Social ties, knowledge spillovers and regional convergence

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Abstract

We take the Fujita & Thisse (2003) growth-cum-geography model to investigate the implications of seeing social ties as an important reason for the generation of knowledge. Moreover, we model migration as an important channel through which the distance decay effect of cross-regional knowledge spillovers materialize. Our results show that in such a setting the full agglomeration of high-skilled workers that are engaged in R&D activities is not a straightforward outcome. The equilibrium with an equally dispersed high-skilled labour force is a stable migration equilibrium, while regions with a larger initial share of high-skilled workers will only attract more workers when migration rates are not too high. When social ties are important in generating knowledge and knowledge spillovers, the full agglomeration of high-skilled workers in one region is not at all certain. In such a case, growth is however not optimal. As such, the trade-off between reaching optimal growth and equal distribution of economic activity remains.

1 Introduction

Migration has many economic and non-economic effects, both for advanced receiving regions and for less-advanced sending regions. For the less-advanced

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sending regions, authors have emphasized the benefits of high-potential workers leaving these regions, for instance due to financial remittances (Khadria, 2000) or through positive knowledge spillovers after migrants returned home (Kuznetsov and Sabel, 2006). From a sociological perspective, however, one would also expect that migration influences the sending region's knowledge potential when migrants are still abroad. Social relationships are likely to endure with former colleagues, friends and family members that stay behind, enhancing knowledge spillovers in the region of origin. Indeed, Singh (2005), Oettl and Agrawal (2008) and Kerr (2008) find significant evidence on a positive relationship between social bonding and knowledge spillovers, despite distance weakening effects.

This paper uses a theoretical model to analyse the effect of enduring social relationships and migration on regional production and growth for an advanced receiving region and a less-advanced sending region. Our model combines insights of well-established models on growth and migration, yet breaks new ground by incorporating social bonding as an important channel for knowledge spillovers through migration. The basic framework underlying our analysis is the 2-region, 3-sector, 2-factor model by Fujita & Thisse (2003), in which trade costs, migration of high-skilled workers and regional growth jointly determine the spatial division of economic activity across regions. In their analysis, knowledge spillovers are important for regional growth, yet only indirectly related to migration by a standard distance-decay effect. We explicitly model the relationship between migration and knowledge spillovers, making it dependent on the migration rate as well as on the size of the sending region. The former aspect emphasizes that migration is a prime channel for knowledge spillovers to occur; the latter aspect acknowledges that the impact of social ties depends on how many people move and how many stay behind.

Our results show that in such a setting the full agglomeration of high-skilled workers that are engaged in R&D activities is not a straightforward outcome. The equilibrium with an equally dispersed high-skilled labour force is a stable migration equilibrium, while regions with a larger initial share of high-skilled workers will only attract more workers when migration rates are not too high. If migration becomes too high, the advantage in numbers of the larger region is compensated by the disadvantage of benefitting less from knowledge spillovers than the receiving region. When social ties are important in generating knowledge spillovers, the full agglomeration of high-skilled workers in one region is not at all certain. In such a case, growth is however not optimal, so that the trade-off between reaching optimal growth and equal distribution of economic activity remains.

The structure of the paper is as follows. Section 2 summarizes the main set-up of the Fujita & Thisse (2003) model, as it lays the groundwork for the analysis to come. Section 3 discusses the importance of social ties for the generation of knowledge and the implications this has for knowledge spillovers across regional borders. This section also proposes how to translate these insights into a modelling framework. Section 4 discusses the implications for convergence and optimal growth of modelling migration as an important channel for knowledge spillovers. Section 5 concludes.

2 The Fujita & Thisse (2003) model

The model we employ to show the importance of migration for regional growth and location of manufacturing is that of Fujita & Thisse, 2003 (henceforth Fujita & Thisse). In this section we will briefly discuss the main structure of their model and we will highlight some of their key equations and results. We use their model because it captures the main elements required for a discussion on the relevance of migration in a geography-cum-growth model. Their framework offers an analytically tractable framework where geography, migration and growth interact to explain regional growth and income disparities in relation to regional agglomeration patterns.[1]

The Fujita & Thisse model assumes a two-region, three sector economy, with two factors of production. We will label the regions R and S, mnemonics for receiving and sending region as will become clear later. The two

[1] Other papers that have highlighted migration in a geography-cum-growth framework are Walz (1996), Baldwin and Forslid (2000) and Hirose (2005). These contributions have in common that they are less tractable then the Fujita & Thisse framework however.

production factors are low-skilled labour (L) and high-skilled labour (H). The division of low-skilled workers across regions is even and fixed, whereas the division of high-skilled workers across regions is endogenous, with λ_r and $\lambda_s = 1 - \lambda_r$ denoting the respective H-shares of the receiving and sending region. The three sectors are a traditional sector (T-sector), a manufacturing sector (M-sector) and an investment good sector (I-sector).

The traditional sector is perfectly competitive, at each point in time producing goods with a constant returns to scale technology, using low-skilled labour only. There are no transportation costs involved in selling T-goods across regional borders so that the T-sector can serve as numeraire sector. By appropriate choice of units this implies a wage rate of one for low-skilled labour in both regions: $w_r = w_s = 1$. Each period consumers spend a fixed share $1 - \mu$ of their total expenditures on traditional goods, which is assumed sufficiently large to always sustain production in both regions.

The remaining share μ of consumer expenditures is spent on manufacturing varieties, which are produced in the M-sector. Consumers exhibit a Dixit-Stiglitz-like love of variety with $\sigma > 1$ as the fixed elasticity of substitution. Accordingly, manufacturing varieties are produced under monopolistic competition and increasing returns to scale. The production of a manufacturing variety requires the exclusive use of a patent, which is to be acquired from the investment good sector. In addition, manufacturing production requires one unit of low-skilled labour to actually produce the good. The total costs of manufacturing production thus consists of a fixed cost that equals the price paid for the patent and a marginal cost of one, the wage rate of low-skilled workers. Selling manufacturing output in the other region carries iceberg-type of transportation costs $\Upsilon > 1$: in order to sell an amount q in the other region, an amount of $\Upsilon \cdot q > q$ must be shipped.

The I-sector provides patents for new manufacturing varieties, using high-skilled workers only. The productivity of high-skilled workers in producing patents depends on past ideas and innovations, implying a positive technological spillover as in Romer (1990). More specifically,

$$
\begin{aligned}
h(j) &= \alpha M && (1)\\
K_i &= \left[\int_0^{\lambda_i} h(j)^\beta dj + \eta \int_0^{1-\lambda_i} h(j)^\beta dj\right]^{1/\beta} && (2)\\
&= M\left[\lambda_i + \eta(1-\lambda_i)\right]^{1/\beta} &&\\
n_i &= K_i\lambda_i. && (3)
\end{aligned}
$$

for $i = r, s$. In these equations, $h(j)$ denotes personal knowledge of high-skilled workers, which is the same in both regions by its dependence on the world-wide number of manufacturing varieties M. The parameter α is a general productivity parameter of individual learning. The production of patents in a region is n. It depends on the number of high-skilled workers involved in the region's I-sector, indicated by λ_i,[2] as well as on the productivity of each worker K_i. The latter is the regional knowledge stock, which is the result of complementary interaction between all high-skilled workers $(0 < \beta < 1)$, wherever they reside. However, there is a fixed distance decay effect regarding the contribution of the personal knowledge of high-skilled workers from the other region: $0 \leq \eta \leq 1$.

Equations (1)-(2) imply that individual learning is perfect and independent of where high-skilled workers reside, but that high-skilled productivity in generating patents is region-specific, as in localized spillovers models. This has important implications for optimal growth in the Fujita & Thisse model. In the Fujita & Thisse framework the growth rate of the economy depends on the number of newly-created manufacturing varieties: $\dot{M}/M = g(\lambda_r) = \left[\lambda_r K_r(\lambda_r) + (1-\lambda_r)K_s(\lambda_r)\right]/M$. With imperfect knowledge spillovers, this implies that the growth of M will be highest when all high-skilled workers agglomerate in one region, that is when either λ_r or λ_s is one. When high-skilled workers are fully dispersed, growth is lowest. This makes migration vital for reaching optimal growth in the Fujita & Thisse framework.

Where high-skilled workers will locate depends on the real wage they will

[2]The total mass of high-skilled workers is set to one, $H_r + H_s = 1$.

receive, as customary in new economic geography models.[3] Since only the high-skilled work in the I-sector, and assuming free entry and exit of firms in the I-sector, high-skilled wages are directly related to the price of a patent. The market price of a patent Π_i should equal the unit costs of producing a patent. Hence,

$$w_i^* = \Pi_i K_i(\lambda_i)$$

is the equilibrium wage of high-skilled workers in either region, which depends on the price of the patent as well as on high-skilled productivity.

The *real* wage also depends on the location of manufacturing production though. Since M-goods carry transportation costs, regions producing more manufacturing varieties will have a lower price index, making it attractive for high-skilled labour to migrate to that region. The location decision of manufacturing firms, in turn, depends on consumer expenditures. Firms prefer being close to their potential market, to save on transportation costs. The migration of high-skilled workers to a region therefore makes it attractive for manufacturing firms to move there as well, which is the demand-linked cumulative causation effect that is so common to new economic geography models. On the other hand, low-skilled labour is immobile across regions so that some transportation costs will always have to be incurred. Moreover, transportation costs implies a better shield against foreign competition the smaller a region, and this market-crowding effect makes it attractive to locate in the smaller region. Depending on the level of trade costs, therefore, the market-crowding effect may dominate the demand-linked circular causality effect, as customary in new economic geography models. The location of patent production is irrelevant to the location decision of manufacturing firms. Patents are assumed to be freely transmittable across regions and once the patent has been acquired, the manufacturing firm can choose freely where to locate. As such, Fujita & Thisse find that when transportation costs are high, manufacturing production will always take place in both re-

[3] Apart from wages, high-skilled workers also own assets in the form of shares in manufacturing firms. However, as will become clear, the holding of assets is irrelevant for the location decision of high-skilled workers.

gions, irrespective of the division of high-skilled workers. For sufficiently low transportation costs manufacturing production tends to agglomerate in the region that has the higher share of high-skilled labour.

Apart from being a new economic geography framework, the Fujita & Thisse model also features growth, requiring insight in how consumers determine their optimal consumption paths and how this depends on patent production and migration decisions. Fujita & Thisse (2003: 125-126) assume that all consumers choose an expenditure path $\varepsilon_j(t), j = L, H$ whereas the mobile high-skilled consumers also choose an optimal location path $r_H(t) \in \{R, S\}$. Indirect utility at time t is given by $\nu_j(t) = \varepsilon_j(t)[P_{i_{j(t)}}(t)]^{-\mu}$ for all consumers, with $P_{i_{j(t)}}$ the price index of the M-good in region of residence. However, moving between regions incurs a psychological cost $C(t)$ that is expressed in units of lifetime utility. This implies lifetime utility of

$$U_j = \int_0^\infty e^{-\gamma t} \ln[v_j(t)]dt - \sum_h e^{-\gamma t} C(t_h),$$

where the latter part is only relevant for high-skilled workers and where $\gamma > 0$ is the subjective discount rate that is the same for all consumers. Preferences are intertemporal CES with unit elasticity of intertemporal substitution. High-skilled workers are assumed to hold assets as well, which takes the form of an equal share in all manufacturing firms. Low-skilled worker do not hold assets. The assets yield an interest rate $v(t)$ that is determined in perfectly competitive bond markets that is freely accessible to all consumers, wherever they reside. Following Barro and Sala-i-Martin (1995: 66) the intertemporal budget constraint is written as:

$$\int_0^\infty \varepsilon_j(t) e^{-\bar{v}(t)t} dt = a_j + W_j(0), \qquad j = L, H$$

with $a_L = 0$ and $a_H > 0$. $W_j(0) = \int_0^\infty e^{-\bar{v}(t)t} w_{r_j(t)}(t)dt$ is the present value of the consumer's wage income over time. Note that for low-skilled workers $w = 1$ at all times in both regions. For any given location path, the optimal consumption path is governed by the familiar Euler condition, $\dot{\varepsilon}_j(t)/\varepsilon_j(t) = \nu(t) - \gamma$. Since this must hold for all consumers, this also determines the aggregate expenditure path $\dot{E}(t)/E(t)$.

Given this set-up, and under the expectation that migration takes place to the receiving region R, Fujita & Thisse show that the migration rate of high-skilled workers at time t is governed by:

$$\dot{\lambda}(t) = \frac{\delta}{\gamma} e^{\gamma t} \ln \left[\frac{a_H + W(0,t)}{a_H + W(0,T)} \right] - \delta \mu e^{\gamma t} \int_t^T e^{-\gamma t} \ln \left[\frac{P_r(z)}{P_s(z)} \right] dz \qquad (4)$$

where T is the point in time beyond which high-skilled labourers would not want to postpone migration and where δ is the speed of adjustment in workers' migration. The equation essentially says that migration depends on a comparison of real returns between moving to R at time t and T, under the expectation that high-skilled workers indeed move from S to R.

This finalizes the set-up of the Fujita & Thisse model. Focusing on steady state growth paths the next step is to determine how the location of manufacturing production and high-skilled workers interact to explain persistent income divergence across regions. Their results are summarized in two propositions. Proposition 1 (Fujita & Thisse, 2003: 140) shows that when patents are freely mobile, only stable spatial configurations can be attained that involve full agglomeration of high-skilled labour in one region. Provided transportation costs are sufficiently low, also manufacturing production will agglomerate in that region. For higher transportation costs manufacturing production is dispersed, but with the major share in the region where high-skilled labour agglomerated. Proposition 2 (Fujita & Thisse, 2003: 143) deals with the welfare effects for the workers in both regions, establishing a trade-off between standard new economic geography core-periphery welfare effects of high-skilled agglomeration and optimal growth effects. If the additional growth boosted by agglomerating R&D in one region is sufficiently large, such core-periphery growth paths Pareto-dominate growth paths with a symmetrically dispersed R&D sector for all types of labour involved (low-skilled labour, skilled labour in R and skilled labour in S).

3 Knowledge spillovers and social ties

The key point of departure for this paper is the importance of social ties in generating knowledge and its consequences for knowledge spillovers across regional boundaries. In general, individuals learn by getting formal education or by gathering practical experience. However, they also profit from knowledge spillovers that arise from the nonrival public good nature of knowledge (Arrow, 1962). By building systems through which individuals can acquire knowledge, societies unintentionally enlarge individual knowledge by generating knowledge spillovers.

The existence of knowledge spillovers is well understood in the literature on regional growth disparities. Knowledge spillovers are seen key to generating growth and explaining growth differences across regions. The extent to which knowledge spills over across regions is typically related to geographical distance by adding a distance decay effect. Empirical evidence suggests that knowledge spillovers seem to be geographically localized (e.g. Jaffe et al., 1993; Asheim and Gertler, 2005). This has been taken up in models linking new economic geography and growth by adding distance decay effects to the extent to which knowledge can cross regional boundaries. In new-economic-geography-cum-growth literature this has amounted to a parameterization of regional knowledge spillovers that allows for a specification where knowledge spillovers are purely local ('local spillover models') and specifications that exhibit perfect interregional knowledge spillovers ('global spillover models'), see Baldwin et al. (2003) for an overview and details of specification. The Fujita & Thisse (2003) framework clearly fits in that tradition.

A possible explanation for the localization of knowledge spillovers is that scientists create knowledge in such a way that parts of it remain unclear for other scientists, firms or workers (Polanyi, 1966). Knowledge has thus two parts: a codified part and a non-codified part (Agrawal, 2006). The codified elements are easily accessible and applicable to others in society and could easily spill over. The non-codified elements are harder to absorb. Some parts remain tacit, either because the scientist lacks the incentive to codify all knowledge, or because it is impossible to do so (Powell and Swart, 2005).

To be able to fully use this knowledge requires direct interaction with its creator, which is obviously easier when you are (geographically) close to that person.

The importance of geographical proximity is even greater when taking into account sociological views on interaction, which assert that the ease of interaction is related to the sense of social belonging that individuals experience. Each group of persons that is geographically close has a natural urge to form its "own imagined community" (Anderson, 1983), in which for every community certain specific ground rules and behaviour exists. As a result, all societies will claim to be different from one another, giving rise to a sense of "us" versus "them". Being in the same community improves interaction, as individuals will understand each other's way of reasoning better than individuals from different societies would.

This notion is confirmed by Paasi (1996) with his analytical framework that bases forms of socio-spatial integration and distinction on differing regional identities. The identity of a region is mostly expressed in structures of expectations; it weaves together elements which are significant in the institutions and habits of a region. Basically, residents of a region act in a regular fashion and thus knowledge acquisition and creation of knowledge occurs in a distinctive way. The notion of regional identity enables to construct a classification between current residents of a region and people living outside the region. Paasi identifies two scales of socio-spatial integration; on the one hand there is one's original identity (thus "we" or "other"), on the other hand there is one's current location (thus "here" or "there"). The combination of these two scales yields four options of socio-spatial integration; the first two options deal with original residents of both "here" and "there", while the other two deal with migrants, who have entered the other region. At some point in time regional identities of the two regions become interwoven, as the residents of both regions become less and less distinct from the migrants entering their region, which is due to increasing interaction and mutual understanding.

This implies that regional knowledge stocks can be different in content at first, due to different regional identities, inhibiting instantaneous learning from regions that are not geographically close. Moreover, since "communication. . . is taken as the basis of knowledge" (Nooteboom, 1993), to be able to transfer the tacit parts of the knowledge stock also requires mutual understanding. Both economists (Glaeser et al., 2002; Knack and Keefer, 1997) and sociologists (Granovetter, 1973; Coleman, 1988) claim that strong ties amongst individuals lower the costs to exchange information, not only because of access to previously established networks of knowledge, but also since reputations are built when individuals frequently interact. Empirical evidence for the role of communication for knowledge spillovers is provided by Singh (2005), Oettl and Agrawal (2008) and Kerr (2008). All of them conclude that enduring social ties between individuals stimulate knowledge spillovers between regions.

With social ties being of crucial importance for the cross-regional occurrence of knowledge spillovers, migration becomes an important channel through which the distance decay effect of knowledge spillovers can be overcome. When people move to another region, mutual understanding will be stimulated through explicit communication with the previously denounced "other" region. Through migration, knowledge of the other region becomes accessible. This holds both for the region of immigration, where migrants bring their knowledge and communicate about it with the locals, as well as for the region of emigration. Especially if migrants retain their social relationships with those they leave behind, their newly acquired knowledge will spill over to their old region. Agrawal et al. (2008) empirically investigate the importance of socially induced knowledge spillovers. Using patent citation data, the authors find a substitution effect between spatial proximity and social proximity. While co-location facilitates knowledge spillovers, co-ethnicity plays a significant role in knowledge diffusion when distance increases. The marginal increase in knowledge spillovers between ethnically related inventors living 1,000 miles apart is equal to 5 percent, while a distance of 3,000 miles increases the degree of knowledge spillovers by 13 percent. Thus, there exists an empirical justification to add social ties as diffusion channel for knowledge.

To incorporate these findings in the Fujita & Thisse model in a sensible manner requires striking the right balance between analytical rigour and tractability. As such, we retain the main set-up of the Fujita & Thisse model, yet propose a different handling of how knowledge spillovers occur, relating it explicitly to migration. Our proposed changes relate to the individual learning specification, equation (1), as well as to migration's function as an important channel for the transmission of knowledge from abroad, equation (2). The way regional knowledge stocks affect high-skilled productivity and patent production remains as in Fujita & Thisse.

Regarding individual learning we assume, in line with the above, that learning implies getting to understand both the tacit and codified component of existing knowledge. Regarding tacit knowledge we relate this to social interaction with the local labour force, while learning the codified knowledge part is modelled by relating it to the manufacturing varieties that are around. Attaching a weight $0 \leq \delta \leq 1$ to indicate the relative importance of these two components, we get:

$$h_i(j) = \alpha \lambda_i^{\delta} M^{1-\delta}. \tag{5}$$

where all variables are as before except that we add a subscript $i = r, s$ to $h(j)$ since social ties imply that individual learning is (partly) region specific. Equation (5) says that individuals learn about the tacit component of knowledge from social interaction with residents from their own region, while they also learn from the codified knowledge that is implicit in each manufacturing variety. It includes Fujita & Thisse's (2003) specification as a special case ($\delta = 0$).

As in Fujita & Thisse the human capital stock of societies is based on an accumulation of individual knowledges. However, to benefit from knowledge from the other region migration is required. Hence,

$$K_r = \left[\int_0^{\lambda_r} h_r(j)^{\beta} dj + \eta_r \int_0^{\lambda_s} h_s(j)^{\beta} dj \right]^{1/\beta} \tag{6}$$

$$K_s = \left[\int_0^{\lambda_s} h_s(j)^\beta dj + \eta_s \int_0^{\lambda_r} h_r(j)^\beta dj \right]^{1/\beta}, \tag{7}$$

where $0 \leq \eta_r, \eta_s \leq 1$ are region-specific distance decay effects that depend on migration.[4] The exact specification of η_i requires some thought. First, η should rely on the migration rate, for that is the main channel through which knowledge spills over from other regions in our framework. When migration increases more knowledge can be transmitted, while zero migration would imply that no knowledge spillovers can be reaped. Second, one incoming worker is unlikely to make a substantial difference in the receiving region, but its impact on the region of origin will be more substantial. Here social ties come into play, which are more prominent the smaller the sending region is. What is learned in the new region may then be easily shared with old friends and colleagues who stayed at home.[5] Consequently, the level of η should depend on the size of a region. The larger the receiving region, the less substantial will be the impact of incoming migrants. By contrast, outgoing migration will have a smaller impact the larger the sending region. The larger the group left behind, the less likely it is that knowledge spills over from the receiving to the sending region. Finally, we want η to be maximally one to ensure that the knowledge stock cannot be larger than would be the case when all high-skilled workers live in one region.

These considerations are satisfied by the following specification for η:

$$\eta_r = \dot{\lambda}_s \cdot (1 - \lambda_r) \qquad \text{and} \qquad \eta_s = \dot{\lambda}_s \cdot (1 + \lambda_s)\lambda_r. \tag{8}$$

It establishes that the knowledge stock of a region consists of individual

[4] While empirical literature shows distance matters for the magnitude of knowledge spillovers, e.g. Jaffe et al. (1993) and Asheim and Gertler (2005), we will ignore distance in absolute terms in the remainder of the analysis. Socially induced knowledge spillovers work as a way to overcome mental distance, and as such leave absolute distance relatively unimportant for knowledge diffusion, as confirmed by the analysis of Agrawal et al. (2008).

[5] We do not differentiate between the degree of social ties here. It does not matter in the model whether high-skilled workers are socially tied on direct relationships (family, former work colleagues or classmates) or on indirect relationships (graduated at the same university, common friends). The model tries to establish the effect of social ties on regional disparities, and the current setup suffices to deliver some new insights.

knowledges of the 'own' region and that of other regions, provided there is migration that helps to overcome incongruities in understanding and/or knowledge bases. When $\dot{\lambda}_s$ is zero, no spillovers occur, while $\eta_s > \eta_r$ for all levels of λ_r and λ_s.[6] For the receiving region labeled r, this implies that the skilled workers from abroad take with them the knowledge stock from their region of origin, which may benefit the new location. Yet, one worker is unlikely to make a substantial difference, implying that the knowledge spillovers to be reached depend on the extent of incoming migration. Exactly the opposite might occur for the region from which the migrant has left, the sending region s. Due to strong social ties, what is learned in the new region of residence may easily be shared with old friends and colleagues who stayed at home.[7] It then matters for the extent of knowledge spillovers how many stay behind. The larger the group left behind, the more likely it is that knowledge spills over from the receiving to the sending region.

Substituting for (5) in (6) and (7) yields the final equations for the regional knowledge stocks:

$$K_i = M^{1-\delta}\left[\lambda_i^{1+\delta\beta} + \eta_i(1-\lambda_i)^{1+\delta\beta}\right]^{1/\beta} \qquad i = r, s. \tag{9}$$

where we applied $\lambda_r + \lambda_s = 1$ and put $\alpha = 1$ for convenience. For notational convenience we define $k_i \equiv \left[\lambda_i^{1+\delta\beta} + \eta_i(1-\lambda_i)^{1+\delta\beta}\right]^{1/\beta}$ for $i = r, s$ so that $K_i = M^{1-\delta}k_i$. The equation shows some resemblance with equation (2), Fujita & Thisse's equation for regional knowledge stocks. It differs clearly however regarding the way knowledge spillovers occur between regions, reserving a central role for migration. Moreover, we have supplied a micro-foundation for the region-specificity of knowledge stocks.

[6] Note that this would imply that once people have migrated their potential to act as a channel for spillovers ceases to exist. The implicit assumption therefore is that social ties only play a role during or just after the actual migration phase. This assumption is however not restrictive in steady-state migration equilibrium, as this requires zero migration.

[7] We do not differentiate between the degree of social ties here. It does not matter in the model whether high-skilled workers are socially tied on direct relationships (family, former work colleagues or classmates) or on indirect relationships (graduated at the same university, common friends). The model tries to establish the effect of social ties on regional disparities, and the current setup suffices to deliver some new insights.

4 Migration, social ties and regional convergence

In the Fujita & Thisse framework growth would be optimal if all high-skilled labour agglomerates in one region. We will now verify to what extent this is also true when migration is an important channel for knowledge to spill over. In the model used, growth is related to the generation of new manufacturing varieties world wide and, since patents are footloose, therefore relies on the production of patents in both regions. Hence,

$$g = \dot{M}/M = M^{-\delta}\left[\lambda_r k_r(\lambda_r, \dot{\lambda}_s) + \lambda_s k_s(\lambda_r, \dot{\lambda}_s)\right] \tag{10}$$

since $\dot{M} = (n_r + n_s) = \sum_i \lambda_i K_i$. Equation (10) implies that also in the migration-induced knowledge spillover model the growth rate of manufacturing varieties is highest when all high-skilled agglomerate in one region. This is a logical outcome in view of imperfect cross-regional knowledge spillovers. The question is therefore to what extent will high-skilled workers fully agglomerate in one region?

The answer to this question lies in an investigation of the stability of the dispersed equilibria as in new economic geography models: for each value of $0 \leq \lambda_r \leq 1$ it must be checked whether this is an equilibrium that involves no (further) migration, and, if so, whether this is a stable equilibrium in the sense that a small additional movement of labour would imply migration flows that lead back to λ_r. To shed light on this issue we recall that migrants essentially compare the real returns between moving to the receiving region R and staying in the sending region S, where real wages also depend on the location of manufacturing production. The introduction of social ties as an important factor for knowledge accumulation does not alter this basic mechanism. Moreover, the Fujita & Thisse framework incorporates migration costs that increases in the rate of migration, which can be interpreted as resembling increased costs of leaving one's social network.[8] In steady-state

[8]Not quite, of course, as a better proxy for it would be to include the *number* of inhabitants staying behind. Fujita & Thisse interpret the dependence of migration costs

equilibrium, where workers choose to not longer migrate, the comparison of real returns of migration therefore boils down to:

$$\frac{\nu_r}{\nu_s} = \frac{\gamma + k_r(\lambda_r)}{\gamma + k_s(\lambda_s)} \left(\frac{P_r(t)}{P_s(t)}\right)^{-\mu} \equiv \Phi(\lambda_r) \tag{11}$$

where it has been assumed that migration takes place from region S to region R. In (11) $\nu_j(t) = \varepsilon_j(t)[P_{i_{j(t)}}(t)]^{-\mu}$ is indirect utility at time t and individual expenditure $\varepsilon_j(t)$ equals $a^*(\lambda)\,[\gamma + k_i(\lambda_i)]$ in region $i = r, s$, with $a^*(.)$ denoting total asset value of manufacturing firms (see Fujita & Thisse, 2003: 136-7 for further details). Steady state equilibrium implies that $\Phi(\lambda_r) = 1$.

Equation (11) makes explicit that the willingness to migrate depends on the relative productivity of high-skilled workers in both regions as well as on relative price indices. In the Fujita & Thisse framework, k_r/k_s is symmetric around $\lambda_r = 1/2$, implying that $k_r \gtreqless k_s \Leftrightarrow \lambda_r \gtreqless 1/2$. Hence, in their model the fully dispersed equilibrium is a steady-state equilibrium, since with both high-skilled and low-skilled labour evenly distributed across regions, also manufacturing firms will be evenly distributed, making regional price indices the same as well.

By contrast, in our framework social ties imply that migration affects the receiving and sending region differently. Though for positive migration rates, $\eta_s(1/2) > \eta_r(1/2)$ also $k_r(1/2) < k_s(1/2)$, which implies that an equal division of labour across regions cannot be a steady-state migration equilibrium, *unless migration is zero*. And that is exactly what will be the case. Unlike the Fujita & Thisse framework, when a small number of high-skilled workers move towards region R, $k_r < k_s$ making such a move inconsistent in expectations. In new economic geography terms: $\lambda_r = 1/2$ is a stable spreading equilibrium. A formal condition settling this, assuming that manufacturing is equally spread across regions (hence $P_s = P_r$) and using the definitions of k_i, is:[9]

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on migration rates as a reflection of increased costs of finding housing and employment in the new region of residence.

[9] It is convenient to rewrite k_r to $\left[\left(\frac{1-\lambda_s}{\lambda_s}\cdot\lambda_s\right)^{1+\delta\beta} + \eta_r{\lambda_s}^{1+\delta\beta}\right]^{1/\beta}$ when doing the calculations.

$$k_r \gtreqless k_s \Leftrightarrow \begin{cases} \dot{\lambda}_s \gtreqless \overline{\dot{\lambda}_s}(\lambda_r) & \text{for} \quad \lambda_r < \underline{\lambda}_r < 1/2 \\ \\ \dot{\lambda}_s \lesseqgtr \overline{\dot{\lambda}_s}(\lambda_r) & \text{for} \quad \underline{\lambda}_r < \lambda_r < 1 \end{cases} \tag{12}$$

where $\overline{\dot{\lambda}_s}(\lambda_r) \equiv \dfrac{1 - [\lambda_r/\lambda_s]^{1+\beta\delta}}{(1-\lambda_r) - (1+\lambda_s)\lambda_r [\lambda_r/\lambda_s]^{1+\beta\delta}}$ and where $\underline{\lambda}_r$ is the value for λ_r at which the denominator of $\overline{\dot{\lambda}_s}(\lambda_r)$ switches sign.[10] Since $\overline{\dot{\lambda}_s}(1/2) = 0$, any positive migration at $\lambda_r = 1/2$ implies $k_r < k_s$. Moreover, since $\overline{\dot{\lambda}_s}(1) = 0$ and $\overline{\dot{\lambda}_s}(0) = 1$, the other regional distribution that is consistent with a steady-state equilibrium entailing zero migration and a symmetric distribution of manufacturing activity is when all high-skilled agglomerate in the receiving region, that is when $\lambda_r = 1$.[11]

Proposition 1 *When social ties are important for knowledge generation and when knowledge spillovers across regions depend on migration, an equilibrium with symmetric spreading of high-skilled labour is a stable migration equilibrium.*

When λ_r deviates from 1/2, however, high-skilled workers may want to agglomerate in one region. We recall in this respect that condition (12) has been derived under the assumption that high-skilled labour migrates towards the receiving region. In the Fujita & Thisse model this assumption is consistent with $\lambda_r > 1/2$. Since in their framework the spreading of high-skilled labour is never a stable equilibrium, this assumption always holds: a slight deviation of λ_r above 1/2 for whatever reason, implies migration towards region r until all high-skilled have moved there. The region with the size advantage is also the region of immigration. This is clearly different in our framework. As (12) makes clear, when manufacturing activity is symmetrically dispersed across regions, only migration rates below $\overline{\dot{\lambda}_s}(\lambda_r)$ are consistent with enduring migration to R as the larger region. If migration becomes

[10] Numerical simulations show that $\underline{\lambda}_r$ is lower that 1/2 for all values of β and δ, hovering around a value of $\underline{\lambda}_r = 0.45$.

[11] Which could be either of the two regions of course. Which region is actually the receiving region is completely endogenous in our model.

too high, the advantage in numbers of the larger region R is compensated by the disadvantage of benefitting less from knowledge spillovers than the receiving region ($\eta_r < \eta_s$). In the migration-induced spillovers model it is not at all certain that the larger region will be the immigrant region.

But there are more implications from (12). To make these clear, it is helpful to use a graph. To that end, Figure 1 portrays condition (12) as a function of the initial distribution of high-skilled labour across regions. The graph has been drawn for $\beta = 0.8$ and $\delta = 0.5$ but is representative of all possible combinations of these values. The dark, solid lines give the migration rates for which $k_r = k_s$. The relative magnitudes of k_r and k_s with respect to these lines are as indicated by the text boxes. Note that the relevant area for consideration in the graph is for migration rates between 0 and 1. The lines highlight that to become an attractive region for migration, it is indeed not enough to be the larger region. Migration to the larger region R will only occur when the migration rate does not surpass a certain threshold of migration, to make the productivity gain in the receiving region not higher than in the sending region. This stands in sharp contrast to the Fujita & Thisse analysis, where migration does not play a role in determining knowledge spillovers. In their case, $k_r \gtreqless k_s \Longleftrightarrow \lambda_r \gtreqless 1/2$, which is independent of the migration rate.

(Insert Figure 1 about here)

What's more, however, is that Figure 1 also indicates that if region R is initially the smaller region, that is when $\lambda_r < 1/2$, it actually becomes the sending region. To verify what this implies, warranting substitution of η_s in k_r and η_r in k_s in the derivation of $\overline{\dot{\lambda}}_s(\lambda_r)$, Figure 1 also portrays condition (12) that is consistent with R being the sending region. This is the dashed, grey line in Figure 1.[12] The underlined text boxes indicate the relative positions of k_r, k_s with respect to this line. It appears that situations with $\lambda_r < 1/2$

[12] In that case, the denominator of $\overline{\dot{\lambda}}_s(\lambda_r)$ becomes $(1 + \lambda_s)\lambda_r - (1 - \lambda_r)\left[\lambda_r/\lambda_s\right]^{1+\beta\delta}$ while the condition itself remains the same. The value for $\underline{\lambda}_r$ changes though and becomes much higher (around 0,9).

are in most instances consistent with seeing R as a sending region. Only values of λ_r just below $1/2$ require that migration is not too high.

Combining these insights, it thus appears that the sending region cannot be the initially larger region, for that would imply $k_s > k_r$. This is consistent with the idea that to be attractive for migration, a region should have an advantage, which in new economic geography-like frameworks is regional size. However, for a larger region to be an immigrant region, immigration rates should not be too high.

Proposition 2 *When social ties are important for knowledge generation and when knowledge spillovers across regions depend on migration, regions should have a size advantage to become an immigrant region. A larger region only becomes an immigrant region if migration rates are below the threshold level* $\overline{\dot{\lambda}_s}(\lambda_r)$*.*

Propositions 1 and 2 have been derived for an equal division of manufacturing activity across regions, that is for $M_r = M_s$ and $P_r = P_s$. In general this might not be true of course. However, in the Fujita & Thisse framework, as well as in ours, the decision of manufacturing firms where to locate stands in close relation to the location of high-skilled workers — only high-skilled labour is mobile across regions. Since by Proposition 1 the symmetric spreading of high-skilled labour is a stable equilibrium, also the symmetric equilibrium spreading of manufacturing activity will be a stable equilibrium. Hence, in contrast to the Fujita & Thisse framework, and independent of transportation costs (see below), the symmetric equilibrium involves both spreading of manufacturing activity and high-skilled labour across regions. When migration is an important channel for knowledge to spill over, identical regions are a spatial long-run equilibrium.

Proposition 3 *When social ties are important for knowledge generation and when knowledge spillovers across regions depend on migration, initially identical regions are a stable equilibrium.*

In reality regions are unlikely to be identical initially, warranting an analysis of stability when regions are initially slightly divergent, for instance when

$\lambda_r = 0.6$. The situation will then be different since it can not longer be assumed that manufacturing firms will be evenly spread across regions initially. It must therefore be verified whether also in such a situation full convergence is a long-run outcome.

With a larger fraction of the high-skilled labour force initially living in region R, also overall expenditures will be higher in region R. Consequently, it may pay off for manufacturing firms to locate where the market is largest, for instance to save on transportation costs. On the other hand, with more manufacturing firms being located in one region, wages for low-skilled workers will be bid up where they must remain equal in nominal terms. This implies that the price index in the larger region must be higher for both regions to sustain some manufacturing activity. In the model we employ here, the mechanisms driving the location of manufacturing firms are the same as in the Fujita & Thisse model. From their analysis we obtain

$$\frac{P_r(t)}{P_s(t)} = \left(\frac{E_s(\lambda_r)}{E_r(\lambda_r)}\right)^{1/(\sigma-1)} \tag{13}$$

as the market outcome when manufactures are produced in both regions ($M_r > 0$; $M_s > 0$). This equation holds as long as relative regional expenditure falls within certain limits that are related to the level of transportation costs. More specifically, it holds when $\phi < E_r/E_s < 1/\phi$ where $0 < \phi < 1$ denotes a freeness of trade parameter that is monotonically and inversely related to the iceberg transportation costs.[13].

The expenditure ratio is given by

$$\frac{E_r(\lambda_r)}{E_s(\lambda_r)} = \frac{L/2 + \lambda_r a^*(\lambda_r)[\gamma + k_r(\lambda_r)]}{L/2 + \lambda_s a^*(\lambda_r)[\gamma + k_s(\lambda_r)]}$$

where $a^*(.)$ is the total asset value of manufacturing firms, which are owned by high-skilled labour (Fujita & Thisse: 134-135). Following their analysis, while applying our specifications for k_r and k_s, yields:

[13] To be precise, $\phi \equiv \Upsilon^{-(\sigma-1)}$.

$$\frac{E_r}{E_s} = \begin{cases} 1 + \dfrac{2\mu}{\sigma-\mu}\dfrac{\gamma+\eta_r^{1/\beta}}{\gamma+M^{-\delta}\eta_r^{1/\beta}} = \dfrac{\sigma+\mu}{\sigma-\mu} & (\lambda_r = 1) \\ 1 & (\lambda_r = 1/2) \\ \left[1 + \dfrac{2\mu}{\sigma-\mu}\dfrac{\gamma+\eta_s^{1/\beta}}{\gamma+M^{-\delta}\eta_s^{1/\beta}}\right]^{-1} = \dfrac{\sigma-\mu}{\sigma+\mu} & (\lambda_r = 0) \end{cases} \tag{14}$$

which are exactly identical to the expressions in Fujita & Thisse's since $\eta_r(1)$ and $\eta_s(0)$ are zero in the zero migration equilibrium. The spreading of manufacturing firms across regions thus sustains the stability of the zero-migration equilibria. Combining (13) and (14), we see that when all high-skilled workers reside in region R (S), $P_r/P_s < (>)\ 1$. Moreover, when $\lambda_r = 1/2$ price indices are the same. It is therefore labour migration that drives long-run outcomes so that even when regions are different initially, convergence can be a long-run stable outcome.

5 Conclusion

We have taken the Fujita & Thisse (2003) growth-cum-geography model to investigate the implications of seeing social ties as a main reason for the generation of knowledge and migration as an important channel through which the distance decay effect of cross-regional knowledge spillovers materializes. Our results show that in such a setting the full agglomeration of high-skilled workers that are engaged in R&D activities is not a straightforward outcome. The equilibrium with an equally dispersed high-skilled labour force is a stable migration equilibrium, while regions with a larger initial share of high-skilled workers will only attract more workers when migration rates are not too high. If migration becomes too high, the advantage in numbers of the larger region is compensated by the disadvantage of benefitting less from knowledge spillovers than the receiving region. When social ties are important in generating knowledge spillovers, the full agglomeration of high-skilled workers in one region is not at all certain. In such a case, growth is however not optimal, so that the trade-off between reaching optimal growth and equal distribution of economic activity remains.

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Figure 1: Threshold migration levels