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Putting New Economic Geography to the Test: Free-ness of Trade and Agglomeration in the EU Regions

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Abstract

Based on a New Economic Geography model by Puga (1999), we use the equilibrium wage equation to estimate two key structural model parameters for the NUTS 2 (Nomenclature of Units for Territorial Statistics) EU regions. The estimation of these parameters enables us to come up with an empirically based *free-ness of trade* parameter. We then confront the empirically grounded free-ness of trade parameter with the theoretical relationship between this parameter and the degree of agglomeration. This is done for two versions of our model: one in which labor is immobile between regions, and one in which labor is mobile between

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regions. Overall, and in line with related studies, our main finding is that agglomeration forces still have only a limited geographical reach in the EU. Agglomeration forces appear to be rather localized.

1. Introduction

In his review of Fujita, Krugman and Venables (1999), but in fact of the whole New Economic Geography (NEG) literature, Neary (2001) reminds us that the real test for the NEG is beyond mere theory and to bring out its empirical and policy relevance. This paper addresses the empirical relevance of the NEG. In doing so, we take the basic message of Leamer and Levinsohn (1995, p.1341), “estimate don’t test” seriously. We will show the usefulness of the NEG, but we will not really test it against alternative theories, though we will control for fixed “1st nature” endowments and, indirectly, for human capital or (pure) technological externalities. We also take their second message seriously and that is “don’t treat theory too casually”. For this paper their advice means that our empirical analysis is well grounded in NEG theory and that, in turn, we will explicitly address the theoretical implications of the empirical findings.

Estimations that take the NEG as a starting point often run into problems. It is well-known that agglomeration patterns can be found at all levels of aggregation (country, region, city). But this not necessarily implies that neo-classical theories of location are without merit. Geographical concentration of factor endowments or pure technological externalities could lead to agglomeration in neo-classical models. In the same vein, the absence of agglomeration does not imply that the NEG models are not relevant. NEG models are characterized by multiple equilibria, of which the symmetric or spreading equilibrium is one. In addition, one could point out that the application of these models to different economies with different (labor market) institutions (like the U.S.A. or the EU countries), or to different geographical scales (country versus city level) sits uneasy with the tendency in empirical NEG applications of a ´one size fits all’ approach. Finally, from a more methodological angle, there are important questions about the (spatial) econometrics involved as well as about data measurement (see Combes and Overman, 2003). The conclusion is that the same empirical facts about agglomeration can be explained using different theoretical approaches. On the one hand this is good news, because it means that the facts are not in search of a theory. On the other hand it leaves unanswered the question as to the relevance of NEG and, within NEG, as to the relevance of specific NEG models. Recent theoretical work by Robert-Nicoud (2004) and Ottaviano and Robert-Nicoud (2004) also emphasizes these problems.

In this paper we will address some of the above issues. More in particular, based on a NEG model (Puga, 1999), we derive the equilibrium wage equation and estimate this equation. This procedure gives estimates of two key structural model parameters for our sample of the NUTS 2 EU regions, and it enables us to derive empirically based estimates for the so-called free-ness of trade parameter. In doing so we follow the suggestion by Head and Mayer (2004a, p. 2663), who state that for future NEG empirics to progress "it is critical to identify the free-ness of trade". To our knowledge this is the first paper that tries to do so systematically. Subsequently, we will use the estimates of this empirical exercise to find out for the case of the EU regions what the free-ness of trade estimates imply for the degree and geographical range of agglomeration forces.2 Using the model by Puga (1999) as our benchmark model, we confront our estimates of the free-ness of trade parameter with the theoretical relationship between this parameter and the degree of agglomeration. Our results will be applied to two different settings: one in which labor is immobile between regions, and one in which labor is mobile between regions.

The paper is organized as follows. In section 2, the basic model is briefly presented and the equilibrium wage equation is derived and this equation is the vehicle for our empirical analysis. In terms of long-run equilibria section 3 describes two worlds that are consistent with this wage equation, but have different predictions as to what happens with the degree of agglomeration when trade costs fall. The first world is described by the now familiar Tomahawk diagram that is not only to be found in the core NEG model by Krugman (1991) but essentially in a very broad class of NEG models (Ottaviano and Robert-Nicoud, 2004). With two regions there is a symmetric or spreading equilibrium and there are two equilibria consistent with complete agglomeration. Ever-increasing economic integration will ultimately result in complete agglomeration in this model. In the second world the possible set of long-run equilbria is richer and (stable) incomplete agglomeration may belong to the set of long-run equilbria. Here, for high levels of economic integration agglomeration will turn into (renewed) spreading.

Section 4 presents our basic estimation results. Our estimation of the equilibrium wage equation yields coefficients for the transportation cost parameter and the substitution elasticity and thereby, for any given distance between a pair of regions, an estimate for the free-ness of trade parameter. Subsequently, section 5 confronts the findings of section 4 with our benchmark model. Analysing the break conditions of each model gives an indication whether or not more economic integration will lead to more agglomeration. By using bilateral country trade data section 6 extends the analysis to the sectoral level. Finally, section 7 concludes. Overall, our main finding is that agglomeration forces do not extend very far. Agglomeration forces appear to be rather localized.

[2] Note that by doing so we address two from the five empirical hypotheses that, according to Head and Mayer (2004a) follow from the NEG literature.

2. The Model and the Wage Equation

In this section we give a brief description of the model and focus on the derivation of the equilibrium wage equation. The model we use encompasses the two most important NEG models: the Krugman (1991) model with inter-regional labor mobility, and the Krugman and Venables (1995) model without inter-regional labor mobility. We take Puga (1999) as a starting point because he presents a general model that encompasses these two core models and in fact many other NEG models as special cases. The model without interregional labor mobility is considered to be more relevant in an international context, because it is a stylised fact that labor is internationally less mobile than nationally. For the EU, however, it is not a priori clear if this is true in the long run. Economic integration could stimulate international labor mobility. In the context of NEG such a gradual change to more labor mobility can have serious implications, as we will discuss below. We will now introduce and summarize the basic set-up of the Puga model (for more details see, besides Puga (1999), also Fujita, Krugman, and Venables (1999), chapter 14).

Demand

Assume an economy with two sectors, a numéraire sector (H), and a Manufacturing (M) sector. As a short cut one often refers to H as the agricultural sector to indicate that this industry is tied to a specific location. Every consumer in the economy shares the same, Cobb-Douglas, preferences for both types of commodities:

$$U = M^{\delta} H^{(1-\delta)}$$

The parameter δ is the share of income spent on manufactured goods. M is a CES sub-utility function of many varieties.

(1) $$M = \left(\sum_{i=1}^{n} c_i^{\rho} \right)^{1/\rho}$$

Maximizing the sub-utility subject to the relevant income constraint, that is the share of income that is spent on manufactures, δE, gives the demand for each variety, j:

(2) $$c_j = p_j^{-\varepsilon} I^{\varepsilon-1} \delta E ,$$

in which $I = [\sum_i (p_i)^{(1-\varepsilon)}]^{1/(1-\varepsilon)}$ is the price index for manufactures, $\varepsilon = \frac{1}{1-\rho}$ the elasticity of substitution, and E= income.

Firms also use varieties from the M sector as intermediate inputs. Assuming that all varieties are necessary in the production process and that the elasticity of substitution is the same for firms as for consumers, we can use the same CES-aggregator function for producers as for consumers, with the same corresponding price index, I. Given spending on intermediates, we can derive demand functions for varieties of producers which are similar to those of consumers.

Total demand for a variety, j, can now be represented as:

(3) $$c_j = p_j^{-\varepsilon} I^{\varepsilon-1} Y \ ,$$

where Y is defined as $Y = \delta E + \mu npx^*$. The first term on the right hand side of Y comes from consumers, representing the share of income E that is spent on all M-varieties, the second term on the right hand site comes from firm demand for intermediate inputs, this is equal to the value of all varieties in a region, npx*, multiplied by the share of intermediates in the production process, μ (see below).

Manufacturing Supply

Next, turn to the supply side. Each variety, i, is produced according to the following cost function, C(xi):

(4) $$C(x_i) = I^{\mu} W_i^{(1-\mu)} (\alpha + \beta x_i)$$

where the coefficients α and β describe, the fixed and marginal input requirement per variety. The input is a Cobb-Douglas composite of labor, with price (wages) W, and intermediates, represented by the price index I. Maximizing profits gives the familiar mark-up pricing rule (note that marginal costs consists of two elements, labor and intermediates):

(5) $$p_i(1 - \frac{1}{\varepsilon}) = I^{\mu} W^{(1-\mu)} \beta \ ,$$

Using the zero profit condition, $p_i x_i = I^{\mu} W_i^{(1-\mu)} (\alpha + \beta x_i)$, and the mark-up pricing rule (5), gives the break-even supply of a variety i (each variety is produced by a single firm):

(6) $$x_i = \frac{\alpha(\varepsilon - 1)}{\beta}$$

Equilibrium with Transportation Costs in the 2 Region Model

Furthermore, transportation of manufactures is costly. Transportation costs T are so-called iceberg transportation costs: $T_{12}>1$ units of the manufacturing good have to be shipped from region 1 to region 2 for one unit of the good to actually arrive in region 2. Assume, for illustration purposes, that the two regions – 1 and 2 – are the only regions. Total demand for a product from, for example region 1, now comes from two regions, 1 and 2. The consumers and firms in region 2 have to pay transportation costs on their imports. This leads to the following total demand for a variety produced in region 1:

$$x_1 = Y_1 p_1^{-\varepsilon} I_1^{\varepsilon-1} + Y_2 p_1^{-\varepsilon} (T_{12}\ )^{-\varepsilon} I_2^{\varepsilon-1}$$

We already know that the break-even supply equals $x_1 = \frac{\alpha(\varepsilon - 1)}{\beta}$, equating this to total demand gives (note that the demand from region 2 is multiplied by T12 in order to compensate for the part that melts away during transportation):

$$\frac{\alpha(\varepsilon-1)}{\beta} = Y_1 p_1^{-\varepsilon} I_1^{\varepsilon-1} + Y_2 p_1^{-\varepsilon} (T_{12})^{1-\varepsilon} I_2^{\varepsilon-1}$$

Inserting the mark-up pricing rule, (5), in this last equation and solving for the wage rate gives the two-region version of the wage equation in the presence of intermediate demand for varieties.3 This version of the NEG model is also known as the vertical linkages model, because this model introduces an extra agglomeration force: the location of firms has an impact on production costs. The wage equation for the 2 region case can be stated as:

(6) $$W_1 = Const.(I_1)^{-\mu/(1-\mu)} (Y_1 I_1^{\varepsilon-1} + Y_2 (T_{12})^{1-\varepsilon} I_2^{\varepsilon-1})^{1/\varepsilon(1-\mu)}$$

where the constant, Const, is a function of (fixed) model parameters.

Similarly for the n region (n=1,…r) case we arrive at the following equilibrium wage equation:

(7) $$W_r = Const\{I_r\}^{-\mu/(1-\mu)} \left[\sum_s Y_s I_s^{\varepsilon-1} T_{rs}^{\ (1-\varepsilon)}\right]^{1/\varepsilon(1-\mu)}$$

W_r is the region's r (nominal) wage rate, Ys is expenditures (demand for final consumption and intermediate inputs), Is is the price index for manufactured goods, ε is the elasticity of substitution for manufactured goods and T_{rs} are the

[3] The reason to derive a wage equation instead of a traditional equilibrium price equation is twofold. First, labor migration between regions is a function of (real) wages, second, data on regional wages are easier to obtain than regional manufacturing price data, see section 4.

iceberg transportation costs between regions r and s. Note that when we want to estimate wage equation (7) for our sample of NUTS2 EU regions we need to come up with a specification of the transportation costs T_{rs} , this will be done in section 4. In particular we will have the answer the question how transportation costs vary with the distance between regions. In the short-run, when the spatial distribution of firms and labor is fixed, the model reduces to three equations with three unknowns (wages W, expenditures Y, and the price index I). In the long-run the spatial distribution of economic activity is endogenous because then footloose firms and, depending on the particular version of the model used, manufacturing workers can move between sectors and regions.

Equation (7) closely resembles the "old-fashioned" market potential function. Regional wages are higher in regions that have easy access to high-wage regions nearby. This is reflected by the term $\sum YT_{rs}^{(1-\varepsilon)}$, known as nominal market access (Redding and Venables, 2003). Wages are also higher when there is less competition, this is the extent of competition effect, measured by the price index I_s. Note, that the price index I_s does not measure a competition effect in the sense in which this term is normally used (price are fixed mark-ups over marginal costs and there is no strategic interaction between firms). A low price index reflects that many varieties are produced in nearby regions and are therefore not subject to high transportation costs, this reduces the level of demand for local manufacturing varieties. Since firms' output level and price mark-up are fixed, this has to be off set by lower wages. Hence, a low (high) price index I_s depresses (stimulates) regional wages W_r. The inclusion of the price index in the market access term in the wage equation is important since it makes clear that we are dealing with real market access (RMA) as opposed to the gravity equation or market potential function where typically only nominal market access matters.

Finally, the term $I\text{-}^{\mu/(1-\mu)}$ in wage equation (7), is known as supplier access, SA (Redding and Venables, 2003). A lower value of I, lowers production costs and allows a higher break-even wage level. Supplier access means that when the price index is low (high), intermediate input-supplying firms are relatively close (far) to your location of production, which strengthens (weakens) agglomeration. A better supplier access (a lower value of I) lowers wage costs. This effect is stronger the larger the share of intermediate products, μ, in the production process. Note that with μ=0 (no intermediate inputs) only the real market access term is left in the wage equation.

Wage equation (7) will do for our empirical purposes.[4] In the short-run when the spatial distribution of fims and workers is fixed, demand differences between regions will be fully reflected in regional wage differences. Or, in other words,

[4] This has an additional advantage in that we do not have to consider the long-run adjustment mechanism, that is, whether or not firms are mobile or instead labor (see Puga, 1999, p. 310).

regional differences in real market access, RMA, and supplier access, SA, (both of which are fixed in the short run) will result in regional wage differences. In the long run when firms and workers can move, these differences will also give rise to re-location of firms and workers (which amounts to saying that in the long run RMA and SA are endogenous).[5] All that matters for our empirical analysis is that wage equation (7) is the equilibrium wage equation and can be estimated. However, to learn more about the relationship between economic integration and agglomeration the wage equation will not do and we have to address the nature of the long-run equilibria.

3. The Relation between Economic Integration and Agglomeration[6]

3.1 Interregional Labor Mobility: The Tomahawk

NEG models that have the same set-up as Puga (1999) predict that with interregional labor mobility economic integration will lead to complete agglomeration of the footloose agents in the end. The intuition behind this is simple and is illustrated, for the two region case in chart 1. Assume that there are two regions. Economic integration implies lower transportation costs. In chart 1 this is a movement from left to right along the horizontal axis, from low to high φ's (more on the important role of φ below). The parameter φ is called the free-ness of trade or "phi-ness" of trade parameter (Baldwin et al., 2003) and, in terms of our model, is defined as $\varphi_{rs} \equiv T_{rs}^{\;1-\varepsilon}$ It is easy to interpret: $\varphi_{rs} = 0$ denotes autarky and the absence of economic integration whereas $\varphi_{rs} = 1$ denotes free trade and full economic integration between regions r and s. In empirical work this gives an extra degree of freedom: one has to choose a functional form for T_{rs}. The vertical axis in chart 1 shows the share of the footloose production factor in region 1.

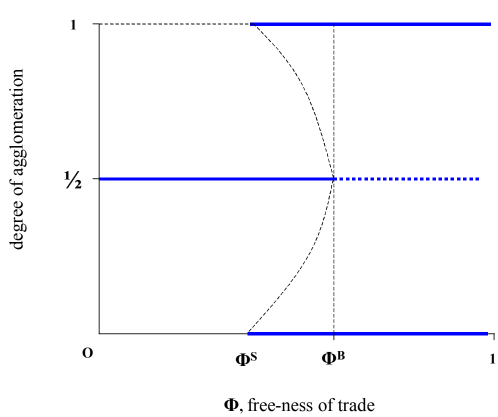
Assume that the initial situation is one of autarky ($\varphi = 0$) and that (footloose) labor is equally distributed over the two regions, indicated by the horizontal solid line at ½. Because the regions are identical this situation is also a long-run

[5] Whether or not in the long run both prices (here, wages) and quantities (here, mobile firms and workers) act as adjustment mechanism, depends on the inter-sectoral elasticity of manufacturing labor supply (see Head and Mayer, 2004b). With an infinite elastic labor supply all the adjustment has to come from the quantity side (and there will be no regional wage differences). In case, as we will assume too, of a positively sloped labor supply function to the relative (= manufacturing/agricultural) wage at least part of the adjustment will come through regional wages, see the next section for an analysis of this issue.

[6] Our discussion in this section is based on the 2 core NEG models as discussed in Puga (1999), but compare also Fujita, Krugman and Venables (1999), chapters 4 and 5 with chapter 14.

equilibrium. This is why this situation is known as the symmetric or spreading equilibrium. What happens if the degree economic integration increases, that is moving from left to right in the chart? Mobile workers have to decide if re-locating to the other region, say from region 1 to 2 (that becomes slightly larger than region 1), is beneficial for them. Initially, re-locating is not beneficial because transportation costs are still quite high and relocating means that exporting from region 2 to region 1 is still too expensive. Furthermore, competition in region 2 increases. This implies that prices and wages in region 2 have to go down in order to be able to sell the break-even amount. A defecting worker will return to its original location. But if transportation costs decline beyond a certain point, the advantages of moving to region 2, outweighs the disadvantage of exporting to region 1. This stimulates further migration towards region 2 until all workers and firms have moved towards this region. Chart 1, the Tomahawk chart, gives the theoretical relationship between economic integration φ and the degree of agglomeration.

Chart 1: The Tomahawk



Source: Authors' calculations.

As chart 1 illustrates the point where it becomes profitable to agglomerate is indicated by φB, in the literature this point is known as the so-called break point: the point where the symmetric equilibrium (degree of agglomeration = ½) is no longer a stable equilibrium (indicated by the dashed horizontal line). At this point the re-location decision of a worker means that others will follow, triggering a process of agglomeration. So, in our NEG model version with interregional labor mobility we either have perfect spreading or full agglomeration as a long-run equilibrium. Analysing the effects of increasing economic integration on agglomeration is now reduced to the question where an economy is located on the horizontal axis in chart 1, that is, one is interested in whether or not an economy is in actual fact to the left or to right of φ^B.[7] Where we are on the horizontal is an empirical question to which the estimations of the free-ness of trade parameter based wage equation will give us the answer in sections 4 and 5. Furthermore, the estimates for φ help us to infer φ^B.

Puga (1999, eq. 16) derives the following analytical solution for the break-point for the 2 region case (dropping subscripts r and s):

$$\phi^B = (T^{1-\varepsilon})^B = \left[1 + \frac{2(2\varepsilon - 1)(\delta + \mu(1-\delta))}{(1-\mu)[(1-\delta)(\varepsilon(1-\delta)(1-\mu)-1] - \delta^2\eta}\right]^{(1-\varepsilon)/(\varepsilon-1)} \tag{8}$$

The elasticity η is the elasticity of a region's labor supply from the H-sector to the manufacturing sector. If $\eta = 0$, no inter-sector labor mobility is possible, if $\eta = \infty$ there is perfect labor mobility between sectors, that is to say the inter-sectoral labor supply elasticity is infinite. In the latter case wages in the manufacturing sector and the H-sector are identical until a region becomes specialized in manufactures. If $0 < \eta < \infty$ migration from the H-sector to the manufacturing sector can be consistent with a wage increase in both sectors. The inclusion of an upward sloping labor supply function thus implies that the model is more general than Krugman (1991, where $\eta = 0$), or Krugman and Venables (1995, where $\eta = \infty$). Most importantly, if $0 < \eta < \infty$, the bang-bang long run solutions as in Tomahawk model might disappear once we do no longer allow for inter-regional labor mobility. This is discussed next.

3.2 No Interregional Labor Mobility: The Bell-Shaped Curve

How relevant is the Tomahawk chart for the analysis of EU integration and agglomeration? In international trade theory it is standard to assume that labor is mobile between sectors, but not across national borders. This assumption reflects the stylised fact that labor is less mobile across borders than within regions or countries. Without interregional labor mobility agglomeration, however, is still possible (see Krugman and Venables, 1995, Puga, 1999, Fujita, Krugman and Venables, 1999).

[7] For the purpose of this paper the sustain point, φ^S is deemed not relevant under the assumption that we are only interested in the case where we move from less to more economic integration, that is, we only move from left to right along the horizontal axis in chart 1. The characteristics of break and sustain points are analysed in detail by, for example, Neary (2001), Robert-Nicoud (2004) and Ottaviano and Robert-Nicoud (2004).

The absence of interregional labor mobility still allows agglomeration in the presence of intermediate goods. Firms may find it to be advantageous to agglomerate because of intermediate input linkages, they want to be near the suppliers of these inputs, recall the discussion about the supplier access term in wage equation (7) from the previous section. The labor required to sustain the agglomeration of firms comes from the immobile H sector. To persuade workers to move from the H-sector to the manufacturing sector, each firm has to offer workers in this sector a higher wage than the existing wage in this sector: the more inelastic labor supply is to manufacturing wages, the higher this wage offer has to be. Agglomeration in this class of NEG models, and opposed to the case where the Tomahawk chart applies, is associated with increasing wage differences *between regions*. In the peripheral region, wages decrease, because once firms agglomerate in the more attractive region, labor that is released in the manufacturing sector, increases labor supply in the agricultural sector.

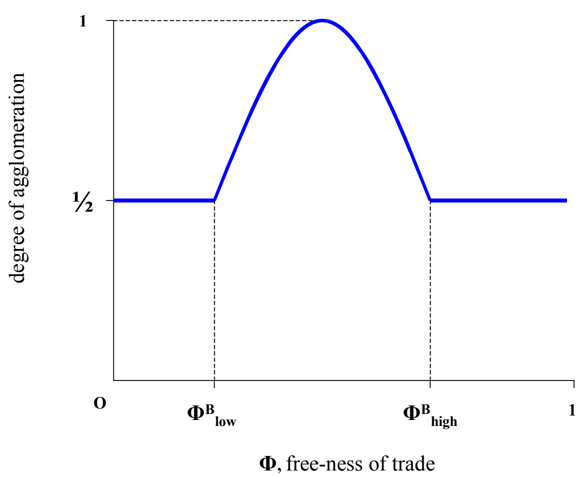
The point to emphasize here is that (with $0<\eta<\infty$) agglomeration drives up wages in the core region. This ultimately reduces the incentive for firms in the manufacturing sector to concentrate production in the region where manufacturing economic activity is agglomerated for a number of reasons. First, an increased demand for labor raises production costs in the region where manufacturing is concentrated. Second, the importance of being close to a specific market diminishes as transportation costs become less important due to increased economic integration, that is when φ, the degree of economic integration, increases. Third, the peripheral region, with its lower wage rate becomes more and more attractive.

Without interregional labor mobility the long-run relationship between the free-ness of trade (economic integration) and agglomeration might look like chart 2 which has aptly been called the bell-shaped curve by Head and Mayer (2004a).[8] As in chart 1 for the 2 region case we have φ on the horizontal axis and the degree of concentration on the vertical axis. For low degrees of economic integration (to the left of φBlow) we have spreading and similar to the previous section, once economic integration passes the break-point (here φBlow) a process of agglomeration starts. The main difference with the previous model, is that agglomeration can be partial and go along with interregional wage differences. If

[8] It might but it need not, this depends on exact parameter configuration, see the Appendix in Puga (1999) or Robert-Nicoud (2004). The point to emphasize is that what really distinguishes chart 2 from chart 1 is that once agglomeration has arrived the economy will stay in the agglomeration regime in chart 1as economic increases further whereas in chart 2 for high levels of economic integration (high levels of φ) agglomeration will turn into (renewed) spreading. Here we assume that the latter possibility occurs with "smooth", that is, partial agglomeration, equilibria like depicted in chart 2 but one can also come up with a double Tomahawk (Robert-Nicoud, 2004, p. 22–23) to depict this second possibility.

economic integration is pushed far enough, a second(!) break point, denoted φBhigh, will be reached. From φBhigh onwards we have re-newed spreading, no agglomeration is left whatsoever and interregional wages will now be equal (because both regions will have the same number of manufacturing firms and an equally sized manufacturing sector).

Chart 2: The Bell-Shaped Curve



solutions for φBlow and φBhigh are the (real) solutions to the quadratic equation in φ (Puga, 1999, equation (33)):

$$(9)\quad [\varepsilon(1+\mu)-1][(1+\mu)(1+\eta)+(1-\mu)\gamma]\varphi^2-2\{[\varepsilon(1+\mu^2)-1](1+\eta)-\varepsilon(1-\mu)[2(\varepsilon-1)-\gamma\mu]\}\varphi$$
$$+(1-\mu)[\varepsilon(1-\mu)-1](\eta+1-\gamma)=0$$

If, depending on the exact parameter configuration for ε,γ, μ and η, these solutions exist, this expression gives us the two break-points. To follow Head and Mayer (2004a) we would like to answer the question for the case of the EU regions "where in the bell are we?" Finally, and this must be emphasized, since the difference between the two classes of NEG models (chart 1 versus chart 2) only comes to the fore when we are dealing with long-run equilibria, the equilibrium wage equation (7) is at home in both classes of NEG models. This means that our estimations of the free-ness of trade parameter φ based on the equilibrium wage equation can be confronted with the Tomahawk chart as well as the above bell-shaped curve!

4. The Estimation of the Wage Equation

Before we can estimate wage equation (7) we have to take the following issues into account. First, we have to specify the distance function. We considered two options:

- $T_{rs}=T^{D_{rs}}$, where the transports costs increase exponentially with the distance between r and s, and T represents the transportation cost parameter that does not vary with distance (applied by Hanson, 2001, Brakman, Garretsen, and Schramm, 2004).
- $T_{rs}=TD_{rs}^{\gamma}$, where the parameters T, $\gamma > 0$ (Crozet, 2004). The size of the distance decay parameter γ needs to be estimated and the data will decide whether transportation costs rise or fall more or less than proportionally with increased distance between r and s. If $0 < \gamma < 1$ transportation costs rise less than proportionally with distance, and reflects that economies to scale (or distance) are possible with respect to transportation.

We opted for the second possibility because in that case the data decide whether transportation costs rise or fall more or less than proportionally with increased distance between r and s. The distance variable D_{rs} will be measured in km. between NUTS 2 regions. The distance from a region r to itself, D_{rr} can be modelled in several ways. We use the proxy $0.667\sqrt{\frac{area}{\pi}}$ in which area is the size of region r in km^2, (see Head and Mayer, 2000 for a discussion of this measure for internal distance). Given our specification for T_{rs} we can calculate $\varphi_{rs} \equiv T_{rs}^{1-\varepsilon}$, for each combination of D_{rs} and D_{rr}.

A second issue that we need to address is that we cannot estimate equilibrium wage equation (7) directly. There are no (sufficient) regional price index data for NUTS 2 regions and this means that Ir cannot be measured as such. In addition, even if we somehow get around measuring the regional price indices, the equilibrium price index is itself a function of the regional wages Wr. As can already be guessed from equation (2), the equilibrium price index in region r is also not only a function of wages in other regions but also of the price index in other regions. This follows directly from the fact that in the model with intermediate inputs firms there are 2 inputs (labor and manufacturing goods).

This "price index" problem can be solved in two ways. First, as for instance shown by Hanson (2001), one can make use of other equilibrium conditions (of a non-tradable service) to get rid of the price index altogether. This has its drawbacks too. For the case of the EU regions this leads to new data requirements that cannot (easily) be met. Also, this strategy may imply that one needs additional assumptions that are troublesome for the present analysis (in particular that interregional real wages are always equalized which clearly too strong an assumption to make for the case of the EU regions). We can, in principle, express the price index in region r as an average of the wage in region r and the wages in centre regions corrected for the distance between region r and these centre regions (see the Appendix for an explanation and further references).[9]

As a third and final issue, we observe that regional wages across Europe may differ for reasons that have nothing to do with the demand and cost linkages from the NEG literature. This leads us to another issue that needs to be addressed. Positive human capital externalities or (pure) technological externalities might also give rise to a spatial wage structure! These externalities imply that regions may simply differ in terms of their marginal factor productivity and this is something we would like to take into account when estimating the wage equation. Also, the physical and political geography of Europe might be a factor in explaining regional wage differences, these are the fixed endowments that are truly fixed geographically (Combes and Overman, 2003).

To take these alternative explanations for regional wage differences on board as control variables we proceeded as follows. We allow for labor productivity to differ across the EU regions. We cannot measure human or technological externalities separately (due to lack of relevant data on NUTS 2 level). The Appendix derives the corresponding equilibrium wage equation once labor productivity is no longer assumed to be equal across regions. Relative marginal labor productivity is [MPL_{EU} /MPL_r], where MPL_{EU} is the average real gross value added per employee in the NUTS 2 regions and MPL_r is the real gross value added per employee for region r. By allowing for MPL-differences the wage equation changes into:

$$W_r = \text{constant} \cdot \left(\frac{MPL_{EU}}{MPL_r} \right)^{(1-\varepsilon)/\varepsilon} I_r^{-\mu/(1-\mu)} \left[\sum_{s=1}^{R} Y_s \left(T_{rs} \right)^{1-\varepsilon} I_s^{\varepsilon-1} \right]^{1/\varepsilon}$$

where, MPL = marginal productivity of labor in a specific region (indicated by the subscript).

The possibility that the physical geography (climate, elevation, access to waterways etc.) or the political geography (borders, country-specific institutional wage arrangements etc.) might also explain regional wage differences will be addressed below. As proxies for physical geography we will use for the NUTS 2 regions the mean annual sunshine radiation (in kWH/m^2) and the mean elevation above sea level. We will also use dummy variables when a region borders the sea,

[9] Another solution to be able to estimate the wage equation if data on the price index I are lacking is to simply assume that $I_r=I_s$. This assumption (see Niebuhr, 2004 for an example) effectively boils down to stating that only nominal market access matters, which is not relevant for our case.

has direct access to (navigable) waterways, or is a border region. To capture the possibility of country-specific determinants of wages (like the centralisation of wage setting) we also use country-dummies as control variables. The physical and political geography variables capture the fixed (= not man-made) features of the economic geography that may have a bearing on regional wages. By fixed we mean that these variables are not determined by the location decisions of mobile firms or workers.[10]

The log-transformation of the equilibrium wage equation gives the specification that, see wage equation below, actually has been used as the central wage equation in our estimations, and by adding physical and political geography control variables we thus end up with:

$$(7') \qquad \log(W_r) = \text{constant} + \frac{1-\varepsilon}{\varepsilon(1-\mu)} \log\left(\frac{MPL_{EU}}{MPL_r}\right) - \frac{\mu}{1-\mu}\log(I_r) + \frac{1}{\varepsilon(1-\mu)}\log\left[\sum_{s=1}^{R} Y_s (T_{rs})^{1-\varepsilon} I_s^{\varepsilon-1}\right] + \sum_i \beta_i Z_i$$

where $(T_{rs})^{1-\varepsilon} = (TD_{rs})^{\gamma(1-\varepsilon)}$ and internal distance $D_{rr} = 0.667\sqrt{\frac{area}{\pi}}$ in which area is the size of region r in km^2 ; and Zi = set of additional control variables for each region that potentially consists of mean annual sunshine; mean elevation above sea-level; and dummy variables (country dummy, border-region dummy, access to sea dummy, access to navigable waterway dummy), for more information on the data used and the definition of variables see the *Appendix*.

What is immediately apparent from the wage equation is that the supplier access (SA) term is correlated with the real market access (RMA) term. The multicollinearity between RMA and SA is discussed at length by Redding and Venables (2003) and Knaap (2004), and it leads these authors to opt for either SA or RMA in the actual estimations. We follow these authors and opt thereby for RMA. In our case the lack of data on regional price indices makes this choice rather straightforward! In some of our estimations we have, following Redding and Venables (2003), experimented with including the distance of each region to the economic centers as an (time-invariant) approximation for supplier access, this did, however, not affect our main results. Implicitly we will assume that in our estimations SA is constant.

In addition, there are other econometric issues to be addressed like the endogeneity of the variables (wages and income) that make up the real market

[10] This is why we decided not use the regional production structure as control variable. In NEG models this is clearly an endogenous variable. NEG models are all about the simultaneous determination of demand and production across regions.

access term (Hanson, 2001, Mion, 2003). We have estimated wage equation (7') in levels and also, without the time-invariant control variables, in 1st differences. In doing so, we have also performed IV-estimations and used both non-linear least squares (NLS) and weighted least squares (WLS). In particular, when estimating in levels, the Glejser test indicated the presence heteroscedasticity so we choose WLS. But for the sake of comparison (for instance with Crozet, 2004) we also present the NLS regression. The sample period is 1992–2000. Our goal for this paper is not solve all these econometrical issues since the estimation of the wage equation is only a means to an end. The means is to arrive at "reasonable" estimates for the substitution elasticity ε and the distance parameter γ so as to be able to infer the free-ness of trade parameter. Table 1 gives the results of estimating equation (7') in levels. The 1st column gives the WLS results of estimating (7'). The 2nd column does the same but now the estimation is the second stage of a 2SLS regression where in the first stage regression wages and income were regressed upon the exogenous controls *Z*, a time trend, and 1-period lagged wages or income. This is a simple way to instrument wages and income. The third column shows the estimation results for a 2SLS regression of wage equation (7') but now we use NLS instead of WLS.

To save space we only show the estimation results for our 2 key variables (results for other variables and/or other specifications are available upon request).

The coefficient for the substitution elasticity is relatively high (indicating relative weak economies of scale) but many studies find values in the range of 7–11 (see for instance Broda and Weinstein, 2004 for sectoral evidence for the U.S.A. or Hanson and Xiang, 2004 for recent international evidence). The distance coefficient $\gamma < 1$ which indicates that transportation costs increases less than proportionally with distance (see Crozet 2004 for an opposite finding).[11]

[11] Estimating in 1st differences (in 2SLS) instead of in levels, gave significant (and correctly signed) results for ε and γ too. But, more in line with Crozet, the substitution elasticity is much lower (between 2–3) and $\gamma>1$ (around 1.8). Our concern here is, however, not so much the estimated coefficients as such but their compound effect on the free-ness of trade parameter φ. In this respect, the 1st difference results yield a free-ness of trade parameter that is very similar to the one based on the estimations in levels shown in table 1.

Table 1: Estimating Wage Equation (7'), 1992–2000 (t-values between Brackets)

	Levels , WLS	Levels, 2SLS, WLS	Levels, 2SLS, NLS
Variable: ε	9.62 (24.9)	9.53 (16.9)	5.48 (11.7)
Variable: γ	0.21 (33.4)	0.19 (22.1)	0.32 (13.0)

Note: t-values for 2SLS have been corrected for the fact that fitted values for wages and income from the first stage regression are included in the second stage. Number of obs.: 1st column: 1830; 2nd column: 1566.

Source: Authors' calculations.

transportation cost. To be able to show what the estimations mean for the relationship between economic integration and agglomeration, we need to go back to the underlying theoretical model as introduced in sections 2 and 3, and in particular to charts 1 and 2. In doing so, we take the estimates of the second column of table 1 as our empirical benchmark, ε=9.53, and γ=0.19. Note that the various estimations of ε and γ yielded roughly the comparable results in terms of the implied value of the free-ness of trade parameter.[12]

5. Economic Integration and Agglomeration: φ Meets φ^B

Given the estimates we are now ready to confront our estimations with the theoretical insights with respect to the relationship between economic integration and agglomeration from section 3. In section 3 we explained that when it comes to this relationship we distinguish in this paper between two relevant classes of NEG models. In our analysis based on Puga (1999), the distinguishing feature between both classes was the assumption about interregional labor mobility. With interregional labor mobility, full agglomeration is the only feasible outcome whenever the degree of economic integration passes a certain threshold level, recall *Tomahawk* chart 1. In the absence of interregional labor mobility, agglomeration outcomes are less extreme (partial agglomeration). More importantly, if the degree

[12] As explained above, the inclusion of both the supplier access (SA) term and the real market access (RMA) term in our estimation of (7') is troublesome a priori, because of the expected degree of multicollinearity between SA and RMA. Because of lack of data we cannot directly compute SA but, see the Appendix (equation 3''), we can approximate the price index I_r for each region by filling the following values for γ (0.19) ε (9.53) and, not based on estimations, μ (0.3). If we confront the resulting SA (= $I_r^{\mu/(1-\mu)}$) with the RMA (the $\sum$ term in (7')) we indeed find a high degree of correlation, 0.64.

of economic integration continues to increase the degree of agglomeration will diminish and ultimately the economy returns to a spreading equilibrium, recall the *bell-shaped curve* from chart 2.

Armed with our estimations for the structural parameters ε=9.53 and γ=0.19 for the EU *NUTS 2* regions, we would like to know what these estimations imply when confronted with the Tomahawk and bell-shaped charts, that is when confronted with our NEG model. In this way we are able to say more about the relationShip between economic integration, here proxied by φ, and the extent of agglomeration. The break-points φ^B for both the Tomahawk and bell-Shaped Curve can be derived from equations (8) and (9). In order to be able to infer for any pair of regions r and s with bilateral distance D_{rs} the implied value for the free-ness of trade parameter φ_{rs} based on our estimates for γ and ε, we have to take into consideration that the NUTS 2 regions are not of equal size and that therefore the internal distance D_{rr} matters to assess the free-ness of trade between a region r and any other region s. This is why the associated value of φ_{rs} is in fact a measure of relative distance D_{rs}/D_{rr} and thereby of relative transportation costs T_{rs}/T_{rr}.

We dub the break-point φ^B_{labmob} for the version of the NEG model with interregional labor mobility, see equation (8). Given certain restrictions on the model parameters (see Puga (1999), p. 315), this break-point gives us the critical value of φ below which the symmetric equilibrium (no agglomeration) is locally stable. If, however, $\varphi > \varphi^B_{labmob}$ we have complete agglomeration just like chart 1 illustrates. Note, however, that due to presence of internal distance we thus have to adjust the definition of φ^B as follows, that is we have to define the free-ness of trade in terms of relative distance D_{rs}/D_{rr} (see Crozet, 2004, equation 16, p. 454 for a similar approach) and this holds for the break points in both the model with and without interregional labor mobility:

$$\phi^B = \left[\left[T(D_{rs})^{\gamma} \Big/ T(D_{rr})^{\gamma} \right]^{1-\varepsilon} \right]^B = \left[\left[\frac{D_{rs}}{D_{rr}} \right]^{\gamma(1-\varepsilon)} \right]^B \quad (10)$$

The break-condition (8) is not affected by our particular definition of the free-ness of trade parameter as given in equation (10), and this is also true for the break-condition (9). For the bell-shaped curve depicted by chart 2, and provided that equation (9) gives us 2 real solutions we know that (φ^B_{low} and φ^B_{high} denote the 1st and 2nd breakpoint in chart 2):

- for phi-values where $\varphi < \varphi^B_{low}$ or $\varphi > \varphi^B_{high}$ the spreading equilibrium is locally stable (there is no agglomeration),
- for phi-values where φBlow < φ < φBhigh, the economy is on the Bell part of the bell-shaped curve where the equilibria display (partial) agglomeration.

From equation (9) it is thus clear that the value of the 2 break- points φ^B_{low} and φ^B_{high} do as such *not* depend on the specification of the transportation costs function. Given, see equations (8) and (9), parameter values for μ,η,δ and ε, we can arrive at a specific value for the various break points φ^B. If we then use this in equation (10) and also plug in our estimates for ε and γ, we know the threshold value for the relative distance $\frac{D_{rs}}{D_{rr}}$ that corresponds with the break point. Comparing this threshold with the actual relative distance between regions r and s provides then information as to the spatial reach of agglomeration forces.

Before we can confront our estimation results with the break-point conditions (8) and (9) and taking into account that the definition of the free-ness of trade as given by equation (10), we thus finally need some benchmark numbers for the parameters μ,η,δ (given that we already have an estimate for ε). Recall that these 4 parameters suffice to yield the break-points for the 2 models. For the last parameter we can start with our own estimations for the substitution elasticity (see Table 1) for the other three parameters we follow Puga (1999) and Head and Mayer (2004a) and use as our benchmark values $\mu=0.3, \eta=200, \delta=0.1$. It is important to keep in mind that the conclusions are of course sensitive to the choice of parameter values. Having said this, an extensive sensitivity analysis showed that our main conclusions hold up for a broad range of parameter values (not shown here but available upon request).

Table 2 gives for both the Tomahawk and Bell curve and for a number of alternative parameter values the break points φ^B_{low}, φ^B_{high}, and φ^B_{labmob} respectively. That is to say, these are the results for the break points when we apply the benchmark values for the 4 parameters to equations (8) and (9). Generally speaking it is true in *both* versions of the NEG model that the range of values of φ for which the symmetric equilibrium is stable shrinks and, conversely, for which (partial) agglomeration is stable expands whenever, *ceteris paribus*, $\mu,\eta,$or δ get larger and/or ε gets smaller (see also Puga, 1999, eq. 18). The economic intuition for this is clear. If the importance of intermediate inputs in production increases (larger μ) it gets more attractive for firms to agglomerate in order to benefit from the intermediate cost and demand linkages between firms as explained in section 3. If the elasticity of labor supply increases, firms will find that relatively low manufacturing wages can already persuade workers to move from the H-sector to the manufacturing sector. This decreases the strength of this congestion or spreading force. Also, a larger expenditure share of manufacturing goods benefits agglomeration because it increases the relevance of demand linkages. Finally, a lower value for the substitution elasticity stimulates agglomeration. Note, that this elasticity provides a measure of the (equilibrium) economies of scale, where the economies of scale are measured as $\varepsilon/(\varepsilon-1)$. A decrease of ε thus means an increased relevance of firm specific increasing returns to scale which boosts agglomeration.

Table 2: The Break-Points for Alternative Parameter Settings (Benchmark Parameter Values in Bold, Including the Estimated Value for ε)

Key parameters	Φ^{B}_{low}	Φ^{B}_{high}	Φ^{B}_{labmob}
M=0.2 ,η=200,δ=0.1, ε=9.53	0.55	0.77	0.20
M=0.2 ,η=200,δ=0.1 , ε=4	0.44	0.90	0.05
M=0.3 *,η=200, δ=0.1, ε=9.53*	0.30	0.89	0.11
M=0.2 ,η=250,δ=0.1 , ε=9.53	0.51	0.83	0.18
M=0.2 ,η=200,δ=0.05, *ε=9.53*	0.55	0.77	0.33
M=0.1 ,η=200,δ=0.05 and *ε=5*	Symm	Symm	0.52
M=0 ,η=0,δ=0.1 and *ε=8*	Symm	Symm	0.65

Notes: symm indicates that the symmetric equilibrium is stable for all values of phi. The break-points are derived for the case of n=2 regions. In case n>2, analytical solutions for the break-points do not exist unless, sse the Appendix in Puga 1999, one sticks to the assumption of equidistance between all regions, see the main text for a further discussion of this issue.

Source: Authors' calculations.

Table 2 gives rise to the following three conclusions.

First, the values for the various break-points are indeed sensitive to the parameter settings even though the direction of change can thus be predicted.

Second, it matters whether one chooses the model version with or without interregional labor mobility. As a rule, over the whole range of permissible φ's, $0 < \varphi < 1$, the agglomeration range is smaller (!) in the bell-shaped world than in the Tomahawk world. Also, the symmetric equilibrium gets unstable for lower values of φ. Hence, a process of economic integration gives rise more quickly to agglomeration in the model without interregional labor mobility.

The third and, most important, conclusion relates for our set of benchmark parameters values (see table 2), the empirical estimates for the free-ness of trade parameter from table 1 with the break-conditions (8) and (9). With μ=0.3 *, η=200, δ=0.1* and *ε=9.53* (from table 1, second column), we get from break conditions (9) and (8) respectively that φ^{B}_{low} =0.30, φ^{B}_{high} =0.89 and, for the tomahawk, that φ^{B}_{labmob} =0.11. Combining this with our estimates of γ=0.19 and ε=9.53 we can derive the critical or threshold relative distance D_{rs}/D_{rr} that corresponds with each of these 3 break-points.

From condition (9) or (8) we get values for φ^B and we also know, see equation (10), that $\phi^B = \left[\left[\frac{D_{rs}}{D_{rr}}\right]^{\gamma(1-\varepsilon)}\right]^B$ and given our estimates for the distance parameter γ and the substitution elasticity ε we get the hypothetical relative distance that corresponds with the break point.

More precisely we get for

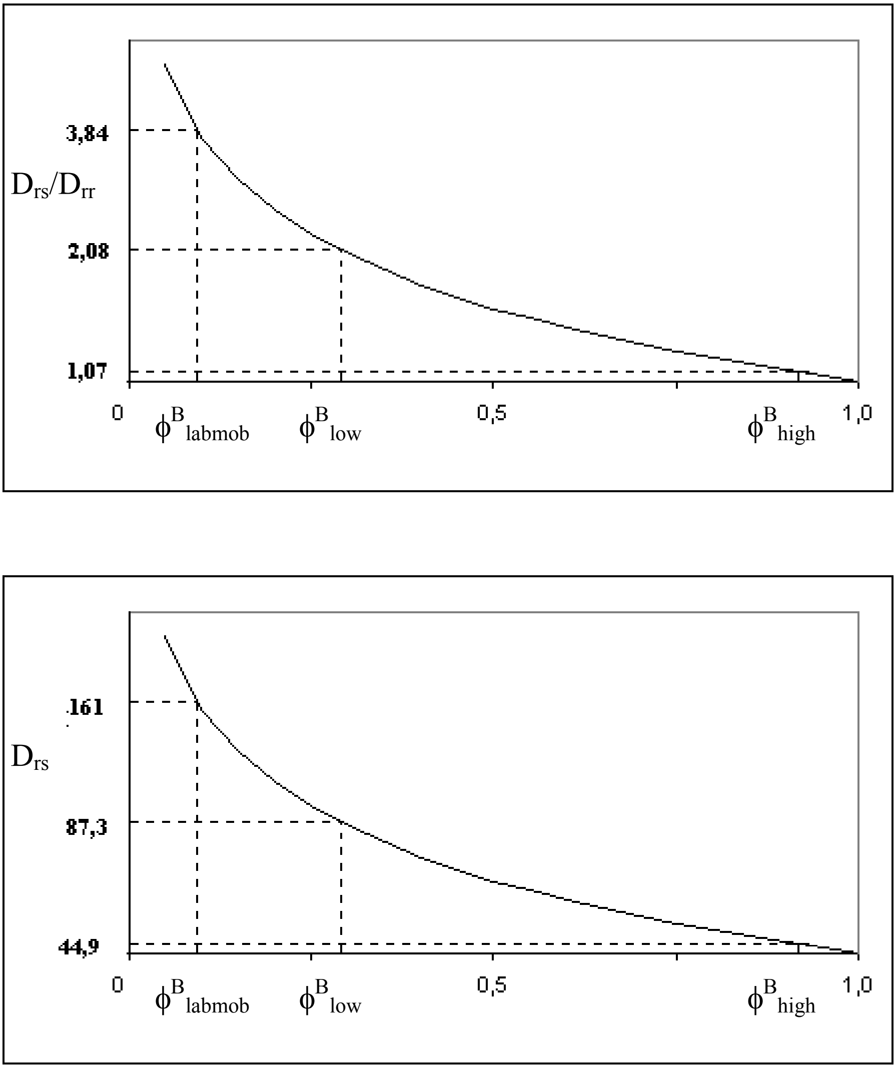
- $\varphi^B_{low} = 0.30 \rightarrow D_{rs}/D_{rr} = 2.08$
- $\varphi^B_{high} = 0.89 \rightarrow D_{rs}/D_{rr} = 1.07$
- $\varphi^B_{labmob} = 0.11 \rightarrow D_{rs}/D_{rr} = 3.84$

These results imply that the agglomeration does not extend further than 1–4 times the internal distance of a region. To see this, note that the average internal distance for the *NUTS 2* regions is 42 km. With this value for internal distance D_{rr} we get from the perspective of region *r* a "critical" or threshold external distance D_{rs} for the model underlying the bell-shaped curve of 87.3 km. for φ^B_{low} and 44.9 km. for φ^B_{high}. This means that for any actual D_{rs}>87.3 km we are in chart 2 to the left of the first break-point where spreading rules. Along similar lines, it is only when the actual D_{rs}<44.9 km. that spreading rules again. In between, that is for 44.9 km<D_{rs}<87.3 km, we are on the part of chart 2 with (partial) agglomeration. For the Tomahawk, chart 1, the threshold external distance D_{rs}=161 km. Here, the range or radius of agglomeration forces is thus somewhat stronger but still rather limited if one considers the fact that the distance between any pair of economic centres for the case of the EU *NUTS 2* regions is often much larger than 161 km. Chart 3 summarizes our findings.[13] The conclusion about the rather limited spatial reach of agglomeration forces does not change when we substitute our benchmark parameter values for one of the other possibilities shown in table 2. In most other cases and compared to our benchmark, the values for φ^B_{low} and φ^B_{labmob} are higher which means that the threshold distance D_{rs} beyond which agglomeration forces are no longer present is even *lower* than for the set of benchmark parameter values.

Chart 3 summarizes our findings. The top panel of chart 3 gives for our three respective break points the relative threshold distance D_{rs}/D_{rr} and the bottom panel does the same for the external distance D_{rs} under the assumption that the internal distance is 42 km.

[13] Our third conclusion is in line with the findings by Crozet, 2004, table 6). He conducts a similar analysis the major difference being that the break point analysis is limited to the Krugman (1991) model (the break condition (8) with μ=η=0) and the fact that Crozet estimates his model for 5 EU countries (for each country separately).

Chart 3: Break Points and Threshold Distances



Note: Top panel: ε=9.53, γ=0.19; Bottom panel: ε=9.53, γ=0.19 , D_{rr}=42 km. Benchmark parameter values: μ=0.3, η=200, δ=0.1

Source: Authors' calculations.

To put our results into perspective, in the *Appendix* we estimate a simple market potential function to get some idea about what the centre regions are in our sample of EU+ regions. We list 39 regions with the highest market potential (we stopped when London entered the list), this is, of course, rather ad-hoc but it nevertheless gives an indication as to what chart 3 implies. For these 39 centre regions, the average distance to each other is 309 km. (of these regions, the region Limburg in Belgium has the lowest average distance to the other 38 regions: 220 km.). Set against chart 3 these distances imply that *on average* agglomeration forces emanating from a centre region *r* are too small or weak to affect other centre regions. Another way to illustrate our results is to take one particular region like the "most central" region, Limburg in Belgium (with D_{rr}=18.5 km*.),* or the region with highest market potential, Nordrhein-Westfalen in Germany (with D_{rr}=69.4 km*.),* and to calculate for these individual regions their threshold distance D_{rs}. Also for these 2 regions the spatial strength of agglomeration forces is such that only a very limited number of the other 38 regions are affected. For the region of Nordrhein-Westfalen for instance, 7 (14) other regions fall within the reach of Nordrhein-Westfalen, that is have a distance to Nordrhein-Westfalen that is lower than the threshold D_{rs} that corresponds to φ^{B}_{low} (φ^{B}_{labmob}).

To understand what we do and do not claim, it is important to be clear as to what we have done. For our sample of NUTS 2 regions, we estimate the wage equation (7') and this helps us to arrive at the free-ness of trade parameter for any region r with distances D_{rs} and D_{rr}. Once we do this we can derive region-specific free-ness of trade parameters. The NEG theory (the Tomahawk and bell-shaped curve) gives us the break-points, but only for the case of 2 regions. Solutions for these break points for the case of n>2 only exist for the case where distance is normalized (this is an innocent assumption to make as long as n=2 but no longer so when n>2 because it means assuming equidistant regions).[14]

Using our estimates for the substitution elasticity and the distance parameter from table 1 we can calculate implied threshold distances between regions r and s at which a break point occurs. This implied distance is shown in chart 3, and gives

[14] Suppose that we stick to the assumption of equidistant regions for n>2, then it can be shown (Puga, 1999, Appendix), that the number of regions (n) enters the break conditions (8) and (9) as an additional parameter. For a large number of regions, like our sample of NUTS 2 regions, the result is that when n increases $\varphi^{B} \approx 0$, which means that the corresponding threshold distance D_{rs} also approaches zero km. This would mean that for any real distance D_{rs} between any pair of regions we are always in the agglomeration regime. Symmetry is no longer viable (which is not very surprising in the sense that symmetry, every region having exactly a share of 1/n of the footloose production, is a rather stringent condition when n is large). Besides, it is not clear how to call an equilibrium in which n-1 regions have the same share of the manufacturing production but the n^{th} region is larger: is this symmetry or agglomeration? Most importantly, however, the underlying assumption of equidistant regions is hard to maintain for n>2 to start with. If one wants to analyse the long run equilibria and the associated break points for n>2 regions, analytical solutions do not exist and one has to restore to simulations which also has clear drawbacks.

an idea about the geographical reach of agglomeration forces. Or stated differently, these differences "indicate how far the agglomeration forces emanating from a region extend across space" (Crozet, 2004, p. 454). For a region r with an internal distance of D_{rr} , we arrive at the threshold distance D_{rs} at which the balance between agglomerating and spreading forces changes sign. We thereby establish in chart 3 for any region r for both NEG models the radius (measured by D_{rs}) within which agglomeration or spreading forces dominate. This is of course a partial analysis. An alternative approach would be to confront our estimation from table 1 with a NEG model and corresponding break-points for n regions, where n is the number of NUTS 2 regions. The difficulty with such a strategy is that we have to rely on simulations since no analytical solutions thus exist (or make sense) for the break-points in case of n>2 regions (see footnote 14).

5.1 Choosing between Models and Some Sub-Sample Estimations

The discussion so far begs the question, which of the two models is the most relevant. A priori, our preference is with the second class of NEG models, in which labor is not mobile between regions. It implies less extreme agglomeration patterns (compare charts 1 and 2). This seems more in line with the stylized facts for the EU and elsewhere. These models also incorporate the stylised fact that labor mobility is larger within countries than between countries. Having said this, we cannot dismiss the first of class of NEG models out of hand for basically three reasons:

- Both models assume wage flexibility. With wage rigidity (Faini, 1999, Puga, 2002) we return to the Tomahawk chart because agglomeration by definition does not lead to a wage differential between regions and there will be no thus wage gap (and even no wage cost differential) between core and peripheral regions.
- Wage rigidity is larger within EU countries than between EU countries, this might be relevant in deciding which (regions versus countries) which NEG model is relevant.
- Even though interregional labor mobility is relatively low in the EU (compared to for instance the U.S.A.), labor mobility is higher within than between countries and this might be relevant in deciding which class of NEG models applies for what geographical scale. Also, with increasing economic integration in the EU interregional labor mobility might increase in the future which might make the world of the Tomahawk curve more relevant.

Given the stylised facts on wage rigidity and labor (im)mobility within the EU, does this mean that the “bleak conclusions” of the Tomahawk model as to the impact of ongoing economic integration on agglomeration are pervasive? No, not necessarily. One can think of alternative congestion forces for core regions besides higher wages that also give rise to a bell-shaped curve even with (!) interregional labor mobility. The best example is due to Helpman (1998) and Hanson (2001) where instead of immobile workers (a non-traded input) we have a non-traded consumption good, in their case housing but one think of various non-traded services of which the price rises when agglomeration increases. This can be looked upon as agglomeration costs. Ottaviano, Tabuchi and Thisse (2002) show that such a non-traded good may act as a powerful dispersion force that may act as a brake on agglomeration.[15]

Finally, and partly inspired by the relevance of the workings of the labor market, we checked whether our estimation results and hence the conclusions with respect to the implied free-ness of trade φ would change if we (i) changed the sample period; (ii) estimated wage equation (7') for a sub-set of countries. To start with the first issue, recall that the estimation results in table 1 are based on a pooled estimation for all EU regions for the period 1992–2000. We also estimated wage equation (7') for each of these years separately. Assuming that the degree of economic integration in the EU, if anything, increased during the 1990s, one might expect the degree of competition as measured by the mark-up of price over marginal cost, $\varepsilon/(\varepsilon\text{-}1)$, to fall and thus the substitution elasticity ε to fall overt time. Similarly, one might expect the distance parameter γ to fall during these years. It turns out that, however, that both substitution elasticity and the distance parameter hardly change over time. This also means that the implied free-ness of trade parameter hardly changes over time. For our preferred estimation procedure (WLS, 2SLS) for instance, we got (t-value between brackets) for ε a coeffcient of 10.1 (11.4) and 8.9 (10.8) for respectively the period 1992–1995 and 1997–2000, and similarly for γ a coeffcient of 0.18 (14.5) and 0.20 (14.4).

As indicated above, the degree of interregional labor mobility and wage flexibility is important in deciding which of the 2 models is more relevant. National labor market institutions are important determinants of labor mobility and wage flexibility and these institutions differ markedly between EU countries. In corporatist countries for instance there is coordination of wage bargaining with relatively little room for interregional wage differences and, if anything, interregional labor market adjustments have to be realized through labor mobility. Relatively, that is to say compared to non-corporatist countries where there is ceteris paribus more room for interregional wage differences. This would imply that the Tomahawk (Bell curve) model seems more relevant for corporatist (non-corporatist) countries. We have therefore also estimated wage equation (7') for the period 1992–2000 for a group of corporatist countries (Belgium, Germany, Netherlands, Austria, Sweden, Denmark and Ireland) as well as for a group of non-corporatist countries (UK, France, Spain, Portugal, Italy and Greece).[16] For both

[15] The key here for the possibility of (renewed) spreading at low trade costs (a large φ) arises in NEG models when the strength of the spreading or congestion forces do not fall when trade costs fall: "with any (…) congestion force unrelated to trade costs, the equilibrium pattern of location will return to dispersion for some (low) trade costs threshold" (Head and Mayer, 2004a, p. 2652).

[16] The classification is based on Schramm (1999).

groups the estimation results for ε and γ are such that the relative threshold distances D_{rs}/D_{rr} that correspond to the three φ break points (given the estimates for ε and γ), see chart 3, are nearly the same as those shown in chart 3. Also, using other criteria to split the sample into groups of countries, like the size of countries (area per km^2), showed that our conclusions w.r.t. the implied relative threshold distance, as shown by chart 3, are quite robust.

6. Bilateral Country Trade Flows and Sector φ's

Our estimations are based on *aggregate* data for each *NUTS 2* region. That is to say, we did not use regional data on the distribution of wages, valued added or other variables for the various *sectors* in a region. The reason is simply that these data are not available at the NUTS 2 level. In order to arrive at an "educated guess" what the free-ness of trade parameter could look like for various manufacturing *sectors* for the EU, we follow Head and Mayer (2004a). They explain that the free-ness of trade parameter can be approximated through the use of bilateral trade and production data. These data are available at the *country* level (and, not at the EU regional level). Based on Head and Ries (2001), they define a very simple estimator for the free-ness of trade parameter which can be derived from any basic NEG model:

$$\varphi\text{trade} = \sqrt{m_{ij}m_{ji} / m_{ii}m_{jj}}$$

where the numerator denotes the imports of country i from country j and vice versa; the denominator denotes for both country i and country j the value of all shipments of a industry minus the sum of shipments to all other countries (Head and Mayer, 2004a, p. 2618)

If the bilateral trade between these 2 countries is relatively important (unimportant), φ_{trade} is relativey high (low): $0<\varphi_{trade}<1$. The advantage of this "estimator" for the free-ness of trade parameter is that no actual estimations are required. Head and Mayer calculate φ_{trade} for 21 industries and two country pairs (Canada/U.S.A. and France/Germany) for 1995 and then confront their implied free-ness of trade parameter with *industry-specific* Bell curves. These are derived by plugging in industry-specific values for the respective parameters in the break condition (9).[17] The main result is that, almost without exception, for each of the 21 industries φ_{trade} is rather low (in the range of 0.1–0.2) to the effect that for both

[17] For the data-sets and the actual values used to come up with industry specific measures for the intermediate input share, the labor supply elasticity, the share of manufacturing gods in total expenditure, and the substitution elasticity for manufactures (a.k.a. the increasing returns parameter) see Head and Mayer (2004a, pp. 2664–2665).

pairs of countries most industries are still to the left of the Bell part: that is, φ_{trade}-$<\varphi^B_{low}$.

We applied Head and Mayer's methodology for the case of the EU to see how our results compared to their findings and also to see if our main conclusions from the previous section carry over to the sector level. In our first experiment we took Germany as our benchmark country and paired Germany with 3 other EU countries (Spain, UK, and the Netherlands) and with a new EU member (Poland). Using as much as possible the Head and Mayer sector classification (see table 4 below) we calculated φ_{trade} for the 4 country pairs for the years 1985, 1990, 1994 and 1998. For the first 3 years we used World Bank data and for 1998 we used the OECD STAN data. Data for Poland were only available for 1990 and 1994. In line with the findings by Head and Mayer, the respective values for our φ_{trade} gradually increase over time but they remain relatively low. Only for a few sectors we came up with a φ_{trade} that exceeds the break point φ^B_{low} in the Bell-curve model and φ_{labmob} in the Tomahawk case. The sectors with agglomeration in some years are clothing, wood, plastics and drugs, ferrous metals, and transport. The overall picture is, however, one of a "pre-agglomeration" degree of economic integration (results not shown here but available upon request).

Table 3: Sector-Specific Free-ness of Trade

IOcode	*Sector*	φ_{trade}	φ^B_{low}	φ^B_{labmob}
1	Agriculture	0.027	NA	NA
2	Energy	0,012	NA	NA
3	FoodBevTobacco	0.047	0.46	0.22
4	Clothing	0.1355	0.21	0.18
5	Wood	0.046	0.39	0.36
6	Paper	0.033	0.17	0.16
10/8	Plastics and Drugs	**0,127**	0.109*	0.104
9	Petro	0.017	symm	0.71
11	Minerals	0.036	0.47	0.44
12	Ferrous metals	**0.038**	0.0**	aggl
13	Non-ferrous metals	0.029	0.09	0.06
14	Fab. Metals	0.050	symm	0.69
15/16	Machinery (and Computers)	0.253	0.43	0.36
17	Electrical	0.090	0.67	0.39
19/20	Ships/railroad/transport***	0.0112	0.46	0.39
21	Vehicles	**0.132**	0.10****	0.08
23	Instruments	0.0155	0.57	0.45
18	Services	0.162	NA	NA

Note: * $\varphi_{bell-top}$=0.545; ** $\varphi_{bell-top}$=0.50; **** $\varphi_{bell-top}$=0.49
***=based on railroad which has lowest φ^B of these 3 sectors in Head and Mayer, 2004a
NA=not available; symm= local stability of symmetric equilbria for all values of φ;
aggl= only full agglomeration stable.

Our second experiment was to compute φ_{trade} for the bilateral sector trade between the group of 15 EU countries versus the group of 10 accession countries, the new EU members from central and eastern Europe. Based on GTAP data for 1997, table 3 gives the computed free-ness of trade parameter φ_{trade} and compares this implied degree of economic integration with the two break-points φ^{B}_{low} (the Bell-curve model) as well as with φ_{labmob} (the Tomahawk model). The parameter values needed for the derivation of these 2 break-points for the various manufacturing sectors are taken from Head and Mayer (2004a, Appendix). For "non-manufacturing sectors" agriculture, energy and services such a theoretical benchmark was not readily available. For the manufacturing sectors the overall conclusion must be that the degree of economic integration for most sectors is such that we are not (yet) in the agglomeration regime. The exceptions are (see the scores in bold) Plastics and Drugs, Ferrous Metals, and Vehicles. However, even for these 3 sectors the free-ness of trade parameter is such that these sectors are only at the start of the upward sloping part of the Bell curve (see the respective $\varphi_{bell\text{-}top}$ values which gives the peak of the Bell curve for these sectors).[18]

In our view the results in table 3 with a free-ness of trade parameter based on bilateral trade data on the *country* level are in line with our calculations of φ for the case of the NUTS 2 regions. In the previous section it was only for regions that are relatively near to each other (in terms of D_{rs}/D_{rr}), that we found it possible to come up with implied values for φ that clearly exceeded the φ break-points for our two benchmark NEG models.[19]

7. Conclusions

The estimation of the equilibrium wage equation from a model by Puga (1999) for the EU *NUTS 2* regions yielded information on the so called free-ness of trade parameter, the NEG variable that stands for the degree of economic integration. The confrontation of the estimated free-ness of trade parameter with our two theoretical benchmarks as to the relationship between economic integration and agglomeration led us to conclude that the agglomeration regime is only relevant for regions that are relatively close to each other. At least in our 2 region setting, agglomeration seems to be a rather localized phenomenon. This last conclusion

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[18] Where $\varphi_{bell\text{-}top}$ is simply taken to be the midpoint $\frac{\phi^{B}_{low} + \phi^{B}_{high}}{2}$

 Compared to our calculations for the 3 break points in the previous section, the most notable difference is that in table 4 φ^{B}_{labmob} is on average larger. This is mainly due to the fact that Head and Mayer assume that the share of manufactured goods (which in their case refers to the share of the goods produced by a specific sector only) is smaller that the benchmark of $\delta=0.1$ that we used in the previous section (a lower δ ceteris paribus means weaker agglomeration forces).

was substantiated by free-ness of trade estimations based on bilateral trade data on the EU country level.

Where does this leave us? In our view the main findings of this paper are in line with the notion that agglomeration in the EU seems to be most relevant at lower geographical scales. Our findings are also in line with related studies like Davis and Weinstein (1999), Forslid et al. (2002), Midelfart et al. (2003), Head and Mayer (2004a) and, also in terms of the methodology employed, Crozet (2004). The relevance of the proximity of agglomeration effects is also underlined by Brülhart, Crozet, and Koenig (2004) w.r.t the impact of the EU enlargement and its impact on incumbent EU regions. In their survey Head and Mayer (2004a) conclude that it seems that agglomeration forces are very localized, unable to generate core-periphery patterns in Europe at a large geographical level at least as long as labor remains so sensitive to migration costs. Our results back up this conclusion and they also show that if the degree of interregional labor mobility would increase (in our terms a move from the Bell curve towards the Tomahawk) that the geographical reach of agglomeration forces would increase. Finally, and this must be emphasized, even though we have gone at some length to take the NEG theory seriously empirically, these are very much preliminary results. Clearly, more research is needed in order to tell which NEG model is the most relevant at which geographical scale for the EU. As such, our results are very much illustrations of the potential empirical relevance of the NEG approach. Nevertheless, the main findings are interesting because they constitute, to our knowledge, one of the first attempts to confront estimations of the key structural NEG model parameters with theoretical NEG predictions as to how economic integration may impact upon the spatial distribution of economic activity. There is much that can be done to improve upon our initial findings. In this respect the NEG approach needs to be taken even more seriously. Two avenues of research come to mind. The first one is to come up with NEG models that incorporate key features like the difference between interregional and international labor mobility within a single model (see Behrens et al., 2003, Crozet and Koenig, 2002). This might lead to additional testable hypotheses that allow for a better choice between various NEG agglomeration mechanisms. The second one is simply to engage in better testing by making use of (econometric) insights from outside NEG proper and by making use of new (micro) data sets that are increasingly becoming available (Fingleton, 2004, Combes and Overman, 2003).

Appendix

A1. Data Description

Nominal wage is defined as compensation of employees per worker (NUTS 2 level, except for Germany – NUTS 1).

The measure of regional purchasing power is gross value added (all sectors). Time series are nominalised by using the GVA-series of Cambridge Econometrics, which are denominated in euro's of 1995, and the price deflator of national GDP (AMECO-database).

In the RMA we included the NUTS 2 regions of EU14 (=EU-15 excluding Luxembourg) + Norway, Czech Republic, Poland, Hungary, Switzerland. MPL (marginal labor productivity) is proxied by real gross value added per employee. EU+= EU 14 (= EU excluding Luxembourg) + Norway, Switzerland, Hungary, Poland, Czech Republic. For the approximation of the price index I_r see the appendix.

For wages we used the EU 14 only. All wage, income and production data are taken from The European Regional Database (summer 2002 version) from Cambridge Econometrics.

Distance is in km.

A set of additional control variables for each NUTS 2 region that potentially consists of mean annual sunshine; mean elevation above sea-level; and dummy variables (country dummy, border-region dummy, access to sea dummy, access to navigable waterway dummy). The variables mean annual sunshine radiation in kWh/m² (sunshine) and mean elevation above sea-level in metres are taken from the SPESP database (see:http://www.mcrit.com/SPESP/SPESP_reg_ind_final%20report.htm).

A2. Introducing Regional Factor Productivity Differences in the Model with Intermediate Inputs

Free entry and exit and the use of the zero-profit condition leads to the equilibrium output for firm *i* in region *r*:

$$x_{ir} = \frac{\alpha.(\varepsilon - 1)}{\beta_{ir}}$$

The point to notice is here is that the marginal input requirement β_{ir} is now region specific which means that factor productivity can differ between regions. Suppose the regional factor productivity gap can be approximated by the difference in marginal labor productivity in region r and the average of the marginal labor productivity for the EU NUTS 2 regions

We define $MPL_{EU+}/MPL_{ir}=\beta_{ir}$

The equilibrium demand facing each firm *i* is

$$x_d = \frac{p^{-\varepsilon}}{I^{(1-\varepsilon)}} Y$$

Summing over all firms, using the mark-up pricing rule $p = \frac{\varepsilon}{\varepsilon - 1} \beta_r W^{1-\mu} I^{\mu}$, and taking iceberg transportation costs into account gives:

$$x_r = \sum_{s=1}^{R} \left[\left(\frac{\varepsilon}{\varepsilon - 1} \frac{W_r^{1-\mu} I^{\mu} T_{rs} \beta_r}{I_s} \right)^{-\varepsilon} T_{rs} \frac{Y_s}{I_s} \right]$$

where T_{rs} is transportation costs, and I is the price index of manufactures.
This expression is equal to the break-even supply of each firm:

$$\frac{\alpha.(\varepsilon - 1)}{\beta_r} = \left(\frac{\varepsilon}{\varepsilon - 1} W_r^{1-\mu} I^{\mu} \beta_r \right)^{-\varepsilon} \sum_{s=1}^{R} \left[\left(\frac{T_{rs}}{I_s} \right)^{1-\varepsilon} Y_s \right]$$

The wage in region *r* determined by solving this break even equation for the wage W_r, and this gives:

$$W_r = \beta_r^{\frac{1-\varepsilon}{\varepsilon.(1-\mu)}} \varepsilon^{\frac{1}{\mu-1}} (\varepsilon - 1)^{\frac{\varepsilon-1}{\varepsilon.(1-\mu)}} I_r^{-\mu/(1-\mu)} \alpha^{\frac{-1}{\varepsilon.(1-\mu)}} \sum_{s=1}^{R} \left[\left(\frac{T_{rs}}{I_s} \right)^{1-\varepsilon} Y_s \right]^{\frac{1}{\varepsilon.(1-\mu)}}$$

where $I_r=[\sum(T_{rs}\, p_s)^{1-\varepsilon}]^{1/(1-\varepsilon)}$

The log transformation of this expression results in the log transformation of wage equation (7), equation (7') in the main text:

$$\log(W_r) = \text{constant} + \frac{1-\varepsilon}{\varepsilon.(1-\mu)} \log(\beta_r) - \frac{\mu}{1-\mu} \log(I_r) + \frac{1}{\varepsilon.(1-\mu)} \log\left[\sum_{s=1}^{R} Y_s (T_{rs})^{1-\varepsilon} I_s^{\varepsilon-1} \right]$$

The productivity gap β_r is thus measured as $MPL_{EU+}/MPL_r=\beta_r$

To really be able to estimate this specification of the wage equation we finally need to approximate the price index *I*

A3. How to Approximate the Price Index I?

For the model without intermediate inputs (μ=0), we do so as follows:

For each region we focus on two prices: the price in district *r* of a manufactured good produced in district *r* and the *average* price outside district *r* of a manufactured good produced outside district *r*. The determination of the simplified local price index for manufactures requires a measure of distance between region *r* and the regions outside. The distance from the economic center is an appropriate measure in our view. This center is obtained by weighing the distances with relative Y. Here we make use of the estimation results based for a simple market-potential function for our sample of EU *NUTS 2* regions. Regions with largest market-potential MP, see table A1, are considered to be centres where for each region its MP is defined as:

$$MP = \log\left[\sum_s Y_s e^{-\kappa_2 D_{rs}}\right]$$

Table A1: Regions with Largest Market Potential, 1995 Data (in Descending Order of Market Potential)

1995	κ_2= .007
1	Nordrhein-Westfalen
2	Limburg
3	Limburg(B)
4	Luik
5	Noord-Brabant
6	Vlaams-Brabant
7	Baden-Württemberg
8	Rheinland-Pfalz
9	Gelderland
10	Antwerpen
11	Waals-Brabant
12	Brussel
13	Namen
14	Utrecht
15	Ile de France
16	Oost-Vlaanderen
17	Hainaut
18	Bayern
19	Zuid-Holland
20	Zeeland
21	Nord-Pas de Calais
22	Saarland
23	Luxembourg(B)
24	West-Vlaanderen
25	Picardie
26	Champagne-Ard.

27	Alsace
28	Noord-Holland
29	Overijssel
30	Flevoland
31	Niedersachsen
32	Lorraine
33	Vorarlberg
34	Ostschweiz
35	Zurich
36	N_W Schweiz
37	London
38	Kent
39	Zentralschweiz

The distance between a region r and the nearest center region (out of the list of the 35 regions with the largest MP for the *NUTS 2* regions, see table A1) gives us $T_{r,center}$ in the equation below:

$$I_r = \left[\lambda_r W_r^{1-\varepsilon} + (1-\lambda_r)\left(\overline{W}_r T_{r,center}\right)^{1-\varepsilon}\right]^{1/(1-\varepsilon)},$$

where $\overline{W}_r$ is the average wage outside district *r*, and weight λ_r is region *r*'s share of employment in manufacturing, which is proportional to the number of varieties of manufactures (λ is proxied by (regional employment) / (EU+employment)).

This simplified price index makes it possible to directly estimate our specification of the wage equation with factor productivity differences and *without* intermediate inputs.

The productivity gap between EU regions and the EU average also affects the price index equation, because marginal costs changes into (with μ=0):

$$MCir = Wir\beta ir,$$

and so the simplified price index equation finally becomes –dropping subscript *i*:

$$I_r = \left[\lambda_r (W_r \beta_r)^{1-\varepsilon} + (1-\lambda_r)\left(\overline{W} T_{r,center}\right)^{1-\varepsilon}\right]^{1/(1-\varepsilon)}.$$

Now we are ready and our specification for the wage equation from the main text for the case of μ=0 and hence with the above approximation for the price index.

For the model with intermediate inputs this "trick" to approximate the price index, now the price index for *intermediates*, will not do as easily. The reason is that the equilibrium price index is now not only a function of wages but also of itself:

$$I_r = \left[\sum_{s=1}^{R} \frac{\varepsilon}{\varepsilon - 1} \beta T_{rs} W^{1-\mu} I^{\mu} \right]^{1/(1-\varepsilon)} \qquad (3'')$$

This follows directly from the fact that we now have two factors of production (labor and the intermediate goods) and that the equilibrium price a manufacturing firm charges is

$$p = \frac{\varepsilon}{\varepsilon - 1} \beta_r W^{1-\mu} I^{\mu}$$

As a result the equilibrium price index, the summation of the price each firm charges corrected for distance (the suppliers access variable), is a function of both the wage *W* and the price index *I*.

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