Vertical and Horizontal Innovation : Effects of Globalization and Migration on Inequality, Growth and Human Capital Accumulation

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Vertical and Horizontal Innovation: Effects of Globalization and Migration on Inequality, Growth and Human Capital Accumulation

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Abstract

In this paper I consider two symmetric countries/regions which trade in final goods. In each country is active the manufacturing sector and both vertical and horizontal innovation conduced by individuals with heterogenous ability. I show that a more globalized world, as represented by lower iceberg-type transportation cost, spurs human capital accumulation, and widens skill premium within each country. However, it may be the case that globalization reduces the per-capita output growth rate of each region, but has positive effect on output level. Moreover, when a region has larger domestic market it also has higher human capital accumulation, higher skill premium, and higher per-capita mass of product lines, i.e. the country with larger domestic market invents a larger mass of varieties. This implies that skilled labor force residing in larger domestic market benefits of higher consumption flows. I show that even if a country has larger domestic market full agglomeration of either activity does not happen: both the regions remain active in both manufacturing and R&D. I show that the same result hold in the case of localized spillovers and specialized knowledge between regions.

Keywords: R&D and Growth, Globalization, Migration
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1 Introduction

Core-Periphery models predict and describe economic mechanisms and rational behavior that result in spatial agglomeration of production and workers-consumers in a region (Baldwin et. *al.*, 2004, Fujita and Thisse 2002, Fujita,

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Thisse and Venables, 1999). In the Core-Periphery models the classical agglomeration forces are the "market access effect" and the "cost of living effect". The former force concerns the rational choice by firms to locate in larger market in order to save on transportation cost, the second force concerns the local cost of living for consumers that can be lower in larger domestic market. The Core-Perihery models also identify the dispersion force called "market crowding effect", which reflects the fact that firms have the tendency to locate in regions with relatively few competitors. However, full agglomeration does not happen any time, in fact in developed and developing countries we often observe the existence of the same type of industrial activities, even if they are more concentrated in a region than in others. When we look at very similar regions with respect to their development level - such as E.U. countries, E.U. and U.S.- lack of full agglomeration is observable. What I mean is that considering interactions between symmetric regions with respect to the level of development could be an interesting task as looking the interections beween asymmetric regions. Dinopoulos and Segerstrom's (1999) work is an excellent case of this study.

In this framework there exist two symmetric countries or regions A and B, in each of which there exists a manufacturing sector that produces the existing mass of final products (varieties), and a research sector which, through an uncertain process, can introduce both a better version of any existing variety and a completely new industry line. The two regions trade in final goods. Differently from large part of the New Economic Geography (NEG) literature[1] both the sectors produce under CRS technology, but legal institutions create a monopolistic power in the economy: every time a new invention is created the inventing firm can obtain a patent grant which allows it to exclusively manufacture that product for an infinite time. This form of intellectual property rights allows to produce under monopolistic competition.[2]

Notwithstanding the assumed symmetry of regions, and because of the existence of horizontal innovation, countries can produce different varieties each other, at least for a fraction of the existing mass of product lines. This form of specialization can arise from the natural characteristics of each country, that is from the first nature exogenous characteristics of the country.

In this paper I consider both vertical and horizontal innovation activity. The former type of innovation consists of introducing a better and upgraded version of any existing product: the researchers try to invent a novel, useful and non-obvious upgraded version of any existing good which replaces the previous version of the same good. Therefore vertical innovation generates the Shumpeterian creative destruction effect. With horizontal innovation each research

[1] See Ottaviano and Thisse (2004), Baldwin and Martin (2004), Baldwin et al. (2003), Fujita and Thisse (2002a,b), Fujita et al. (1999).

[2] This is not aligned with the standard NEG literature, in which the modern sector produces under competitive monopolistic competition due to the existence of fixed costs. This is also true for the Geographic models incorporated into endogenous growth models, where capital (especially human capital and knowledge capital) also represents a fixed cost for the modern sector (Baldwin and Martin, 2004; Baldwin et al. 2003, Duranton and Puga, 2004; Duranton and Puga, 2001). As usual in NEG models the existence of a fixed input requirement allows to immediately determine the mass of active firms in the economy.

firm tries to introduce a completely new product line. Furthermore, I assume heterogeneous individuals at different levels. As in Dinopoulos and Segerstrom (1999), there exists heterogeneous individual ability to accumulate human capital through schooling. Moreover I assume, as in Howitt (1999), that there exists a different ability within skilled workers for creating completely new product line. The introduction of a new variety requires the individual to be endowed of the Schumpeterian "entrepreneurial ingenuity" (see Schumpeter 1934, 1939). Different skilled workers are endowed with a different entrepreneurial capacity, and each skilled worker can decide in each moment which type of innovative activity to undertake.

Starting with two symmetric countries/regions with respect to population size and the per-capita mass of varieties, I show the existence of a unique balanced growth path.

Static comparative analysis shows that trade liberalization - as represented by the reduction in the transportation cost - reduces the incentive to accumulate human capital through schooling and increases skill premium. Moreover, and differently from Dinopoulos and Segerstrom (1999), a more globalized world can reduce the per-variety aggregate Poisson arrival rate of innovation, and therefore the per-capita output growth rate of each country. Therefore I show that a more globalized world widens skill premium within each country and can reduce the per-capita output growth rate of each region. However, I show that globalization determines positive effect on output and consumption level for all population. Finally, and differently from Baldwin and Martin (2004) and Baldwin et *al.* (2003, chap. 7), this economy is free from the strong scale effect on per-capita output growth rate of the economy (see Jones, 2004).

Moreover, I analyze the effect of larger market size of one country with respect to the other country, as represented by larger population size. I assume immobile unskilled labor force. In fact, some empirical studies show low labor mobility between E.U. countries.[3] The country with larger domestic market has higher incentive to accumulate human capital through schooling, higher skill premium, and higher per-capita mass of varieties than the region with "narrow" domestic market. The higher skill premium allows to skilled labor force residing in the larger market to have larger consumption flows. Therefore, asymmetry in market size, determines consumption (output) level effects between skill labor of the two countries. The higher skill premium in the larger domestic market could generate further migration of skilled labor towards the larger country, and therefore full agglomeration of skilled workers and R&D sector can takes place. On the production side, saving on transportation cost is the standard agglomeration force in the for production. However, I show that the per-variety Poisson arrival rate of innovation is the dispersion force which impedes full agglomeration of skilled labor force in the country with the larger domestic market. Asymmetry in market size has undetermined effect on per-capita output growth rate of each country.

[3] See Bentivolgli and Pagano (1999), Bentolila and Dolado (1991), Decressin and Fatas (1995).

The economy does not experience catastrophic agglomeration. In fact, the "backward linkages" works only for the manufacturing production side of the economy but not for the demand side. The existence of the dispersion force - represented in this context by the per-product line aggregate Poisson arrival rate of innovation - and the assumption of immobile unskilled labor force impedes full agglomeration of both the research effort and manufacturing in a country. I also show that these results are valid in the case of localized spillovers.

The paper is organized as follows. Section 2 sets up the model, section 3 derives the balanced growth equilibrium properties of the economy, section 4 derives comparative static analysis, section 5 concludes.

2 The Model

2.1 Households

I assume an economy with two symmetric countries (or regions) A and B which trade in final goods. Each country produces a mass of varieties, respectively n^A and n^B. Since there exists symmetry between the two regions, I assume that the mass of varieties is equal, i.e. $n^A = n^B = n$, and that the two countries can produce different product lines each other at time $s \geq 0$. I denote the mass of different industry lines between countries with the fraction $\psi(s) \in [0,1]$.[4] Let households differ in their uniformly distributed personal ability $\theta \in [0,1]$ of their individual members to become skilled workers.[5] All individuals have identical intertemporally additively separable preferences for an infinite set goods and services indexed by $\omega \in \left[0, n^A + n^B\right]$, produced by the private sector, and are endowed with a unit labor/study time endowment whose supply generates no disutility. Then each individual has the same preferences in each country, and consumes all the existing varieties in the economy because of the love for variety preferences. Therefore the total mass of different varieties demanded by each

[4] It could be possible that the two countries produce a different set of products, at least at time 0. In particular, since there exists both vertical and horizontal innovation and that not necessarily the two countries produce exactly the same varieties at time 0, I assume that the mass of different industry lines in each country/region at time 0 is expressed by the fraction $\psi(0) \in [0,1]$ of the existing varieties n in each country. Moreover, since there exist horizontal innovation, it would be really a coincidence that in the same moment two inventors working in different countries introduced exactly the same completely new variety in the same instant of time (moreover, since each inventor can grant the same patent protection for both the countries, the first that wins the patent race will obtain the patent protection for both the countries even in the case in which two researchers invent the same product in the same instant of time). This implies that the fraction of different industry lines $\psi(s) \in [0,1]$ can vary in time, but it has maximum at 1 and minimum at 0. In order to simplify matter, and because there exists a continuum of varieties, I assume that along the balanced growth path the fraction of different product lines between the two regions is constant and equal to its initial value $\psi(0) \in [0,1]$. Notice that all the analysis is valid for any value of the parameter $\psi(s) \in [0,1]$.

[5] As Dinopoulos and Segerstrom (1999) all members of households θ have the same ability level equal to θ, and all households have the same number of members at each point in time.

consumer is $[1+\psi(s)]\, n(s)$.[6] I index the variables without suffix referring to countries A and B because of the symmetry.

The intertemporal and instantaneous preferences are described as follows:

$$\int_0^{\infty} N_0 e^{-(\rho-g_N)s} \log u_\theta(s)\, ds \tag{1}$$

where

$$u_\theta(s) \equiv \left[\int_0^{[1+\psi(s)]n(s)} \left(\sum_{j=0}^{j^{\max}(\omega,s)} \lambda^{j}_{(\omega,s)} q_\theta(j,\omega,s) \right)^{\alpha} d\omega \right]^{\frac{1}{\alpha}}$$

with $0<\alpha<1$, and $u_\theta(s)$ being the instantaneous utility function of household with ability θ. The consumption value for an individual with ability θ is defined as

$$c_\theta(s) \equiv \int_0^{[1+\psi(s)]n(s)} p(j,\omega,s)\, q_\theta(j,\omega,s)\, d\omega,$$

and the intertemporal budget constraint for each individual with ability θ is

$$W_\theta(t) + Z_\theta(t) = \int_t^{\infty} N_0 e^{-\int_t^s [r(\tau)-g_N]d\tau} c_\theta(s)\, ds$$

where N_0 is the initial population of the economy (with $N_0^A = N_0^B$) and g_N is its constant growth rate common for both the countries A and B, ρ is the constant and common rate of subjective time preferences - with $\rho > g_N$ - and $r(s)$ is the market interest rate. $q_\theta(j,\omega,s)$ is ability $\theta \in [0,1]$ household's per member quantity flow of quality $j \in \{0,1,2,...\}$ of good/service $\omega \in [0,[1+\psi(s)]\, n(s)]$ at time $s \geq 0$ - $p(j,\omega,s)$ being the price of good ω of quality j at time s - $c_\theta(s)$ is the nominal expenditure. $W_\theta(t)$ and $Z_\theta(t)$ are human and non-human wealth levels. A new vintage of good/service delivers $\lambda > 1$ more quality services than its previous version. Different versions of the same good ω are regarded by consumers as perfect substitutes after adjusting for their quality ratios, and $j^{\max}(\omega,s)$ denotes the time s top quality of good ω. As usual I assume that in equilibrium only the top quality product will be produced and acquired by the consumers. It is easy verify that the elasticity of substitution between each pair of varieties is equal to $\varepsilon \equiv \frac{1}{1-\alpha} > 1$. I assume Bertrand competition at all dates between the incumbent and the innovating firm as common in ladder quality models.

[6] Since $n^A = n^B = n$, and because the fraction of different product lines at time s is $\psi(s) \in [0,1]$, each individual of each country will decide to consume the entire mass of different varieties $[1+\psi(s)]\, n(s)$ existing at time $s \geq 0$.

Individuals are finitely lived members of infinitely lived households, being continuously born at the constant rate β, and dying at the constant rate δ, with $\beta - \delta = g_N > 0$. $D > 0$ denotes the exogenous given duration of their life.[7]

Each individual chooses to train and becomes skilled at the beginning of her life; the duration of her training period - in which the individual cannot work - is exogenously fixed at $T < D$.

Hence an individual with ability θ decides to train if and only if the following arbitrage condition is satisfied:

$$\int_t^{t+D} e^{-\int_t^s r(\nu)} w_L(s)\, ds < \int_{t+T}^{t+D} e^{-\int_t^s r(\nu)} \max(\theta - \gamma, 0)\, w_H(s)\, ds, \tag{2}$$

with $0 < \gamma < 1/2$. Notice that an individual with ability $\theta > \gamma$ is pustulatedly able to accumulate human capital $(\theta - \gamma)$ after training, while an individual with ability lower than γ (i.e. $\theta < \gamma$) never gets any skill from schooling.

Like Dinopoulos and Segerstrom (1999) I will focus on the balanced growth path (BGP) equilibrium, in which all variables grow at a constant rate and w_L, w_H, and c_θ are all constant, furthermore $r(s) = \rho$ at all dates. Considering equation (2) with the equality, the ability threshold θ_0 is easily obtained which renders individual indifferent to becoming skilled or to remaining unskilled for all her life. Hence the individual will train if and only if her ability is higher than

$$\theta_0 = \left[\left(1 - e^{-\rho D}\right) / \left(e^{-\rho T} - e^{-\rho D}\right)\right] \frac{w_L}{w_H} + \gamma = \sigma \frac{w_L}{w_H} + \gamma. \tag{3}$$

where $\sigma \equiv \left(1 - e^{-\rho D}\right) / \left(e^{-\rho T} - e^{-\rho D}\right)$. An individual with ability $\theta > \theta_0$ will decide to train and will accumulate quantity $(\theta - \gamma)$ of human capital. The higher the individual ability, the higher the accumulated human capital and the higher is the total amount of wages earned by the individual. Budget constraint in (1) implies that an individual with higher ability will benefit from a higher value of consumption flow.[8]

Following the same steps as in Dinopoulos and Segerstrom (1999) the reader can easily verify that the supply of unskilled labor at time t in each country is

$$L(t) = \theta_0 N(t) = \left(\sigma \frac{w_L}{w_H} + \gamma\right) N(t) \tag{4}$$

[7] As in Dinopoulos and Segerstrom (1999) it is easy to show that the above parameters must satisfy $\delta = \frac{g_N}{e^{g_N D} - 1}$ and $\beta = \frac{g_N e^{g_N D}}{e^{g_N D} - 1}$, in order for the number of births at time t to match the number of deaths at $t + D$.

[8] Up to now I have considered the choice between to accumulate human capital through schooling or to remain unskilled as referred to individuals residing in any country, i.e. I have not introduced the suffix referring to a specific country A or B because of the symmetry between the two regions.

and the supply of skilled labor at time t in each country is

$$H(t) = (\theta_0 + 1 - 2\gamma)(1 - \theta_0)\frac{\phi}{2}N(t), \tag{5}$$

where $\phi = \left(e^{g_N(D-T)}\right) / \left(e^{g_N D} - 1\right) < 1$. Along the steady state the growth rate of both unskilled and skilled labor is equal to g_N.

2.2 Manufacture

The production of the existing goods and services is conducted by private monopolistic firms which are protected by a perfectly enforceable patent law for the production of their products. The public institutions provide a legal protection for the innovation represented by an infinitely lived patent granted to the researcher who introduce a novel, useful, and non-obvious improvement of any existing variety. The intellectual property rights spur the innovation and the research effort by legally providing monopolistic rents to the inventing firm. The same legal institutional protection is granted for all the researchers/firms that introduce a completely new industry line never existed before in the marketplace, that is for researchers expanding the mass of the existing product lines. Once a new variety is introduced in the marketplace, it will be target of further quality improvements. Patent law allows the researcher to gain monopolistic rents for all the effective duration of the patent, because - as usual in neo-Schumpeterian growth models with vertical innovation (see e.g. Grossman and Helpman, 1991 and Aghion and Howitt, 1998) - the incumbent monopolist can be replaced by the next innovator in the same sector.

Manufacturing firms hire unskilled workers to produce any consumption good/service $\omega \in [0, (1+\psi)n]$ of the second best quality under a one-to-one constant returns to scale (CRS) technology, described by a simple unit cost function w_L.[9] I assume the same production technology for both the countries. I choose the unskilled labor as the numeraire of the economy, so that $w_L^A = w_L^B = w_L = 1$.[10] In each industry the top quality product can only be manufactured by the firm that has discovered it - or by the firm that has acquired the patent from the inventor - whose rights are protected by a perfectly enforceable patent law. In fact, I consider the case in which each inventor obtain patent grant in both the regions, which are assumed to have the same patent law protection. Unskilled labor is assumed immobile between countries, but completely mobile within each country between all the existing industry lines.[11]

[9] It could be possible to introduce a technical coefficient $x > 0$ common in all industries without alter the qualitative results of the model. I prefer to adopt a one-to-one technology as in Grossman and Helpman (1991) for the sake of simplicity.

[10] I am assuming the existence of multinational enterprises which can plant the production in any country. This allows to have the same unskilled wage for both the countries. I also assume that each firm can plant the production in only one of the two countries. By considering a symmetric situation in which $N_0^A = N_0^B$, each firm can plant the production indifferently in any country.

[11] For this assumption see the introduction where I refer empirical works supporting it.

As mentioned above - in the neo-Schumpeterian growth models with vertical innovation - the next quality of a given good or service is invented by the R&D performed by challenger researchers in order to replace the incumbent producer and gain monopolistic rents. During the temporary monopoly the patent holder can sell her product at a price higher than the marginal cost. By assuming no-drastic innovation, Bertrand competition implies that each monopolist will charge the limit price λ.

In light of the instantaneous household preferences, I can boil down the consumer θ demand quantity for each product $\omega \in [0, (1+\psi)\, n]$ to

$$q_{\theta,\omega} = \frac{\frac{1}{\lambda} c_\theta \lambda_{(\omega,s)}^{j\alpha\varepsilon}}{\int_0^{(1+\psi)n} \lambda_{(\tilde{\omega},s)}^{j\alpha\varepsilon} d\tilde{\omega}} \tag{6}$$

Summing up the demand for each product ω for all the population in each country A and B, I obtain the total demanded quantity for each variety $\omega \in [0, (1+\psi)\, n]$:

$$q_\omega = \int_0^1 q_{\theta,\omega} d\theta = \frac{\frac{1}{\lambda} Nc\lambda_{(\omega,s)}^{j\alpha\varepsilon}}{\int_0^{(1+\psi)n} \lambda_{(\tilde{\omega},s)}^{j\alpha\varepsilon} d\tilde{\omega}} \tag{7}$$

where $c \equiv \int_0^1 c_\theta d\theta$ indicates the per-capita consumption fraction of any product $\omega \in [0, (1+\psi)\, n]$ for individuals of each country (region) A and B. In equilibrium the above quantities does not coincide with the production of every consumption good by the firm that monopolizes it. In fact, I assume the existence of iceberg-type transportation cost between countries, and no transportation cost within each country.[12] For each unit of product sold abroad each firm must produce $\tau > 1$ units of product. As usual τ captures all the costs of selling to distant market, not just transport costs. Therefore, any exporting firm must manufacture the total quantity τq_ω in order to satisfy the optimal consumers demand for any variety.[13] It follows that the monopoly

[12] Each region/country is defined as an area in which transportation cost within the same region is zero, or at least infinitesimal or insignificant. Therefore the spatial distinction between regions arises whenever transportation cost becomes significant. This reasoning line is usual in NEG literature. Moreover because of this definition of regions it follows the assumption that any product line can be manufactured in only one country. In fact, if each variety could be manufactured in both the regions there would not be any transportation cost and therefore I can refer to this economy as a single region or country.

[13] Both the countries have an equal mass of industry lines as indicated by the fraction $(1-\psi)$, and a different mass of industry lines as indicated by ψ, at least along the balanced growth path. Moreover, in equilibrium, each variety is manufactured in only one country. An inventor gets patent grant for a variety in both the countries, and the next vintage of the same variety can be invented and manufactured in any country. I can assume that each new industry line can be manufactured in any country. In such a case the mass of industry line manufactured in a region can be a fraction $\zeta \in [0, 1+\psi]$ of the existing varieties of each region. Otherwise, I can assume that the newly created product lines, i.e each horizontal innovation, can be only manufactured in the country in which resides the inventing firm/researcher. Afterwards any invention improving on these different product lines can be manufactured in any

profit flows accruing to the monopolist which manufactures the state-of-the-art quality product $\omega \in [0, (1+\psi)\, n]$ are:

$$\pi\,(\omega, s) = q_{\omega}\,[\lambda - 1] + q_{\omega}\,[\lambda - \tau] = \frac{cN\left(k + k^{'}\right)\lambda^{j\alpha\varepsilon}_{(\omega,s)}}{(1+\psi)\, n\Lambda} \tag{8}$$

where $k \equiv [1 - 1/\lambda]$, $k^{'} \equiv [1 - \tau/\lambda]$[14], and $\Lambda \equiv \frac{\int_0^{(1+\psi)n} \lambda^{j\alpha\varepsilon}_{(\tilde{\omega},s)} d\tilde{\omega}}{(1+\psi)n}$ is the average quality level in each industry line.

Up to now I have envisaged the profit flows for an improved version of any existing product line. I obtain similar relationship for the profit flows of a monopolistic firm producing a completely new variety. The only difference with the above expressions concerns the quality jumps achieved in a new product line. Following Howitt (1999), each horizontal innovation results in a new product whose quality parameter is drawn randomly from the distribution of the existing industry lines, hence I consider the average value of the existing quality jumps in both the countries. Then, for each completely new variety the consumers' demand in each country is

$$q_{\omega} = \int_0^1 q_{\theta,\omega} d\theta = \frac{\frac{1}{\lambda} N c \Lambda}{\int_0^{(1+\psi)n} \lambda^{j\alpha\varepsilon}_{(\tilde{\omega},s)} d\tilde{\omega}} \tag{9}$$

where $\Lambda \equiv \frac{\int_0^{(1+\psi)n} \lambda^{j\alpha\varepsilon}_{(\omega,s)} d\omega}{(1+\psi)n}$ is the average quality level in each variety.[15] It follows that the monopoly profit flows accruing to the monopolist which manufactures a new product line is:

$$\pi_v\,(\omega, s) = q_{\omega}\,[\lambda - 1] + q_{\omega}\,[\lambda - \tau] = \frac{cN\left(k + k^{'}\right)\Lambda}{(1+\psi)\, n\Lambda} \tag{10}$$

2.3 R&D Sector

In such an economy there exists both vertical and horizontal innovation. The former type of innovation concerns the introduction of an upgraded version of any existing variety. The second type of innovation consists of introducing a completely new product line in the marketplace. The incumbent producer of any existing variety is challenged by outsider R&D firms that employ skilled

country because of the multinational enterprises. In such a case the mass of industry lines manufactured in a region can be a fraction $\zeta \in [\psi, 1]$ of the existing varieties of each region. In both the cases the qualitative results of the model hold.

[14] I assume that $\tau < \lambda$, and that each inventor gets the same patent grant in both the countries. Notice that, in the case of local technological spillovers, the creative destruction discount factor would be $I\,(\omega, s)$. See section 4.3 for this case.

[15] For the case of localized spillovers the same average quality level in each variety $\Lambda^A = \Lambda^B = \Lambda$ is guaranteed by the symmetry between regions.

workers in order to introduce a better version of the existing goods and services. As usual in the quality ladder models à la Grossman and Helpman (1991) and Aghion and Howitt (1992, 1998), the Arrow's effect is at work. Each incumbent monopolist has no informational advantage over the outsider firms. Hence it has not incentive to perform R&D because it destroys its own monopolistic rents, thus reducing its innovation value with respect to that of any other outsider firm. Therefore the monopolist does not find it profitable to undertake any R&D at the equilibrium wage. Instead each outsider firm has the incentive to perform R&D in any existing industry line. Moreover each research firm could find it profitable to start up with a completely new product line.

Furthermore, as usual there exists a perfect global stock market that channels consumer savings to firm engaged in R&D.

2.3.1 Vertical R&D

Let $v(\omega, s)$ denotes the expected discounted profits of a successful firm in industry ω at time s. Because each leader is targeted by R&D firms in both countries that try to discover the next quality leader product,[16] the shareholder suffers a loss $v(\omega, s)$ with probability $2I(\omega, s)\,ds$, where $I(\omega, s)$ denotes the Poisson arrival rate of innovation targeting the industry $\omega \in [0, (1+\psi)\,n]$ in each country. Whereas the event of no innovation occurs with probability $[1 - 2I(\omega, s)]\,ds$. Over a time interval ds, the shareholder of a stock issued by a successful R&D firm receives a dividend $\pi(s)\,ds$ and the value of the firm appreciates by $dv(\omega, s) = \dot{v}(\omega, s)\,ds$. Since the stock market is assumed perfectly efficient, the expected rate of return of a stock issued by a successful R&D firm must be equal to the riskless rate of return r:

$$rds = \frac{\dot{v}(\omega, s)}{v(\omega, s)}\left[1 - 2I(\omega, s)\,ds\right] ds - \frac{v(\omega, s) - 0}{v(\omega, s)}\left[2I(\omega, s)\right] ds + \frac{\pi(s)}{v(\omega, s)} ds$$

Taking the limits as $ds \to 0$, I obtain the following condition:

$$v(\omega, s) = \frac{\pi(\omega, s)}{\rho + 2I(\omega, s) - \frac{\dot{v}(\omega,s)}{v(\omega,s)}} \tag{11}$$

where I have posed $r = \rho$ since I analyze the balanced growth path. Hence the discounted expected profit value for each product boils down to (see the Appendix A)

$$v(\omega, s) = \frac{cN\left(k + k'\right)\lambda_{(\omega,s)}^{j\alpha\varepsilon}}{\left[\rho + 2I(\omega, s) + \alpha\varepsilon\frac{2I}{(1+\psi)n}\ln\lambda\right](1+\psi)\,n\Lambda}. \tag{12}$$

[16] When any existing product is target of further quality improvement only by R&D firms that operate in the same country in which the product is manufactured, i.e. in the case of local knowledge spillovers, the shareholder suffers a loss $v(\omega, s)$ with probability $I(\omega, s)\,ds$, where $I(\omega, s)$ denotes the Poisson arrival rate of innovation targeting the industry $\omega \in [0, (1+\psi)\,n]$ in each country; whereas the event of no innovation occurs with probability $[1 - I(\omega, s)]\,ds$.

The industry-wide arrival rate of innovation in industry $\omega \in [0, (1+\psi)\, n]$ at time s in each country is $I(\omega, s)$, which represents the aggregate summation of the Poisson arrival rate of innovation generated by all R&D firms targeting product $\omega \in [0, (1+\psi)\, n]$.

Every R&D firm can produce an instantaneous Poisson arrival rate of innovation in the already existing product line it targets by using a CRS technology described by unit cost function bw_H, with $b > 0$ common to all industries in both the countries. The Poisson specification of the innovation process implies the independence of the individual instantaneous arrival rate of the innovation.[17] Then a firm i which engages in R&D in industry ω at time s and discovers the next higher-quality product with instantaneous probability $I_i(\omega, s)$ incurs the R&D cost flow $\frac{b}{\iota} w_H I_i(\omega, s)$, where each researcher has productivity ι, that is ι is the Poisson arrival rate of innovation of each researcher engaged into vertical R&D. Each R&D firm that is located in a country chooses its R&D intensity $I_i(\omega, s)$[18] to maximize expected discounted value

$$v(\omega, s)\, I_i(\omega, s)\, ds - \frac{b}{\iota} w_H I_i(\omega, s)\, ds$$

Since the R&D sector is characterized by a perfectly competitive environment, with free entry and exit and CRS technology, for all industries $\omega \in [0, (1+\psi)\, n]$ targeted by positive R&D, along the balanced growth path the following no-arbitrage condition holds

$$v(\omega, s) = \frac{cN\left(k + k'\right) \lambda^{j\alpha\varepsilon}_{(\omega,s)}}{\left[\rho + 2I(\omega, s) + \alpha\varepsilon \frac{2I}{(1+\psi)n} \ln\lambda\right] (1+\psi)\, n\Lambda} = \frac{b}{\iota} w_H \tag{13}$$

The industry lines with a higher number of quality jumps achieved along the quality ladder have a larger demand from the consumers, and therefore have larger profit flows. These firms will be subjected to a larger industry-wide Poisson arrival rate $I(\omega, s)$ from each country. The no-arbitrage equation (13) implies that the Poisson arrival rate targeting the product lines with higher demand, and hence gaining higher profits, will have a correspondingly higher Poisson arrival rate. In fact, higher profit flows spur more innovative effort until

[17] Each individual contribution to R&D by each skilled worker gives an independent contribution to the aggregate instantaneous probability of innovation. There does not exist any externality among researchers in the individual productivity even though there exists reciprocal collaboration at the idea-creation moment. Each researcher benefits from the whole knowledge accumulated in an industry, but the 'parallel' interaction between two or more researchers working in the same firm in order to introduce the next innovation does not alter their individual productivity. This implies that R&D productivity is the same if each research worker undertakes R&D by employing herself as if they are working together in the same firm.

[18] As in Dinopoulos and Segerstrom (1999), I assume that the returns to R&D investment are independently distributed across firms, across industries, and over time. Therefore the industry-wide instantaneous Poisson arrival rate of innovation in industry line ω at time s is $I(\omega, s) = \sum_i I_i(\omega, s)$ in each country.

the higher increasing creative destruction exactly offsets the higher rents in that product line. This process will continue and in equilibrium equation (13) will be satisfied for each variety $\omega \in [0, (1+\psi)n]$.[19]

2.3.2 Horizontal R&D

Let $v_v(\omega, s)$ denotes the expected discounted profits of a successful firm in industry ω at time s, since the stock market is assumed perfectly efficient, the expected rate of return of a stock issued by a successful R&D firm will be

$$v_v(\omega, s) = \frac{cN\left(k + k'\right)\Lambda}{\left[\rho + 2I(\omega, s) + \alpha\varepsilon\frac{2I}{(1+\psi)n}\ln\lambda\right](1+\psi)n\Lambda}. \tag{14}$$

where $v_v(\omega, s)$ denotes the expected discounted profit flows of a successful firm introducing a completely new industry line ω at time s.

In each country every R&D firm can produce an instantaneous Poisson arrival rate of innovation for a completely new industry line by using a CRS technology described by unit cost function aw_H, with $a > 0$ common to all firms and to both the countries. Also the horizontal R&D sector is characterized by a perfectly competitive environment, with free entry and exit and CRS technology, therefore each time a new variety is invented, the research firm must equalize the discounted expected profit flows to the total R&D costs. Moreover, once a new product is introduced in the marketplace it will be target of further quality improvements. Then, along the balanced growth path, the following no-arbitrage condition for each new industry line must hold[20]

$$v_v(\omega, s) = \frac{cN\left(k + k'\right)\Lambda}{\left[\rho + 2I(\omega, s) + \alpha\varepsilon\frac{2I}{(1+\psi)n}\ln\lambda\right](1+\psi)n\Lambda} = \frac{a}{\iota_v}w_H \tag{15}$$

Along the balanced growth path the existence of positive and finite vertical and horizontal innovation is guaranteed by the no-arbitrage equation between vertical and horizontal innovation

[19] Following Segerstrom (1998), I assume that the expected Poisson arrival rate of innovation depends on its current value. That is, whenever researchers observe a high $I(\cdot)$ today, they expect a high $I(\cdot)$ tomorrow.

[20] As for any vertical innovation a firm j which engages in R&D at time s and discovers the next industry line with instantaneous probability $\iota_v h_j(\omega, s)$ incurs the R&D cost flow $aw_H h_j(\omega, s)$, where ι_v is the Poisson arrival rate of innovation for each researcher engaged into horizontal innovation, and $h_j(\omega, s)$ is the skilled labor force employed in firm j. Each R&D firm that is located in a country chooses its R&D labor intensity $h_j(\omega, s)$ to maximize expected discounted profits $v_v(\omega, s)\,\iota_v h_j(\omega, s)\,ds - aw_H h_j(\omega, s)\,ds$, which boil down to $v_v(\omega, s) = \frac{a}{\iota_v}w_H$. Moreover the R&D sector is characterized by a perfectly competitive environment, with free entry and exit and CRS technology. In this case I can interpret each horizontal innovation as a first step along the quality ladder of a new variety, with productivity of the product starting at the average quality level.

$$\frac{1}{\theta_0^*}\frac{a}{\iota_v}w_H \leq \frac{b}{\iota}w_H \tag{16}$$

which in equilibrium holds with the equality in order to guarantee positive value of both the types of innovation activity. Equation (16) univocally determines the ability threshold $\theta_0^* = \frac{\iota a}{\iota_v b}$. Each researcher endowed with an ability θ^* higher than the threshold ability θ_0^* will find it profitable to start up with a completely new product line. Therefore I assume heterogeneous individuals at all levels. The individual ability distribution $\theta \in [0,1]$ allows to distinguish between unskilled and skilled workers, and hence between individuals that accumulate human capital through schooling and individuals that remain unskilled for all their life. This choice is an optimal intertemporal decision, given the ability level of each individual. Among the skilled workers - as in Howitt (1999) - I am assuming heterogeneous individuals in the horizontal innovation process. In fact, the horizontal innovation is far less pre-specified on the basis of the current state of knowledge, and it requires a creativity effort better interpreted in the spirit of Schumpeter's (1934, 1939) entrepreneurial ingenuity. In the spirit of Schumpeterian (1934, 1939) analysis, what is really more complicated is the inventive activity of a completely new industry line. Hence, the individuals endowed with an ability higher than the threshold θ_0^* find it profitable to start up with a new product line. Notice that the individual ability distribution $\theta \in [0,1]$, and the skilled entrepreneurial ingenuity ability distribution $F(\theta^*)$ are not correlated and are completely independent each other.

In equilibrium a constant fraction of population and of skilled workers will decide to start up with a new industry line in the economy. I can describe the dynamic evolution of new varieties with a simple differential equation very familiar in the neo-Schumpeterian endogenous growth models

$$\dot{n} = \iota_v \left[\int_{\theta_0^*}^{\infty} \theta^* dF(\theta^*)\right] 2H(t) = 2m(\theta_0^*) H(t) \tag{17}$$

where $m(\theta_0^*) \equiv \iota_v \left[\int_{\theta_0^*}^{\infty} \theta^* dF(\theta^*)\right]$ is the cumulated entrepreneurial activity belonging to $[0,\infty)$, and where I define $F(\theta^*)$ to be the cumulate distribution of the "entrepreneurial ability", with the usual properties $F^{'}(\theta^*) > 0$, $F(0) = 0$, and $F(\infty) = 1$.

3 Balanced Growth Path

Given the economic environment described in section 2, I analyze the general equilibrium implications of the economy. Like Dinopoulos and Segerstrom (1999) I focus on the balanced growth path properties of the model.

3.1 New Varieties

Along the balanced growth path completely new varieties of goods and services are created gradually. This is a fundamental difference with the standard New Economic Geography (NEG) literature. In fact, in this strand of literature, the number/mass of varieties does not evolves gradually along the balanced growth path or outside it. The process through which the existing varieties are created is often described as instantaneous and immediate.[21] In this framework, differently from the NEG literature, the creation of new varieties happens gradually over time. The creation of each new variety requires a creative and innovative effort from very talented skilled workers. In the spirit of the Schumpeterian's analysis (1934,1939) the entrepreneurial ingenuity is the fundamental ingredient to starting up with a completely new industry line, also interpreted as a new market niche along the existing product lines.

For both the countries the no-arbitrage equation between vertical and horizontal innovation activity univocally determines the steady state fraction of skilled workers that will find it profitable to introduce a new sector, rather than to upgrade any existing industry line. By defining $z \equiv \frac{n}{N}$ as the per-capita mass of varieties in each symmetric country, I can derive the limit mass of varieties produced in the economy, that is the long-run attractor for the mass of product lines in each country:

$$\frac{\dot{z}}{z} \equiv \frac{\dot{n}}{n} - \frac{\dot{N}}{N} = 2m\left(\theta_0^*\right)\frac{H}{n} - g_N \tag{18}$$

that admits a unique and globally stable steady state value for each country. Denote the steady state value of z as:

$$\bar{z} = \frac{m\left(\theta_0^*\right)\left(\theta_0 + 1 - 2\gamma\right)\left(1 - \theta_0\right)\phi}{g_N} \tag{19}$$

where I have used equation (4).[22] Any per-capita mass of varieties to the left (right) of the steady state value $\bar{z}$ will increase (decrease) over time. Hence the equilibrium point of the per-capita mass of varieties for each country is globally stable. It is noteworthy that $\bar{z}$ indicates the steady state per-capita mass of varieties, but the effective mass of per-capita industry lines manufactured in a country can be different from this value.[23]

[21] In the NEG literature, the zero profit condition and the existence of a fixed cost for the production of the non traditional sector determines respectively the number of varieties (and hence of the existing producing firms) and the firm size (see for example Baldwin et *al.* 2004, Ottaviano and Thisse 2004)

[22] Notice that defining the per-capita mass of product lines in the whole economy, i.e. in both the regions, as $\tilde{z} \equiv \frac{(1+\psi)n}{2N}$, I have the same globally stable steady state value for $\tilde{z}$ as for z.

[23] I refer the reader to footnote 13.

3.2 Labor market equilibrium and Creative destruction

In this section I show that, along the balanced growth path, there exists a unique value of the threshold ability parameter θ_0. Since each final good monopolist employs unskilled labor economy-wide to manufacturing products, the unskilled market clearing equilibrium condition is

$$2N\theta_0 = \int_0^{(1+\psi)n} \left[\frac{\frac{1}{\lambda}Nc\left(\lambda_{(\omega,s)}^{j\alpha\varepsilon} + \Lambda\right)}{(1+\psi)\,n\Lambda} + \frac{\tau\frac{1}{\lambda}Nc\left(\lambda_{(\omega,s)}^{j\alpha\varepsilon} + \Lambda\right)}{(1+\psi)\,n\Lambda} \right] d\omega = \frac{2}{\lambda}Nc\,(1+\tau)\,, \tag{20}$$

where I consider the unskilled labor force of both the regions. In fact, since each variety can be manufactured in any country and in only one of them, and because of the existence of multinational enterprises and symmetry between regions, I equal the total mass of unskilled labor force to the total mass of production of both the regions. This allows me to be as general as possible, because in such a case the fraction of products manufactured in each country can assume any value among the admissible ones, i.e. the industry lines active in one country can be the fraction $\zeta \in [0, 1+\psi]$. Notice that along the balanced growth path because of the symmetry of the two countries, each region maintains balanced trade.[24]

From equation (20) it is easily derived the steady state value of the per-capita consumption c of each country

$$c = \frac{\lambda\theta_0}{1+\tau} \tag{21}$$

Substituting equation (21) into equation (8) allows me to rewrite total profit flows in the industry line $\omega \in [0, (1+\psi)\,n]$ as

$$\pi\,(\omega) = \frac{\lambda\theta_0 N\left(k+k'\right)\lambda_{(\omega,s)}^{j\alpha\varepsilon}}{(1+\tau)\,(1+\psi)\,n\Lambda}. \tag{22}$$

By considering equation (22), and since the no-arbitrage condition $v\,(\omega,s) = \frac{b}{\iota}w_H$ must hold along the balanced growth path, it is possible to write down the profit flows for each good/service as

$$\frac{\lambda\theta_0 N\left(k+k'\right)\lambda_{(\omega,s)}^{j\alpha\varepsilon}}{(1+\tau)\,(1+\psi)\,n\Lambda} = \frac{b}{\iota}w_H\left[\rho + 2I\,(\omega,s) + \alpha\varepsilon\frac{2I}{(1+\psi)\,n}\ln\lambda\right], \tag{23}$$

[24] The symmetry of the two countries implies that - along the balanced growth path - the mass of industry lines manufactured in each country ζn is equal. That is, along the balanced growth path, each country manufactures $\frac{1}{2}(1+\psi)\,n$ product lines. This guarantees balanced trade.

which - since $w_H = \frac{\sigma}{\theta_0 - \gamma}$ - can be rewritten as

$$\frac{\lambda N \theta_0 \left(k + k^{'}\right) \lambda_{(\omega,s)}^{j\alpha\varepsilon}}{(1+\tau)(1+\psi) n \Lambda} = \frac{\sigma \frac{b}{\iota}}{\theta_0 - \gamma} \left[\rho + 2I(\omega, s) + \alpha\varepsilon \frac{2I}{(1+\psi) n} \ln \lambda\right]. \tag{24}$$

I obtain the industry-wide Poisson arrival rate targeting product $\omega \in [0, (1+\psi) n]$ for each region

$$I(\omega, s) = \left[\frac{\lambda N \theta_0 (\theta_0 - \gamma) \left(k + k^{'}\right) \lambda_{(\omega,s)}^{j\alpha\varepsilon}}{\sigma \frac{b}{\iota} (1+\tau)(1+\psi) n \Lambda} - \left(\rho + \alpha\varepsilon \frac{2I}{(1+\psi) n} \ln \lambda\right)\right] \frac{1}{2} \tag{25}$$

From the above equation I obtain the aggregate Poisson arrival rate of innovation for each country, i.e. $\int_0^{(1+\psi)n} I(\omega, s)\, d\omega$,

$$I = \frac{\lambda N \theta_0 (\theta_0 - \gamma) \left(k + k^{'}\right)}{2\sigma \frac{b}{\iota} (1+\tau)} \frac{1}{(1 + \alpha\varepsilon \ln \lambda)} - \rho n \frac{(1+\psi)}{2(1 + \alpha\varepsilon \ln \lambda)} \tag{26}$$

As for unskilled labor it is possible to boil down the market clearing equilibrium condition for skilled labor force. Using equation (5), and the CRS technology production function of innovating firms, the skilled labor market equilibrium condition for each country is

$$(\theta_0 + 1 - 2\gamma)(1 - \theta_0) \frac{N\phi}{2} = bI + am(\theta_0^*) H \tag{27}$$

where the LHS represents the total supply of skilled workers in each country, and the RHS represents the total demand of skilled workers in the same country. The first term of the RHS considers the skilled workers engaged into vertical innovation which aim to upgrading the existing product lines, and the second term of the RHS represents the constant fraction of skilled workers choosing to start up with a new industry line. Equation (27) boils down to

$$(\theta_0 + 1 - 2\gamma)(1 - \theta_0) \frac{\phi}{2} \left[1 - am(\theta_0^*) + m(\theta_0^*) \frac{b\rho(1+\psi)}{(1+\alpha\varepsilon \ln \lambda) g_N}\right] = \frac{\lambda \left(k + k^{'}\right) \theta_0 (\theta_0 - \gamma)}{2 \frac{\sigma}{\iota} (1+\tau)(1 + \alpha\varepsilon \ln \lambda)}$$

where the term between square brackets on the LHS is strictly positive. From last equation I can state the following

Proposition 1 *Along the balanced growth path, under a symmetric equilibrium, there exists a unique value of the threshold ability parameter $\theta_0 > \gamma$. Moreover along the balanced growth path there exists a positive relationship between the parameter τ (transportation cost) and the threshold ability parameter θ_0.*

Proof. See the Appendix B ■

Along the balanced growth path any increase in the transportation cost - as represented by an increase in the production vanished along the way - reduces the incentive to accumulate human capital through schooling in both the countries. Therefore, a more globalized economy spurs human capital accumulation, and widens skill premium in both the regions.

4 Comparative Static analysis

4.1 Effects of trade liberalization

In this section I analyze the effects of more costly transportation on human capital accumulation, on skill premium, and on per-capita output growth rate of each country. As in Dinopoulos and Segerstrom (1999) analysis I show that a more globalized world increases both human capital accumulation and wage inequality. However, in this framework, and differently from Dinopoulos and Segerstrom's (1999) analysis, a more globalized world can reduce the per-variety innovation rate, and therefore the per-capita output growth rate of the economy.

To see these results let us consider proposition 1: along the balanced growth path, any increase in the iceberg-type transportation cost raises the threshold ability parameter θ_0, this in turn implies lower skill premium (see equation 3). Along the balanced growth path the profit flows of each manufacturing firm producing the top quality product $\omega \in [0, (1+\psi) n]$ are

$$\pi(\omega, s) = \frac{\theta_0 \lambda \left(k + k'\right) \lambda_{(\omega,s)}^{j\alpha\varepsilon}}{\bar{z}\Lambda (1+\tau)(1+\psi)} \tag{28}$$

I consider the no-arbitrage equation between the discounted expected profit flows for each product line $\omega \in [0, (1+\psi) n]$ and the vertical research cost

$$v(\omega, s) = \frac{\frac{\theta_0 \lambda \left(k+k'\right) \lambda_{(\omega,s)}^{j\alpha\varepsilon}}{\bar{z}\Lambda(1+\tau)(1+\psi)}}{\left(\rho + 2I(\omega, s) + \alpha\varepsilon \frac{2I}{(1+\psi)n} \ln \lambda\right)} = \frac{b}{\iota} w_H \tag{29}$$

Appendix B shows that, under some parameter conditions, any increase in the iceberg-type transportation costs raises the profit flows of each product line. This in turn determines an increase in the per-variety Poisson arrival rate of innovation and therefore in the per-capita output growth rate of each country. In fact, along the balanced growth path, the no-arbitrage equation (29) must be satisfied in each instant of time. Since any increase in the transportation cost determines a reduction in the skill premium, and then of the research costs, and an increase in the profit flows, the validity of the no-arbitrage equation is guaranteed with an increased per-variety innovation rate in each country. The same results are obtained whenever profit flows decrease as transportation costs rises.

These effects strongly contrast with Dinopoulos and Segerstrom's (1999) findings. In fact, a more globalized world, that is a world with lower transportation costs, can contribute to widening wage inequality between skilled and unskilled workers as in Dinopoulos and Segerstrom (1999), but at the same time it can produce lower per-capita output growth rate for each symmetric country. Therefore, in this framework - with both vertical and horizontal innovation - a more globalized world can determine a lower per-capita output growth rate and higher wage inequality. These result can be summarized in the following

Proposition 2 *When some parameter conditions are satisfied (inequality B4-B5 are a case) a more globalized world, as represented by lower iceberg-type transportation cost, spurs human capital accumulation, increase skill premium, raises the per-capita mass of product lines, and reduces the per-capita output growth rate in each symmetric country.*

Proof. *See the Appendix B* ■

The economic mechanisms for these results are easily explained. As the iceberg-type transportation cost decreases, the incentive to accumulate human capital through schooling rises. At the same time the higher mass of skilled workers concentrate relatively more on horizontal innovation than on vertical innovation. In fact, along the balanced growth path, the per-capita mass of product lines increases. The increase in labor skill demand from vertical and horizontal R&D firms raises skill premium and therefore the research cost. If some parameter conditions are satisfied, the profit flows decrease or their increase does not compensate the increase in R&D cost. The increase in the mass of varieties dilutes the more aggregate vertical research effort on more industry lines, and therefore reduces the per-product line Poisson arrival rate of innovation. This in turn implies a reduction in the per-capita output growth rate of each country. However, globalization increase the utility level and the consumption level of each consumer, that is globalization has positive effect on output levels. This effect comes form love for variety utility function specification. In fact, utility of any consumer increases more when a new product line is consumed than in the case of consuming one less product lines of better quality. Since globalization increase the per-capita product lines this in turn has positive effect on utility level and therefore on output level.

4.2 Migration effects

Since I start from a symmetric equilibrium, the migration phenomena could be described as larger initial population size of one country than the other country. In order to analyze asymmetry in population size between countries, comparative static analysis suffices in showing all the relevant and fundamental effects.[25] To fix ideas, let suppose that country A has higher population size than country B.[26]

[25] It is obvious that the migration should be analyzed by introducing a differential equation in the model. As in large part of NEG literature the migration differential equation should depend on nominal or real wage differential, if the mobile factor is labor. However, this type of analysis should require the out-of-the-steady state analysis of the endogenous variables of the model. Like Dinopoulos and Segerstrom (1999) underline, out-of-the-steady-state analysis of their model is a very difficult task and the same authors concentrate on the steady-state solution. Moreover, as said above, the static comparative analysis is sufficient in showing all the relevant economic effects and mechanisms governing such an economy.

[26] The analysis would be the same if the country B had a higher population size than country A, or if migration takes place from a country towards the other country. In fact, along the

As shown in the Appendix C, any increase in the population size in one country increases the incentive to accumulate human capital through schooling in the same country. Moreover, the reduction in the threshold ability parameter θ_0^A in region A, increases skill premium in the same country. In this framework - along the balanced growth path - if country B starts with lower population size than country A - the skill wage of country A will be higher than the skill wage of country B. In fact, as the per-capita mass of varieties increases in one country, the demand for skilled labor rises for both vertical and horizontal innovation, which takes place in each of the existing industry lines. In fact, any reduction in the threshold ability parameter θ_0^A increases the per-capita mass of product lines $\bar{z}^A$ since $\partial z^A / \partial N^A = \frac{\partial z^A}{\partial \theta_0^A} \frac{\partial z \theta_0^A}{\partial N^A} > 0$ (see the Appendix C). The increase in demand for skilled workers spurs the increase in skill premium which is paid to the whole research sector (vertical and horizontal). Therefore the research cost rises along the new balanced growth path in the country with larger domestic market.

The higher skill premium could determine further migration of skilled workers towards the country with larger domestic market, i.e. in this case towards country A. However, full agglomeration of skilled labor force does not happen because of the existence of a dispersion force represented by the Poisson arrival rate of innovation. In fact, the higher skill premium in the larger domestic market spurs migration of skilled labor towards the same country, but this agglomeration force is compensated by the reduction in the Poisson arrival rate of innovation in the same country. Each vertical R&D firm residing in any country can introduce an upgraded version of any existing variety. The increase in skill premium in the larger domestic market due to higher per-capita mass of varieties invented in the same region, increase the research cost of any R&D firm residing in the same country. The profit flows decrease or increase less than the increase in the research cost (see the Appendix C). Free entry and CRS technology in R&D imply that along the new balanced growth path the per-product line creative destruction effort have to decrease. Appendix C also shows that the per-product line aggregate innovation rate $I^A / (1 + \psi) n$ decreases along the balanced growth path as the population size increases in country A.

In fact, each researcher observe, along the new balanced growth path, a lower per-industry Poisson arrival rate of innovation; as researchers observe a low $I(\cdot)$ today, they expect a low $I(\cdot)$ tomorrow, and therefore each R&D firm residing in the larger market invests lesser in vertical R&D than each vertical R&D firm residing in the "narrow" market. This dispersion force compensates the agglomeration force of higher skill premium until, along the new balanced growth path, no-arbitrage conditions (15) and (13) are satisfied. Hence each vertical R&D firm concentrate more on upgrading the product lines in the "narrow" market, and then to upgrading the product-lines in the larger market. The larger skilled labor force residing in country A concentrate more on horizontal innovation than on vertical innovation.

balanced growth path, both skilled and unskilled labor force are constant fractions of the population size.

These results can be summarized in the following

Proposition 3 *The country/region with larger domestic market has: a) higher human capital accumulation both in absolute and relative terms; b) higher skill premium; c) larger mass of product lines; d) lower per-product line Poisson arrival rate of innovation.*

Proof. *See the Appendix C* ■

The opposite effects are at work in the other country, from which a little mass of population emigrates. In country B, which has lower initial population size, increases the threshold ability parameter θ_0^B, and therefore individuals are discouraged to accumulate human capital through schooling. The skill premium decreases and so does the research cost. The per-capita mass of varieties decreases along the balanced growth path. The per-variety Poisson arrival rate of innovation in country B rises.

Moreover, since a larger mass of the existing varieties in now produced in country A than in country B, the manufacturing production cost decrease for each firm producing in country A, since each firm sells a larger quantity of its production in the larger domestic market. This mechanism is a little different from the standard demand-linked circular causality of the Core-Periphery models. In fact, in this framework each firm has the incentive to plant the production in the larger market, i.e. in the country with larger population size. This is because of the reduction in the production and transportation cost. On the other side, however, the consumers pay the same price λ for each product, either it is manufactured in the same country where she resides or if it is manufactured abroad. Changes in spatial allocation of demand spurs the reallocation of the manufacturing firms. Because of the possibility of multinationalization of each manufacturing firm, this could produce an agglomeration phenomena of the manufacturing production in the country with larger domestic market, i.e. in this case country A. Agglomeration in country A continues until the unskilled labor supply is able to clear the labor demand for manufacturing, i.e. until the unskilled market clearing condition is satisfied.

Therefore - along the balanced growth path - if a country A has larger domestic market, it will have more human capital accumulation, higher skill premium, and higher the per-capita mass of varieties. This in turn dilutes the aggregate vertical innovation effort along an increased per-capita and absolute mass of varieties - since $\frac{\partial z}{\partial \theta_0} < 0$ along the balanced growth path - thus reducing the per-variety Poisson arrival rate of innovation. The opposite effects happen in country B.

Notice that asymmetry in domestic market size, or migration from a country towards the other, produces effects on the output level but does not determine different per-capita output growth rate between countries. The per-capita output growth rate of each region can vary in relation to the relative change in the Poisson arrival rate of innovation in each country, but it will be the same for both the regions. This result comes from the love for variety utility function: each individual prefers to consume all the existing varieties, and hence the per-capita growth rate is the same for both the regions. However, asymmetry in population size determines level effects: in larger domestic country skill premium is higher and therefore skilled labor force can afford larger consumption flows. The country with larger domestic market produces larger mass of variety, both in absolute and per-capita terms, and skilled labor force residing in it has higher per-capita consumption level. Since the unskilled labor force has the same nominal and real wage in both the regions, each unskilled worker has the same consumption flow in each country.

4.3 Multiple interpretations

This model considers complete patent protection for each new product for both the regions/countries. Moreover, the results hold for any value of the fraction of different product lines $\psi \in [0, 1]$. Up to now I have assumed that each R&D firm can introduce an upgraded version of any existing variety manufactured in both the countries. Now I consider a sort of local knowledge and localized spillovers. In such a case the industry lines produced in the countries must be completely different each other, i.e. $\psi(s) = 1$, $\forall s$. This assumption can be interpreted as a sort of localized spillovers. Studies from Jaffe (1993), Coe and Helpman (1995, 1997), Keller (2002) show the importance of the spatial proximity for knowledge diffusion and utilization. In fact, as Baldwin and Martin (2004) maintain: "The diffusion of knowledge across regions and countries does exist but diminishes strongly with physical distance which confirms the role that social interactions between individuals, dependent on spatial proximity, have in such diffusion." A similar argument, and some empirical evidence, can be found in cities. For example Black and Hernderson (1999) maintain that "a goal of the paper is to develop a model of urban evolution that is consistent with basic observed patterns. An urbanized economy has different type of cities specialized in different traded goods, with city size and educational attainments varying by city type".

The existing industry lines in a country generate a sort of specialized and local knowledge which depends on spatial proximity and on traditions and customs of the same country. Since each country produces a different mass of goods and services, the research activity along the specialized industry lines in a country creates a sort of local and specialized knowledge. This means that the creative destruction, which can hit any existing product lines in a country, only depends on the total mass of vertical research firms that reside in the same country. In fact, I capture the concept of localized spillovers by assuming that the creative destruction only comes from vertical R&D conducted in the same country by research firms residing in it. The creation of completely new product lines can be interpreted as the creation of new market niches along the existing industry lines in each country. Therefore, also the creation of completely new product line in a country can be only conducted by the total mass of research firm that reside in the same country.

In the case of localized spillovers any variation in the transportation cost determines the same economic mechanism and results analyzed in the paper.[27]

Moreover, by allowing for perfectly mobile skilled labor force, the qualitative results indicated in section 4.2 continue to hold when I consider that a country has larger population size than the other country. Furthermore, the same results also hold when the larger domestic market come from a migration phenomena. In such a case I must assume that skilled workers instantaneously learn local knowledge when they emigrates. In fact, whenever local knowledge learning takes time, or require to pay a cost, skilled workers can not have any economic incentive to emigrate. The time consuming learning would be a dispersion force stronger than the higher skill premium.

5 Conclusions

I have considered an economy with two symmetric countries. In each country are active the manufacturing sector and the R&D sector which both produce under CRS technology. I allow for the existence of both vertical and horizontal innovation in the economy. The evolution of the existing varieties is gradual over time, and each variety is object of a gradual and uncertain upgrading process. The other point concerns the fact that individuals with different ability levels endogenously decide which type of activity undertake for her lifetime. Like Dinopoulos and Segerstrom (1999) I allow for human capital accumulation by individual with heterogeneous ability: each individual chooses either to remain unskilled or to accumulate human capital through schooling. Furthermore, I also allow for heterogenous ability within skilled population in the R&D process. In fact, following Howitt (1999) and Schumpeter (1934, 1939), the evolution of the varieties depends on the entrepreneurial ability of the skilled workers: only very talented skilled workers have the shumpeterian "entrepreneurial ingenuity" for introducing a new product line.

This work shows that a more globalized world spurs human capital accumulation in the whole economy, and widens skill premium within each symmetric country. Moreover, a more globalized world increases the per-capita and absolute mass of existing varieties, and whenever some parameter restrictions are satisfied, the increase in R&D cost coming from both vertical and horizontal R&D firms outweigh the increase in the profit flows (and of course outweigh the reduction in the profit flows). The larger mass of skilled labor dilutes along a larger mass of product lines, and the per-variety Poisson arrival rate on innovation decreases. This in turn reduces the per-capita output growth rate of each region. However, globalization increase the utility level and the consumption level of each consumer, that is globalization has positive effect on output levels. Moreover the per-capita output growth rate of the economy is free from the strong scale effect (see Jones, 2004).

Comparative static analysis shows that the country with larger domestic market has larger incentive to accumulate human capital through schooling, higher skill premium, and higher per-capita mass of varieties. Moreover the same

[27] This can be easily verified by simply substituting $\psi(s) = 1$ in all the parts of the paper.

country has a lower per-product Poisson arrival rate of innovation. The larger domestic market size of a country and the higher skill premium does not produce a catastrophic agglomeration. In fact, the demand-linked circular causality only works for the production side of the economy since larger market implies lower manufacturing production costs, but does not imply lower price for each consumer. For the R&D sector, the higher skill premium in the larger market is compensated in the same country by lower instantaneous per-variety Poisson arrival rate of innovation. This dispersion force impedes full agglomeration in a country of the research sector. Therefore, along the balanced growth path, even if there exists asymmetry in population size between countries, both of them actively operate in both the manufacturing and the research sector, i.e. the traditional and the modern sector remain active in both the countries.

Asymmetry in population size only determine level effects on consumption. I show that the country with larger domestic market produces larger per-capita and absolute mass of product lines, and the skilled labor force residing in that country benefit of higher consumption flows. The effect of migration, or of asymmetry in population size, on per-capita output growth rate of the both regions is undetermined.

Appendix A

In this first part I derive equation (12). Along the balanced growth path all the variables grow at a constant rate, by substituting equation (8) into equation (11), it follows that

$$\frac{\dot{\pi}(\omega,s)}{\pi(\omega,s)}=\frac{\dot{v}(\omega,s)}{v(\omega,s)}=\frac{\dot{c}}{c}+\frac{\dot{N}}{N}+\frac{\dot{\lambda}^{j\alpha\varepsilon}_{(\omega,s)}}{\lambda^{j\alpha\varepsilon}_{(\omega,s)}}-\frac{\dot{n}}{n}-\frac{\dot{\Lambda}}{\Lambda}=-\alpha\varepsilon\frac{2I}{(1+\psi)\,n}\ln\lambda$$

where I is the countrywide aggregate summation of the Poisson arrival rate of innovation for each region A and B. The last equality comes from the fact that - along the balanced growth path - the growth rate of new industry lines equals the population growth rate, i.e. $\frac{\dot{n}}{n}=\frac{\dot{N}}{N}$. In addition, the number of quality jumps in the industry line ω is constant, i.e. $\frac{\dot{\lambda}^{j\alpha\varepsilon}_{(\omega,s)}}{\lambda^{j\alpha\varepsilon}_{(\omega,s)}}=0$. In fact, I am considering the change in the expected firm value of industry line ω, i.e. $\frac{\dot{v}(\omega,s)}{v(\omega,s)}$, in the case in which no innovation occurs in that sector, as described in the stock market equation; therefore the number of quality jumps j in that industry line remains unchanged. Moreover, I assume that - along the balanced growth path - the fraction of different varieties between the two countries is constant, i.e. $\frac{\dot{\psi}}{\psi}=0$. Notice that in the case of specialization of each country in the production of each industry line - that is in the case of localized spillovers when $\psi(s)=1$, $\forall s$ - equation (12) boils down to $\frac{cN\left(k+k'\right)\lambda^{j\alpha\varepsilon}_{(\omega,s)}}{\left[\rho+I(\omega,s)+\alpha\varepsilon\frac{2I}{2n}\ln\lambda\right]2n\Lambda}$.

Q.E.D.

Appendix B

In this part of the appendix I show the existence of a positive relationship between the threshold ability θ_0 and the iceberg-type transportation cost τ for each country.

Let us consider equation (27) that I rewrite as

$$(\theta_0+1-2\gamma)(1-\theta_0)\frac{\phi}{2}\left[1-am(\theta_0^*)+m(\theta_0^*)\frac{b\rho(1+\psi)}{(1+\alpha\varepsilon\ln\lambda)g_N}\right]=\frac{\theta_0(\theta_0-\gamma)\lambda\left(k+k'\right)}{2\frac{\sigma}{\iota}(1+\tau)(1+\alpha\varepsilon\ln\lambda)}$$

The LHS of this equation is a strictly concave quadratic polynomial in θ_0 with roots $(2\gamma-1)$ and 1, and the RHS of the same equation is a strictly convex quadratic polynomial in θ_0 with two real roots 0 and γ.

Therefore there exists one and only one real and positive solution $\theta_0\in(\gamma,1)$.

Using the Implicit Function Theorem for the above equation I am able to show the positive relationship between the threshold ability θ_0 and the transportation cost τ,

$$\frac{\partial\theta_0}{\partial\tau}=-\frac{\frac{-\frac{1}{\lambda}(1+\tau)-\left(k+k'\right)}{(1+\tau)^2}\frac{\lambda\theta_0(\theta_0-\gamma)}{2\sigma(1+\alpha\varepsilon\ln\lambda)}}{(\theta_0-\gamma)\phi\left[1-am(\theta_0^*)+m(\theta_0^*)\frac{b\rho(1+\psi)}{(1+\alpha\varepsilon\ln\lambda)g_N}\right]+(2\theta_0-\gamma)\frac{\lambda\left(k+k'\right)}{2\frac{\sigma}{\iota}(1+\tau)(1+\alpha\varepsilon\ln\lambda)}}>0 \tag{B1}$$

Q.E.D.

I now turn to consider the effects of a higher iceberg-type transportation cost on the profit flows. By considering the following equation

$$\pi(\omega, s) = \frac{\lambda\theta_0 \left(k + k'\right) \lambda^{j\alpha\varepsilon}_{(\omega,s)}}{\bar{z}\Lambda(1+\tau)(1+\psi)} \tag{B2}$$

Any increase in the transportation cost produces a changes in profit flows described by the following

$$\begin{aligned}\frac{\partial\pi}{\partial\tau} &= \frac{\partial\theta_0}{\partial\tau}\lambda^{j\alpha\varepsilon}_{(\omega,s)}\Lambda\lambda\left(k+k'\right)(1+\tau)(1+\psi)\left(\bar{z}-\frac{\partial z}{\partial\theta_0}\theta_0\right)+\\ &\quad -\lambda^{j\alpha\varepsilon}_{(\omega,s)}\Lambda\lambda\bar{z}(1+\psi)\theta_0\left[k+k'+\frac{1}{\lambda}(1+\tau)\right]+\\ &\quad +\theta_0\lambda\left(k+k'\right)\frac{\partial\left(I/(1+\psi)n\right)}{\partial\tau}*\\ &\quad *\left[\frac{\partial\lambda^{j\alpha\varepsilon}_{(\omega,s)}}{\partial\left(I/(1+\psi)n\right)}-\lambda^{j\alpha\varepsilon}_{(\omega,s)}\frac{\partial\Lambda}{\partial\left(I/(1+\psi)n\right)}\bar{z}(1+\tau)(1+\psi)\right]\end{aligned} \tag{B3}$$

where - in order to determine the sign of the derivative $\frac{\partial\pi}{\partial\tau}$ - I have only written the numerator of the derivative since the denominator is strictly positive. The first term of equation (B3) is positive since $\frac{\partial\theta_0}{\partial\tau} > 0$ and $\frac{\partial z}{\partial\theta_0} < 0$; the second term is negative; moreover it is necessarily true that $\frac{\partial\lambda^{j\alpha\varepsilon}_{(\omega,s)}}{\partial(I/(1+\psi)n)} > 0$, and $\frac{\partial\Lambda}{\partial(I/(1+\psi)n)} > 0$. Let us suppose that an increase in the transportation cost raises the expected profit flows, i.e. $\frac{\partial\pi}{\partial\tau} > 0$. Sufficient conditions can be:

$$\frac{\partial\theta_0}{\partial\tau}\left(k+k'\right)(1+\tau)\left(\bar{z}-\frac{\partial z}{\partial\theta_0}\theta_0\right) > \bar{z}\theta_0\left[k+k'+\frac{1}{\lambda}(1+\tau)\right] \tag{B4}$$

and

$$\theta_0\lambda\left(k+k'\right)\frac{\partial\left(I/(1+\psi)n\right)}{\partial\tau}\left[\frac{\partial\lambda^{j\alpha\varepsilon}_{(\omega,s)}}{\partial\left(I/(1+\psi)n\right)}-\lambda^{j\alpha\varepsilon}_{(\omega,s)}\frac{\partial\Lambda}{\partial\left(I/(1+\psi)n\right)}\bar{z}(1+\tau)(1+\psi)\right] \tag{B5}$$

I prove that having both $\frac{\partial\pi}{\partial\tau} > 0$ and $\frac{\partial(I/(1+\psi)n)}{\partial\tau} < 0$ is an economic impossibility. In fact, an increase in the transportation cost raises the threshold ability parameter θ_0, and consequently decreases the skill premium w_H, and the research costs. If the profit flows increase as the transportation cost increases, along the balanced growth path the no-arbitrage equation (29) can be satisfied if and only if there will be an increase in the Poisson arrival rate of innovation in each industry line. But this necessarily determines an increase in the per-variety Poisson arrival rate of innovation $I/\left(1+\psi\right)n$. This contradicts the starting assumption of a negative effect of higher transportation cost on the per-product line Poisson arrival rate of innovation. Therefore, in the case in which the above parameter conditions are satisfied, i.e. (B4) and (B5), along the balanced growth path any increase in the transportation cost depresses human capital accumulation, reduces the skill premium in each country, reduces the per-capita mass of industry lines, but increases both the per-variety innovation rate and the per-capita output growth rate of the country as measured by the intertemporal utility function (1). For each new varieties the same reasoning line applies if the following condition is satisfied

$$\frac{\partial\theta_0}{\partial\tau}\left(k+k^{'}\right)(1+\tau)\left(\bar{z}-\frac{\partial z}{\partial\theta_0}\theta_0\right)-\bar{z}\theta_0\left[k+k^{'}+\frac{1}{\lambda}(1+\tau)\right]>0 \quad \text{(B5bis)}$$

where, as above, I have only considered the numerator of the derivative $\frac{\partial\pi}{\partial\tau}$ for each new variety.

Moreover in the case in which $\frac{\partial\pi}{\partial\tau}<0$, for any parameter values for which $\left|\frac{\partial\pi}{\partial\tau}\right|<\frac{b}{\iota}\left|\frac{\partial w_H}{\partial\tau}\right|$ and $\left|\frac{\partial\pi_v}{\partial\tau}\right|<\frac{a}{\iota_v}\left|\frac{\partial w_H}{\partial\tau}\right|$, it will be that $\frac{\partial(I/(1+\psi)n)}{\partial\tau}>0$.

Q.E.D.

Appendix C

I now turn to analyze the effects of asymmetric size population between countries. To fix ideas suppose that country A has larger population size than country B. The analysis would be the same if I studied migration from country B to country A because of the initial symmetry of the two countries.

Let us consider equation (27). It is easy to calculate the skilled labor market clearing condition for country A as

$$\left(\theta_0^A+1-2\gamma\right)\left(1-\theta_0^A\right)\frac{\phi}{2}\left[1-am\left(\theta_0^*\right)\right]=\frac{\theta_0^A\left(\theta_0^A-\gamma\right)\lambda\left(k+k^{'}\right)}{2\frac{a}{\iota}(1+\tau)(1+\alpha\varepsilon\ln\lambda)}-\frac{n}{N^A}\frac{b\rho(1+\psi)}{2(1+\alpha\varepsilon\ln\lambda)}$$

where I have not substituted the steady state value of per-capita mass of varieties $\bar{z}^A$ to the second term on the RHS. As above there exists one and only one real and positive solution $\theta_0^A\in(\gamma,1)$. Moreover, using the Implicit Function Theorem for the above equation I am able to show the inverse relationship between the threshold ability θ_0^A and the increase in the population size of the country A:

$$\frac{\partial\theta_0^A}{\partial N^A}=-\frac{n\frac{b\rho(1+\psi)}{2(1+\alpha\varepsilon\ln\lambda)}\frac{1}{(N^A)^2}}{\left(\theta_0^A-\gamma\right)\phi\left[1-am\left(\theta_0^*\right)\right]+\left(2\theta_0^A-\gamma\right)\frac{\lambda\left(k+k^{'}\right)}{2\frac{a}{\iota}(1+\tau)(1+\alpha\varepsilon\ln\lambda)}}<0. \quad \text{(C1)}$$

Hence, along the balanced growth path, any increase in the population size in one country raises the incentive to accumulate human capital through schooling. Conversely, any migration from one country towards the other country reduces the incentive to accumulate human capital in the country with the "narrow" domestic market. Moreover I can obtain the effect of an increase in the population size in one country on the profit flows of a typical monopolistic firm. From equation (B2) I obtain:

$$\begin{aligned}\frac{\partial \pi^{A}}{\partial N^{A}} &= \left[\lambda \frac{\partial \theta_{0}^{A}}{\partial N^{A}}\left(k+k^{'}\right)\lambda_{(\omega,s)}^{j\alpha\varepsilon}+\lambda\theta_{0}^{A}\left(k+k^{'}\right)\frac{\partial \lambda_{(\omega,s)}^{j\alpha\varepsilon}}{\partial\left(I^{A}/\left(1+\psi\right)n\right)}\frac{\partial\left(I^{A}/\left(1+\psi\right)n\right)}{\partial N^{A}}\right]* \\ &\quad *\left[\bar{z}^{A}\Lambda\left(1+\psi\right)\left(1+\tau\right)\right]-\left[\lambda\theta_{0}^{A}\left(k+k^{'}\right)\left(1+\psi\right)\left(1+\tau\right)\lambda_{(\omega,s)}^{j\alpha\varepsilon}\right]* \\ &\quad *\left[\frac{\partial z^{A}}{\partial \theta_{0}^{A}}\frac{\partial \theta_{0}^{A}}{\partial N^{A}}+\frac{\partial \Lambda}{\partial\left(I^{A}/\left(1+\psi\right)n\right)}\frac{\partial\left(I^{A}/\left(1+\psi\right)n\right)}{\partial N^{A}}\right] \end{aligned} \tag{C2}$$

which is strictly negative whenever $\left|\frac{\partial \lambda_{(\omega,s)}^{j\alpha\varepsilon}}{\partial\left(I^{A}/(1+\psi)n\right)}\right| > \left|\frac{\partial \Lambda}{\partial\left(I^{A}/(1+\psi)n\right)}\right|$, since $\frac{\partial \theta_{0}^{A}}{\partial N^{A}}<0$, $\frac{\partial\left(I^{A}/(1+\psi)n\right)}{\partial N^{A}}<0$, $\frac{\partial z^{A}}{\partial \theta_{0}^{A}}<0$, and $\frac{\partial \lambda_{(\omega,s)}^{j\alpha\varepsilon}}{\partial\left(I/(1+\psi)n\right)}>0$.

From equation (26) it is easy to boil down the per-product line aggregate arrival rate of innovation for each country

$$\frac{I^{A}}{\left(1+\psi\right)n}=\frac{\theta_{0}^{A}\left(\theta_{0}^{A}-\gamma\right)\lambda\left(k+k^{'}\right)}{2\bar{z}^{A}\frac{\sigma}{\iota}b\left(1+\tau\right)\left(1+\alpha\varepsilon\ln\lambda\right)}-\rho\frac{\left(1+\psi\right)}{2\left(1+\alpha\varepsilon\ln\lambda\right)} \tag{C3}$$

from which I obtain the negative relationship between an increase in the population size and the per-variety aggregate Poisson arrival rate of innovation, i.e. $\frac{\partial\left(I^{A}/(1+\psi)n\right)}{\partial N^{A}}$ is equal to

$$\left[\lambda\left(k+k^{'}\right)2b\frac{\sigma}{\iota}\left(1+\tau\right)\left(1+\alpha\varepsilon\ln\lambda\right)\right]\left[\frac{\partial \theta_{0}^{A}}{\partial N^{A}}\bar{z}^{A}\left(2\theta_{0}^{A}-\gamma\right)-\theta_{0}^{A}\left(\theta_{0}^{A}-\gamma\right)\frac{\partial z^{A}}{\partial \theta_{0}^{A}}\frac{\partial \theta_{0}^{A}}{\partial N^{A}}\right]<0 \tag{C4}$$

where - in order to determine the sign of the derivative $\frac{\partial\left(I^{A}/(1+\psi)n\right)}{\partial N^{A}}$ - I have only written the numerator of the derivative since the denominator is strictly positive. The inequality in (C4) follows since $\frac{\partial \theta_{0}^{A}}{\partial N^{A}}$ and $\frac{\partial z^{A}}{\partial \theta_{0}^{A}}$ are strictly negative.

Q.E.D.

Appendix D

In this Appendix I show the change in real wage. Following Segerstrom (1998), in solving for a balanced growth equilibrium it is implicitly assumed that the nominal wage is constant because it is the numeraire. Since quality-adjusted prices are falling over time due to innovation in both the countries, the real wage $\tilde{w}$ must be rising. In the whole economy an innovation occurs, on average, every

$\frac{1}{2I/(1+\psi)n}$ unit of time in a typical industry line, and leads to a proportional real wage increase of λ. It follows that $\lambda\tilde{w}(0) = \tilde{w}(0)\, e^{g\frac{1}{2I/(1+\psi)n}}$, which implies that $g = 2\frac{I}{(1+\psi)n} \ln\lambda$. Notice that real wage growth rate is the same for both unskilled and skilled wage, since along the balanced growth equilibrium the skill premium is a constant value of the numeraire (see equation 3). Notice that the traditional cost-linked circular causality of the Core-Periphery models does not work in such a case. In fact, the price paid by any consumer is the same wherever she resides.

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