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Does Technological Progress Magnify Regional Disparities?

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Abstract

We study how technological progress in manufacturing and transportation together with migration costs interact to shape the space-economy. Rising labor productivity in the manufacturing sector fosters the agglomeration of activities, whereas falling transport costs associated with technological and organizational innovations fosters their dispersion. Since these two forces have been at work for a long time, the final outcome must depend on how drops in the costs of producing and trading goods interact with the various costs borne by migrants. Finally, when labor is heterogeneous, the most efficient workers of the less productive region are the first to move to the more productive region.

Keywords: new economic geography, technological progress, labor productivity, migration costs, labor heterogeneity

JEL classification: J61, R12

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1 Introduction

The main thrust of this paper is that a steady flow of technological innovations in the manufacturing sector is a powerful force that fosters the concentration of manufactures in a few regions. One telling example is given by the Industrial Revolution that exacerbated regional disparities by an order of magnitude that was unknown before. Pollard (1981), who paid special attention to the geographical implications of the Industrial Revolution, claimed that "the industrial regions colonize their agricultural neighbours [and take] from them some of their most active and adaptable labour, and they encourage them to specialize in the supply of agricultural produces, sometimes at the expense of some preexisting industry" (Pollard, 1981, p. 11). The development of China provides additional evidence that sizable regional disparities are often associated with rapid economic growth (Xu *et al.*, 2013). Understanding this state of affairs is the main purpose of economic geography. The main tenet that cuts across economic geography is that falling transport costs lead to the geographical concentration of economic activities (Krugman, 1991; Fujita *et al.*, 1999; Baldwin *et al.*, 2003). In this paper, we argue that the collapse in transport costs is not the sole reason for the uneven geographical distribution of activities that emerged in the aftermath of the Industrial Revolution and during the rapid take-off of emerging economies. To be precise, we show that a massive flows of innovations in the manufacturing sector and the resulting hike in labor productivity explain why some regions fare much better than others.

Furthermore, ever since Sjaastad (1962), it is well known that migration generates substantial pecuniary and non-pecuniary costs caused by differences within and between nations. For example, in China the *Hukou system* restricts migrations to large cities and increases the rural-urban income inequality (Au and Henderson, 2006; Yang, 1999). Specifically, migrants must acquire different permits in order to access health care, schooling facilities and housing. They are also imposed various hurdles to get those permits and may still have to pay taxes to their home village for public services they do not consume. The estimations undertaken by Tombe and Zhu (2015) suggest that the average cost of intra-provincial migration is around 51 percent of annual income, whereas the average cost of inter-provincial migration ranges from 94 to 98 percent of annual income in 2000. In addition, human beings have a pervasive drive to form and maintain lasting relations with others, implying that individuals are embedded in social networks that are hard to maintain—even in the age of globalization—when they move away from their local environment. This is probably why, everything else being equal, migrants prefer to move to closer locations than to distant ones (Crozet, 2004). For example, Zhang and Zhao (2013) find that, on average, Chinese migrants are willing to give up 15 percent of their income to reduce the distance to their home town by 10 percent. Even within European countries, migration is sluggish and governed by a wide range of intangible and time-persistent factors. For example, Falck *et al.* (2012) show that actual migration flows among 439 German districts are positively affected by the similarity of dialects that were prevalent in the source and destination areas more than 120 years ago.

Our objective being to explain the organization of the regional economy, we concur with the recent literature that recognizes increasingly the role of migration costs for the distribution of economic activities (Bryan and Morten, 2015; Redding, 2015; Tombe and Zhu, 2015). In this paper, we combine *migration costs* and *labor-saving technological progress*. When there are no migration costs, manufactures are concentrated in one region, which becomes the core of the economy. When there is no technological progress, the initial configuration is the only equilibrium. As a consequence, the interregional distribution of activities is the outcome of the interplay between these two forces. To achieve our goal, we develop a parsimonious model with one sector—manufacturing or tradable services—that features increasing returns and monopolistic competition. By incentivizing workers to stay put even when they may be guaranteed a higher living standard in an other places, migration costs act as a force that fosters either the stickiness and or the dispersion of activities while, as in the economic geography literature, increasing returns and transport cost play the role of an agglomeration force.

Our main findings may be summarized as follows. We assume that one region is initially bigger than the other—even by a trifle. First, when labor productivity is low, workers do not move. In contrast, when labor productivity has grown enough, workers with the lowest migration costs move to the larger region. As productivity keeps growing, the utility differential rises, and thus more workers move to the core region. To put it differently, *rising labor productivity generates regional disparities through the partial agglomeration of firms and workers.* Given the massive role played by labor productivity gains in the process of economic development, it is fair to say that our analysis provides a historically relevant explanation for the geographical concentration of economic activities that started with the Industrial Revolution. Note that our approach to technological progress is consistent with different narratives. In particular, it does not rely on technological spillovers that occupy central stage in the modern literature (Behrens and Robert-Nicoud, 2015).

Second, *real wages are higher in the larger region than in the smaller and the gap widens with the difference in market size.* Even though labor productivity gains are the same in both regions, the difference in market size appears sufficient to explain why more firms that are located in the larger region can pay a higher wage to their workers. This concurs with empirical evidence showing that a higher market potential ($MP_r = \Sigma_s Y_s/d_{rs}$ where Y_s is the GDP of region s and d_{rs} the distance between regions r and s) is associated with a higher degree of activity and higher wages. After a careful review of the state of the art, Redding (2011) concludes that there is "a causal relationship between market access and the spatial distribution of economic activity," while Head and Mayer (2011) summarize their analysis over the period 1965–2003 by saying that "market potential is a powerful driver of increases in income per capita." Note also that one of the more remarkable geographical concentrations of activities is what is known as the "manufacturing belt"—an area one-sixth the area of the U.S. that accommodated around four-fifths of the country's manufacturing output for a century or so. Klein and Crafts (2012) conclude that "market potential had a substantial impact on the location of manufacturing in the USA throughout the period 1880–1920 and ... was more important than factor endowments."

Third, everything else being equal, we show that high transport costs foster the concentration of activities in the larger region, while falling transport costs trigger the dispersion of activities. The intuition is easy to grasp. When transport costs are high, the utility differential exceeds migration costs for a large number of workers, who move to the larger region. Since the interregional price and wage differences narrow when transport costs fall, workers have fewer incentives to move. As a consequence, if the utility differential is not sufficiently large to spark particular workers' migration when transport costs are high, this is even more evident when transport costs are low. What is more, a drop in transport costs may trigger the return of the last migrants, which goes hand-in-hand with a re-dispersion of activities. In other words, *falling transport costs incite workers to stay put or to return to their hometown.* This agrees with Helpman (1998) and Tabuchi (1998) who focus on the crowding effects of the housing market within the larger region. Rossi-Hansberg (2005) considers a different setting with a continuum of regions, several sectors, and positive transport costs. As transport costs decrease, firms become less sensitive to distance, which implies that peripheral locations will have better access to the core region and so will produce more than before. As a result, lowering transport costs fosters the geographical dispersion of activities. In the same spirit, Behrens *et al.* (2013) find that, absent interregional transportation costs, large American cities would shrink compared to small cities as local market access no longer matters. The above result is also in accordance with one of their counterfactuals undertaken by Allen and Arkolakis (2014) who show that the hike in transportation costs due to the elimination of the interstate highway system in the US worsens the access of inland locations and leads to more concentration on the coasts.

We are now equipped to answer the question raised in the title of this paper: *technological progress* or, equivalently, rising total factor productivity, *fosters the agglomeration of manufactures, whereas falling transport costs fosters their dispersion.* Indeed, the former magnifies interregional price and wage differences whereas the latter reduces these gaps. By implication, falling production costs and falling transport costs do not have the same implications for the organization of the spatial economy. Since these two forces have been at work for a long time, we may safely conclude that the final outcome depends on how the decrease in the cost of producing and trading goods interact with the rise or decline in the various costs borne by migrants.

In the foregoing, we assume that labor is homogeneous. This assumption does not allow us to capture a trend that started long ago, the geographical concentration of talent. As observed by Pollard (1981), ever since the beginning of the Industrial Revolution, the core regions attracted some of the most productive and adaptable workers from the peripheral regions. Focussing on the contemporary period, Moretti (2012) equally asserts that “geographically, American workers are increasingly sorting along educational lines.” Similar conclusions have been obtained in different works for different countries. In an attempt to account for this fact, we assume that workers are heterogeneous in that they are endowed with different amounts of skill units. Under such circumstances, we establish that *the more efficient workers living in the less productive region move toward the more productive region by decreasing order of efficiency.* To be precise, we show that high-skilled workers face a wider wage gap than low-skilled workers, as observed by Dahl and Sorenson (2010) for Danish scientists and engineers. As a consequence, interregional income and welfare differences reflect differences in the geographical distribution of skills and human capital (Glaeser and Maré, 2001; Combes *et al.*, 2008; Moretti, 2011).

What is more, the concentration of skilled workers brings about a welfare hike for the unskilled living in the core and a welfare drop for those who are in the periphery. This has two major implications. First, by raising the price of an efficient unit of labor, *the migration of the more productive workers pulls up the less productive workers residing in the core region.* Specifically, the unskilled in the larger region enjoy higher nominal wages than their counterparts in the smaller region. The presence of more skilled workers is thus beneficial to the unskilled, a result that echoes Moretti (2012) who observes that the creation of a skilled job gives rise to more unskilled jobs than does the creation of an unskilled job. Thus, differences in regional economic performance seem to be driven by differences in human capital levels.

Prior to discussing the related literature, we want to stress that our results are obtained by using a disarmingly simple model. First, we use the CES model of monopolistic competition. Second, we consider a sorting device in which composition does not matter, whereas empirical evidence shows that the labor force composition and firms' selection matter for city size. For example, Behrens *et al.* (2014) and Eeckhout *et al.* (2014) provide spatial sorting schemes of heterogeneous workers that are much richer than ours. Even though we would be the last to deny that a more general setting is always preferable to a specific one, we do not see the simplicity of our model as a flaw. In the first place, our main results are intuitive enough for their not being tied to the specifics of our setup. For example, as discussed in the concluding section, they remain valid in the linear model of monopolistic competition developed by Ottaviano *et al.* (2002). In the second, we argue in Section 5 how our baseline model can be used to cope with various extensions, which include endogenous technological progress, amenities and a multi-regional setup.

Related literature. The number of contributions to economic geography is daunting but the effects of total factor productivity (TFP) on the location of activity has been overlooked (Desmet and Rossi-Hansberg, 2014, is a noticeable exception). Baldwin *et al.* (2003) remains one the best syntheses of the classical models. A common feature of these models is that the dispersion force lies in the immobility of a second type of workers (farmers) who are evenly distributed between regions. Using the logit to describe workers' mobility, Tabuchi and Thisse (2002) revisit the standard core-periphery model and show that, as transport costs steadily fall, the presence of migration costs triggered first the concentration and, then, the redispersion of manufactures. The second-generation models focus on cities rather than large-area regions. They aim to explain the city composition when workers and firms are heterogeneous, the dispersion force being the congestion cost within cities (see Behrens and Robert-Nicoud (2015) for a survey). However, these models typically assume that cities produce the same good or, equivalently, different goods that are traded at zero cost. They do not recognize that cities are anchored in specific locations and embedded in intricate networks of trade relations that partially explain their size and industrial mix. In the wake of Eaton and Kortum (2002), a third strand of literature, which builds on spatial quantitative models, recognizes that locations are asymmetric, locations are endowed with different amenities and technologies, while labor mobility lies in between the polar extremes of perfect mobility and immobility (Bryan and Morten, 2015; Diamond, 2015; Redding, 2015; Tombe and Zhu, 2015). These models confirm that migration costs significantly affect the location of activity.

The paper is organized as follows. In the next section, we present the model and derive some preliminary results. In Section 3, we characterize the spatial equilibria and study their stability when labor is homogeneous. Section 4 shows how technological progress leads to the emergence of regional disparities, while Section 5 studies the concentration of human capital when workers are heterogeneous in skills. In the concluding section, we analyze in detail the differences and similarities between Krugman's model (1991) and our model. We then discuss several extensions of our baseline model.

2 The model and preliminary results

The economy is endowed with two regions, denoted $r, s = 1, 2$, a manufacturing or tradable service sector producing a horizontally differentiated good, one production factor (labor), and a population of workers of mass L. Workers are imperfectly mobile between regions because they bear a positive cost when they move from one region to the other. Each region, which is formally described by a one-dimensional space, can accommodate firms and workers. To keep the analysis simple, we disregard the housing and commuting costs associated with the concentration of activities in one region. Indeed, it is readily verified that competition on the land market reduces the utility gap at a rate that grows with the total number of migrants. In this event, the economy ends up with a more dispersed pattern of activities because of the difference in housing and commuting costs between the two regions. In particular, high commuting costs act as a dispersion force that puts a break on the agglomeration process (see, e.g. Ottaviano *et al.*, 2002). Apart from this, the nature of our results remains the same. Note also that we discuss in the last section what our results become when a Krugman-like agricultural sector is taken into account.

The differentiated good is made available under the form of a continuum n of varieties. Workers are endowed with one efficiency unit of labor and share the same preferences. The preferences of a worker located in region $r = 1, 2$ are given by the CES utility:

$$U_r = \left(\sum_s \int_0^{n_s} q_{sr}(i)^{\frac{\sigma-1}{\sigma}} \mathrm{d}i \right)^{\frac{\sigma}{\sigma-1}},$$

where n_s is the number of varieties produced in region $s = 1, 2$, $q_{sr}(i)$ the consumption of variety i produced in region s and consumed in region r, and $\sigma > 1$ the elasticity of substitution between any two varieties.

The budget constraint of a worker located in region r is given by

$$\sum_s \int_0^{n_s} p_{sr}(i) q_{sr}(i) \mathrm{d}i = w_r,$$

where $p_{sr}(i)$ is the price of variety i produced in region s and consumed in r, while w_r is the wage rate in region r.

Labor markets are competitive and local, implying that wages need not be equal between the two regions. The equilibrium wage in region r is determined by a bidding process in which the region r-firms compete for workers by offering them higher wages until no firm earns strictly positive profits. Thus, a firm's operating profits are equal to its wage bill.

The individual demand in region r for variety i produced in region s is then as follows:

$$q_{sr}(i) = \frac{p_{sr}(i)^{-\sigma}}{P_r^{1-\sigma}} w_r, \tag{1}$$

where the price index P_r that prevails in region r is given by

$$P_r \equiv \left(\sum_s \int_0^{n_s} p_{sr}^{1-\sigma}(i) \mathrm{d}i \right)^{\frac{1}{1-\sigma}}. \tag{2}$$

Firms operate under increasing returns and no scope economies. Thus, each firm produces a single variety and each variety is produced by a single firm, so that n_s is also the number of firms set up in region s. The production of a variety needs a fixed requirement of $f > 0$ units of labor and a marginal requirement of $c > 0$ units of labor. In this paper, technological progress means that f, c, or both fall. The technology is identical in all locations - regions have no specific comparative advantage - and for all the varieties - firms are symmetric. Hence, we may drop the variety-index i.

Labor productivity is measured through the marginal and fixed labor requirements needed by a firm to produce a variety of the differentiated good. In this context, technological progress, or rising labor productivity, takes the form of steadily decreasing marginal or fixed requirements of labor. In this paper, we consider an exogenous technological progress that permits an increase in the output per worker. We are agnostic about the concrete form taken by the various innovations developed before, during and after the Industrial Revolution. In order to insulate the impact of technological progress, we assume that technologies are the same in both regions.

Goods mobility is described by iceberg transport costs: $\tau_{rs} = \tau > 1$ units of a variety have to be shipped from region r for one unit of that variety to be available in region $s \neq r$, while transport costs are zero when a variety is sold in the region where it is produced ($\tau_{rr} = \tau_{ss} = 1$). Therefore, we have $p_{rr} = p_r$ and $p_{sr} = \tau p_s$. If λ_s denotes the share of workers living in region s (with $\lambda_1 + \lambda_2 = 1$), for the demand $\lambda_s L q_{rs}$ in region s to be satisfied, each firm in region r must produce $\tau \lambda_s L q_{rs}$ units.

The profits earned by a firm located in region r are thus given by

$$\pi_r = p_r L \left(\sum_s \lambda_s \tau_{rs} q_{rs} \right) - w_r \left(f + cL \sum_s \lambda_s \tau_{rs} q_{rs} \right). \tag{3}$$

Factorizing L in this expression shows that L plays the role of a scaling factor of f. Therefore, without loss of generality, we may assume that $L = 1$. In this case, a lower value of f is equivalent to a larger population size.

Given the individual demand (1), the profit-maximizing price is

$$p_r = \frac{\sigma c}{\sigma - 1} w_r. \tag{4}$$

Assuming free entry and exit, profits (3) are zero in equilibrium:

$$(p_r - c w_r) \sum_s \lambda_s \tau_{rs} q_{rs} = w_r f. \tag{5}$$

Plugging (4) into (5) and solving for the total output $q_r = \lambda_r q_{rr} + \tau \lambda_s q_{rs}$ yields

$$q_r^* = \frac{(\sigma - 1) f}{c}. \tag{6}$$

Last, labor market balance in region r implies

$$n_r \left(f + c \sum_s \lambda_s \tau_{rs} q_{rs} \right) = \lambda_r. \tag{7}$$

Using (6) and (7), we obtain:

$$n_r = \frac{\lambda_r}{\sigma f}. \tag{8}$$

The balance condition of the product market yields the wage equation in region r:

$$\sum_s \frac{\phi_{rs} \lambda_s w_s}{\sum_t \phi_{ts} \lambda_t w_t^{1-\sigma}} = w_r^{\sigma}, \tag{9}$$

where $\phi_{rs} \equiv \tau_{rs}^{1-\sigma} \in [0, 1)$. Choosing labor in region 2 as the numéraire, we have $w_1 = w$ and $w_2 = 1$. Setting $\lambda_1 \equiv \lambda \geq 1/2$ and $\lambda_2 \equiv 1 - \lambda$, for any given λ the wage equation (9) in the larger region may be rewritten as follows:

$$\lambda = \frac{w^{\sigma} - \phi}{w^{\sigma} - (w + 1)\,\phi + w^{1-\sigma}}, \tag{10}$$

where $\phi \equiv \tau^{1-\sigma} \in [0, 1)$. The Walras law implies that trade between the two regions is balanced.

Differentiating the right-hand side of (10) with respect to w shows that it increases in w. Therefore, for any given $\lambda \geq 1/2$ the equation (10) has at most one solution $w^*(\lambda)$. Furthermore, when λ rises from 1/2 to 1, the right-hand side of (10) also rises, so that $w^*(\lambda)$ increases with λ. Since $w = 1$ when $\lambda = 1/2$, (10) has one solution, and this solution is such that $w^*(\lambda) \geq 1$. Thus, even though the labor and product markets are more competitive in region 1 than in region 2, the nominal wage is higher in the larger region than in the smaller one. Furthermore, the interregional wage gap widens when the two regions become more asymmetric. However, for any given λ the nominal wage gap shrinks when the two regions get more integrated. This is because the interregional difference in prices get smaller when ϕ increases, which fosters the interregional convergence of wages. In the limit, when the two markets are fully integrated ($\phi = 1$), the size difference becomes immaterial and there is wage equalization ($w^* = 1$). Thus, unlike models in which cities are floating islands, such as those discussed in the introduction, the level of transport costs affects the interregional income distribution.

Using (2), (4) and (10) as well as the inequality $w > 1$, we get

$$P_1^{1-\sigma} - P_2^{1-\sigma} = \phi \left(\frac{\sigma c}{\sigma - 1} \right)^{1-\sigma} \frac{(w^\sigma - 1)\, w^{1-\sigma}}{w^\sigma - (w+1)\,\phi + w^{1-\sigma}} > 0.$$

It then ensues from this expression that $P_1(\lambda) < P_2(\lambda)$. Although wages are higher in region 1 than in region 2, the price index in the larger region is lower than that in the smaller one. Hence, workers residing in the larger region enjoy a higher real wage than those located in the smaller region.[1]

Since the indirect utility of an individual living in region r, which is equal to her real wage, is given by

$$V_r(\lambda) = \frac{w_r(\lambda)}{P_r(\lambda)},$$

$V_1(\lambda)$ exceeds $V_2(\lambda)$ if and only if $\lambda > 1/2$. Let $\Delta V(\lambda) \equiv V_1(\lambda) - V_2(\lambda)$ be the interregional utility differential. Since $\mathrm{d}\lambda/\mathrm{d}w > 0$, we obtain

$$\frac{\mathrm{d}\Delta V(\lambda)}{\mathrm{d}\lambda} = \underset{+}{\frac{\partial \Delta V(\lambda)}{\partial \lambda}} + \underset{+}{\frac{\partial \Delta V(\lambda)}{\partial w}} \underset{+}{\frac{\mathrm{d}w^*}{\mathrm{d}\lambda}} > 0,$$

which means that the utility differential increases with the size of the larger region. In other words, *the incentive to move from region* 2 *to region* 1 *gets stronger as the larger region grows in size.* It is worth stressing, however, that this incentive weakens as the

[1]This result might come as a surprise to the reader because larger cities are often places where the cost of living is higher. To a large extent, this is because housing and nontradables are more expensive in large cities than in small ones. Housing and nontradables are absent in our model because the focus is on regions, not on cities.

two regional markets get more integrated, the reason being that the economic differences between regions fade away.

Thus, we have the following proposition.

Proposition 1 *Assume any given distribution of firms and workers such that $\lambda > 1/2$. Then, the real wage in the larger region exceeds that in the smaller region. Furthermore, the interregional gap widens when the distribution of workers becomes more uneven.*

3 Spatial equilibrium with homogeneous labor

3.1 Migration dynamics

Because the equilibrium wage w is uniquely determined by the wage equation (10), the interregional utility differential can be expressed as a function of λ:

$$\Delta V(\lambda) \equiv V_1(\lambda) - V_2(\lambda) = \frac{\sigma - 1}{cf^{\frac{1}{\sigma-1}}\sigma^{\frac{\sigma}{\sigma-1}}}\left[w\left(\phi - \lambda\phi + \lambda w^{1-\sigma}\right)^{\frac{1}{\sigma-1}} - \left(1 - \lambda + \lambda\phi w^{1-\sigma}\right)^{\frac{1}{\sigma-1}}\right] > 0 \tag{11}$$

when $\lambda > 1/2$. This expression reveals the striking difference between a fall in c and a fall in τ: for a given value of λ, the utility differential $\Delta V(\lambda)$ rises when c decreases whereas $\Delta V(\lambda)$ falls when τ decreases, and thus these two parameters affect differently migration incentives. This is because market integration makes the two regions more similar in terms of prices and wages, whereas a rising labor productivity exacerbates existing regional disparities.

A distribution λ^* is a *spatial equilibrium* when no worker has an incentive to move to another region. Proposition 1 implies that the symmetric distribution $\lambda^0 = 1/2$ is an equilibrium. However, this equilibrium is unstable as long as a few region 2-workers have a high mobility. Therefore, we may dismiss the symmetric configuration as a plausible outcome and assume that the initial distribution is given by $\lambda^0 = 1/2 + \varepsilon$, where $\varepsilon > 0$ may be arbitrarily small. Since no region 1-worker wants to move to region 2, it must be that $\lambda^* \geq \lambda^0$. The decision made by a region 2-worker to migrate relies on the utility differential $\Delta V(\lambda)$ and the migration cost she bears when moving to region 1.

Migration costs have the nature of a dislocation cost, or a utility loss. It is unquestionable that most individuals have idiosyncratic preferences about locations. Let $m(\theta) > 0$

be the migration cost of a θ-type worker initially located in region 2 and $F(1) = 1$. It is notationally convenient to rank region 2-workers by increasing order of migration costs, so that $m(\theta)$ increases over $[0, 1]$ with $0 < m(0) < m(1) < \infty$. Furthermore, amenities are a major driver in consumers' locational choices (Albouy *et al.*, 2013; Diamond, 2015). Our setup can be extended to account for consumers who have heterogeneous preferences about amenities by using a discrete choice model to show that, when region 1 is endowed with more amenities than region 2, the probability of moving to the former exceeds that of moving to the latter, which leads to more agglomeration in region 1 (Tabuchi and Thisse, 2002; Redding, 2015). Note that workers' imperfect mobility may be captured through the introduction of mobility costs as in here or as individuals who face different probabilities to migrate. This approach can be modeled by using the Gumbel taste distribution (Tabuchi and Thisse, 2002) and the Fréchet taste distribution (Redding, 2015). This modeling strategy leads to results similar to ours'.

If $\Delta V(\lambda^0) < m(0)$, then λ^0 is a spatial equilibrium. If $\Delta V(1) > m(1)$, then there exists a spatial equilibrium in which all firms and workers are concentrated in region 1. Otherwise $\lambda^0 < \lambda^* < 1$ is a spatial equilibrium if

$$\Delta V(\lambda^*) = m(\theta^*)$$

holds. In this expression, θ^* is the marginal migrant, while the mass of region 2-workers moving to region 1 is equal to

$$\lambda^* - \lambda^0 = (1 - \lambda^0)F(\theta^*).$$

Since $\Delta V(\lambda^0) > m(0)$ and $\Delta V(1) < m(1)$, the intermediate value theorem implies that the equilibrium condition

$$\Delta V[\lambda^0 + (1 - \lambda^0)F(\theta)] = m(\theta) \tag{12}$$

has at least one solution.

Since both $\Delta V(\cdot)$ and $m(\cdot)$ are increasing functions, these two curves may have several intersection points. If one of these functions have a higher slope than the other, the equilibrium is unique. However, as we work with an unspecified function $m(\cdot)$, we cannot rule out the possibility of several intersection points, whence of several equilibria. In this context, it is commonplace to use some stability concept to discriminate between the different equilibria. This requires the use of a specific adjustment process. When consumers have a low mobility, the equation of motion (13) can be shown to be a good approximation of a forward-looking dynamics (Oyama, 2009). Since we focus on the impact of migration costs when these costs are significant, we find it reasonable to expect the myopic approach to pin down the first-order results. In what follows, we therefore use the myopic evolutionary dynamics:

$$\overset{\bullet}{\theta} = k\left\{\Delta V[\lambda^0 + (1-\lambda^0)F(\theta)] - m(\theta)\right\}, \tag{13}$$

where k is a positive constant. The spatial equilibrium λ^* is said to be (asymptotically) *stable* when the adjustment process (13) leads the off-equilibrium workers back to λ^*.

Clearly, the smallest solution of (12) is always stable, which means that migration costs increase faster than the utility differential when the number of migrants increases in a neighborhood of λ^*. If there exist several equilibria, the number of solutions to (12) is odd because $\Delta V(1) < m(1)$. Thus, the second smallest solution to (12) is unstable whereas the third one is stable, and so on. All stable equilibria involve *regional disparities* for the following reasons: (i) more firms and workers choose to be located in the larger region, and (ii) the region 1-workers enjoy utility levels exceeding that of region 2-workers because real wages are higher in the larger region than in the small one. Note, however, that the inframarginal migrants reach a utility level that decreases with θ, while the marginal migrant reaches a utility level equal to that of the region 2-workers.

To sum up, we present the next proposition.

Proposition 2 *Assume an initial distribution of activities $\lambda^0 \in (1/2, 1)$. If $\Delta V(\lambda^0) > m(0)$ and $\Delta V(1) < m(1)$, then there exists at least one stable interior equilibrium and any stable interior equilibrium is such that $\lambda^0 < \lambda^* < 1$. If $\Delta V(\lambda^0) < m(0)$, the initial distribution λ^0 is a stable equilibrium. Last, if $\Delta V(1) > m(1)$, full agglomeration is a stable equilibrium.*

3.2 How transport costs matter?

Consider now the standard thought experiment of economic geography which studies the impact of falling transport costs on the location of the manufacturing sector. For any given λ, the differences between the interregional price and the wage gaps shrink when transport costs fall, thereby making the larger region less attractive. Hence, *the real wage gap shrinks when transport costs fall.* Since $m(\cdot)$ is an increasing function, the value of θ^* must decrease for the spatial equilibrium condition (12) to be satisfied. As a consequence, the last migrants to region 1 prefer to move back to their place of origin because this allows them to avoid incurring the dislocation cost m, which now exceeds the value of $\Delta V(\lambda^*)$. Stated differently, there is reverse migrations, and thus *falling transport costs trigger the redispersion of economic activities*, like in Helpman (1998) but through a different channel. Hence, unlike Krugman (1991), the integration of regional markets does not spark the agglomeration of manufactures.

4 The impact of rising labor productivity

In this section, we turn our attention to the effect of a rising labor productivity and show that a steadily increase in labor productivity brings about the partial agglomeration of the manufacturing sector. To avoid undue complexity, we assume that productivity gains stem from exogenous technological progress. Although both c and f are likely to be affected by technological progress, we will see that falling marginal and fixed requirements of labor do not have the same implications for workers.

4.1 Marginal labor requirement

We consider a new thought experiment in which the marginal labor requirement c steadily decreases. It follows from (11) that $\Delta V(\lambda^0)$ decreases with c, thereby the equation

$$\Delta V(\lambda^0) = m(0)$$

has a unique solution c_0 in c. The initial distribution λ^0 is a spatial equilibrium as long as c exceeds c_0. To put it differently, as long as c is greater than c_0, a rising labor productivity has no impact on the geographical distribution of the manufacturing sector. However, once c falls below c_0, $\Delta V(\lambda^0)$ exceeds $m(0)$, so that the region 2-workers with the lowest migration cost move to region 1. In this case, the new stable equilibrium is such that $\lambda^* > \lambda^0$. As c steadily falls, λ^* keeps rising because more region 2-workers migrate to region 1.

The following proposition summarizes.

Proposition 3 *Assume that the marginal labor requirement falls steadily. Then, for any initial distribution of activities* $\lambda^0 \in (1/2, 1)$*, there exists a threshold* c_0 *such that (i)* λ^0 *is a stable spatial equilibrium for all* $c > c_0$*; and (ii)* λ^* *increases steadily when* $c < c_0$ *falls.*

The reasons for Proposition 3 are easy to grasp. When c falls, the following three effects are at work. First, the productivity hike implies that fewer workers are needed to produce the existing varieties. Although the equilibrium output q_r^* increases with falling c from (6), every firm hires the same number of workers to produce a larger output because $cq_r^* + f$ is independent of c. By implication, the total number of varieties remains the same. As a consequence, when c falls, $1/P_1^* - 1/P_2^*$ rises, and thus the real wage gap widens. As long as $\Delta V(\lambda^0)$ remains smaller than the migration cost $m(0)$, no region 2-worker moves ($\lambda^* = \lambda^0$), but all workers are better off because of the price drop and the production hike. Second, because λ^0 exceeds 1/2, it ensues from Proposition 1 that the nominal wage is higher in region 1 than in region 2. As long as $\lambda^* = \lambda^0$, (10) implies that a decreasing marginal labor requirement does not affect the equilibrium wage w^*. In contrast, when λ starts rising above λ^0, (10) shows that the nominal wage in region 1 also rises. Third, when λ is above λ^0, the wage paid in region 1 also increases, which may result in a price hike in region 1. However, since $p_1^*/w^* = c\sigma/(\sigma - 1)$, a falling c lowers p_1^*/w^*, thus implying that w^* rises faster than the equilibrium price p_1^*.

Consequently, once c falls below the threshold c_0, $\Delta V(\lambda^0)$ exceeds $m(0)$ and a few region 2-workers move to the larger region. Since more (fewer) varieties are produced in region 1 (2) when c decreases further, while w^* rises faster than p_1^*, w_1^*/P_1^* increases at a higher rate than $1/P_2^*$. Therefore, $\Delta V(\lambda)$ grows when c falls. Let $\lambda(c)$ by the smallest stable solution of the equation

$$\Delta V(\lambda) = m\left[F^{-1}\left(\frac{\lambda - \lambda^0}{1 - \lambda^0}\right)\right].$$

If c takes on a value such that $\lambda(c) < 1$, then $\lambda^* = \lambda(c)$. Let c_1 be the solution to $\Delta V(1) = m(1)$. When c falls below c_1, then $\lambda^* = 1$. To sum up, the distribution of activities displays some sluggishness during the first phases of technological progress. Once the labor productivity level is sufficiently high, firms and workers get agglomerate gradually in the larger region. This process is illustrated in Figure 1 where the path of stable spatial equilibria is described by the green line.

Insert Figure 1 about here

4.2 Fixed labor requirement

Consider now a fall in the fixed requirement of labor. As shown by (4), the price of existing varieties is unaffected. Even though a firm's output q_r^* increases with falling f, the productivity hike implies that some workers are freed from producing the existing varieties, that is, the number of firms and varieties in each region increases from (8). Since their number is greater in region 1 than in region 2, a larger number of new varieties are launched in region 1 than in region 2, which implies that $1/P_1^* - 1/P_2^*$ increases with falling f. In this case, the total number of varieties produced in the economy increases, but it does so more in region 1 than in region 2.

Because $\Delta V(\lambda^0)$ is decreasing in f, the equation $\Delta V(\lambda^0) = m(0)$ has a single solution, which is denoted f_0. Applying the argument used to prove Proposition 3, we obtain the following result.

Proposition 4 *Assume that the fixed labor requirement falls steadily. Then, for any initial distribution of activities* $\lambda^0 \in (1/2, 1)$*, there exists a threshold* f_0 *such that (i)* λ^0 *is a stable spatial equilibrium for all* $f > f_0$*; and (ii)* λ^* *increases steadily when* $f < f_0$ *falls.*

A drop in c leads to a higher total output $Q^* = n^* q_r^* = (\sigma - 1)/\sigma c$ through a bigger output per firm, whereas $n^* = 1/\sigma f$ does not change. On the other hand, a fall in f increases the number of firms and varieties, $n^* = 1/\sigma f$ but does not affect Q^*. Thus, although falling marginal and fixed labor requirements are not congruent in terms of their effects on the economy, the above two propositions have a clear implication: *a steady flow of labor-saving innovations brings about a gradual transition from an almost dispersed configuration of the manufacturing sector to a partially agglomerated one.* Rising labor productivity widens the real wage gap, which eventually outweighs some workers' migration costs and generates interregional migration.

Remark 1. Our results are unaffected if we use iceberg-like migration costs rather than additive costs (Song *et al.*, 2012). To show it, consider a θ-type migrant initially located in region 2 who ends up with $\mu(\theta) \in (0,1)$ unit of labor when residing in region 1; the cumulative distribution of migration costs is denoted by $G(\cdot)$. What makes this specification of migration costs different from that used in the paper is that productivity gains raise the level of migration costs, while additive migration costs as a share of utility go down with productivity increases.

Without loss of generality, we may rank region 2-workers by decreasing order of migration costs, so that the function $\mu(\cdot)$ is increasing over $[0,1]$ with $0 < \mu(0) < \mu(1) < 1$. Thus, there exists a unique marginal migrant θ^* who satisfies the equation:

$$\mu(\theta)V_1\left[\lambda^0 + (1-\lambda^0)\int_\theta^{\mu(1)} x\mathrm{d}G(x)\right] = V_2\left[\lambda^0 + (1-\lambda^0)\int_\theta^{\mu(1)} x\mathrm{d}G(x)\right].$$

In other words, the region-2 workers who face low migration costs ($\theta > \theta^*$) will move to region 1, whereas those who have high migration costs ($\theta < \theta^*$) will stay put. The remaining of the analysis still applies.

Remark 2. Industrialization and urbanization are fed by large rural-urban migrations. Although our model does not account for an agricultural sector, we may capture the impact of such migrations by studying how the regional economy changes when the labor force L rises. We have seen that an increase in L amounts to a decrease in f. Therefore, it follows from Proposition 4 that *the manufactures get more agglomerated when the population grows*. In other words, rising rural-urban migrations exacerbate the tendency toward the regional agglomeration of manufacturing activities.

5 Spatial equilibrium with heterogeneous labor

So far, we have assumed that all workers are equally productive. In this section, workers are vertically differentiated by their skill level. Specifically, an e-worker born in region r owns $e > 0$ skill units, which means that *workers are heterogeneous in both their productivity e and birthplace r*. It is empirically well documented that the skilled are more mobile than the unskilled (Moretti, 2012; Diamond, 2015). Therefore, we may assume that $m(e)$ is a decreasing function of e. Without loss of generality, we may avoid the technicalities associated with different migration costs by assuming that workers bear the same migration cost m. Assuming that m decreases with the skill level strengthens the results obtained in this section.

5.1 Workers' sorting by productivity

Let the total number of skill units available in the two regions be equal to 1 after normalization. When labor is heterogeneous, what determines the productive size of region r is no longer the number of workers λ_r residing in this region, but the number of skill units E_r available therein. In other words, λ_r is to be replaced by E_r in the analysis developed above. Observe that what matters in our model is the value of E_r, not the composition of the group of workers residing in region r.

Individual types are initially distributed in region $r = 1, 2$ according to the continuous density function $g_r(e) \geq 0$ defined over $[0, \bar{e}]$ where $\bar{e} > 0$ is the highest skill level available in the global economy. The corresponding regional labor supply functions are then given by

$$E^0 \equiv E_1^0 = \int_0^{\bar{e}} e g_1 (e) \, \mathrm{d}e \qquad E_2^0 = 1 - E^0 \equiv \int_0^{\bar{e}} e g_2 (e) \, \mathrm{d}e.$$

The assumption of perfect substitutability is made for analytical convenience but our analysis can be extended to the case where E_r is a CES-bundle of different types of skills, which allows one to study the impact of different degrees of substitution or complementarity between various types of labor (Behrens *et al.*, 2014; Eeckhout *et al.*, 2014).

Since a region endowed with a given number of skill units is equivalent to a region endowed with the same number of workers having the same unit productivity, the productivity of a region is no longer determined by the number of workers located there. Region 1 is called the *skilled region* and 2 the *unskilled region* if $E_1^0 > E_2^0$ or, equivalently, $E^0 > 1/2$. Since c and f are now expressed in skill units, labor market clearing implies $E_r^0 = \sigma f n_r$ for $r = 1, 2$, so that region 1 accommodates a higher number of firms and produces a larger number of varieties than region 2.

Denoting by w_r the price of one skill unit in region r, the income of an e-type worker residing in region r is equal to ew_r. Therefore, her indirect utility is given by

$$V_r(e) = e \frac{w_r}{P_r},$$

which increases linearly with e.

Both the equilibrium wages w_r^* and price indices P_r^* depend on E as they depend on λ in Section 2. Accordingly, for any skill distribution $E > 1/2$, we can call on Proposition 1 to assert that $w_1^*(E) > w_2^*(E)$ and $P_1^*(E) < P_2^*(E)$. While e varies across types of labor, the variables w_r^* and P_r^* are common to all workers residing in region r. Therefore, e and E_r are complements in the following sense:

$$\frac{\partial^2 V_r(e, E_r)}{\partial e \partial E} > 0.$$

In words, *a higher regional stock of skill units increases the utility of the local residents.*

The interregional utility differential is thus given by

$$\Delta V(e, E) = V_1(e, E) - V_2(e, E) = e\left[\frac{w_1^*(E)}{P_1^*(E)} - \frac{1}{P_2^*(E)}\right], \tag{14}$$

which is positive and increasing in e.

Two cases may arise. In the first one, if $\Delta V(\bar{e}, E^0) < m$, then no region 2-workers migrate, so that the initial distribution is a spatial equilibrium. In other words, the skilled workers in region 2 have too low a skill level for them to move. In the second case, $\Delta V(\bar{e}, E^0) > m$, and thus the real wage gap of the workers endowed with a large number of skill units is higher than their migration cost. As a consequence, *region* 2*-most productive workers choose to migrate to region* 1. But how many workers in region 2 want to migrate?

Let $x \in (0, \bar{e})$ be the least productive region-2 worker who moves to region 1. Thus, the equilibrium number of skill units available in the skilled region is given by

$$E(x) = \int_0^{\bar{e}} e g_1(e)\,\mathrm{d}e + \int_x^{\bar{e}} e g_2(e)\,\mathrm{d}e, \tag{15}$$

while the equilibrium number of workers residing in region 1 is given by

$$\int_0^{\bar{e}} g_1(e)\,\mathrm{d}e + \int_x^{\bar{e}} g_2(e)\,\mathrm{d}e,$$

where the first term is the initial number λ^0 of workers and the second the number of migrants.

As in Section 2, we choose the skill unit in region 2 as the numéraire, so that $w_1 = w$ and $w_2 = 1$. The wage equation (10) then becomes

$$\frac{E(x)}{1 - E(x)} = \frac{w^{\sigma-1}(w^\sigma - \phi)}{1 - \phi w^\sigma}. \tag{16}$$

Clearly, the left-hand side of this expression decreases with x, whereas the right-hand side increases with w. The implicit function theorem thus implies that (16) has a unique solution $w(x)$ while $w'(x) < 0$ for all $x \in (0, \bar{e})$. As a consequence, when the number of migrants moving into region 1 increases, the price of one skill unit in this region also increases.

The expressions (15) and (16) imply that there is a one-to-one correspondence between $w(x)$ and $E(x)$ as well as between x and $w_r(x)/P_r(x)$. As a consequence, the real wage differential may be rewritten as a function of x only. An interior equilibrium e^* is then determined by the solution to the spatial equilibrium condition:

$$\Delta V\,(x) = x\left[\frac{w_1^*(E(x))}{P_1^*(E(x))} - \frac{1}{P_2^*(E(x))}\right] = m. \tag{17}$$

Unlike (14), both the wages and price indices in (17) now depend on x only. Set

$$h(x) \equiv \Delta V(x) - m. \tag{18}$$

We have $h(0) = -m < 0$. Thus, if $h(\bar{e}) > 0$, there exists a solution e^* to (18) where $h'(e^*) > 0$, which implies that e^* is stable because e^* decreases with E.

We can repeat the analysis of Section 4 and show that the equilibrium price w^* of one skill unit rises when c decreases. Similarly, the inverse price index difference $1/P_1^* - 1/P_2^*$ increases when c falls. As a consequence, the locus $h(x)$ is shifted upward when c decreases, which implies that e^* decreases when c falls. Note that the decrease in e^* is not necessarily continuous. Indeed, if there are multiple stable equilibria, some of them may disappear when c falls. In this case, the economy jumps to another stable equilibrium having a larger number of workers in region 1 because this region is more attractive. However, if there is a unique stable equilibrium, e^* gradually decreases when c steadily decreases.

Falling fixed requirements f yield the same qualitative result. Thus, we have the following result.

Proposition 5 *Assume that $E^0 > 1/2$ and $\Delta V(\bar{e}, E^0) > m$. If the marginal or fixed labor requirement steadily decreases, the number of individuals residing in region* 1 *monotonically increases by attracting workers whose productive efficiency decreases.*

This proposition provides a rationale for the well-documented fact that the skilled workers ($e > e^*$) living in a less efficient place tend to move toward a more efficient place. As a result, when there is technological progress the economy ends up with a prosperous region, while the other gets relatively poorer. Furthermore, the per capita income always decreases in region 2, while the per capita income in region 1 depends on the position of the migrants on this region's skill ladder. However, if $g_1(\cdot) = g_2(\cdot)$, the per capita income in region 1 rises with migration. In addition, like in Behrens *et al.* (2014), *the skilled region features a more than disproportionate share of skilled workers* because it accommodates all workers whose type exceeds e^*. Last, since $E/(1-E)$ increases when c decreases, Proposition 5 implies that the price of a skill unit rises in region 1. As a result, the wage gap between the high- and low-skilled workers living in this region, $w_H^* - w_L^* = (e_H - e_L)w^*(E)$, widens whereas it remains constant in region 2. In other words, *through workers' mobility technological progress exacerbates income polarization within the skilled region.* Note that this growing income gap arises despite the growth in the wages earned by the low-skilled.

Having said that, we must keep in mind that these various effects tend to fade when shipping goods gets less expensive. Indeed, as in 3.2, a drop in transport costs reduces the value of the bracketed term in (17), which implies that the utility differential faced by all types of workers diminishes. In other words, market integration weakens the geographical concentration of skills.

The above analysis has interesting welfare implications. First, by raising the price of a skill unit, the migration of the region 2-more productive workers pulls up the less productive workers residing in the core region. Specifically, *technological progress allows the unskilled who live in the leading region to enjoy a higher nominal wage than those who born in the lagging region.* Considering the 25 bottom percent of job earnings in 2013 Japan, we find that the corresponding workers living in the core regions of Japan (the 10 prefectures containing Tokyo, Osaka and Nagoya) earn 23 per cent more than their counterpart residing in the rest of the country. Like in Moretti (2010), the unskilled benefit from the creation of skilled jobs in their region. In Moretti this effect is channelized through the creation of jobs for the unskilled, whereas it manifests here through higher wages. The reason for this difference lies in the assumption of full employment made here.

As shown by (15), when c falls, $E_1(e^*)$ increases whereas $E_2(e^*)$ decreases. However, $E_1(e^*) + E_2(e^*)$ remains constant, and thus the total number of varieties is unaffected by a drop in c. In this case, the region 1-price index falls, so that *technological progress is beneficial to all the residents of the skilled region.* In the unskilled region, fewer varieties are locally produced. However, the drop in c makes all varieties cheaper. The impact of technological progress on those who stay in region 2 is therefore ambiguous. For example, when transport costs are high, it is reasonable to expect the migration of workers from region 2 to region 1 to trigger a hike in the price index of region 2. In this case, technological progress would be detrimental to those who stay behind.

We now consider an asymmetric productivity shock that makes workers in region 1 more productive than those who produce in region 2. In this case, $E_1 + E_2$ is no longer constant: migration leads to a global productivity gain because the migrating workers are more productive in region 1 than in region 2. Thus, the increase in E_1 outweighs the decrease in E_2, which implies a greater number of varieties in the economy. Therefore, *a larger flow of migrants raises even more the individual welfare level in the skilled region.* As in the foregoing, the impact of a drop in c on region 2-residents is ambiguous because the number of varieties produced in region 2 decreases further while region 2-residents have access to a wider range of varieties sold at a lower price. However, the ratio V_1/V_2 is independent of c and rises because relatively more varieties are produced in region 1. As a consequence, when region 1 has a productivity advantage, technological progress exacerbates regional disparities.

Results are less clear-cut when the shock makes the unskilled region more productive. Because migration from region 2 to region 1 generates a global productivity loss that leads to a smaller number of varieties in the economy, fewer region 2-workers (if any) will move to region 1. If the hike in region 2-productivity is sufficiently strong, the migration flow may even be reverse: the most efficient region 1-workers move to region 2. In this case, technological progress reduces regional disparities, and may even reshape the map of activities by making region 2 richer than region 1. A concrete example of such an asymmetric shock is provided by the move of engineers and scientists from Central and North-East China to Eastern China at the beginning of the economic reform period in the late 1970s.

5.2 Extensions

In what follows, we discuss how our baseline model with heterogeneous workers may be extended to account for several empirical regularities.

1. The empirical evidence put forward by Charlot and Duranton (2004) and Bacolod *et al.* (2009) suggests that the more productive workers benefit from living with a high number of other skilled workers. One simple way to account for this effect is to assume that the productivity of a high skilled worker of type e located in region r is given by $e + \psi(e - \hat{e})$ for $e > \hat{e} > 0$ with $\psi > 0$ and $\psi' > 0$, while $\psi(\cdot) = 0$ for the workers $e < \hat{e}$.

If some workers of type $e > \hat{e}$ are located in region 2, the above argument can be repeated mutatis mutandis to show that these workers want to move to region 1 because combining the externality and $E_1 > E_2$ allows for an additional hike in the hedonic price of a skill unit. In this case, E_1 rises faster than E_2 falls, and thus the total number of region 1-varieties increases faster than the number of region 2-varieties decreases, which makes region 1 even more attractive. In a nutshell, *the presence of a positive external effect across the skilled magnifies our results.* The analysis can be extended to consider different types of complementarity between groups of workers, like in Eeckhout *et al.* (2014).

2. Besides market conditions, the decision of an individual to establish a firm depends on her personal characteristics. In other words, the regional economies must be populated with individuals who have different abilities. Introducing both occupational and location choices in our baseline model is a hard task because the number of entrepreneurs/firms and the wage paid in each region vary with the level of transport costs. This is to be contrasted with Behrens *et al.* (2014) where the cutoff entrepreneur is independent of market size while the elasticity of the wage with respect to market size is constant (recall that there is no trade in their model).

As in the foregoing, we assume that individuals are endowed with different numbers of skill units, whereas they are homogeneous as entrepreneurs.[2] Therefore, the workers who choose to become entrepreneurs are those who have few skill units. The initial skill density in the larger region is equal to the density in the smaller region scaled up by a factor exceeding one. When individuals are immobile, the share of entrepreneurs is smaller in region 2 than in region 1. Region 2-individuals who migrate are entrepreneurs in their region of origin and will remain so in their region of destination, the reason being that they belong to the low tail of the skill density. Depending on the shape of this function,

[2]Formally, this is equivalent to assuming that individuals are endowed with one skill unit, while being heterogeneous as entrepreneurs as in Behrens *et al.* (2014).

the cutoff entrepreneur in the larger region may increase or decrease. In the former case, the number of entrepreneurs in region 1 rises, but it is unclear how the average efficiency is affected. In the latter, some entrepreneurs born in region 1 become workers because they compete with region 2-migrants. Hence, the migration of efficient entrepreneurs implies that the entrepreneurial efficiency in the larger region rises. To put it differently, the larger market attracts the best entrepreneurs through migration and occupational choices.

When c decreases, workers' efficiency increases in both regions, which incites a larger number of individuals to start a business. However, it is unclear whether the total number of entrepreneurs increases because migration affects the regional skill densities, whence the intensity of competition in each region.

3. In the foregoing, we have focused on productivity difference only. Our setup can easily be extended to take regional amenities into account. Let $A_r(e) > 0$ be the value of the amenity stock available in region r, which need not be evaluated in the same way across workers. For example, high-income workers may value historical or natural amenities more than low-income workers. Therefore, workers are also heterogeneous in their attitude toward amenities. The indirect utility of an e-worker residing in region r may then be described as follows:

$$V_r(e) = A_r(e)\frac{ew_r}{P_r}, \qquad r = 1, 2$$

which also implies that regions are not endowed with the same hedonic amenities. This leads to a rich array of results, but the solution method developed above remains the same. For example, some workers may be sorted out according to their productivity whereas other groups will be gathered along their preferences for amenities. Similarly, the more efficient workers may settle down in the region with more amenities (Diamond, 2015). This can be shown by assuming that workers' mobility is described by a discrete choice model (Tabuchi and Thisse, 2002; Bryan and Morten, 2015; Redding, 2015).

4. Our setup can be extended to a multi-regional economy when regions are differentiated by (exogenous and endogenous) amenities and/or congestion costs. Redding (2015) shows the existence and uniqueness of a spatial equilibrium when workers' migration behavior is described by a logit-like model. When regions are not too asymmetric, the ordering of regions by population size is the same as the ordering by nominal wages across regions (Zeng and Uchikawa, 2014), which implies the sorting of workers across regions according to educational levels. Otherwise, the model must be solved numerically.

5. In the foregoing, workers are supposed to be endowed with a given number of efficiency units of labor. However, workers may acquire more skills by investing in human capital. Since the price of an efficiency unit of labor is higher in region 1 than in region 2, region 1-workers have stronger incentives to improve their skill. In doing so, they make the larger region even more productive, whence attractive. As a consequence, more region 2-workers will migrate. As a consequence, when the skilled of the larger region become more efficient, more region 2-workers with low skills will move to region 1, thus exacerbating the income polarization therein (Behrens *et al.*, 2014).

6 Concluding remarks

We have shown that a core-periphery structure may stem from technological progress in the manufacturing sector. Given the dramatic labor productivity growth observed ever since the beginning of the Industrial Revolution, we find this explanation both plausible and relevant. Therefore, the prime mover responsible for the emergence of regional disparities could well be *technological innovations in the manufacturing sector rather than technological innovations in the transportation sector*. Our results have been proven by using a paper-and-pencil method that is disarmingly simple, whereas standard economic geography models often appeal to numerical simulations. This has allowed us to study in a detailed way the various effects at work, and to take on board different types of asymmetry and/or heterogeneity, something which is not easy accomplish in Krugman-like models.

That said, we would be the last to claim that market integration does not play any role. Quite the opposite: we believe that market integration has been, and still is, one of the main drivers shaping the regional economy. To a large extent, explaining the geographical pattern of production in various countries requires combining technological progress and market integration. In contrast, we do not believe that the existence of the primary sector and other activities using immobile inputs is sufficient to explain the existence of partially dispersed patterns of activities in modern economies. Rather, we assert that migration is governed by push and pull effects in which significant and continued migration costs plays the role of a dispersion force.

It is legitimate to ask what Propositions 3 and 4 becomes in Krugman's model which, unlike ours, involves a two-sector economy (manufacturing and agriculture) with two types of sector-specific labor (workers and farmers). Because Krugman's model is not easy to handle analytically, we have undertaken this using the linear model of monopolistic competition which yields results similar to those obtained by Krugman (Ottaviano *et al.*, 2002). If the number of farmers is not too high (otherwise there is always dispersion) and not too low (otherwise there is always agglomeration), the economy gradually shifts from dispersion to agglomeration when labor productivity keeps rising above a certain threshold. Therefore, disregarding the agricultural sector is *not* the reason for our main results. In addition, accounting for housing and commuting costs, which both rise with the size of the core region and fall in the peripheral region, decreases the utility level in the larger region and raises it in the smaller one, thereby lowering the utility differential $\Delta V(\lambda)$. Nevertheless, a fall in c still drives the geographical concentration of the manufacturing sector, which comes to an end when $\Delta V(\lambda)$ is equal to the difference in housing and commuting costs.

Our model, owing to its extreme flexibility, can be extended in several directions. First, it is well known that technological progress follows different trajectories across industries. Therefore, our approach allows one to explain why different industries display contrasted location patterns. Second, for our main results to hold, we need only the following two conditions: $\mathrm{d}\Delta V/\mathrm{d}\lambda > 0$ and $\partial\Delta V/\partial c < 0$, which hold under different preferences. Third, the model could also be extended to account for the internal functioning of regions, which do not often grow at the same pace. This could be done by introducing different microeconomic mechanisms that generate agglomeration (dis)economies, such as those analyzed by Duranton and Puga (2004). In such a context, it would be natural to focus on endogenous technological progress, which is often place-specific, and to add a housing sector to the model. Note that the existence of commuting costs and land prices in the core region holds back the agglomeration process, thereby implying a more dispersed pattern of activities.

Our setup could be used as a building block in models of endogenous regional growth. We expect such models to predict a growing divergence between regions. However, there is no reason to expect the resulting pattern of activities to prevail forever. Indeed, we have assumed in this paper that technological progress affected all regions equally. It is reasonable, however, to believe that labor requirement declines at different rates in various regions. In this case, even when a region becomes the core of the economy, a reversal of fortune becomes possible if the peripheral region experiences a stronger wave of innovations if its high degree of political homogeneity allows it to react faster than larger regions or countries to new opportunities. In this event, the peripheral region or country is able to throw off its history. Such a possible redrawing of the map of economic activities is difficult to explore in standard economic geography models.

Last, in the real world, regional disparities are driven by technological progress, by a fall in transport costs, by increasing population, or by any mix of these factors. Discriminating empirically between these different factors is a very hard task. However, agglomeration economies at the urban level also stem from different sources (Duranton and Puga, 2004). It is only recently that the availability of detailed data sets has allowed the sorting of these various forces, even though much remains to be done to determine their respective magnitude. Given the quality of the recent empirical research on the market potential, we expect the same to hold at the interregional level.

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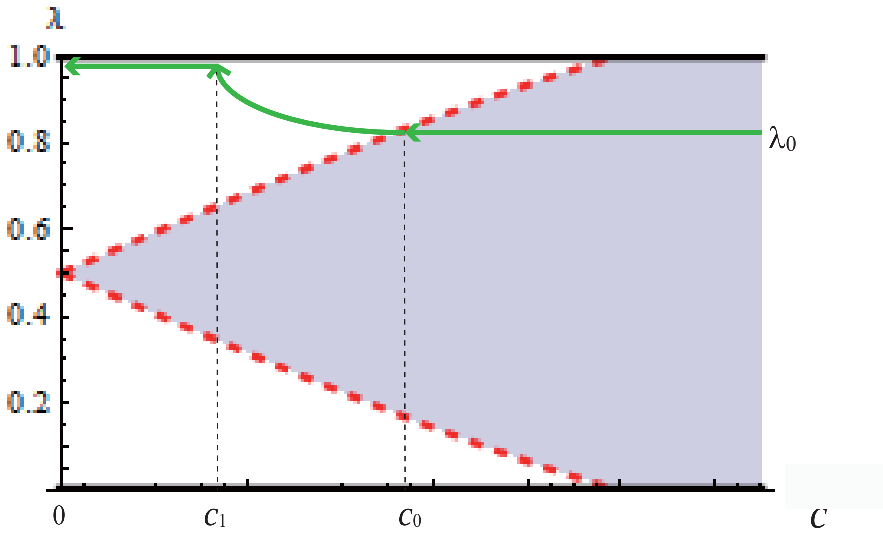

Figure 1: Stable equilibrium path