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ON THE MECHANICS OF THE BRAIN-DRAIN REDUCTION IN POOREST DEVELOPING COUNTRIES

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This article examines how endogenous human capital of the developed countries expressed by professors trained there and endogenous human capital of the developing countries expressed by their students, interact in the developing country's education sector to create higher quality goods. Private and public incentives to invest in human capital accumulation finance the employment of the skilled labor in the education sector, while non rival technology is a by-product of the education process. Both the optimal and the competitive equilibria define the efficient point able to lead the economy to the long-run growth. This point is also the locus where knowledge call policy as the required efficiency to reduce the brain drain phenomenon. Indeed, the model provides theoretical foundations of the relative lack of the high skilled labor in developing countries.

Keywords: Absorption Cost, Abroad Trained Professor, Domestic Trained Professor, Private Education, Public Education
JEL classification: E60, E62, O11, O22

1. INTRODUCTION

The aim of this paper is to provide theoretical foundations of the relative lack of high skilled labors in developing countries.

According to the OECD data on skilled labor migrations, 85% of skilled migrants of developed countries are developing countries natives. This highly skilled labor stock was about 20.5 millions in 2000 and keeps increasing over time (see the figure). The most affected countries are United States, Canada, Australia, Germany and France. Recent comparative data on highly skilled labor immigrants from developing countries living in the OECD member countries show 63.7% increase for skilled immigrants in ten

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years against 14.4% increase for unskilled immigrants only (Docquier Marfouk, 2006). The vast majority of those highly skilled immigrants represent more than a third of total immigration to the OECD countries actually (Beine Docquier Rapoport, 2008). Moreover, the recent June 2009 G8 Conference focused on the Way Western Countries Can Help Africa Overcome Poverty because under-development remains a major goal in Sub-Saharan Africa.

Therefore, the under-development debate began since the 1950s through the standard economic development theory (Hirschman, 1958; Leibenstein, 1957; Lewis, 1954; Myrdal, 1957; Nelson, 1956; Roseinstein Rodan, 1943) remains widely open. Because the *Big-Push* (Roseinstein Rodan, 1943), *the Economic Dualism* (Lewis, 1954), *the Stages of Economic Development* (Rostow, 1960) and *The Strategy of Economic Development* (Hirschman, 1958) for example, couldn't provide real solutions to the Sub-Saharan Africa's growth absence. Indeed, the standard economic development theory fell in the middle of the 1970s, more because of the lack of methodology than the lack of ideology (Krugman, 1993). Therefore, *New Development Economics* research line with well specified methodologies is launched.

Lewis (1954) opens two modeled research lines in development economics. The first line deals with international migrations of the high skilled labor i.e., the *Brain Drain* (Kim, 1976; Delacroix Docquier, 2012) based on Grubel Scott (1966). The second modeled research line due to Lewis (1954) is regional migrations (Fan, 1979; Carvajal Upahiaya, 1986; Bharati Basu, 1999; Todaro, 1980; and Lee, 1976) based on Harris Todaro (1966).

Roseinstein-Rodan (1943) is modeled by Murphy-Shleifer-Vishny (1989) and previously introduced in new economic development theory by Waters (1978), Chen (1994), and Ahn (1990). The rest of the ideas provided by standard economic development theory and introduced in new development economics since the 1990s by Issa (2005) and Nissan Niroomand (2006) for example, are mostly based on Romer (1986) and Lucas (1988). The last two endogenous growth models explain increasing returns and knowledge externalities through the neoclassical growth model of Solow (1956) extended to human capital initiated by Becker (1964) and Schultz (1961). Demography can be connected to endogenous growth models which deal with human capital to study development (Maksymenko Rabbani, 2011; Issa, 2005; Dahan Tsiddon, 1998). Growth models which deal with endogenous technological change and human capital accumulation on the basis of Schumpeter (1942), like Eicher (1996), are initiated by Aghion-Howitt (1992). Without the Schumpeterian creative destruction concept, the endogenous technological change growth line is initiated by Romer (1990). Endogenous technological change research line is not really followed by new development economics yet. The pioneer of new development economists like Oh (1976), Waters (1978) and Gray (1986) still to explain development with exogenous technological change. That is the effort made in this article to deal with the endogeneity character of knowledge which accelerates changes in technology in the process of economic development of the poor countries.

In parallel, early development economists[1] explain Western countries' high economic development levels by their labor productivity efficiency (Maddison, 1982) as well as by their technological change level (Abramovitz, 1956; Kendrick, 1956; Solow, 1957). Using the similar ideas, Wang (1991) explains that, rapid growth of Korea between the 1960s and the 1990s is due to the ability to match the education system to rapid changes in industrial demand. Indeed, poor industrialization is due to low incentives to learn costly technology (Cecen, 1991;[2] Chen, 1994;[3] Waters, 1978; Gray, 1986; Gonçalves, 1986; Nissan Niroomand, 2006). Finally, as an under-developed area, the Sub-Saharan Africa's development absence is mainly due to low incentives to invest both in human capital accumulation and in technological change. Thus, economic reforms including both human capital accumulation and technological change are the best answers to under-development due to low skill labor (Maksymenko Rabbani, 2011; Issa, 2005; Mbaku Kimenyi, 1992; Eicher, 1996). Finally, the brain-drain theory suggests that the observed low high skilled labor stock in Africa is mostly due to their high incentives to migrate to developed countries (Docquier Delacroix, 2012; Miyagiwa, 1991; Haque Kim, 1995; Grubel, 1966; Grubel Scott, 1966; Kim, 1976; Fan, 1979). Therefore, the brain drain must lead to complete cessation for development to settle in poor economies (Kim, 1976).

Indeed, this article provides theoretical foundations in order to give the best answer to the question "*what can be done for the developing countries to be the main economies to benefit from their own skilled labor? Or how highly skilled labor stock can be obtained in poorest developing countries?*"

The theory of economic development provided by this article is based on Eicher (1996) growth model and on Kim (1976) brain drain development economic model in order to study the long run growth in poor countries. The model shows that, the endogenous human capital stock of the developed country expressed by their professors i.e., native developing country's high skilled labor trained in the developed country and back home to work in the education sector (Kim, 1976)[4] on the one hand and the endogenous developing country's human capital stock expressed by their students as well as domestic professors or home trained professors on the other hand, enter together in the developing country's education sector at an exogenously specified student-professor ratio $\gamma \succ 1$ to assimilate the developed country's high technological vintage. Next period, the student stock is able to create higher quality goods in the production

[1] Galor Weil (2000).

[2] Cecen (1991) uses an optimal growth model to show that export of high tech foreign product enhance technological level of the country.

[3] Chen (1994) proves that poor industrialization is due to low incentives to learn costly technology.

[4] Ki Hoon Kim (1976) aim is to propose remedies to eradicate the brain drain on the basis of Grubel-Scott (1966) because it induces losses for the source country. Therefore, one of the remedies given is to make the natives of developing countries back home after completing their studies abroad.

sector as engineers or to generate innovations in the research sector as professors. The interaction between the developing country's student stock and the native professor stock trained in the developed country establishes an equivalency among them in terms of knowledge and skills through the time. The main engine which makes this economic policy successful is the relative wage viewed such as a decision variable for the professors to come back home to teach or to leave again. More precisely, the relative wage decrease makes higher skilled professors leave the developing country's education sector. Then, technological progress is retarded, growth declines and the economy stagnates. Consequently, the development process is slowed. In contrast, the relative wage increase attracts higher skilled professors home i.e., in the developing country's education sector to teach students on new developed country's technological vintage which they are assumed to understand quite well. Then, development accelerates because technological change increases and generates more innovations. The absorption of those innovations in the production sector by the engineers creates higher quality goods and increases the economic growth rate. Because the optimal equilibrium (or the public education curve) is a monotonic increasing function of past and current human capital stocks and the competitive equilibrium (or the private education curve) is a monotonic decreasing function of past and actual human capital stocks, the unique development path exists and is defined by the intercept of the both curves in the space. This Pareto-Optimal point is the locus where *knowledge call policy* is the most efficient because it has the ability to allow the poor economy converges to its long-run development path. This path is, therefore, the only one able to lift the poor economy out of the poverty trap in which it is kept.

The results found are: when incentives to invest in human capital accumulation are supported by the bond market, education is costly and the analysis replicates Eicher-Kim findings i.e., since high native skill labor trained in developed countries gets inside the education system, then high innovations occurrence are associated to low skilled labor supply and to high skilled labor demand and tend to relative wages increase. In contrast, when incentives to invest in human capital accumulation are supported by fiscal policy, the model replicates Stockey (1988), Chari Hopenhayn (1991), Young (1993) and Grossman Helpman (1991) findings where innovations increase allow for more investment in human capital accumulation and tend to relative wages decrease. Finally, the development path is defined by the locus on the plane, where both public and private education curves intercept on the space. This locus estimates the level for which knowledge call policy is the most efficient.

Therefore, crucial parameters which allow the poor country's economic development take-off are highlighted. The mechanics of economic development are thereby the marginal propensity to save, the skilled and the unskilled labor productivities as well as technological change growth rate. This study also shows that, if human capital level of higher skilled professors i.e., professors trained abroad is too high compared to student's capability to learn, the development path may be difficult to reach because the efficient point may not exist and thus knowledge equivalency unable to establish. The exogenously specified student-teacher ratio must moves at a constant rate through the time for the economic policy to be successful. The interaction of both the abroad trained and the domestic trained professors in the education sector creates positive knowledge externalities only and only if the exogenously specified student-professor ratio on the one hand and the exogenously specified domestic and abroad trained professors ratio on the other hand move at the same constant rate.

The scientific contribution provided by this analysis holds on the three following aspects:

First, it is a theory of economic development based on growth theory linked to human capital accumulation and technological change viewed both such as development take-off and brain-drain reduction tools. One easy way to reduce high skilled labor incentives to migrate to more developed countries i.e., the brain drain phenomenon mostly due to human capital formation abroad,[5] is to finance home training at high education levels added to home work duty.

Recent brain-drain studies such as Beine Docquier Rapoport (2008) also consider home human capital accumulation. In unanimity, Beine Docquier Rapoport (2008), Kim (1976) and Fan (1979) conclude to losses for the developing country's economy. Therefore, Kim (1976) recommends a complete cessation of international migration of human capital because losses for source country's economy are too great. This is true since the migration rate of the higher skilled labor reaches 20% or more and/or if the proportion of people with higher education is equal or up to 5% (Beine Docquier Rapoport, 2008). The brain-drain analysis in an endogenous growth model such as Chen (2006; 2008) concludes to the brain-drain increase more for private education than for public education. Other recent brain drain analysis includes uncertainty in the study of the impact of the high skilled labor migration on the source country's economic growth (Beine Docquier Rapoport, 2008; Chen, 2006; 2008). This last characteristic is highlighted in this model by relative wages movements.

Second, in contrast to most studies on development economics based on education where basic human capital accumulation increase is mostly chosen because poor economies are far from their long-run development path (Aghion Howitt, 2003) and thus, research returns may not be interesting enough to be conducted (Eicher, 2003), this analysis focuses on the determinants of high education level in order to establish growth and development theoretical foundations in poor countries since both human capital accumulation and future work take place at home.

Third, this study is a synthesis of Eicher-Kim analysis based on private education on the one hand and of Stockey (1988), Chari Hopenhayn (1991), Young (1993) and Grossman Helpman (1991) based on public education on the other hand. The link among the two approaches mentioned defines a Pareto-optimal point defined by the intercept of

[5] Early studies focused in that direction i.e., Grubel Scott (1966), Bhagwati Hamada (1974), McCullock Yellen (1977) conclude to higher social returns of public education than private returns of education.

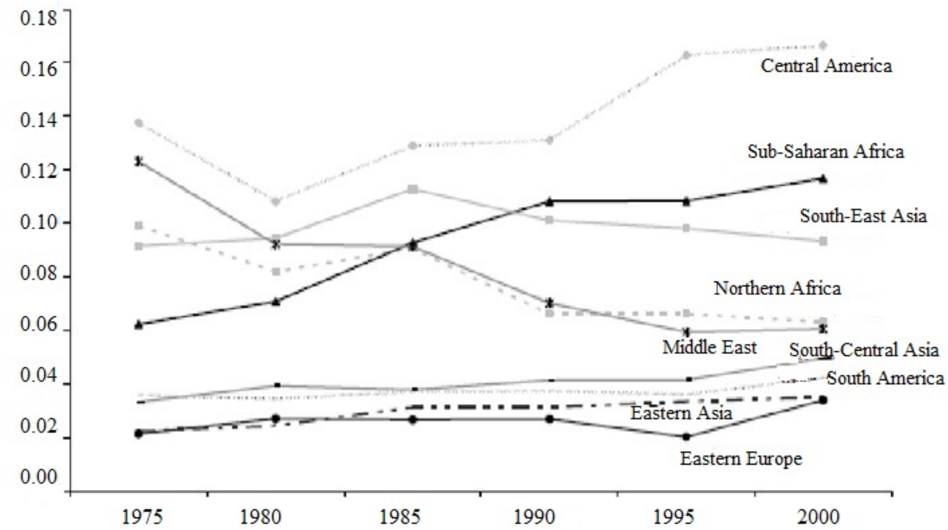
public and private education curves. This locus is the only one, able to make the poor economy converges to its unique long-run development path.

The literature of endogenous growth was initiated by Romer (1986; 1990) and Lucas (1988), the sources of economic development provided are human capital accumulation or education and innovations through research-development. Easterly Levine (2001) then estimates that 60% in PIB variation is explained by growth productivity differentials using the Klenow and Clare sample. Growth literature methodology is also used to analyze development economics issues like already described above (Orlov Roufagalas, 2008; Issa, 2005; Gray, 1986; Oh, 1976).

The brain-drain literature i.e., international migration of skills and talent from developing to developed countries (Kim, 1976; Grubel Scott, 1966), the second research line used in this article, had a pessimistic view[6] in its beginning back in the middle of the 1960s and the 1970s (Grubel Scott, 1966; Berry Soligo, 1969; Lee, 1976; Kim, 1979; Fan, 1979; Todaro, 1980). Now, the brain-drain literature focuses also on skills acquired at home (McKenzie Rapoport (2006) and Docquier Marfouk (2006) data set on emigration rates by education levels). All those studies show that the brain-drain has negative effects in the source country's economy. Therefore, "*poverty*" is the concept which links both growth and brain-drain research lines to economic development (Carvajal Upadhiaya, 1986; Ahn, 1990; Docquier Delacroix, 2012). Because for the brain drain literature, the fundamental cause of underdevelopment is the tendency for the high skilled labor stock to be out of their initial economic system and for the growth literature, it is due to low incentives to invest both in human capital accumulation and in technological change. Equivalently, *poverty* is caused by low labor productivities in poor countries (Azariadis Drazen, 1990; Galor Weil, 2000; Wang, 1991; Chen, 1994; Waters, 1978; Gray, 1986; Gonçalves, 1986).

In section 2 we introduce the main assumptions and the setup of the model. In section 3 we characterize both the optimal and the competitive equilibria. In section 4 we determinate the Pareto-optimal point where knowledge call policy is the most efficient because at this locus, the economy converges to its long-run development path. In section 5 we analyze the determinants of the long-run growth. Finally we conclude in section 6 and open new issues to the development debate such as sustainability in poor countries because of negative effects of high industrialization on environmental quality.

[6] It is crucial in the concern of returns in poorest economies.



Source: Defoort (2008).

Figure 1. Long-Run Trends in High-Skill Emigration, 1975-2000

2. THE ECONOMY

Consider an overlapping-generation model with agents who live for two periods of time. The world is divided in two countries where the one is developed and the other is not. Developed country's variables are indexed by *d*. In contrast, developing country's variables are indexed by $\overline{d}$. The main difference which prevail among the two countries comes from their respective economic development level i.e., the developed country is able to produce high quality goods whereas the developing country can't. This situation is essentially due to their respective human capital investment levels. The developed country produces high quality goods according to the cutting edge non rival technology, A_t (the technology invented at time *t*) and he is a leader in this field. In each of the two countries, the supply side has a 3×3 structure i.e., two production sectors manufacture one homogenous consumption good which differ both in their technological sophistication and their skill intensity. The education sector offers the young agents the opportunity to accumulate human capital while generating ever new technological vintages. At time *t* the education sector of the developing country employs a stock a professors P_t which is the sum of native agents who have done their training abroad or in the developed country back home to teach students on new technological vintage, P_t^d and domestic trained professors' stock, $P_t^{\overline{d}}$ as well as developing country's student stock denoted $S_t^{\bar{d}}$ as well as the cutting edge non rival technological vintage A_t to produce a non rival technological vintage A_{t+1}. More precisely, young agents enter in the education sector together with professors at an exogenously specified student-teacher ratio, $\gamma \succ 1$. For simplicity the analysis refers to P_t^d such as developed country's professors stock to highlight the fact that, this stock of native high skilled labor is endowed with developed country's human capital level and is willing to come back home since relative wage rate is high enough (Kim, 1976). Therefore human capital endowment of P_t^d is assumed to be higher than those of, $P_t^{\bar{d}}$. We also assume that population size is constant at each period of time and normalized to unity. In each period, a new generation of agents enters in the economy with a zero endowment of human capital. Young agents must decide whether to accumulate human capital and get inside the education sector as students $S_t^{\bar{d}}$ or to work in production sector as unskilled labor, $U_t^{\bar{d}}$. Next period, the students become a stock of skilled workers who choose to spend their time in either the research-development sector which is a by production of the education sector as "teachers", $P_{t+1}^{\bar{d}}$ or in the production sector as "engineers", $E_{t+1}^{\bar{d}}$. Following Eicher (1996), we assume the unskilled labor to be retired in his second period of life when old. At the beginning of knowledge call policy, developing country's students are not assumed to be trained outside of their native country but there exist in the developed country, a stock of high skilled developing country's native i.e., professors. The high skilled labor native of the developing country trained in developed country, decide whether to go back home or to stay abroad for work and eventually to leave again one training done.

2.1. The Production

At time *t*, the developed country's non rival technological vintage moves according to higher skilled professor's productivity parameter, $\mu \succ 0$. Technological change growth rate is therefore:

$$g = \frac{A_{t+1} - A_t}{A_t} = \mu P_t^d.$$ [7]

The goal of the economic policy proposed is to make developing country's students understand the developed country's technology through higher skilled native professors

[7] This equation means that, human capital level of the agents trained in the developed country equals to $\mu \succ 0$.

in the education sector. The education function used was initiated by Bagwati Srinavasan (1977) extended to technological change expressed by (1)

$$A_{t+1} - A_t = \mu A_t \min\left\{\gamma P_t^d, S_t^{\bar{d}}\right\}. \tag{1}$$

$\lambda P_t^d = P_t^{\bar{d}}$, $\lambda > 1$ i.e., higher skilled professor stock is lower than domestic professor stock. The link among them highlights a relationship which generates knowledge externalities. Equation (1)[8] can be decomposed into three alternatives even simpler representations such as

$$A_{t+1} - A_t = \mu\gamma A_t (1+\lambda) P_t^d,$$

$$A_{t+1} - A_t = \mu A_t S_t^{\bar{d}},$$

$$S_t^{\bar{d}} = \gamma(1+\lambda) P_t^d.$$

Equation (1) can also be written such as Equation (2) i.e.,

$$A_{t+1} - A_t = \mu A_t \min\left\{\gamma(1+\lambda) P_t^d, S_t^{\bar{d}}\right\}. \tag{2}$$

Like Equation (1), Equation (2) means three things: the first alternative means that, the stock of professors who come from the developed country acts like the engine of growth and technological change. The second alternative means that, the developing country's student stock is fully assimilating the developed country's technology. The third alternative means that, the professors who come from the developed country and the developing country's students are equivalent in knowledge terms. Private education support takes place in the bond market regulated by an endogenous interest rate whereas public education is offered by the social planner through fiscal policy on the unskilled labor income. Since the students agree to get inside the government program, they must stay home to work for the poor country's economic development goal. Both for private and public incentives to invest in human capital accumulation, per-student direct cost is z_t which just equals the student-professor ratio times the professors' wage bill i.e., $\frac{w_t^p}{\gamma}$. Thus, both private and public incentives to invest in human capital accumulation finance the professors' wage bill and generate serendipitous technological change. New

[8] The basic analysis doesn't include heterogeneous professors neither developing country's student stock and focuses on developed countries growth issues only.

technological vintage invented in the education sector is non rival in use and thus not remunerated. But their future use in production needs labor endowed with high productivity in order to absorb the vintage in good production. Consequently, while a higher rate of technological change shifts the production possibility, it simultaneously drains the pool of skilled labor available in the education sector and thus retards future technological change. In a significant way, it drains skilled labor from research to production sector. Indeed, technological change is slowed, good quality decreases too and growth stagnates. Consequently, the skilled labor stocks of both the research and the High-Tech production sectors must grow at the same constant rate in regard to growth and development stabilities in the long-run. The High-Tech sector utilizes the cutting edge non rival technological vintage A_t, the skilled labor of the production or the engineers, $E_t^{\bar{d}}$ to adapt new technology into the production process and the unskilled labor stock, U_t^H to perform routine tasks. The high tech production function is thus expressed by (3) i.e.,

$$H_t = A_t F\left(U_t^H, E_t^{\bar{d}}\right), \tag{3}$$

where F is a linear homogenous monotonic production function. Following Nelson and Phelps (1966), the absorption of new technology in the High-Tech sector is skill intensive. However, once a technology has been absorbed, production requires unskilled labor U_t^L only. Therefore, the low tech production sector uses only old technology, A_{t-1} (absorbed in the previous period) and unskilled labor to perform simple tasks. The low tech production function is then expressed by Equation (4) i.e.,

$$L_t = \delta A_{t-1} U_t^L, \tag{4}$$

where $\delta > 0$ is the unskilled labor productivity parameter. When a new technology is introduced in the High-Tech sector, the recently absorbed technology can now be used in the Low-Tech sector which renders the oldest production method no longer profitable and thus discarded.[9]

Production of the consumption goods takes place in a perfect competitive sector. Rewriting H in intensive form leads to $F\left(U_t^H, E_t^{\bar{d}}\right) = f\left(\frac{U_t^H}{E_t^{\bar{d}}}\right) E_t^{\bar{d}}$ then profit

[9] This is a creative-destruction principle due to Schumpeter (1942) and modeled in an endogenous growth model by Aghion Howitt (1992) where innovations are randomly given in contrast to Segerstrom, Anant and Dinopoulos (1990) where innovations are not randomly given. This line is in development economics highlighted by the works of Gray (1986), Waters (1978) and Cecen (1991).

maximization yields the standard first order conditions (5)-(7) i.e.,

$$w_t^E = A_t\left[f\left(\frac{U_t^H}{\bar{E}_t^d}\right) - f'\left(\frac{U_t^H}{\bar{E}_t^d}\right)\frac{U_t^H}{\bar{E}_t^d}\right], \tag{5}$$

$$w_t^{UH} = A_t f'\left(\frac{U_t^H}{\bar{E}_t^d}\right), \tag{6}$$

$$w_t^{UL} = \delta A_{t-1}. \tag{7}$$

The factor market equilibrium requires (8) and (9) i.e.,

$$w_t^E = w_t^p, \tag{8}$$

$$w_t^{UL} = w_t^{UH}. \tag{9}$$

Equation (8) means that, the skilled labor stock as “engineers” in the production sector or as “professor” in the research sector win the same wage rate income because their marginal productivity is assumed to be the same. Equation (9) means that, the marginal productivities of the unskilled labors of the both sectors of production must be the same. Given the linearity of $F(,)$, the relative wage in the High Tech sector depends only on the relative factor prices i.e.,

$$\frac{w_t^E}{w_t^{UH}} = \varsigma\left(\frac{U_t^H}{\bar{E}_t^d}\right). \tag{10}$$

The derivative function of ζ is positive i.e., $\zeta' \succ 0$. Substituting (6) and (8) into the factor market equilibrium condition (9) yields an expression of the relative factor demand in the High-Tech sector i.e., $\frac{U_t^H}{\bar{E}_t^d} = \varepsilon\left(\frac{A_t}{A_{t-1}}\right)$, where $\varepsilon() \approx f'^{-1}$ which implies $\varepsilon() > 0$, $\varepsilon'() < 0$.

After substituting the rate of technological change in the education sector, the relative wage of the skilled labor can now be expressed such as a function of past investment in human capital stock i.e.,

$$\frac{w_t^E}{w_t^{UH}} = g\left(\frac{\delta}{1+\mu S_{t-1}^{\bar{d}}}\right). \tag{11}$$

The derivative of the previous function is negative i.e., $g'(,) < 0$, $g(,)$ is also the composite of $\varepsilon(,)$ and $\zeta(,)$. Equation (11) highlights the forceful implication of the differing factor intensity and technological sophistication in the two production sectors. Human capital investment increase induces the skilled labor wage rate increase. Indeed, human capital investment increase in *t*-1 must also increase the higher skilled professors' stock. Technological change increases and thereby good quality as well. All that increases the economic growth rate and accelerate the development process. Those changes create a bias in the skilled labor demand and induce relative wages increase. Therefore the production function structure establishes a relationship between human capital investment at time *t* and relative wages at time *t*+1 i.e., there exist a relationship between technological change at time *t* and the skilled labor stock demand at time *t*+1. In the rest of the article, for simplicity we assume $g(x) = 1/x$ which implies $g'(x) = -(1/x2) < 0$ and the relative wages can now be expressed by (12) i.e.,

$$\frac{w_t^E}{w_t^{UH}} = \frac{1+\mu S_{t-1}^{\bar{d}}}{\delta}. \tag{12}$$

The above result means that high human capital investment at time *t*-1 increases also the current professors' stock. Then technological change speeds since the relative wage increase and thereby increases the higher skilled professors' stock in the developing country's education sector too. If the higher skilled professor stock is high enough, knowledge externalities spread all over the domestic professor stock too. Consequently, knowledge call policy provides benefits to domestic professors too even if the main purpose of its implementation is to increase the poor country's high skilled labor stock.

2.2. The Labor Market Constraints

The growth rate of the generation *t* is set to zero and its size is normalized to unity. The labor market constraints at *t* are therefore given by (13)-(15) i.e.,

$$S_t^{\bar{d}} + U_t^{\bar{d}} = 1, \tag{13}$$

$$S_t^{\bar{d}} = E_{t+1}^{\bar{d}} + P_t^{\bar{d}}, \tag{14}$$

$$U_t^{\bar{d}} = U_t^H + U_t^L. \tag{15}$$

Equation (13) means that the whole young generation of t is divided among the future skilled labor and the current unskilled labor stocks. Equation (14) means that the current student stock in t is composed of future professors and engineers of next period i.e., t+1. Finally, Equation (15) means that the sum of the unskilled labor stocks of both the Low-Tech and of the High-Tech sectors of production equals the whole unskilled labor stock of the economy.

2.3. Utility Optimization

Individuals share the same utility function and those born at t derive utility function (16) i.e.,

$$W^{j} = \ln\left(c_{t}^{j}\right) + \beta \ln\left(c_{t+1}^{j}\right). \tag{16}$$

$\beta \succ 0$ is the second period consumption elasticity, $j = U, (S, E)$ represents the respective career paths of the unskilled and the skilled labors, c_{t}^{j} and c_{t+1}^{j} represent per-capita consumptions in t and in t+1 respectively. Each unskilled labor receives a wage rate income w_{t}^{U} during his first period of life and saves the remainder x_{t} for his resting period. Each student borrows b_{t} in the bond market for private incentives to invest in human capital against a future wage rate income w_{t+1}^{E} to finance his tuition z_{t} and his first period consumption, c_{t}^{S}. Fiscal policy conducted by the government finances the incentives to invest in human capital and each student who receives a public financial aid must engage to work for the country once skilled. Therefore, with per-capita funds a_{t} the student pays his tuition cost, z_{t} and his first period consumption, c_{t}^{S}. Indeed, for private human capital accumulation, the budget constraints of the student are given by (19)-(20) whereas (17)-(18) are the unskilled labor budget constraint i.e.,

$$c_{t}^{U} = w_{t}^{U} - x_{t}, \tag{17}$$

$$c_{t+1}^{U} = \left(1 + r_{t}\right) x_{t}, \tag{18}$$

$$c_{t}^{S} = b_{t} - z_{t}, \tag{19}$$

$$c_{t+1}^{E} = w_{t+1}^{E} - \left(1 + r_{t}\right) b_{t}. \tag{20}$$

The first order conditions from the respective maximization problems of the unskilled and the skilled labors provide per-capita savings and borrowing (21) and (22) i.e.,

$$x_t = \theta w_t^U \,, \tag{21}$$

$$b_t = \theta\left[z_t + \frac{w_{t+1}^E}{\beta(1+r_t)}\right]. \tag{22}$$

$\theta = \beta(1+\beta)$ denotes the marginal propensity to save. Since the skilled labor doesn't receive income during his training period until he begins to work, the equilibrium per-capita borrowing increases in their future discounted income, $\frac{w_{t+1}^E}{\beta(1+r_t)}$. An increase in the parameter β depresses student's demand for funds since more consumption is deferred into the future. Higher direct education cost z_t reduces the current period consumption and allow students transfer more income from the future to the present through the increase of their borrowing.[10]

The social planner determines per-capita financial aid such that his budget constraint remains in balanced at each time period i.e., $\alpha a_t = (1-\alpha)\tau_t w_t^U$ where τ_t is the positive tax rate on the unskilled labor income, $\alpha \succ 0$ is the positive fraction of the student stock who receives funds from the government. Per-capita financial aid a_t is therefore

$$a_t = \left(\frac{1-\alpha}{\alpha}\right)\tau_t w_t^U \,. \tag{23}$$

Thus, the respective budget constraints of the unskilled and the skilled labors are in

[10] The demand of education is deeply studied in microeconomics models like Mingat (1988), Levy Garboua (1979) and Anderson (1983). According to Anderson (1983), social level of parents depends on their education level, their career and/or their income. Those variables play a great role in the decision on whether to accumulate human capital or not. Mingat(1982) introduces the "failing risk" as a decision variable to invest in education i.e., the agent compares the anticipated benefit of education to the investment cost such that he engages in human capital accumulation only if his probability of success is high enough. Levy Garboua (1979) shows that the demand of education is determined by the comparison between current and future benefit of education. Theoretical macroeconomics model of education include microeconomics decisions to invest in education (Lucas, 1988) and also maximize intertemporal wealth function to determine the endogenous time spent in education (Azariadis Drazen, 1990). In contrast, empirical models of education mostly use the Mincer equation to estimate the impact of some variables of interest on the decision to accumulate human capital (Mankiw Romer Weil, 1992; Park, 1976; Yoo, 1989).

public human capital investment case, respectively such as

$$c_t^U + a_t = w_t^U - x_t, \tag{24}$$

$$c_{t+1}^U = (1 + r_t)x_t, \tag{25}$$

$$c_t^S = a_t - z_t, \tag{26}$$

$$c_{t+1}^E = w_{t+1}^E - (1 + r_t)a_t. \tag{27}$$

The first-order conditions from the respective maximization problems provide per-capita savings, (28) and financial aids, (29) i.e.,

$$x_t = \theta w_t^U \left[1 - \left(\frac{1-\alpha}{\alpha}\right)\tau_t\right], \tag{28}$$

$$a_t = \left(\frac{1-\alpha}{\alpha}\right)\tau_t w_t^U. \tag{29}$$

Equation (28)[11] means that, the saving rate depends on the marginal propensity to save, θ as well as on the unskilled available income after taxes on public incentives to invest in human capital accumulation, $w_t^U \left[1 - \left(\frac{1-\alpha}{\alpha}\right)\tau_t\right]$. Equation (29) is similar to Equation (23) viewed above and expresses per-capita financial aid a_t given by the ratio of the student-unskilled labor. High tax rate level increases the amount of per-capita financial aids. If the unskilled labor income increases because of the increase of his productivity for example, then per-capita financial aid increases too.

2.4. The Bond Market Equilibrium

The bond market clearing condition expressed by Equation (30) defines the equilibrium interest rate r_t i.e.,

[11] Eicher (1996) agrees with a possible decrease of relative wages since both technological change and growth increase are the resulting effects of unskilled labor productivity increase. This result is quite close to those found by endogenous growth models rejected by the author i.e., Stockey (1988), Grossman Helpman (1991), Romer (1990), Aghion Howitt (1992) and Young (1993).

$$b_t S_t^{\bar{d}} = x_t U_t^{\bar{d}} \ . \tag{30}$$

Per-capita supply and demand of capital in conjunction with the lenders and borrowers determine the equilibrium endogenous interest rate. Substituting *per-capita* saving rate (21) and *per-capita* borrowing (22) in the bond market equilibrium condition, yields the bond market clearing interest rate (31) i.e.,

$$R_t = \frac{w_{t+1}^E}{\beta \left[\frac{U_t^{\bar{d}}}{S_t^{\bar{d}}} w_t^U - Z_t \right]} \ . \tag{31}$$

$R_t = 1 + r_t$, Equation (31) replicates exactly the result of Eicher (1996) where private education financial support is provided by the bond market. The increase in β decreases the interest rate R_t because agents are more patients and invest more.

3. THE OPTIMAL AND THE COMPETITIVE EQUILIBRIA

3.1. The Optimal Equilibria: Human Capital and Relative Wages

The Social Planner uses private education principle to fix the amount of agents able to receive *per-capita* financial aid i.e.,

$$a_t S_t^{\bar{d}} = x_t U_t^{\bar{d}} \ . \tag{32}$$

Solving (32) yields optimal human capital stock expressed by (33) i.e.,

$$S_t^{\bar{d}} = \left[1 + \theta^{-1} \left[\left(\frac{\alpha}{1-\alpha} \right) \tau_t - 1 \right]^{-1} \right]^{-1} . \tag{33}$$

Equation (33) expresses public human capital investment supply. Applying (33) to the expression linking developing country's student stock to higher skilled professor stock expressed by $S_t^{\bar{d}} = \gamma(1+\lambda) P_t^d$ yields Equation (34) i.e.,

$$P_t^d = \left[1 + \theta^{-1} \left[\left(\frac{\alpha}{1-\alpha} \right) \tau_t - 1 \right]^{-1} \right]^{-1} / \gamma(1+\lambda) . \tag{34}$$

To relate Equations (33) and (34) to the labor market needs an additional assumption on the relationship between *per-capita* financial aid, a_t and the tuition cost, z_t i.e., there exists $\sigma \geq 1$ such that

$$a_t = \sigma z_t = \sigma\left(\frac{w_t^E}{\gamma}\right) = \left(\frac{1-\alpha}{\alpha}\right)\tau_t w_t^U \quad \text{then the tax rate is} \quad \tau_t = \frac{w_t^E}{\gamma w_t^U}\left(\frac{\alpha}{1-\alpha}\right)\sigma .$$

Introducing the tax rate in (33) and (34) yields (35) and (36) i.e.,

$$S_t^{\bar{d}} = \left[1+\theta^{-1}\left[\frac{\sigma}{\gamma}\left(\frac{\alpha}{1-\alpha}\right)^2 \frac{w_t^E}{w_t^U} - 1\right]^{-1}\right]^{-1}, \tag{35}$$

$$P_t^d = \left[1+\theta^{-1}\left[\frac{\sigma}{\gamma}\left(\frac{\alpha}{1-\alpha}\right)^2 \frac{w_t^E}{w_t^U} - 1\right]^{-1}\right]^{-1} / \gamma(1+\lambda). \tag{36}$$

The monotonic increasing functions in relative wages (35) and (36)[12] are the benefit of human capital investment. The relative wage increase leads to the skilled labor stock increase and then human capital stocks increase too. Because in this case human capital investment implies almost no cost for the student, education behaves like learning by

[12] In the exogenous technological change growth model of Stockey (1988), innovations are both accidental and a by-product of learning by doing. In Chari Hopenhayn (1991) model, the diffusion of a specific technology concerns an exogenous technology. Those two frameworks relate human capital investment to an exogenous education production function and decisions of education are thus absents. But our case explicitly shows education function as well as decision to invest in human capital accumulation made by the social planner and show out how human capital investment is acquired. Market based economies lead to inequalities. In contrast, planned based economies bring more equality among economic agents. Since human capital investment deserves no private cost, Eicher (1996) results are ruled-out because market power is reduced by social planner intervention. Young (1993) and Grossman Helpman (1991, ch.5.2) are endogenous growth models with human capital and technological change. Because no explicit decision in education investment is done in those models, movements in terms of relative wages can't be explored. Indeed, since investment decision in human capital accumulation is done by someone else and not by students themself, Stockey (1988), Chari Hopenhayn (1991), Young (1993) and Grossman Helpman (1991, ch.5.2) are validated. Eicher (1996) is also validated for private investment in human capital accumulation through the market price. As stipulated by the literature, human capital can be accumulated through several channels and financial supports. Relative wages increase lead to both students and higher skilled professor stocks increase. Therefore, the system increases its capability to lift up the economy out of the poverty trap in which it is kept.

doing and joins theoretical models of growth where human capital is accidental or without cost. Therefore, skilled labor supply increases together with high innovations occurrence which finally decrease relative wages. Indeed, the production sector increases its efficiency because of the increase of the amount of the innovations absorbed. Relative wages became higher in the production sector than in the research sector in response to the labor demand increase in the production sector because of high innovations introduction. Then the skilled labor leaves the research sector for the production sector. The higher skilled professors leave the developing country and/ or the poor country's education sector because relative wages fall in the research sector. Innovations fall because of the decrease of the high skilled labor in research. If the process holds longer, then growth and development are retarded. Indeed, the poor country converges to his initial development path in which the economy is kept into a poverty trap with low growth and low human capital level (Lucas, 1988; Azariadis-Drazen, 1990; Romer, 1986; Wang, 1991; Chen, 1994). Therefore, because the engines of growth and development are absents, the exogenously specified student-teacher ratio is no more balanced and thus, rules-out knowledge equivalency expected among students and professors. Positive externalities of working inside a dynamic team disappeared too. Consequently, only discarded innovations can now slowly stimulate the economy through unskilled labor productivity increase. Then, unskilled labor wage rate income increase is able to provide enough funds to conduct the macroeconomic policy based on the call of higher skilled professors again.

3.2. The Optimal Equilibrium: The Students and the Higher Skilled Professors

The student stock dynamics is expressed by (37) i.e.,

$$S_t^{\bar{d}} = \left[1 + \theta^{-1} \left[\frac{\sigma}{\gamma} \left(\frac{\alpha}{1-\alpha} \right)^{-2} \left[\frac{1 + \mu S_{t-1}^{\bar{d}}}{\delta} \right] - 1 \right]^{-1} \right]^{-1}. \tag{37}$$

Equation (37) is obtained through the use of the relative wage expression i.e., Equation (12). Therefore, like before it establishes again a relationship between current and previous student stocks. Because Equation (37) is a monotonic increasing function, indeed for the economic growth to move at a constant rate, the derivative of the current student stock in its past stock must remains inside the range 0 and 1. Higher skilled professor stock dynamics (38) is therefore such as

$$P_t^d = \frac{1}{\gamma(1+\lambda)} \left[1 + \theta^{-1} \left[\frac{\sigma}{\gamma} \left(\frac{\alpha}{1-\alpha} \right)^{-2} \left[\frac{1 + \mu\gamma(1+\lambda) P_{t-1}^d}{\delta} \right] - 1 \right]^{-1} \right]^{-1}. \tag{38}$$

Equation (38) is also a monotonic increasing function and needs the derivative of the current stock in the past stock to remain inside the range 0 and 1 for its constant evolution over time to hold. If the assumption of constant evolution is ruled-out, then Equations (37) and (38) may be unbounded in regard to human capital accumulation and joins Lucas (1988), King-Rebelo (1987) and Becker *et al*. (1990), Maksymenko Rabbani (2011) human capital concept[13] which contrast with the one we intend to use i.e., embodied human capital related to the labor market (Heckman, 1976; Rosen, 1976).

The functions (37) and (38) express $S_t^{\bar{d}} = \rho\left(S_{t-1}^{\bar{d}}\right)$ and $P_t^d = \rho\left(P_{t-1}^d\right)$ where ρ is a monotonic increasing function. Those equations express finally current human capital supply as an increasing function of its past investment and move such as: $S_t^{\bar{d}} = \rho\left(S_{t-1}^{\bar{d}}\right) \to \infty$ when $S_{t-1}^{\bar{d}} \to \infty$ and $P_t^d = \rho\left(P_{t-1}^d\right) \to \infty$ when $P_{t-1}^d \to \infty$. The increase of relative wages in period *t* increase human capital investment demand and thus increase unskilled labor productivity δ as the resulting positive effect of technology absorption. Unskilled wage rate income increase decreases the borrowing cost because there are more funds left in the bond market. Therefore, human capital stock keeps increasing at a monotonic constant rate. Then if competition among skilled and unskilled workers increases relative wages, it depresses the saving funds mainly drained by unskilled labor force. Indeed, the capital used for human capital investment fall. The resulting increase of the borrowing cost leaves no more funds to the social planner. Knowledge call policy can't be conducted anymore. Therefore, the strictly monotonic increasing functions $S_t^{\bar{d}} = \rho\left(S_{t-1}^{\bar{d}}\right)$ and $P_t^d = \rho\left(P_{t-1}^d\right)$ summarizes two feedback effects that generate transitory dynamics resulting from the interaction between human capital and technological change through relative wages movements. More precisely, relative wages represent both the absorption cost of new innovations in the production sector and human capital investment cost. Those effects are *first*, sudden relative wages increase slowed the development process because unskilled labor income decreases and reduce the social planner's capability to find funds for incentives to accumulate human capital. Indeed, both human capital supply and higher skilled professor stock demand decrease. Higher skilled professors leave the developing country's education sector and no more new innovations are introduced. Technological change stagnates and the economic growth rate fall because the absorption process of new innovations in the production sector no more occur. If the length of time of the cease of the process is long enough, then a possible convergence between the Low and the High-Tech production sectors can happen. All those create an eviction of the economic policy and the goals fixed earlier can't be achieved. *Second*, a sudden relative wages increase depress education support

[13] The AK models of Romer (1986), Lucas (1988) and King-Rebelo (1987) implicitly mixed knowledge that can survive in somebody or human capital to physical capital and/or to knowledge contains in supports such as books.

funds and leave no more human capital investment possibility which therefore block the system meaning innovations. Since convergence between the High-Tech and the Low-Tech production sectors is observed, then average unskilled productivity increases and leaves available funds again in a progressive way. Thus, once again, the economic policy is able to bring back higher skilled professors in the developing country's education sector. Indeed both unskilled labor and skilled labor productivities need to increase together and establish a constant evolution of relative wages. If it is effective, then there is new innovations introduction and technological change growth rate accelerates. The absorption process requires the engineers like before. Development is boosted by high quality goods generated by the production sector. Consequently, relative wages increase produce two opposite effects as just proved. Growth and development may greatly oscillate if constant evolution of key parameters over time is not guarantee. Therefore, an equilibrium relative wages such as a threshold must be established in order to allow the economy reach his long-run stability over time.[14]

3.3. The Competitive Equilibrium: The Relationship between Human Capital and Relative Wages

To express human capital competitive equilibria, we follow Eicher(1996) and assume that, since the young agents enter in the economy as identical agents they must be indifferent between either career path i.e.,

$$W^U = W^S . \tag{39}$$

The above assumption leads to the expression $\frac{w_{t+1}^E}{R_t} = z_t + w_t^U$.[15]

Replacing the endogenous interest rate previously determined in the expression just above leads to the competitive equilibria of current human capital stock in function of relative wages expressed by Equations (40) and (41) i.e.,

$$S_t^{\bar{d}} = \theta / \left[1 + w_t^p / \gamma w_t^U\right], \tag{40}$$

[14] Grossman Helpman (1991, Ch.5.2) makes both human capital and technological change endogenous but assume incentives to accumulate human capital not related to technology absorption cost which is relative wages in our consideration. Maksymenko Rabbani (2011) shows that human capital as positive effects on economic development both in South Korea and in India.

[15] Since agents share identical utility functions and face identical intertemporal transformation possibilities then, $c_t^U = c_t^S$ and $c_{t+1}^U = c_{t+1}^E$.

$$P_t^d = \theta / (1+\lambda)\left[1 + w_t^p / \gamma w_t^U\right]. \tag{41}$$

Developing country's student stock (40) depends on marginal propensity to save and can be assimilated to human capital accumulation cost. Our results are similar to those of Eicher (1996)[16] and in addition, this article shows that, efficient relative wages which ensure a constant evolution of human capital stocks exist. The efficient relative wage is defined by the equality between the competitive and the optimal human capital investment equilibria i.e., the intercept of the respective current human capital stock in function of relative wages of the optimal and the competitive equilibria. The efficient relative wage determined is also unique because the both human capital curves move monotonically in the opposite direction i.e., solving Equation (42)

$$S_t^{\bar{d}} = \theta / \left[1 + w_t^p / \gamma w_t^U\right] = \left[1 + \theta^{-1}\left[\frac{\sigma}{\gamma}\left(\frac{\alpha}{1-\alpha}\right)^2 \frac{w_t^E}{w_t^U} - 1\right]^{-1}\right]^{-1}. \tag{42}$$

Leads to the efficient relative wage expressed by Equation (43) i.e.,

$$\left(\frac{w^E}{w^U}\right)^* = \frac{2-\theta}{\frac{1}{\gamma}\left[\left(\frac{\alpha}{1-\alpha}\right)^2 - 1\right]}. \tag{43}$$

The above efficient relative wage is unique and thus, able to guarantee a stable development path of the economy over time (see Figure 2).

[16] The results of Eicher (1996) come from Mincer (1994) where relative wages and skilled labor move in the opposite direction at least since 1963. Specifically, Eicher (1996) analysis is based on the 1980' observations and finds that, the biased on the skilled labor demand is explained by higher relative wages movements because the absorption of innovations needs the skilled labor demand increase which is low because of its cost. To solve the paradox of the skilled labor supply decrease and relative wages increase, Mincer uses the direct cost of education as the determinant of the labor supply and finds a negative correlation among them since at least 1967.

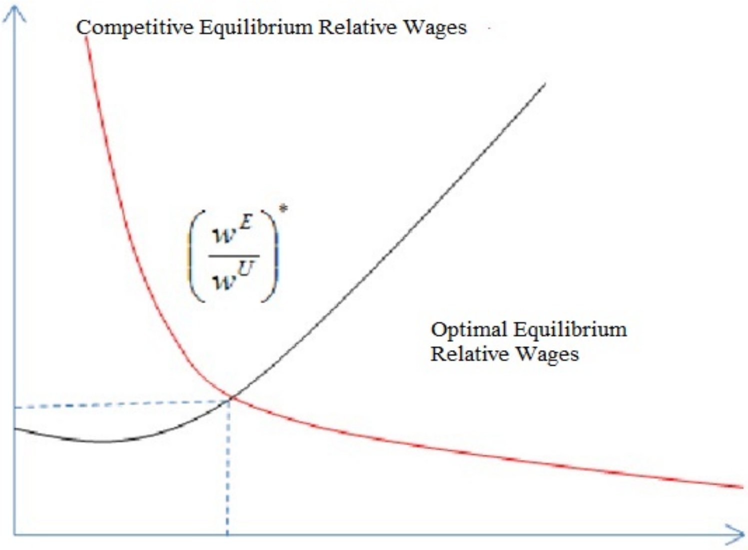


Figure 2. The Efficient Relative Wage

3.4. The General Competitive Equilibrium

Introducing Equation (12) in Equation (40) characterizes the general competitive equilibrium such as a couple of functions of past and current human capital stocks of students and higher skilled professors in private education respectively expressed by (44) and (45)[17] i.e.,

$$S_t^{\bar{d}} = \theta / \left[1 + \left(1 + \mu S_{t-1}^{\bar{d}}\right) / \gamma\delta\right], \tag{44}$$

[17] In contrast to the previous case of public education, the two previous equations replicate human capital accumulation close to the view of Heckman (1976) and Rosen (1976) where human capital is assimilate to the amount of years spent in the education sector. Thus, here human capital can't grow without bound because it is embodied. Romer (1990) defines this kind of human capital as a rival component of knowledge and is commonly measured as the labor force quality through the experience (Gollop and Jorgenson, 1980). The main difference with Eicher (1996) holds on the assumption $g(x) = 1/x$ and thus, Equation (44) still a decreasing function as in the basic framework. Equation (45) is not visited by the basic model because the aim of the basic analysis is to focus on the impact of the relative wages on innovations resulting from human capital investment. The basic analysis, doesn't study knowledge spread on the others professors because it is not a theory of economic development. In contrast, the aim of this article is to provide tools in favor of the development economies using the fact that, development experience of Europe in the 19th century comes from their labor productivity efficiency (Galor Weil, 2000).

$$P_t^d = \theta / \left[1 + \left(1 + \mu(1+\lambda)P_{t-1}^d\right) / \delta\right]. \tag{45}$$

Indeed, human capital competitive equilibria stocks between two successive periods are decreasing functions in their past variables expressed by $\bar{S}_t^d = \phi\left(\bar{S}_{t-1}^d\right)$ and $P_t^d = \phi\left(P_{t-1}^d\right)$, ϕ is a decreasing function which highlights the cost of human capital investment. It can be seen that $\bar{S}_t^d = \phi\left(\bar{S}_{t-1}^d\right) \to 0$ when $\bar{S}_{t-1}^d \to \infty$ and $P_t^d = \phi\left(P_{t-1}^d\right)$ $\to 0$ when $P_{t-1}^d \to \infty$.

In contrast to the optimal equilibrium case viewed before, now the demand of human capital investment is decreasing and the relationships expressed by $\bar{S}_t^d = \phi\left(\bar{S}_{t-1}^d\right)$ and $P_t^d = \phi\left(P_{t-1}^d\right)$ summarize also two feedback effects along the transitory dynamics like in the previous case. They are *first*, relative wages increase drain higher skilled professors in the developing country's education sector. Then, technological change accelerates because new innovations are introduced. The skilled labor demand increases in order to adapt those new findings in the production sector. Good quality increases and growth thus jumps as development is taking-off. *Second*, relative wages increase depress the unskilled labor income and increase the borrowing cost. Private incentives to invest in human capital are then satisfied in a small part only. Because inequalities are introduced, only the agents who have more credibility can access to the bond market. Human capital demand decreases in response to the increase of its cost and leads to the decrease of the incentives to invest in human capital. There is no more need for new innovations absorption through the time. The unskilled labor productivity keeps increasing because low and high-tech production sectors are almost no more significantly skill differentials. Both relative and absolute poverties are back in the developing country. But if cooperation with the developed country is introduced and funds given or if private investors engage projects in the little country for example, available funds are increasing in the bond market. Then private incentives to invest in human capital accumulation tend to increase because borrowing cost fall. The development process is partly boosted but with little inequalities compared to the public case of human capital accumulation. Higher skilled professors come back to the developing country's education sector because of relative wages increase. The exogenously specified student-teacher ratio is satisfied both by domestic and higher skilled professors. Positive effects of knowledge externalities are back and knowledge equivalency among students and professors hold. But without the social planner intervention, technological change growth rate is not sufficiently high to fully rule-out poverty in which the economy remains kept. Finally, development needs the conjunction of the market and the planned economies at the same time. In other words, Government intervention is crucial for the poor country's economic development goal.

4. THE MOST EFFICIENT POLICY

The best economic policy able to lead the poor economy to its long run development path is determined by the most efficient policy. Thus, a perfect foresight equilibria is defined by a sequence of $\left\{\left(\bar{S}_t^d, P_t^d\right)_{t\geq 0}\right\}$ satisfying, (37), (38) and (44), (45) for all $t \geq 0$. Indeed, the sequence $\left\{\left(\bar{S}_0^d, P_0^d\right), \left(\bar{S}_1^d, P_1^d\right), ..., \left(\bar{S}_t^d, P_t^d\right), ...\right\}$ constitutes a pair of perfect foresight equilibria. Therefore, a stationary efficient path corresponds to a perfect equilibria where the variables are hold constant such that $\bar{S}^{d*} = \zeta_1(\bar{S}^{d*})$ and $P^{d*} = \zeta_1(P^{d*})$. Making the optimal and the competitive equilibria paths equal, yields to a problem which consists on looking for the solutions for which the properties define a series of unique points i.e.,

$$\bar{S}_t^d = \theta / \left[1 + \left(1 + \mu \bar{S}_{t-1}^d\right) / \gamma\delta\right] = \left[1 + \theta^{-1}\left[\frac{\sigma}{\gamma}\left(\frac{\alpha}{1-\alpha}\right)^{-2}\left[\frac{1+\mu\bar{S}_{t-1}^d}{\delta}\right] - 1\right]^{-1}\right]^{-1}. \tag{46}$$

The left side is a monotonic decreasing function but the right side is a monotonic increasing function. Therefore, the equality between a monotonic increasing and a monotonic decreasing functions, defines a unique efficient solution of human capital accumulation in function of parameters expressed by Equations (47) and (48) i.e.,

$$\bar{S}^{d*} = \frac{1-\theta}{2\mu}\left[1 + \left[1 + \frac{4\theta(2-\theta)}{\sigma}\left[\frac{\delta\gamma(1-\alpha)}{\alpha(1-\theta)}\right]^2\right]^{1/2}\right] - \mu^{-1}, \tag{47}$$

$$P^{d*} = \frac{1-\theta}{2\mu\gamma(1+\lambda)}\left[1 + \left[1 + \frac{4\theta(2-\theta)}{\sigma}\left[\frac{\delta\gamma(1-\alpha)}{\alpha(1-\theta)}\right]^2\right]^{1/2}\right] - \left(\mu\gamma(1+\lambda)\right)^{-1}. \tag{48}$$

The results provided by Equations (47) and (48) are summarized in proposition 1. Before announcing the proposition, note that the marginal propensity to save and the relative wage must move at the same constant rate. Additional productivity must be taken into account in the remuneration. Those are the properties that must satisfy human capital accumulation when correlated to relative wages as stipulated by Mincer (1994).[18]

[18] Because poor country is far from his technological frontier, benefit of investing in high education is not interesting enough (Aghion and Cohen, 2004). That is why most of the studies of education in economic

The first condition is satisfied by our model but the second condition is less obvious because education satisfies two properties *first*, knowledge spreads is seen as a “signal” by Spence (1973) and according to Nelson and Phelps, education and technical progress can’t be dissociated. *Second*, since education in growth theory is based on endogenous technical progress, then the poor economy can catch the more developed economy whenever Institutions are perfect (Gerschenkron, 1962).

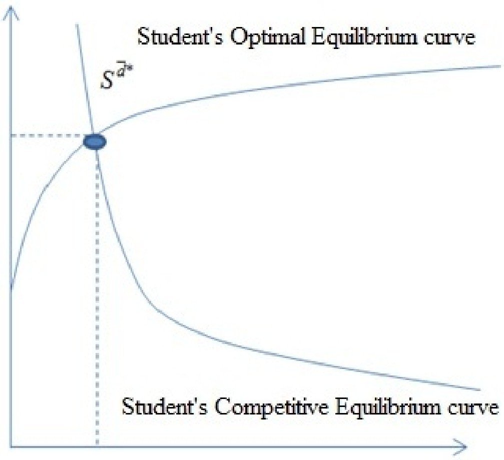


Figure 3a. Expresses the Unique Students’ Stock

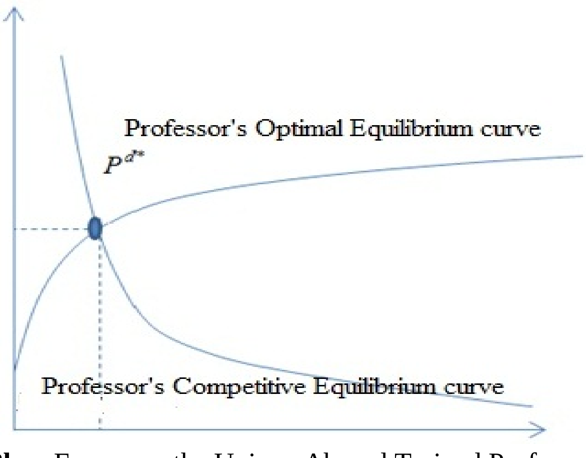


Figure 3b. Expresses the Unique Abroad Trained Professors’ Stock

development mostly focus on basic labor training. This article focuses both on historical growth of Europe and their development experience in order to understand experience and the brain-drain literature.

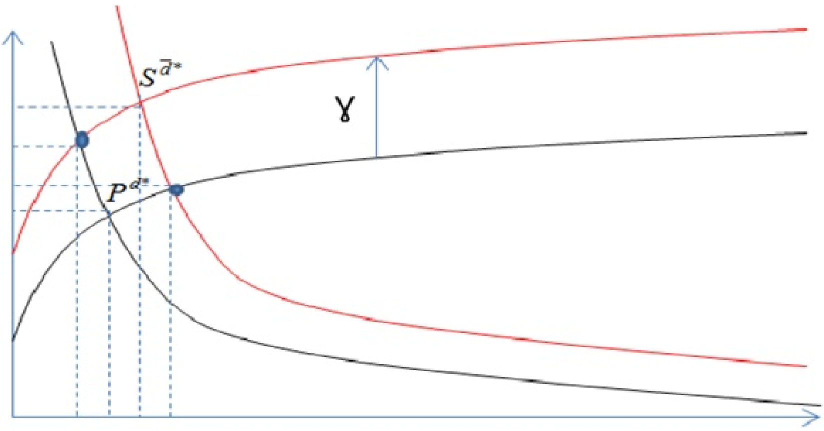


Figure 4. The Summary of the Figures 3a and 3b

Proposition 1.

An increase in the unskilled labor productivity δ, in the exogenously determined student-professor ratio γ, in the fraction of young who receives the financial aid α and in the marginal propensity to save θ increase the efficient student stock $\overline{S^{d*}}$ whereas an increase in the higher skilled professors' productivity μ decreases the efficient student stock $\overline{S^{d*}}$.

An increase in the marginal propensity to save θ, in the unskilled labor productivity δ and in the fraction of young who receive the financial aid α increase the efficient higher skilled professor stock P^{d*} whereas an increase in the developing country's education sector productivity μ, in the exogenously determined student-professors ratio γ and in the domestic-higher skilled professors ratio decrease the higher skilled professor stock P^{d*}.

This analysis uses unskilled labor income as development condition. At initial time agents are assumed to be endowed with zero human capital level in the poor country, unskilled labor savings is used to conduct the economic policy based on income taxes. Student stock increase reduces higher skilled professor stock because of the cost generated. Then professor stock tends to be only composed of home trained skilled labor over time. The margin propensity to save is a signal of funds quantity in human capital investment target. The high the fraction of young who receive education fund is, the high the skilled professors' stock should be in the education sector. When higher skilled professor's productivity is too high, it is harder for the student to follow classes because scientific level is too high compare to initial level endowment. If home trained professor stock is too high compare to higher skilled professors stock, then knowledge externalities do not obviously spread among them. Therefore, the home/ abroad trained professors' ratio λ must moves at a constant rate over time.

5. THE DETERMINANTS OF THE LONG RUN GROWTH

The long run growth rate able to induce the economic development take-off g (its definition is given in the beginning of the model presentation) depends on higher skilled professors' productivity expressed by Equation (49) i.e.,

$$g = \frac{1-\theta}{2\gamma(1+\lambda)}\left[1+\left[1+\frac{4\theta(2-\theta)}{\sigma}\left[\frac{\delta\gamma(1-\alpha)}{\alpha(1-\theta)}\right]^2\right]^{1/2}\right]-(\gamma(1+\lambda))^{-1}. \tag{49}$$

Proposition 2.

The economic growth rate is an increasing function of the marginal propensity to save θ, the unskilled labor productivity δ, and the fraction of young who are given fund α. But it is a decreasing function of domestic-higher skilled professor's ratio λ, the exogenously given student-professor ratio γ and the higher skilled professor's productivity μ.

A high λ means that home trained professor stock is too high and higher skilled professor stock is too low in the poor country's education sector. If so, growth and technological change rates are not boosted enough. For γ, when the stock of student is too high compare to the higher skilled professor stock needed and higher skilled professors' productivity μ too high, then knowledge equivalency is unable to establish. Consequently, this policy needs something to be done before its implementation in order to make students assimilate high developed country's knowledge over time. Funds are one fundamental necessary condition for human capital to be accumulated and δ the unskilled labor productivity is also essential to provide the amount of funds needed. A high α leads to more skilled labor trained in poor country and thus increase the speed of convergence of the economy to his long-run development path.

6. CONCLUSION

We have presented an endogenous growth model which deals with human capital accumulation and technological change in order to increase the economic growth through the reduction of the brain-drain phenomenon in developing countries. Relative wages movements are the main engine which induces higher skilled professors' entry in the education sector of the poor country. Since both the interaction between students and professors trained in the developed country on the one hand and relative wages on the other hand remain constant, then development may hold. Otherwise, the economy remains kept in a poverty trap.

The policy presented needs to be extended in order to include environment components because of negative impacts of high industrialization on sustainability. In other words, sustainability introduction is necessary for the long-run sustainable development path to be reached in poorest developing economies.

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