Imitative Behavior and Evolutionary Dynamics for the Comparative Advantage of International Trade Theory

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Resumen

Afirmamos que los agentes económicos impulsados por un comportamiento imitativo afectan a la especialización industrial de las economías nacionales. Hacemos uso de un modelo simple de dos países, donde los trabajadores y las empresas deciden ser calificados (o no calificados) e innovadoras (o no innovadoras). Se demuestra que las ventajas comparativas y el comercio internacional, bajo el supuesto de un comportamiento racional estratégico de los agentes económicos, pueden llevar a los países ya sea un equilibrio de alto rendimiento social o hacia una trampa de pobreza.

Palabras clave: Conducta imitativa; juegos de población; Teorema de Heckscher-Ohlin; trampas de pobreza.

Abstract

We claim that economic agents driven by imitative behavior may impact the industrial specialization of national economies. We use a simple two-country model, where workers and firms decide to be skilled (or unskilled) and innovative (or non-innovative). We show that comparative advantages and international trade, under the assumption of a rational strategic behavior of the economic agents, can lead countries towards either an equilibrium with high-social-performance or a poverty trap.

Keywords: Imitation theory and games; population games; trade strategy.

1. Introduction

It is widely accepted in the modern literature that the emergence and spread of social welfare disparities between countries, in the 19th and 20th century, are due to changes in technologies, in social capabilities to use such technology and/or in the strategic management of the economy (Freeman, 2001). In order to understand economic performances, however, we need to learn about the strategic foundations of R&D activities and of human capital training.

International trade is considered a fundamental method for exploiting innovative products, and may impact national economies in different ways, depending on a multiplicity of factors such as comparative advantages in endowments of resources (either physical, i.e., innovative firms, or human, i.e., skilled workers), or the ability to assimilate new technologies. Archibugi and Iammarino (2001) show that technological advantages are key factors for encouraging international trade, and thus economic growth. Kaldor (1981) claims that non-price factors are more important in determining the competitiveness of the countries in the globalized world market.

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The increase in international trade volumes fostered international specialization and, at least in developed countries, specialization is mainly drawn by the sectors that grew relatively faster. The reason why those sectors grew so fast is probably due to the relative abundance of factors, either technical or human.

Despite the fact that Begg et al. (1999) show that in order to obtain higher rates of economic growth and competitiveness, a country does not need to become broadly specialized, but must be able to exploit high-technological opportunities. For instance, Rodrik (1996) pointed out that a country in which a factor is extremely abundant might take advantage of international trade even without technological development.

Considering that international trade promotes the tendency for countries to specialize in producing goods that use the most abundant (i.e., cheaper) factor, it may be the case that a country with an abundance of natural resources is involved in a process that leads it to produce low-tech goods with little use of skilled labor, and thus find itself in a poverty trap in the long run.

In this work, we focus on the analysis of the possibility that international trade acted as a catalyst of wealth disparities among countries, concentrating on the strategic foundations of the specialization and division of labor (see Groenewegen, 1987). Our key assumption is that economic agents (firms and workers) imitate the most successful, given the current state of the country. This process of imitation stems from a lack of complete information at the moment when the agents had to decide which economic behavior to follow in the future.

As will become clear in the following paragraphs, this mechanism can explain –at least in part– wealth disparities among countries, even in cases where the GDP and trade balance grow at the same rate.

The reason why a country could be trapped in a "poor" equilibrium (an equilibrium characterized by complete specialization, but firms do not innovate and the labor supply is unskilled) is the difference between individual and social objectives, and this may occur even without failures in the market systems or in individual rationality. The fundamental issue here is to understand the circumstances in which it may happen, and, conversely, the favorable situations in which a country develops, that is to say, its own firms innovate and use highly skilled workers.

Rodrik (1996) pointed out that poor countries must specialize in standardized labor-intensive commodities, while middle-income countries may have a richer menu of options if their labor force is well educated and skilled. In this vein, our model argues that economic agents driven by imitative behavior may set the path of the economy towards high-level (rich) or low-level (poor) equilibria (see Accinelli and Carrera, 2011). So our aim is to show the strategic foundations of Rodrik's model when the labor force (i.e. workers) driven by imitative behavior defines the international trade of a country based on comparative advantage and complementarities between R&D activities and human capital formation.

Hence, in the following sections we are going to study two issues:

1. First, free trade empowers two countries to use their comparative advantage and increase their growth process and social welfare. Countries may converge to a high-level equilibrium.

2. Second, using the specialization process produced by international trade and the utilization of the comparative advantages results in an evolution process of the country to a poverty trap, while another other country that is able to use technological progress increases in welfare and growth to a high-level equilibrium. This case shows the possibility that international trade and the utilization of comparative advantages will deepen the inequality between countries, generating at the same time a new challenge for the first country's policy makers, who should and can reverse this situation.

The remainder of the paper is structured as follows. Section 2 is devoted to explaining the baseline model, while in subsection 2.1 we introduce the strategic-form game and its solution. Section 3 sets out the behavior of the firms and workers within the framework of free trade between countries and the production industry, and the evolution by imitative behavior of the economic agents in each of the local economies. Section 4 concludes the paper.

2. The Model

Let us consider a two-country model where the number of skilled workers increases in the sector using it intensively and it increases its output-production. There is no borrowing and lending and no capital accumulation. There is free access to any available technology under different factor endowments. Let us assume that each country has two different industries, namely A and B; with different factor intensities. Both markets in each country are perfectly competitive. Countries possess a degree of complementarity between productive activities with skilled workers and unskilled workers. Those countries may face different effects of the (un)skilled workers' contribution to its production capabilities.

Based on a model of: two-country, two-industries, two-firms and two-workers, the economy consists of the following list of items:

1) Country *P* is abundant in factor endowments used productively in industry *A*.
2) Country *Q* is abundant in factor endowments used productively in industry *B*.
3) Two different types of firms: innovative *(I-firm)*, and non-innovative *(NI-firm)*, denoted by $F_{hf}, h \in \{A,B\}, f \in \{I,NI\}$.
4) Two different kinds of workers: skilled workers, *s*, and unskilled workers, *ns*.
5) The technology is free access. Innovative firms possess a degree of complementarity between technology and skilled workers, i.e. Skill-Biased Technical Change.
6) The technology for innovative firms in industry $h \in \{A,B\}$ and $j \in \{P,Q\}$ is given by a function $T_{Ihj}: \mathrm{R}^3 \to R$ defined as:

$$y_{Ihj} = A_I(l_s)T_{Ihj}(k,l,z_h), \mathrm{h} \in \{A,B\}, j \in \{P,Q\}$$

Where y_{Ihj} is the total output produced by an innovative firm in industry *h*, using *k* units of physical capital, z_h units of a particular input, and *l* total units of labor used by the firm. A percentage, $l_s = s/l$, of this amount comes from skilled workers and the rest from unskilled workers $l_{ns} = ns/l = (1\text{-}l_s)$. The productivity skill-biased factor: $1 \leq A_I(l_s)$ increases with the percentage of skilled workers hired by the firm, i.e.:

$$A_I(0) < \mathrm{A}_I(l_s) < A_I(1), \forall 0 \leq l_s \leq 1.$$

7) Non-innovative firms do not distinguish between skilled and unskilled workers:

$$y_{NIhj} = T_{NhI}(k,l,z_h), \quad h \in \{A,B\} \text{ and } j \in \{P,Q\}.$$

8) The unitary cost of the primary input z_A is cheaper in the country *P* than in the country *Q*, i.e. $w_{z_{A,P}} < w_{z_{A,Q}}$ and reciprocally for $w_{z_{B,Q}} < w_{z_{B,P}}$.

Thus, the total supply in each industry and country is given by

$$y_{hj} = y_{Ihj} + y_{NIhj}, \quad h \in \{A,B\}, \quad j \in \{P,Q\},$$

the total amount produced by innovative firms plus the total amount produced by the non-innovative firms.

According to the H-O Theory (see Heckscher and Ohlin, 1991), a country will produce at a lower cost those products whose production requires relatively large amounts of the factors of production with which that country is relatively well endowed. We assume that each country has comparative advantages in the sector where it has abundant resources. We consider that industries are characterized by types of firms and productive factors from types of workers. So, countries will have a comparative advantage in producing goods that use that country's abundant factor of production. Hence, the cost to produce $y > 0$ units of output in industry *A* located in country *P* is lower than the cost of production of units of output in this industry *A* when it is located in country *Q*. That is:

$$\begin{aligned} &\max\{c_{AIP}(y), c_{ANIP}(y)\} < \min\{c_{AIQ}(y), c_{ANIQ}(y)\} \\ &\max\{c_{BIQ}(y), c_{BNIQ(y)}\} < \min\{c_{BIP}(y), c_{BIP}(y)\}. \end{aligned} \tag{1}$$

where $c_{hfj} : [0,\infty) \to R$ is the long-run cost function to produce y units of output in industry $h \in \{A,B\}$ by firm $f \in \{I,NI\}$ located in a country $j \in \{P,Q\}$. $c_{hfj}[0,\infty) \to R$

2.1 A Repeated One-Shot Game

We allow for perfect mobility of capital and labor between industries and countries. Firms and workers play the following strategic-form game, $\Gamma = \{S_c, S_w, \pi, b\}$, where by S_c and S_w we denote the set of pure strategies of the firms and workers respectively. The respective matrix or payoffs are symbolized by π and *b*. So:

1. Managers (or owners) of a firm need to choose at the beginning of every period where to invest and the kind of firm for working out such an investment, so this capitalist needs to choose between the following strategies:

   $$S_c = \{IAP, IBP, NIAP, NIBP, IAQ, IBQ, NIAQ, NIBQ\}$$

   where $s_c \in S_c$ if and only if and only if $s_c = fhj, \quad f \in \{I,NI\} \quad h \in \{A,B\}, \; j \in \{P,Q\}$

2. Workers choose in the following set of pure strategies or possible behaviors:

   $$S_w = \{sAP, sBP, nsAP, nsBP, sAQ, sBQ, nsAQ, nsBQ\}$$

   where $s_w \in S_w$ if and only if $s_w = ihj, i \in \{s,ns\}, h \in \{A,B\}, j \in \{P,Q\}$

3. We assume that firms are price takers, and we use the notation p_{hj} to denote the price of the unitary output in market $h \in \{A,B\}$ and county $j \in \{P,Q\}$.

4. Technology is free, but skilled labor is a scarce resource, and we adopt that the total supply of this type of labor is given by s_{hj}.

5. The payoffs are:

a) For innovative firms the payoffs are symbolized by the matrix π whose entrances are given by:

$$\pi_{Ihj}(t,y) = p_{hj}(t)A_I(l_s)T_{Ihj}(h,l,z_h) - c_{Ihj}(y), h \in \{A,B\}, j \in \{P,Q\}.$$

where $y = A_I(l_s)\ T_I(h,l,z_h)$, and $c_{Ihj}(y)$ is the long-run cost to produce y units of output in industry h and country j. Given that skilled workers are a scarcer resource, in time t the supply of skilled workers $l_s(t)$ can be less than the total demand of innovative firms in a given country. So if the long-run cost to produce y units of output in industry h and country j is given by $c^j_{Ih}(y)$ then $c_{Ihj}(l_{sj}(t),y) \geq c_{Ihj}(y) \forall y$ and t, where $c_{Ihj}(l_{sj}(t),y)$ denotes the short-run cost of an innovative firm of industry h and country j when the supply of skilled workers is given by $s_{sj}(t)$.

b) For non-innovative firms:

$$\pi_{NIhj}(t,y) = p_{hj}(t)T_{NIhj}(h,l,z_h) - c_{NIhj}(y), h \in \{A,B\}, j \in \{P,Q\}.$$

c) At the beginning of every period, workers need to choose between being skilled or unskilled. Assuming that workers' salaries depend on industry and country and skilled workers receive a premium[1] at the end of every period when employed by an innovative firm, the benefit of a skilled worker, from country j employed in industry h, increases with the skill premium that the innovative firm pays and decreases with the cost of education. The entries of matrix b are:

$$b_{sjh,I} = w_{jh} + pr_{jh} - \delta_{nssjh},$$
$$b_{sjh,NI} = w_{jh} - \delta_{nssjh},$$

where $w_{sjh} > 0$ is the salary of a skilled worker and $pr_{jh} > 0$ is the premium that innovative firms pay to skilled workers, the number $\delta_{(nssjh)} > 0$ is the cost of education of *ns*-workers to become skilled workers, from country j employed in industry h. The benefits are positive, since $0 < \delta_{(nssjh)} \leq pr_{jh}$. Unskilled workers do not get a skill premium and only receive the salary: $b_{nsjh,I} = b_{nsjh,NI} = w_{nsjh}$.

The sets of mixed strategies for firms and workers are given by the sets of distributions over their types (pure strategies). We consider that these distributions are exactly the distributions of the populations of firms and workers over their respective types. Assuming that the total number of workers is given, let us denote by x_{ihj} the share of i-workers ($i \in \{s,ns\}$) from country j employed in industry h. So, the mixed strategy is given by the profile distribution of workers over their respective types and countries, i.e.

$$x = \left(x_{sAP}, x_{nsAP}, x_{sBP}, x_{nsBP}, x_{sAQ}, x_{sBQ}, x_{nsBQ}\right).$$

1 A seminal paper about the notion of skill premia is due to Acemoglu (1998, 2003) but here we just follow his notion and not his formal definition. They face an education cost (or training cost) for being capable to operate new technologies, and so complement innovative firms (that is to be in the knowledge frontier).

So,

$$\sum_{(i,j,h)\in\{s,ns\}x\{P,Q\}x\{A,B\}} x_{ihj} = 1 \quad \text{and} \quad 0 \le x_{ihj} \le 1.$$

Analogously for the distribution of the firms we have

$$y = \left(y_{IAP}, y_{NIAP}, y_{IBP}, y_{NIBP}, y_{IAQ}, y_{IAQ}, y_{IBQ}, y_{NIBQ}\right).$$

or,

$$\sum_{(f,j,h)\in\{I,NI\}x\{P,Q\}x\{A,B\}} y_{fhj} = 1 \quad \text{and} \quad 0 \le y_{fhj} \le 1.$$

Note that, by strategic complementarities:

- The profit of an innovative firm hiring a skilled worker is greater than that of hiring a unskilled worker,

$$\pi_{Ijh,s} > \pi_{Ijh,ns} \forall j \in \{P,Q\} h \in \{A,B\}.$$

- Analogously for a non-innovative firm hiring an unskilled worker,

$$\pi_{NIjh,ns} > \pi_{NIjh,s} \forall j \in \{\mathrm{P},\mathrm{Q}\}, h \in \{A,B\}.$$

- The profit of a skilled worker engaged by an innovative firm is larger than that of a worker, skilled or not, engaged by a non-innovative firm, i.e.:

$$b_{sjh,I} > b_{sjh,NI} \forall j \in \{P,Q\} h \in \{A,B\}.$$

- When workers are engaged by a non-innovative firm it follows that;

$$b_{nsjh,NI} = b_{sjh,NI} > b_{nsjh,I} \forall j \in \{P,Q\} h \in \{A,B\}.$$

We assume that firms know whether a worker is skilled or not because, at the beginning of the contractual period workers need to hand in a certificate of skills, but workers do not know, at the beginning of the period, the characteristics (innovative or non-innovative) of the firms. These characteristics are revealed only at the end of that period, because only innovative firms pay premiums.

Hence the expected value of a skilled worker from country j employed in industry h is:

$$E(sjh) = x_{Ihj}\left[w_{sjh} + pr_{jh}\right] + w_{sjh}x_{NIhj} - c_{nss}.$$

For an unskilled worker: $\mathbf{E}(nsjh) = s_{sjh}$, where the probability of a worker being employed by an innovative firm is equal to the percentage of this type of firms.

Let us consider, without loss of generality, that workers' salaries are the same in every industry from each country, i.e. $w_{sjh} = w_{nsjh} = w_{ns} = w$. But skilled workers employed by innovative firms obtain high-monetary premia. The education cost of being a skilled worker is offset only if these premiums are obtained. So, workers from country j employed in industry h prefer to be skilled if, and only if, $E(sjh) > E(nsjh)$ and this inequality holds if:

$$x_{Ihj} > x^T_{Ihj} = \frac{c_{nss}}{pr_{jh}}. \tag{2}$$

where x_h^T is a threshold value such that if the share of innovative firms, x_h^j, is larger than this value, then workers prefer to be skilled. Note that, the lower the cost of education, cnss, the higher the skill premia, prjh, and this threshold decreases.

3. The Dynamic for the Populations of Firms and Workers

The dynamics of the model are based on the change in the agents' behavior. Consider that at the end of every period, workers and firms can change their current type. Rational workers and firms will choose the best type according to the expected value of each feasible action. The types are being skilled/unskilled and innovative/non-innovative.

Condition 1. *When a current skilled worker of industry h wants to go to work to an industry k ≠ h, by division of labor he/she could not remain as skilled worker. Hence when changing from industry there is a training cost to be identified as a skilled worker; this cost is denoted by* $c_{AB} = c_{BA} > 0$. *To simplify, assume that skill premia, education and training costs are the same in countries and industries.*

To explain why economic agents imitate, we should think of it as a kind of rational behavior (see Accinelli et al., 2010). Under conditions of imperfect information, which prevent economic agents from choosing the best strategy for the future or behavior, imitation appears as a major trend. Certainly, one might wonder whom and how the agent imitates. Then we shall have different evolutionary processes for a given economy (see Weibull, 1995). We will now analyze this process. Imitation results in agents performing a spectrum of tasks "as others do". We assume that occasionally each individual firm and worker in their finite population gets an impulse to revise his/her (pure) strategy choice (innovative/non-innovative and skilled/unskilled). According to this intuition, we introduce the following characterization for the imitation process:

Definition 1. An imitation process is determined by the following two basic elements:

1. *An individual is a reviewer. A time the rate,* $\gamma_{ihj} \in [0,1]$ *at which an i-worker from country j and industry h asks him/herself whether he/she should continue with his/her current behavior or whether to change it.*
2. *The probability of imitation. This is the specification of the probabilities with which an individual reviewer actually changes their behavior. Under the probability* $\mathrm{p}(mlk/ijh) \in [0,1]$ *the* $i \in \{s,ns\}$ *reviewer worker of the country* $j \in \{P,Q\}$ *and industry* $h \in \{A,B\}$ *becomes a m-worker* $m \in \{s,ns\}$, *of the country* $l \in \{P,Q\}$ *in industry* $k \in \{A,B\}$.

So a reviewer (rational) worker chooses the strategy for the next period according to the expected value of the strategy. Assuming that workers know the true distribution of the firms, then:

Definition 2. Let p (mkl/(ihj) be the probability that a reviewer worker who has a strategy ihj ∈ {s,ns}×{A,B}×{P,Q}, switches to a worker following a distinct strategy, (mkl), and it verifies the function $\phi: R \to [0,1]$, $\phi(x)>0$ *if* $x>0$, $\phi(x)=0$ *if* $x \leq 0$, *such that:*

$$p(mkl/(ihj)) = \phi(E(mkl) - E(ihj)) \tag{3}$$

where E(ihj) is the expected payoff to the strategy ihj, $\forall ihj \neq mkl \in \{s,ns\} x \{A,B\} x \{P,Q\}$.

Let $N_{ihj}(t)$ *be the number of people from country j in industry h following the behavior* $i \in \{s,ns\}$, *in time t. Consider a total fixed number of workers (at all times t):*

$$N = N_{sAP}(t) + N_{nsAP}(t) + +N_{sbP}(t) + N_{nsBP}(t) + N_{sAQ}(t) + N_{nsAQ}(t) + N_{sBQ}(t) + N_{nsBQ}(t) \forall t \geq 0.$$

Let us denote by $x_{ih}^{j}(t) = \frac{N_{ih}^{j}(t)}{N}$ the number of workers from country j in industry h following the i - behavior, in time t.

Then the flow for each subpopulation of workers can be,

$$\forall i \neq m \in \{s, ns\}; h \neq k \in \{A, B\}; j \neq l \in \{P, Q\},$$

represented by the dynamic system:

$$\begin{aligned}
&\dot{x}_{ihj}(t) = \left[\gamma_{mhj} p(jih / mhj) x_{mhj}(t) + \gamma_{ihl} p(ihj / ihl) x_{ihl}(t) + \gamma_{ikj} p(ihj / ikj) x_{ikj}(t) + \gamma_{mkj} p(ihj / mkj) x_{mkj}(t) + \right. \\
&\left. + \gamma_{mhl} p(ihj / mhl) x_{mhl}(t) + \gamma_{mkl} p(ihj / mkl) x_{mkl}(t) + \gamma_{ikl} p(ihj / ikl) x_{ikl}(t)\right] - \\
&- \gamma_{ihj}\left[p(mhj / ihj) + p(mkj / ihj) + p(mhj / ihj) + p(mhl / ihj) + p(ikl / ihj) + p(mkl / ihj)\right] x_{ihj}(t).
\end{aligned} \tag{4}$$

Rearranging the terms, the system (4) can be written like:

$$\dot{x}_{ihj}(t) = \sum_{(m,k,l) \in \neq (i,h,j)} \left(\gamma_{kml} p(ihj / kml) x_{mkl} - \gamma_{ihj} p(kml / ihj) x_{ihj}\right). \tag{5}$$

Or taking into account that $x_{ihj} = 1 - \sum_{((m,k,l) \neq (i,h,j)} x_{mkl}$, system (4) becomes:

$$\dot{x}_{ihj}(t) = \sum_{(m,k,l) \in \{s, ns\} \times \{A, B\} \times \{P, Q\}} \left(\gamma_{ikl} p(jih / ikl) x_{ikl} - \gamma_{ihj} x_{ihj}\right) \tag{6}$$

Workers prefer to follow the behavior with the greatest expected payoff, so the probability that a reviewer worker chooses to change from one industry to another or to become a skilled worker depends on his/her expected payoffs for each own possible strategy or behavior.

Recall that innovative firms prefer to hire skilled workers because the profits of these firms increase with the supply for skilled workers in the country, in time *t*. Following Accinelli and Carrera (2011), we consider that there is skill-biased technical change and the technological function of an innovative *I*-firm in industry *h* is given by a function $T_{Ih} : R^3 \to R$ which is smooth, and such that $q = E_I(l_s)T_{Ih}(k,l,z_h)$, where q is the output that a representative *I*-firm might attain from those inputs: i) a quantity k of physical capital, ii) a quantity l of workers, and iii) a quantity z_h of the distinctive input for industry *h*. Such technology verifies that:

$$\frac{\partial}{\partial l_s} MP_k > 0, and \frac{\partial}{\partial l_s} MP_{z_h} \geq 0 \tag{7}$$

i.e. the productivity of an innovative firm increases and its short-run cost decreases compared to the long-run cost when the supply of skilled workers increases. Hence, the first of the two inequalities (7) says that skilled workers and physical (high-tech) capital are complements. Moreover, Accinelli and Carrera (2011) show that there is a threshold value such that if the share of skilled workers is above it, then workers prefer

to be skilled. Let x^T_{shj} be the threshold value for the country *j* in industry *h*. If in time *t*, the share $x_{shj}(t)$ of skilled workers is larger than the threshold value, x^T_{shj}, hence, in this industry the firms are becoming innovative and workers are becoming skilled.

Therefore, by imitative behavior of economic agents, namely firms and workers, the complementary process between firms and workers is such that the threshold value, x^T_{shj}, is lower in the country where the resource (innovative firm and skilled worker) is abundant. It happens simply because the cost to produce *y* units of output in this industry with abundant resource is lower than the cost to produce the same amount in the country where is relatively scarce.

So, in country *P* the threshold value is lower for the industry *A* than in the country *Q* and inversely for the industry *B*. Then, the next relations holds: $x^T_{sAP} < x^T_{sAQ}, x^T_{sBQ} < x^T_{sBP}$.

3.1 A Divergent Process of Growth

Assume that, in time $t = t_0$, the inequality $x_{sAP}(t_0) > x^T_{sAP}$ holds, and that at the same time $x_{sAQ}(t_0) > x^T_{sAQ}$. This means that, in time $t = t_0$, the country *A* has comparative advantage with respect to the country *B* in the industry *A*. In the absence of free trade for capital and labor force, following Accinelli and Carrera (2011), under the assumption of complementarity, the industry *A* of the country *P* is growing to a high-level equilibrium and, at the same time, this industry, in the country *Q* is immersed in a process where firms are becoming non-innovative, and workers are becoming an unskilled labor force.

Consider that workers only know if they are employed by innovative or non-innovative firms at the end of the contractual period, i.e. when they get the skill premium. Let us denote by *E(sjh)* the expected value (payoff or benefit) of skilled workers within industry $h \in \{A, B\}$ from country $j \in \{P, Q\}$. If the next inequality is verified,

$$E(sjh) = x_{Ihj}(w_{hj} + \mathrm{Pr}_{hj}) + x_{Nihj}w > E(ski) = x_{Ihi}(w + \mathrm{Pr}_{ki}) + x_{NIhi}w_{hi} - c_{ij} \tag{8}$$

then:

1. Workers of the industry $h \in \{A, B\}$ prefer to migrate from country *l* to country $j \neq l \in \{P, Q\}$. Note that the first inequality is verified depending on the training cost of moving from the country and remaining skilled, c_{AB}, but also on the share of innovative firms, $x_{fAP,}$ or the probability that a skilled worker is hired by an innovative firm in this industry *A* from country *P*. The second one stems from the fact that in country *Q* the expected payoff of a skilled worker in industry *B* is higher than the expected value of an unskilled worker.

2. Similar processes are followed in industry *B* of both countries *P* and *Q*. Then skilled workers in industry *B* from country *P* are migrating to country *Q* in industry *B* (see Figure 1).

Therefore country *P* in time $t = t_0$ is in a process of high-specialization in industry *A* and country *Q* becomes specialized in industry *B*. This is because the imitative behavior of the economic agents and each country has comparative advantage.

The above inequality (8) is verified if (considering costs, salaries and prizes as fixed) the share of innovative firms x^P_{fA} is larger than the threshold value for the free trade case, i.e.

$$\underset{x_{fAP}}{\overset{-T}{}} = \frac{x_{fBQ}(S_s + \Pr) + x_{nfAQ}S_s - c_{AB} - x_{nfAP}S_s}{(S_s + \Pr)}$$

Note that, according to the above items (1) and (2), it follows that $N_{sAP}(t)$ *and* N_{sBQ} are increasing the function of time $t > t_0$.

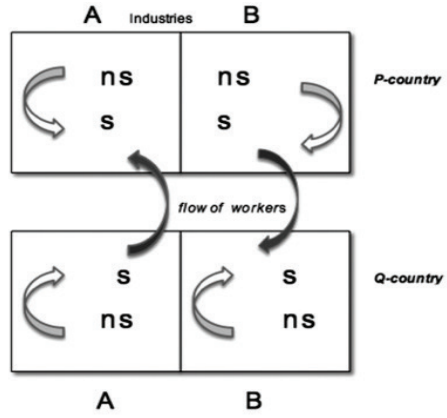

Figure 1. Two countries with specialized industries

3.2 A Poverty Trap Case

Traditional economic theory tells us that specialization is worthy in itself because it leads to a more efficient use of available resources. Unless this has a positive effect on technological progress it will not lead to a higher growth in the long run. Consider now the case where:

$$x_{sAP}(t) < x^{T}_{sAP}, \quad \text{and} \quad x_{sBQ}(t) > x^{T}_{sBQ}.$$

Since country *P* has comparative advantages in industry *A* (according to the Heckscher-Ohlin theory of international trade), the degree of specialization increases in time. However as the supply for skilled workers is lower than the threshold value, firms prefer to be non-innovative and complementary workers prefer to be unskilled because *E(PnsA) > E(PsA)*. Then because of rationality (see equation (3)) we obtain that:

$$p(PnsA / PsA) > 0 \quad and \quad p(PsA / PnsA) = 0 \tag{9}$$

i.e. a reviewer skilled worker from country *P* within industry *A* imitates to become unskilled. Since the probability that a worker is a reviewer increases inversely with the performance of his/her current strategy, then $\gamma^{P}_{sA} > 0$, and the probability that a skilled worker becomes an unskilled worker is positive, i.e.

$$p(PsA \to PnsA) = \gamma_{sAP}\, p(PnsA / PsA) > 0$$

while the reverse probability is zero: $p(PnsA \to PsA) = \gamma_{saAP}\, p(PsA / PnsA) = 0$

Hence the flow from the skilled worker subpopulation to the other subpopulation is positive and given that the $\mathbf{E}(sAP) < \mathbf{E}(nsAP)$ a positive flow to the subpopulation of skilled workers in industry *A* and country *P* does not exist because the expected payoff for being unskilled is higher than the expected value of being skilled.

Using the equation (5) and assuming $P((PsA/ihj) = 0 \forall ihj$ we get:

$$\dot{x}_{sAP} = -\gamma_{sAP}\left[\sum_{jih \neq sAP} P(jih/PsA)\right] \tag{10}$$

Reciprocally, given that the percentage of innovative firms in B of country Q is higher than the threshold value, workers prefer to be skilled, and so $\dot{x}^{Q}_{sB} > 0$. This implies that the productivity of innovative firms increases and firms prefer to become innovative.

Moreover, the country Q is evolving to a low-level equilibrium in industry A, according to the assumption that

$$\max\left\{c_{AIP}(y), c_{ANIP}(y)\right\} < \min\left\{c_{AIQ}(y), c_{ANIQ}(y)\right\}$$

while the country P remains specialized in industry A, where the evolution is to a poverty trap (see Figure 2).

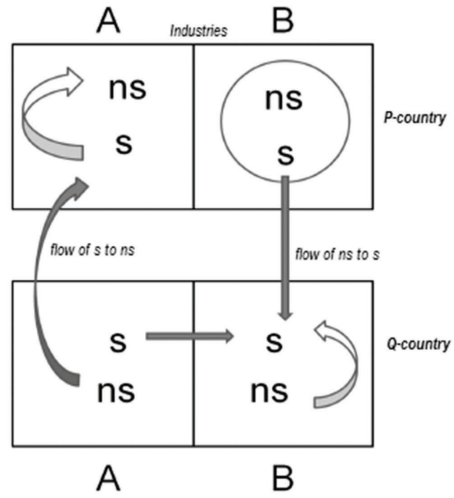

Figure 2. P-country in poverty trap.

Definition 3. *Country is in poverty trap in the sense of being composed of non-innovative firms and unskilled workers, if either: i) it does not take on an industrial specialization where it has comparative advantage from international trade, and ii) the sub-population of workers becomes an unskilled due to an imitative behavior.*

Remark 1. *Note that the social result of the industrial specialization within each country is divergent. Industry A from country P is evolving into a poverty trap. Contrarily, industry B from country Q is moving toward a high-level equilibrium. The openness to international trade aggravates the poor social performance of the economy of country P.*

Although this country could be successful in international trade, using its comparative advantages, it evolves into a poorly industrialized equilibrium with low human capital development.

The particular case of *P*-country evolving into a poverty trap demands a central authority or policy maker, provided that the objectives of such an intervention are well defined and bounded in time.

4. Conclusion

In this paper, international trade is a selection process driven by the evolutionary dynamics of comparative advantages and technological innovation.

Under particular (and local) circumstances in which the economy does not exceed certain thresholds determined by the imitative behavior of the economic agents, although the country has advantages in the international market, it is evolving into a low-level equilibrium, with little technological development and workers who do not select to be skilled. We denote that such a country is immersed in a poverty trap.

This situation shows the possibility that, if a country is not able to use technological change to increase its comparative advantage, the result of the industrial specialization supported by free trade increases the inequality gap between countries.

A central authority can mature programs with the aim of improving competitiveness and, at the same time, high-standards of growth from a socially optimal use of the comparative advantages. However, the participation of policy makers needs to be cautious and with precise objectives.

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