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AGGLOMERATION AND REGIONAL UNEMPLOYMENT DIFFERENTIALS

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Key Words: Regional labor markets, New Economic Geography, job matching, unemployment

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Abstract

This paper develops a solvable general equilibrium agglomeration model, where search frictions for low-skilled immobile workers generate regional unemployment differentials. Contrary to other work in this field, the model yields a higher long-run unemployment rate in the core region. This is because low-skilled manufacturing jobs are more valuable there and unemployment works as a compensating differential. It therefore more closely resembles the classical result of Harris and Todaro (1970). One main difference is that here regions are ex ante equal. I derive expressions for the break and sustain point and analyze the effect of search frictions on their location.

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1 Introduction

Regional unemployment differentials have become a constant target of economic research. This is easily understandable when looking at the stark differences in the performance of regional labor markets, even if they are located in close proximity to each other. For example, regional unemployment

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rates in Germany in 2005 varied between 5 and 30 percent on the NUTS-3 level. Although those rates are spatially correlated, differentials between regions with contiguous borders were 2.57 percentage points on average and reached a maximum at 14 percentage points.

While classical theory proposes that unemployment differentials should decrease over time, a growing body of more modern agglomeration models shows that those differentials might prevail or even increase. This helps to explain why – depending on the specific case explored – it has often been hard to find signs of convergence of unemployment rates.[1] These models usually build on the celebrated core-periphery model by Krugman (1991) or one of its variations. For example, Francis (2003) uses the model by Krugman and Venables (1995), where the presence of an intermediate goods sector creates supply and demand linkages, thus inducing the endogenous generation of industrial agglomeration. He then goes on to show that these forces get even stronger when the model is extended by an efficiency wage consideration that leads to equilibrium unemployment at the regional level. Suedekum (2005) and Zierahn (2011) reach similar results in models that allow for interregional labor mobility. Epifani and Gancia (2005) and Francis (2009) develop models with interregional labor mobility where search costs create unemployment differentials. Migration to the economic core increases relative unemployment there in the short run, but decreases it in the long run. In contrast to the previous literature, vom Berge (2011) argues that both higher or lower unemployment in the core can be an equilibrium outcome of agglomeration models. This pattern emerges when search costs are linked to the regional wage level and unemployment benefits are set nationwide.

This paper contributes to the existing literature in two ways. First, earlier models on unemployment in core-periphery settings are usually only solvable numerically. Among the rare exceptions are the efficiency wage model of Suedekum (2005) and the fair wage model of Egger and Seidel (2008). Here, I develop an analytically solvable agglomeration model where search frictions create unemployment differentials between regions. Second, the model shows a different way to think about unemployment as a compensating differential within a region (see Harris and Todaro, 1970). It explains how higher unemployment rates in core regions might arise and also prevail, but unlike Harris and Todaro (1970) does not assume ex ante different regions. Therefore, the present model can also be regarded as a complement to the spatial mismatch literature (see Gobillon et al., 2003, for an overview) or urban models with unemployment like Zenou and Smith (1995) that try to explain high unemployment rates in core cities.

[1] Elhorst (2003) provides a comprehensive overview of 41 empirical studies in the field.

The model uses a quasi-linear function for household utility to achieve analytical solvability. There are two sorts of labor. Some workers are mobile between regions while others are not. The latter have to decide whether to work in a "save" perfectly competitive sector or in a "risky" monopolistic one where firms face search costs and some job searchers might stay out of job. In such an environment, mobile workers will move to the region that gives them the highest utility level and immobile workers will apply for those jobs that give them the highest expected income, a decision that again depends on where mobile workers settle.

The model shows that the incentive to apply for risky jobs increases when mobile workers move into a region. As a result, the local unemployment rate will go up. This has two effects. First, the negative effect of rising unemployment on consumption has a detrimental effect on high-skilled wages and weakens the strength of the agglomeration forces. Second, because any wage effect feeds back into unemployment the wage differential between regions gets narrowed. This can have a dispersive or accumulative effect on migration.

The paper is organized as follows. Section 2 develops the basic model and states the short-run equilibrium conditions. Section 3 describes the different forces working towards and against agglomeration and sketches their net effect. Section 4 discusses the long-run equilibrium. Section 5 relates some of the findings to the literature and empirical observations. Section 6 concludes.

2 The Model

The model economy consists of two regions that only differ with respect to the number of workers living in them. There are two kinds of labor and no other factor of production. L gives the number of low skilled workers in the first region, L^* in the second. K and K^* represent high skilled workers in both regions, respectively. There are also two sectors in the economy. The first sector only employs low skilled workers and produces a homogenous and freely tradable good with constant returns to scale under perfect competition. The second sector employs both factors producing a differentiated product with increasing returns to scale under monopolistic competition and faces trade costs to transport goods over regional boundaries. Low skilled workers can decide in which sector they want apply for a job. Those in the first region choosing the constant returns sector are denoted by L_A, those choosing the increasing returns sector by L_X.[2] High skilled workers and those employed

[2]For ease of exposition I only show the results for the first region. The following also holds for the second region, this time marked with asterisks.

in sector A face no job risk. The L_X workers seeking a job in sector X are matched to vacancies according to the constant returns technology

$$S = BV^{\eta} L_X^{1-\eta}, \tag{1}$$

where S denotes the number of successful matches, V the number of vacant jobs, η the matching elasticity and B some constant which has to be set properly to make sure that matching probabilities do not exceed unity. The probability of a successful match can be written as $\theta = S/V$ for a vacant job and $\rho = S/L_X$ for a worker and the number of unemployed workers in the first region is given by $U = L_X - S$.

Consumers Following the agglomeration model by Pflüger (2004) the utility function of a representative household is quasi-linear:

$$M = \alpha \log C_X + C_A, \qquad \alpha > 0. \tag{2}$$

C_A and C_X denote consumption of the goods produced by sector A and X, respectively, where C_X forms a compound of varieties of the monopolistic sector from both regions:

$$C_X = \left[\int_0^N x_i^{\frac{\sigma-1}{\sigma}} \mathrm{d}i + \int_0^{N^*} x_j^{\frac{\sigma-1}{\sigma}} \mathrm{d}j \right]^{\frac{\sigma}{\sigma-1}}, \qquad \sigma > 1 \tag{3}$$

where N (N^*) is the number of different varieties produced in the home (foreign) region, $x_i(x_j)$ is the consumption of a home variety i (foreign variety j) and σ stands for the elasticity of substitution. The household budget constraint demands that income Y satisfies

$$\int_0^N p_i x_i + \int_0^{N^*} p_j x_j + C_A = Y \tag{4}$$

where p_i (p_j) is the price of home (foreign) sector X goods in region 1 and sector A is chosen to be the numeraire sector with its price level normalized to unity. Utility maximization by the familiar two-stage budgeting reveals that demand for the two sector aggregates is

$$C_X = \alpha P^{-1}; \qquad C_A = Y - \alpha \tag{5}$$

and for each single variety

$$x_i = \alpha p_i^{-\sigma} P^{\sigma-1}; \qquad x_j = \alpha p_j^{-\sigma} P^{\sigma-1} \tag{6}$$

which shows that the parameter α represents the amount of income spent for sector X goods. Spending on these varieties is independent of income. P represents the price index of all goods in the increasing returns sector and is given by

$$P = \left[\int_0^N p_i^{1-\sigma} + \int_0^{N^*} p_j^{1-\sigma} \right]^{\frac{1}{1-\sigma}} . \tag{7}$$

Plugging (5) into (2) leads to the indirect utility function

$$I = -\alpha \log P + Y + [\alpha(\log \alpha - 1)] . \tag{8}$$

Firms To characterize production of sector X firms I make two simplifying assumptions. First, there is a large group of firms so that no single firms decision affects market prices. Second, each firm is sufficiently large so that it does not face uncertainty with respect to the number of people it can hire. This means a fraction θ of all posted vacancies will be actually filled. Additionally, goods can be supplied to the other region at a certain cost which are of the iceberg type. Thus, the price of a home variety sold in the foreign region is higher than its original price by a factor τ, so that $p_i^* = \tau p_i$. A single firms profit in the first region is given by

$$\Pi_i = p_i X_i - c \left(W_X + \frac{\gamma}{\theta} \right) X_i - R \tag{9}$$

where

$$X_i = (K + L_A + S)\, x_i + (K^* + L_A^* + S^*)\, \tau x_i^* . \tag{10}$$

The first part of (10) represents production for the first region, while the second part shows the amount produced for the second. Production for foreign consumer is τ times bigger than actual consumption because the iceberg-specification assumes some of the goods to "melt" away en route. Demand comes from all employed workers in a region, so we assume that the unemployed have no income from benefits or savings. Costs in equation (9) consist of three parts. First, low skilled work is a variable input in the production process, with its input coefficient being c. The wage is denoted by W_X. Second, firms cannot expect to fill each vacancy they pose, but with a nominal vacancy cost of γ the additional cost per hired worker is γ/θ. Third, each firm needs one unit of high skilled work as a fixed input and pays the wage R. Profit maximization then yields the optimal price for a variety

$$p_i = \frac{\sigma}{\sigma - 1} c \left(W_X + \frac{\gamma}{\theta} \right) . \tag{11}$$

Bargaining of the low-skilled There are three more equilibrium conditions to pin down low skilled wages W_X, the rate of successful matches θ and the number of unemployed workers in each region U. Low skilled workers can decide if they want to take a job in sector A and earn a wage of 1 with certainty, or if they want to apply for a job in sector X yielding the wage W_X. Their probability of success is ρ in the latter case, otherwise they become unemployed and their income is zero. Workers are committed to their primary decision so that a changeover of the unemployed to the A-sector is ruled out.[3] Assuming that workers are risk neutral, an equilibrium condition for the wage level of the low skilled is

$$W_X = \frac{1}{\rho}. \tag{12}$$

To avoid any interference between this assumption and utility in equation (2) low skilled households are regarded as representative. Their composition mirrors the proportion of unemployed low skilled workers in the region. When firms and job seekers meet they split the matching rent by Nash bargaining according to

$$\arg\max_{W^X} (W_X - 0)^{\beta} (J - W_X)^{1-\beta}, \qquad 0 \leq \beta \leq 1, \tag{13}$$

where J is the value of a filled vacancy from the perspective of a firm and β is a parameter of bargaining power. This yields

$$W_X = \beta J \tag{14}$$

as a second equilibrium condition. The final condition is found by noting that posting of a vacancy costs firms γ (measured in units of the numeraire), but gains them J with probability θ. Thus, in equilibrium one gets

$$J = \frac{\gamma}{\theta}. \tag{15}$$

Using (12), (14) and (15), the matching probabilities become

$$\theta = B(\beta\gamma)^{1-\eta}; \qquad \rho = B(\beta\gamma)^{-\eta}. \tag{16}$$

Thus, the number of unemployed workers in the first region can be rewritten as

[3] Here one can think of a fixed and sector specific training investment that is sunk after the initial decision and prevents workers from changing sectors (see Monfort and Ottaviano, 2002, for an example). Modeling this explicitly brings no additional insight and I omit it for simplicity.

$$U = L_X - S = V\beta\gamma - S = S\left(\frac{1}{\rho} - 1\right). \tag{17}$$

Keeping in mind that the number of high skilled workers in a region equals the number of local firms, the number of employed low skilled workers is[4]

$$S = KcX_i = KR(\sigma - 1)\rho\frac{\beta}{\beta + 1}, \tag{19}$$

and (17) becomes

$$U = KRq; \qquad q \equiv (\sigma - 1)\frac{\beta}{\beta + 1}\left[1 - B\left(\beta\gamma\right)^{-\eta}\right]. \tag{20}$$

q is a compound of parameters indicating the strength of the labor market friction. Thus, there are three channels that influence the number of unemployed workers in a region. First, unemployment rises if search frictions grow stronger. Second, given a certain number of high skilled workers there will be higher unemployment when firms are more profitable (higher R) and low skilled workers can thus demand higher wages. Third, an increase in the number of firms (higher K) raises job opportunities in the increasing returns sector which makes more workers apply for "risky" jobs.

High-skilled wages Combining equations (10) and (6) with the result from (20) and using the zero profit condition leads to

$$\begin{aligned} \sigma R &= \frac{\alpha\left(K + L - KRq\right)}{K + K^*\phi} + \frac{\alpha\phi\left(K^* + L^* - K^*R^*q\right)}{K^* + K\phi}; \\ \sigma R^* &= \frac{\alpha\phi\left(K + L - KRq\right)}{K + K^*\phi} + \frac{\alpha\left(K^* + L^* - K^*R^*q\right)}{K^* + K\phi}. \end{aligned} \tag{21}$$

with $\phi = \tau^{1-\sigma}$. Equation (21) shows the wage of mobile high skilled workers R as a function of regional demand (represented by the nominators) and supply (represented by the denominators). This is a system with two equations and two unknown and can be solved for high skilled wages in both

[4]To be able to use the equilibrium condition in (12) we need to assure that there are still workers employed in the numeraire sector of region 1. A sufficient condition for this to hold is

$$\hat{l} > \frac{\alpha(\sigma - 1)\rho}{\sigma - \alpha q}\frac{\beta}{\beta + 1}, \tag{18}$$

where $\hat{l}$ is the fraction of low skilled workers in region 1 compared to the whole population of the model economy.

regions. These can then be used to calculate all the other short-run equilibrium variables for both regions, the price indices P and P^*, utility I and I^* and unemployment rates $u = \frac{U}{K+L}$ as well as u^*.

3 Agglomeration forces and unemployment

It follows from (8) that the differential in utilities of high-skilled households between both regions is

$$I - I^* = \alpha \ln(P^*/P) + (R - R^*). \tag{22}$$

To write this equation as a function of the distribution of mobile workers across regions, define $k \equiv K/(K+K^*)$, $l \equiv L/(K+K^*)$, and k^* and l^* respectively.[5] The price part of equation (22) can then be written as

$$\alpha \ln(P^*/P) = \frac{\alpha}{1-\sigma} \ln \left[\frac{k\phi + k^*}{k + k^*\phi} \right] \tag{23}$$

and the wage part

$$R - R^* = \Omega \left[\frac{k+l}{k+k^*\phi} - \frac{k^*+l^*}{k^*+k\phi} + \frac{\alpha q}{\sigma} \frac{(1+\phi)(k^*l - kl^*)}{(k+k^*\phi)(k^*+k\phi)} \right] \tag{24}$$

with

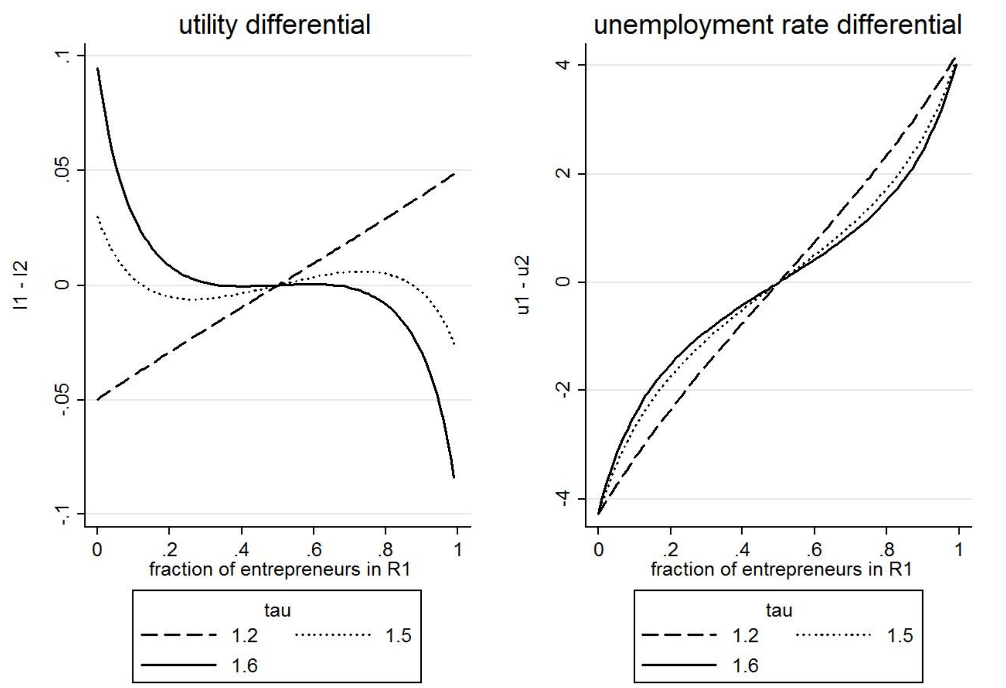
$$\Omega = \frac{(1-\phi)\alpha\sigma(k+k^*\phi)(k^*+k\phi)}{(\sigma+\alpha q)\left[\phi\sigma + (1-\phi)kk^*((\alpha q - \sigma)\phi + \sigma + \alpha q)\right]}.$$

There are four general forces at work in the model. First, equation (23) represents a supply linkage that arises because more firms in the core region will decrease the local price level of the composite good produced by the increasing returns sector. Second, there is a demand linkage because the bigger population in the core has a positive effect on firm profitability, thus influencing the regional differential in high-skilled nominal wages. This is captured in the first two terms in brackets of equation (24). Those forces work towards agglomeration of activity in the increasing returns sector. Third, firms face less competition in the smaller region because transport costs insulate them to a certain extent from goods that are produced in the core. This competition effect is dispersive.

Finally, labor market frictions lead to an additional force. When there are plenty of high-skilled workers in a region, many low-skilled workers decide to try their luck in the risky sector. There is a direct and an indirect effect of

[5] This implies that $k^* = 1 - k$.

Figure 1: Utility and unemployment differential at varying transport costs



rising unemployment on high-skilled wages. On the one hand it directly decreases local demand, which has a negative effect on wages (see the third term in brackets of equation (24)). On the other hand, any regional differential in high-skilled wages feeds back into unemployment through the bargaining process of the low-skilled, which narrows the gap. This is captured by Ω.

In the short-run, high-skilled workers are assumed to be immobile between regions. To illustrate the short-run equilibria of the model, the left panel of figure 1 depicts the utility differential of high-skilled workers on the y-axis and the distribution of high-skilled workers across the two regions on the x-axis for three levels of transport costs.[6] Starting with high transport costs, the utility differential slopes downwards so that high-skilled workers in the agglomeration are worse off that those in the periphery. For medium transport costs we get this result only if agglomeration is strong. When high-skilled workers are spread relatively even across regions, there is an incentive to move into the larger region until a certain level of agglomeration is reached. When transport costs are sufficiently low utility is always higher

[6] The other parameters are set to $\alpha = 0.3$, $\sigma = 5$, $\beta = 0.5$, $\eta = 0.5$, $\gamma = 5$, $B = 1$ and $l = l^* = 1$.

in the core.[7] The right panel of figure 1 plots the regional unemployment rate differentials arising with the various levels of transport costs and the distribution of high-skilled workers. When the high-skilled worker count in the core is high, the regional unemployment rate rises which increases the differential. This effect can be amplified or dampened by the differential in firm profitability (see equation (20)), but it cannot be reversed, as stated by the following proposition:

Proposition 1. *In a setting with two ex ante identical regions* ($l = l^*$) *the equilibrium unemployment rate will be higher in the core. The differential gets bigger as agglomeration increases.*

Proof. See Appendix A.1. □

Without any labor market frictions ($q = 0$) there is of course no unemployment and the regional unemployment differential is zero. Reasoning along similar lines as illustrated in Appendix A.1 leads to:

Proposition 2. *The equilibrium unemployment rate differential increases when search frictions increase.*

4 Long-run equilibria

In the long-run, high-skilled workers move to the region that offers them higher utility. An equilibrium is reached when there is no incentive for further migration or when all mobile worker reside in the region yielding the higher utility. As usual in the NEG literature, one might want to know what happens to the long-run equilibria of the model as the costs of transporting goods between regions fall.[8] Pflüger (2004) shows that the model

[7]This result seems to be quite unrealistic. It would be easy to introduce additional spreading forces to omit complete agglomeration. An example would be a restriction to the local housing market.

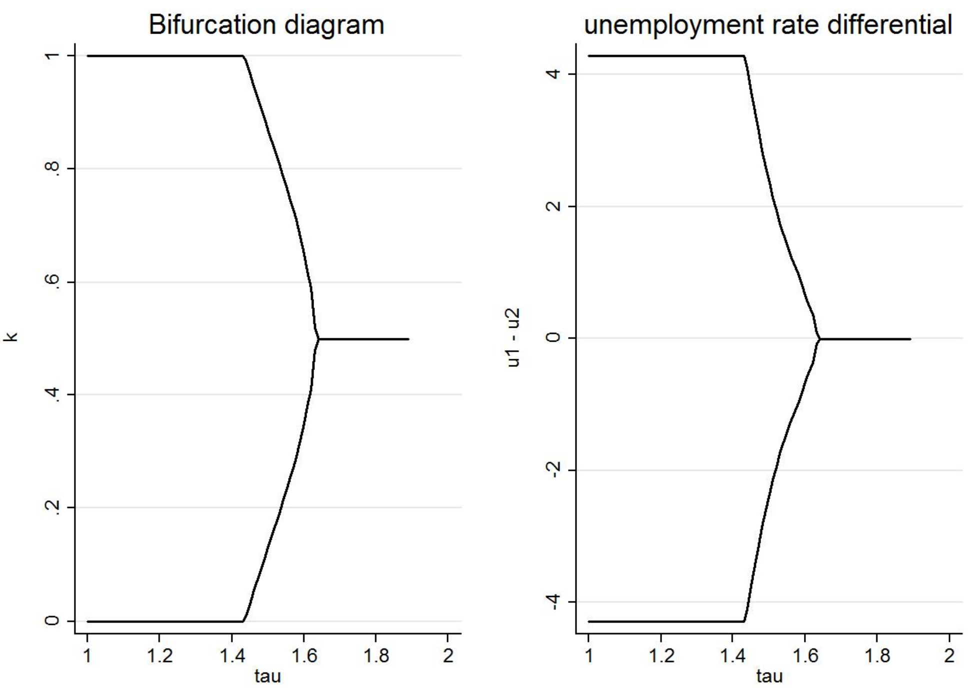
[8]We are usually not interested in models with agglomeration forces so strong that full agglomeration is the only long-run equilibrium irrespective of the size of transport costs. The proper 'no-black-hole' condition is given by

$$l + l^* > \frac{\sigma + \alpha q}{\sigma - 1}.$$

Likewise, a 'no-unconditional-dispersion' condition ensures that there is a certain range of transport costs where agglomeration can occur in the long run:

$$l + l^* < \left(\frac{\sigma + \alpha q}{\sigma - 1} + 1 \right) \frac{\sigma}{\alpha q}.$$

Figure 2: Bifurcation diagram and unemployment differential



with a quasi-linear specification exhibits a 'supercritical pitchfork bifurcation'. There is a symmetric equilibrium as long as transport costs are sufficiently high. When transport costs fall this equilibrium eventually breaks and two asymmetric equilibria arise where mobile workers are partly concentrated. When transportation is very cheap, complete agglomeration in one of the regions is the only stable equilibrium. Figure 2 shows the bifurcation diagram of all possible stable equilibria for varying transport costs as well as the respective unemployment differentials.

The point where the symmetric equilibrium becomes unstable and the two arms of the pitchfork appear ('break point') can be found by setting $k = k^* = 1/2$ and solving for $\partial(I - I^*)/\partial k = 0$. Assuming that both regions are of symmetrical size ($l = l^*$) the corresponding level of transport costs can be shown to be

$$\phi_B = -\frac{(\sigma + \alpha q)^2 - 2l(\sigma - 1)(\sigma + \alpha q)}{(\sigma + \alpha q)(\sigma - \alpha q) + 2(\sigma - 1)(\sigma + l(\sigma - \alpha q))}. \tag{25}$$

To see how the break point behaves when labor market frictions are introduced, one can compare it to the case without any frictions. The break point with frictions lies at lower transport costs than the one without frictions if

$$\phi_B\big|_{q>0} > \phi_B\big|_{q=0}$$

or

$$\alpha q < \left(\frac{\sigma-1}{2\sigma-1}\right)\left[2l(2l(\sigma-1)-1)-2\sigma-\frac{\sigma^2}{\sigma-1}\right]$$

holds true. Thus, if there is a sufficient number of immobile workers (large l) the direct effect is large and search frictions work as a dispersing force. For small l the indirect effect outweighs the direct one and the symmetric equilibrium breaks at a higher level of transport costs.

To find the level of transport costs ϕ_S where complete agglomeration is reached as a long-run equilibrium ('sustain point'), one can set $k = 1$ and evaluate equation (22) at $I - I^* = 0$. Because of the log-linear structure of the utility differential, the solution can only be stated in implicit form:

$$\frac{\sigma+\alpha q}{1-\sigma}\ln\phi_S = \left[l\left(1-\frac{\alpha q}{\sigma}\right)+1\right]\phi_S + l\left(1+\frac{\alpha q}{\sigma}\right)\phi_S^{-1} - (1+2l). \tag{26}$$

It is nonetheless possible to evaluate the effect of increasing search frictions on the location of the sustain point by totally differentiating expression (26) with respect to ϕ and q, which gives

$$\frac{d\phi_S}{dq} = \frac{\alpha l\left(\phi_S^{-1}-\phi_S\right)+\dfrac{\alpha\sigma}{\sigma-1}\ln\phi_S}{l(\sigma+\alpha q)\phi_S^{-2}-\dfrac{\sigma(\sigma+\alpha q)}{\sigma-1}\phi_S^{-1}-l(\sigma-\alpha q)-\sigma}. \tag{27}$$

It can be shown that this differential is positive for all feasible combinations of parameters. So we get:

Proposition 3. *Introducing or increasing search frictions for the low-skilled shifts the sustain point towards a lower level of transport costs. The effect on the break point is ambiguous.*

Proof. See Appendix A.2. □

Figure 2 also indicates that the unemployment rate differential in long-run equilibrium is bigger for small transport costs. There are two reasons for that. First, falling transport costs increase the importance of the demand linkage compared to the competition effect for any given k, increasing relative profitability in the core.[9] Second, the distribution of mobile workers becomes

[9]This does not necessarily hold true for very small transport costs (see Appendix A.3).

less symmetric as more high-skilled workers move into the core. Both effects widen the gap because now more immobile workers apply for jobs in the X-sector of the larger region thus driving up the unemployment rate. This result is summarized in the final proposition:

Proposition 4. *Falling transport costs lead to a rise in the equilibrium unemployment differential between core and periphery. This trend stops when agglomeration is complete.*

Proof. See Appendix A.3. □

5 Discussion

The above results are – as usual – driven by a set of highly stylized assumptions. Importantly, I assume throughout the model that high-skilled labor is perfectly mobile in the long-run while low-skilled workers cannot move between regions at all. This assumption reflects the empirical regularity that the high-skilled are typically more mobile than the low-skilled (Hunt, 2000). Additionally, I assume that only the low-skilled face the risk of becoming unemployed while high-skilled workers always find jobs. This is again a strong simplification, but the empirical literature suggests that unemployment is a more severe problem for the low-skilled (Nickell and Bell, 1996).

Like in other agglomeration models regional migration flows need not level out all labor market disparities in the long run, but might even enforce them. A stable equilibrium of unemployment differentials can arise where the core region faces a higher unemployment rate than the periphery. This result differs from the majority of other models in the NEG literature that focus on cases where unemployment becomes lower in the core.

The present model therefore more closely resembles the classic outcome of the migration model proposed by Harris and Todaro (1970). People there decide between living in a rural area with safe but low income and moving to an urban area with considerably higher income but the risk of staying unemployed. In contrast, low-skilled workers are now mobile between sectors, not regions. Strengthening agglomeration forces do not induce them to migrate to more favorable locations, but to make more risky and potentially gainful job search decisions. The unemployed can thus be said to be the victims of "Great Expectations".

Can the proposed correlation between agglomeration and unemployment be observed in reality? The results are mixed. It has been shown that unemployment rates in Europe are lower in core regions compared to the periphery when looking at sufficiently aggregated data (see Suedekum, 2005).

But this regularity typically breaks down when looking at more disaggregated data(see vom Berge, 2011; Glaeser, 1998, pg. 146). It is tempting to suggest that there are different kinds of frictions in local labor markets working into opposite directions. The net effect might then depend on the regional context under study. A detailed study of the interplay of those various frictions in regional models sounds promising. This is a subject for further research.

6 Conclusion

This paper develops a solvable general equilibrium agglomeration model that can account for unemployment differentials between regions. Labor market frictions are introduced by assuming that firms in the increasing returns sector face search costs when looking for (immobile) workers. Workers then have to decide if they want to take the risk of applying for those jobs and not getting an offer or work in a risk-free numeraire sector. I show that the incentive to take a risk increases for immobile workers when more mobile workers move into a region, because they can bid up their wage level. This leads to an increase in the unemployment rate as a compensating differential.

This has two effects. First, rising unemployment reduces demand and thus high-skilled wages. This constitutes an additional dispersion force. Second, because any wage effects feed back into unemployment the high-skilled wage differential between regions gets narrowed. This can have a dispersive or accumulative effect on migration.

The occurrence of higher unemployment in core regions differs from the majority of modern agglomeration models and more closely resembles the classical result of Harris and Todaro (1970). One main difference to the latter is that the present model explains how higher unemployment rates in core cities might arise and also prevail without the need to assume ex ante different regions.

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A Appendix

A.1 Proof of Proposition 1

Using equation (20) together with (21) and (24) the unemployment rate differential can be written as

$$u - u^* = q\left[\frac{k}{k+l}R - \frac{k^*}{k^*+l^*}R^*\right] = q \cdot \tilde{\Omega} \cdot \Delta$$

where

$$\tilde{\Omega} \equiv [(\sigma + \alpha q)(\phi\sigma + (1-\phi)k(1-k)((\alpha q - \sigma)\phi + \sigma + \alpha q))]^{-1}$$

$$\Delta \equiv \frac{\alpha\sigma\phi(1+l+l^*)}{(k+l)(1-k+l^*)}\left[k^2(\phi-1)(2k-3+l-l^*) + k(\phi(1+l^*-l)+2l-1) - l\right].$$

Thus, to verify proposition 1 we need to show that

$$\frac{\partial(u-u^*)}{\partial k} = q \cdot \frac{\partial\tilde{\Omega}}{\partial k} \cdot \Delta + q \cdot \frac{\partial\Delta}{\partial k} \cdot \tilde{\Omega} > 0 \qquad \forall \qquad k > \frac{1}{2}.$$

Assuming $l = l^*$ and being aware of the BHC it can indeed be shown that in this case $\tilde{\Omega} > 0$, $\Delta > 0$, $\frac{\partial\tilde{\Omega}}{\partial k} > 0$ and $\frac{\partial\Delta}{\partial k} > 0$.

A.2 Proof of Proposition 3

This appendix proves that $\frac{d\phi}{dq}$ in equation (27) is positive for all feasible parameter values. First, note that the nominator in equation (27) is positive for all $\phi \in \,]0;1]$. Next, observe that for the left hand side (LHS) of equation (26) we have $\lim_{\phi\to 0} LHS = \infty$, $\lim_{\phi\to 1} LHS = 0$ and

$$\frac{\partial LHS}{\partial\phi} = -\frac{\sigma+\alpha q}{\sigma-1}\phi^{-1} < 0, \qquad \frac{\partial^2 LHS}{\partial\phi^2} > 0.$$

The right hand side (RHS) of the equation is characterized by $\lim_{\phi\to 0} RHS = \infty$ and $\lim_{\phi\to 1} RHS = 0$ with another root at

$$\phi_1 = \frac{l(\sigma+\alpha q)}{l(\sigma-\alpha q)+\sigma},$$

an inflexion point at $\sqrt{\phi_1} > \phi_1$ and

$$\frac{\partial RHS}{\partial\phi} = \sigma^{-1}\left(l(\sigma-\alpha q) + \sigma - l(\sigma+\alpha q)\phi^{-2}\right), \qquad \frac{\partial^2 RHS}{\partial\phi^2} > 0.$$

Using the 'no-unconditional-dispersion' condition, we get that

$$\left.\frac{\partial LHS}{\partial \phi}\right|_{\phi=0} > \left.\frac{\partial RHS}{\partial \phi}\right|_{\phi=0} \quad \text{and} \quad \left.\frac{\partial LHS}{\partial \phi}\right|_{\phi=1} < \left.\frac{\partial RHS}{\partial \phi}\right|_{\phi=1}.$$

At ϕ_S we therefore get

$$\left.\frac{\partial LHS}{\partial \phi}\right|_{\phi_S} > \left.\frac{\partial RHS}{\partial \phi}\right|_{\phi_S}$$

or

$$l(\sigma + \alpha q)\phi_S^{-2} - \frac{\sigma(\sigma + \alpha q)}{\sigma - 1}\phi_S^{-1} - l(\sigma - \alpha q) - \sigma > 0.$$

A.3 Proof of Proposition 4

The indirect effect of decreasing transport costs through migration directly follows from Proposition 1. Using the terms from Appendix A.1 and assuming $l = l^*$ it is easy to show that $\partial(u - u^*)/\partial\phi = 0$ for $k = 1$. If agglomeration is incomplete $(1 > k > 1/2)$ we get that

$$\lim_{\phi \to 0} \frac{\partial(u - u^*)}{\partial \phi} > 0$$

$$\lim_{\phi \to 1} \frac{\partial(u - u^*)}{\partial \phi} < 0 \quad \text{if} \quad 2l < \sigma/\alpha q$$

with $\partial^2(u - u^*)/\partial\phi^2 < 0$ for all $\phi \in \ ]0; 1]$. Although the derivative might become negative for very low transport costs, we only need to show that there is always a point $\hat{\phi} > \phi_S$ that yields $\partial(u - u^*)/\partial\phi|_{\hat{\phi}} > 0$. Since the supply linkage is always positive, we know that at the sustain point we have $R - R^* < 0$. This means that the point ϕ_1 from Appendix A.2 satisfies the condition $\phi_1 > \phi_S$ because here $R - R^* = 0$. Evaluating the derivative at this point yields

$$\left.\frac{\partial(u - u^*)}{\partial \phi}\right|_{\phi_1} \geq 0 \quad \text{if} \quad 2l \leq \sigma/\alpha q.$$