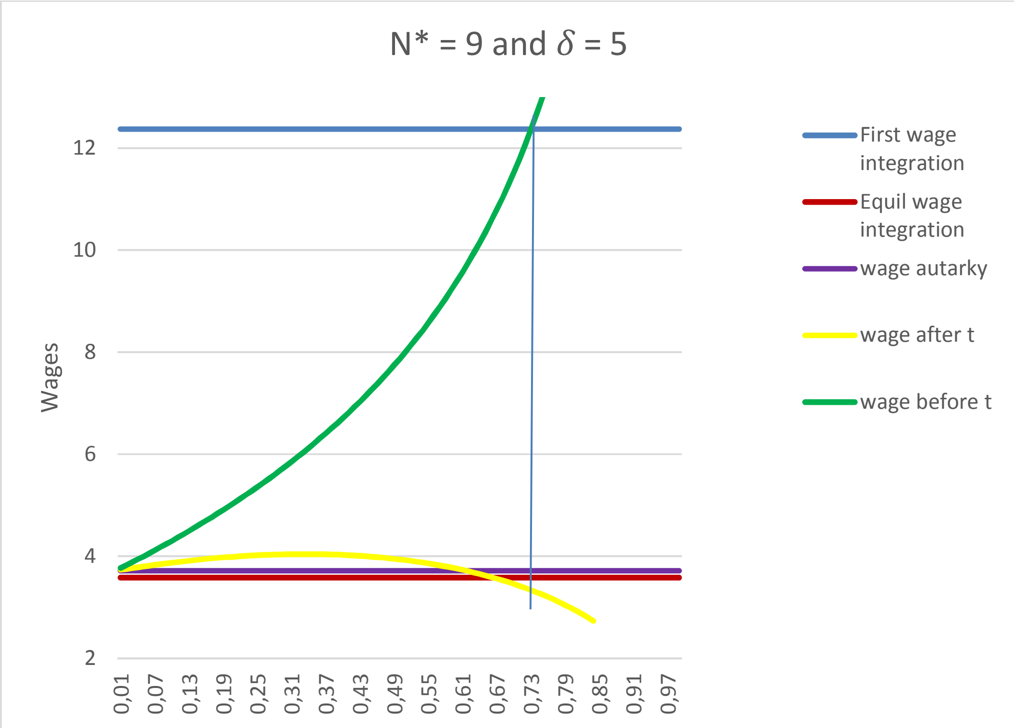
In the graphs, condition 36 is satisfied if yellow line is above red line for any $t' \geq t_{min}$.

Graph1:



N* = 75 and δ = 1
Wages
8
7
6
5
4
3
2
0,01
0,06
0,11
0,16
0,21
0,26
0,31
0,36
0,41
0,46
0,51
0,56
0,61
0,66
0,71
0,76
0,81
0,86
0,91
0,96
First wage integration
Equil wage integration
wage autarky
wage after t
wage before t

Graph 2:



It seems that two conditions should be combined so that economic integration is both harmful and unavoidable: (a) big difference between $N$and $N^*$and (b) high δ. If only condition (a) is satisfied, integration will probably be welfare improving for both economies. If only condition (b) is satisfied, economic integration may be a threat for South, but it is easily avoided by a tax system.

5. Conclusion – a summary of results.

It has been seen that $N > N^*$is a sufficient condition for economic integration, since wages paid by firms from North is greater than wages in South under autarky.

At the first moment, integration means gains for workers of South. However, this initial gain diminishes as the number of workers of South contracted by 'multinationals' increases. It happens because when, say, g engineers of South work for multinationals, the number of innovators in South becomes $\alpha(N^* - g)$. Less innovators means lower productivity of all workers of South as long as $\delta > 0$.

In the end of this harmful process, wage of workers of South may still be higher than their initial wage under autarky. In this case, economic integration brings welfare gains for everyone and the story ends here.

However, depending on parameters of equations 25, the equilibrium wage of workers of South under integration may be lower than their wage under autarky. If it is the case, there may be room for government intervention.

The government can prevent the economy from integration by creating an income transfer from engineers to innovators. This transfer should be high enough so that wages of engineers before taxes become equal to the amount offered by the first multinational arriving in the South (note that engineers of multinationals will have to pay taxes as well). As was seen, there always exist a percentage (t) of income taxes that equalizes those wages and, then, prevent integration.

Nonetheless, imposing such income-transfer mechanism is not necessarily the best strategy, even if integration process drives wages to lower level than in autarky. To be sure those taxes are desirable, it is important to compare the equilibrium wage under complete integration with the wage of engineers *after* they pay taxes. It may be the case that the percentage t has to be so high to prevent integration that it leads the economy to a too inefficient situation – very few engineers with high wages, but paying much taxes, and lots of innovators earning less, but receiving transfers. As consequence, equilibrium wages in this isolated economy may be even lower than final wages under integration. In this scenario, economic integration – desirable or undesirable - is unavoidable.

The worst situation – undesirable and unavoidable economic integration – occurs when size difference between economies is significant and unformal education is very relevant.

Finally, if we assume that engineers and innovators represent the skilled labor of the economy, $N > N^*$ does not mean necessarily bigger population in North; rather it would indicate only that North has more skilled labor than South.