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 (NEG) model by Puga (1999), we use the equilibrium wage equation to estimate two key structural model parameters for the NUTS II EU regions. These estimations enable us to come up with an empirically grounded *free-ness of trade* parameter. In line with NEG theory, the estimation results show that a spatial wage structure exists for the EU regions. By going back to the theoretical model we then analyze the implications of the free-ness of trade parameter for the degree of agglomeration. Our main findings suggest that agglomeration forces still have only a limited spatial reach in the EU. Agglomeration forces appear to be rather localized. At the same time, confronting our empirical results with the underlying new economic geography model also brings out the limitations of empirical research in new economic geography.

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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 to go 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. 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. In doing so, we will have to face the difficulties that arise in NEG models when empirical findings are confronted with the underlying model. In this sense our paper is also about the (current) limitations of empirical research in NEG.

Assessing the empirical relevance of NEG is not easy. It is well known that agglomeration patterns can be found at all levels of aggregation (country, region, city). But this does not necessarily imply 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 (labour market) institutions (like the USA 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, 2004). 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. In recent theoretical work by Robert-Nicoud (2004) and Ottaviano and Robert-Nicoud (2004) this last issue is also stressed.

In this paper we will address some of the above issues. More in particular, based on a seminal NEG model (Puga, 1999), we estimate the equilibrium wage equation. This procedure gives estimates of two key structural model parameters for our sample of the NUTS II 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". In our view the estimation of the wage equation and the implications for the free-ness of trade parameter for the sample of EU regions is already very useful. One of the 5 key predictions of NEG (Head and Mayer, 2004a) is that agglomeration raises factor prices and this is precisely what the estimation of the wage equation sets out to establish. But in this paper the estimation of the wage equation and its structural parameters is to some extent only a means to an end. Using our estimation results, we subsequently also try to find out what the estimations imply for the degree of agglomeration across the EU regions. To be able to do this, we have to confront our estimations with the underlying NEG model. Here, we are after a second of the 5 key predictions of NEG that at some point a fall in trade costs, here an increase of the free-ness of trade, will induce agglomeration. In order to be able to do this, we have to take the estimation results back to the theory. As we will show, by taking NEG empirics this one step further we will only be able to confront the free-ness of trade and the degree of agglomeration for the EU regions by making rather strong assumptions. In fact, this confrontation between NEG empirics and theory illustrates the limitations of NEG research in our view. Nevertheless, this additional step, from empirics back to NEG theory, is crucial in our view because in many ways the hallmark of NEG is the analysis of the impact of changes in the free-ness of trade on the degree of agglomeration, the latter being an endogenous variable.

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 spatial allocations of economic activity that are consistent with this wage equation, but have different predictions as to what happens with the degree of agglomeration when the free-ness of trade increases. Section 4 presents our basic estimation results. The estimation of the equilibrium wage equation yields coefficients for the transport 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. The estimations show that a spatial wage structure exists for the EU regions. Subsequently, section 5 confronts the findings of section 4 with our benchmark model and here we discuss the implications of our findings for the degree of agglomeration for the EU regions. As it turns out, one is, however, only able to do so by making short cuts. By using bilateral country trade data, section 6 extends the analysis to the sector level. Finally, section 7 concludes. Overall, and taking the limitations of our analysis into account, our main finding is that agglomeration forces do not extend very far. Agglomeration forces appear to be rather localized.

2 The Model and the Wage Equation

In this section we give a brief description of the Puga (1999) 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. 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 intranationally. 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. 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 part 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 $Y = \delta E + \mu n p x^*$. 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 side 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); x^* denotes the equilibrium supply of a manufacturing variety by a single firm, see below.

Manufacturing Supply

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

(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) $x_i = \dfrac{\alpha(\varepsilon - 1)}{\beta} = x*$

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 $x_1 = \dfrac{\alpha(\varepsilon - 1)}{\beta}$, equating this to total demand gives (note that the demand from region 2 is multiplied by T_{12} 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.[2] 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) $W_r = Const\{I_r\}^{-\mu/(1-\mu)} \left[\sum_s Y_s I_s^{\varepsilon-1} T_{rs}^{\ (1-\varepsilon)}\right]^{1/\varepsilon(1-\mu)}$

[2] 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.

W_r is the region's r (nominal) wage rate, Y_s is expenditures (demand for final consumption and intermediate inputs), I_s is the price index for manufactured goods, ε is the elasticity of substitution for manufactured goods and T_{rs} are the iceberg transport costs between regions r and s. Note that when we want to estimate wage equation (7) for our sample of NUTSII EU regions we need to come up with a specification of the transport costs T_{rs} , this will be done in section 4. In particular we will have to answer the question how transport 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 regions or sectors. This mobility and hence the endogenous location choice are really the key feature of NEG.

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, 2004). 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 market potential function where typically only nominal market access matters.

Finally, the term $I^{\mu/(1-\mu)}$ in wage equation (7), is known as *supplier access, SA* (Redding and Venables, 2004). 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.[3] In the short-run when the spatial distribution of firms and workers is fixed, demand differences between regions will be fully reflected in regional wage differences. Or, in other words, 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).[4] All that matters for our empirical analysis in section 4 is that wage equation (7) is the equilibrium wage equation and that it can be estimated. However, it will trun out in section 5 that 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 [5]

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 Figure 1. Economic integration implies lower transportation costs. In Figure 1 this is a movement from left to right along the horizontal axis, from low to high values for φ. 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: φ_{rs} =0 denotes autarky and the absence of economic integration whereas φ_{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 Figure 1 shows the share of

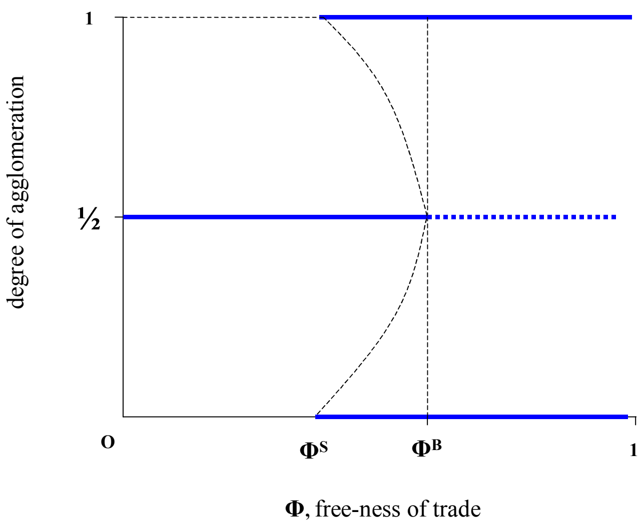
[3] This has an additional advantage in that we do not have to consider the long-run adjustment mechanism, that is, whether or not firms are mobile or instead labor (see Puga, 1999, p. 310).

[4] 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-sector elasticity of manufacturing labour supply (see Head and Mayer, 2004b). With an infinite elastic labour 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 postively sloped labour supply function w.r.t. 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. In section 5 (see Figure 3) we will return to this topic of price versus quantity adjustment.

[5] 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.

the footloose labor and hence the degree of agglomeration in region 1. Figure 1 gives the well known Tomahawk figure that results from NEG models, like Krugman (1991), with interregional labour mobility and it shows how changes in free-ness of trade might change the degree of agglomeration.

Figure 1 The tomahawk



As Figure 1 illustrates the point where it becomes profitable for the footloose firms and workers to agglomerate in either region 1 or 2 is indicated by φ^B, 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. 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 Figure 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.[6]
Puga (1999, eq. 16) derives the following analytical solution for the break-point for the 2 region case (dropping subscripts r and s):

[6] 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 Figure 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).

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

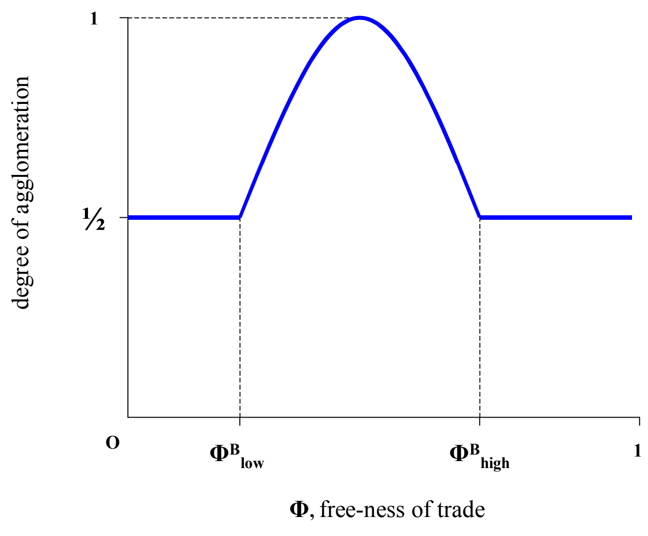
We introduce equation (8) because it will be used in sections 5 and 6. The elasticity η is the elasticity of a region's labor supply from the H-sector to the manufacturing sector. If η = 0, no inter-sector labor mobility is possible, if η = ∞ there is perfect labor mobility between sectors, that is to say the inter-sector 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 < η < ∞ 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 η = 0), or Krugman and Venables (1995, where η = ∞). Most importantly, if 0 < η < ∞, 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 briefly discussed next.

No interregional labor mobility: the Bell-Shaped Curve

How relevant is the Tomahawk Figure for the analysis of EU integration and agglomeration? In international trade theory it is standard to assume that labour is mobile between sectors, but not across national borders. This assumption reflects the stylised fact that labour is less mobile across borders than within countries. Without interregional labour mobility agglomeration, however, is still possible (see Krugman and Venables, 1995). Firms may find it 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 manufacturing 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 labour 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 Figure 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 labour supply in the agricultural sector. The point to emphasize here is that an upward sloping labour supply function (with 0<η<∞), 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.

Without interregional labor mobility the long-run relationship between the free-ness of trade (economic integration) and agglomeration *might* look like Figure 2 which has aptly been called the *bell shaped curve* by Head and Mayer (2004a).[7] As in Figure 1, for the 2 region case we have φ on the horizontal axis and the degree of agglomeration on the vertical axis. For low degrees of economic integration (to the left of φ^{B}_{low}) we have spreading and similar to the previous section, once economic integration passes the break-point (here φ^{B}_{low}) 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 economic integration is pushed far enough, a second(!) break point, denoted φ^{B}_{high}, will be reached. From φ^{B}_{high} 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).

Figure 2 Bell-shaped curve



[7] It might but it need not, this depends on the exact parameter configuration, see the Appendix in Puga (1999) or Robert-Nicoud (2004). The point to emphasize is that what really distinguishes Figure 2 from Figure 1 is that once agglomeration has arrived the economy will stay in the agglomeration regime in Figure 1as economic integration increases further whereas in Figure 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

The solutions for φ^{B}_{low} and φ^{B}_{high} are the (real) solutions to the quadratic equation in φ (Puga, 1999, equation (33)):

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

As with equation (8), equation (9) will be used in sections 5 and 6. 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 (Figure 1 versus Figure 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.

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 T_{rs} increase exponentially with the distance between r and s, and T represents the transport 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 transport costs rise or fall more or less than proportionally with increased distance between r and s. If $0 < \gamma < 1$ transport 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 transport costs rise or fall more or less than proportionally with increased distance between r and s. Also, from a theoretical point of view, the second option is to be preferred (McCann, 2005**).** The distance variable D_{rs} will be measured in km. between *NUTSII* regions. The distance from a region *r* to itself, D_{rr} can be modelled in several ways. For internal distance we use the

"smooth", that is, partial agglomeration, equilibria like depicted in Figure 2 but one can also come up with a double tomahawk (Robert-Nicoud, 2004, p. 22-23) to depict this second possibility.

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} once we have estimates for ε and γ.

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 *NUTSII* regions and this means that I_r 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 W_r. 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 could try to make use of other equilibrium conditions to get rid of the price index altogether. This has its drawbacks too. For the case of the EU regions this would lead to new data requirements that cannot (easily) be met. Also, this strategy may imply, as it does in Hanson (2001), 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, however, by expressing 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 solve this problem (see Brakman, Garretsen and Schramm (2004) for more details. The Appendix illustrates this procedure of simplifying the price index.[8]

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. 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 labour productivity. Introducing labour productivity as an additional explanatory variable in the wage equation

[8] 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.

would, however, probably not be very useful. Regional wages would then be a function of regional labour productivity and these 2 variables are clearly connected: regional labour productivity is an endogenous variable. Instead, we opted for an estimation strategy of the wage equation where wages are function of the RMA and SA terms of equation (7) only expect for the inclusion of truly fixed, hence exogenous controls. The physical and political geography of Europe are therefore also taken into account in explaining regional wage differences (Combes and Overman, 2004).

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 was taken into account as follows. As proxies for physical geography we will use for the *NUTSII* 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, 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 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.[9]

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:

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

where $\phi_{rs} \equiv (T_{rs})^{1-\varepsilon} = (TD_{rs})^{\gamma(1-\varepsilon)}$ and internal distance D_{rr}= 0.667 $\sqrt{\frac{area}{\pi}}$ in which area is the size of region r in km^2 ; and Z_i = 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

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

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 (2004) and Knaap (2004). 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 (2004), 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 (it may vary over time but not between regions).

In addition, there are other econometric issues to be addressed like the endogeneity of the variables (income) that make up the real market 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, and, following Hanson (2001), experimented with measuring the RMA term at a higher level of aggregation (NUTSI) than wages (NUTSII). 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.

The sample period is 1992-2000. Our goal is not solve all these econometrical issues since the estimation of the wage equation is to some extent only a means to an end in this paper. 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, where income Y_s is for NUTSI regions. To further deal with the ever-present problem of endogeneity in NEG estimations, we instrumented income too. Table 1 gives the WLS results of estimating (7') where the estimation is the second stage of a 2SLS regression where in the first stage regression income was regressed upon its initial level in 1991, a country specific time trend, country dummies and a border dummy. This is a simple way to instrument income.

Table 1 Estimating Wage Equation (7') for the EU regions, 1992-2000

	coefficient	t-statistic
Substitution elasticity ε	3.85	9.09
Distance parameter γ	0.34	9.18
Constant	-0.62	4.23
Dummy border regions	-0.015	2.25
Dummy river regions	-0.03	2.57
Sunshine	-0.05	6.60
Dummy coastal regions	0.01	1.97
Elevation	0.0005	5.48

t-values for 2SLS have been corrected for the fact that fitted values from the first stage regression are included in the second stage; Number of obs.: 1566;
13 country dummies were also included (not shown here) and with the exception of Denmark and Finland were all significant.

The coefficient for the substitution elasticity ε is in line with other studies (indicating relative strong weak economies of scale), see for instance Broda and Weinstein, 2004 for sector evidence for the USA or Hanson and Xiang, 2004 for recent international evidence**.** The estimation results for the distance coefficient imply that $\gamma < 1$ which indicates that transport costs increases less than proportionally with distance. Also note, that the fixed controls perform quite well, they are significant and have mostly the expected sign. *The estimation results support the idea of a spatial wage structure:* wages fall the further one moves away from economic centres. A better real market access, the RMA-term in wage equation (7'), imply higher wages in region r. The prediction from NEG models like Puga (1999) that agglomeration leads to higher factor prices in the centre-regions is thus confirmed by the estimation results in Table 1. When we estimated wage equation (7') for each individual year for our sample period 1992-2000 we also found a spatial wage structure. Moreover, the estimation results for the two key parameters (ε and γ) for each year were such that the implied free-ness of trade did not really change between 1992 and 2000. The 1990s are for the EU a period associated with increasing economic integration but thus does not show up in an increase of the free-ness of trade parameter over time.

The fact that we find a spatial wage structure runs counter to those NEG models where wages between regions are equalized because of an infinitely elastic labour supply, see section 2. With an infinitely elastic labour supply adjustment between centre and peripheral regions takes place (in the long run) through movements of firms and workers only, which implies equalization of RMA across regions (Head and Mayer, 2004b, p. 8).[10] This observation will used in the next section, see Figure 3. Finally, as indicated before, the estimation of the coefficients for ε and γ enables us to put a number on the free-ness of trade parameter: ϕ_{rs}.

The finding that a spatial wage structure exists for the EU regions is important in its own right but, as stated in the introduction of the paper, we want to go beyond the estimation of the wage equation *and also address what these kind of estimations mean for the relationship between economic integration and agglomeration*. This relationship is at the heart of NEG theory. In order to be able to do this, we need to go back to the underlying theoretical model as introduced in sections 2 and 3. In doing so, we take the estimates of Table 1 as our empirical benchmark, ε=3.85 and γ=0.34.[11]

5 Free-ness of Trade and Agglomeration: The Bumpy Road from Empirics back Theory

To analyze the implications of (changes in) the free-ness of trade for (changes) in the degree of agglomeration, the mere estimation of the wage equation as such is clearly not sufficient. To be able to analyze these implications with our equilibrium wage equation, this equation should be able to allow for the degree of agglomeration to change when key parameters like the free-ness of trade change. In the wage equation the degree of agglomeration or the spatial distribution of economic activity shows up in the real market access (and supplier access) term. The level of real market access RMA for region r depends crucially on the share of the footloose firms and workers that are located in region r itself and in nearby regions. In estimating the wage equation we have taken RMA and thus implicitly the degree of agglomeration as given. Ultimately, the hallmark of NEG (see Ottaviano and Thisse, 2004) is, however, that the location of footloose firms and factors of production is endogenous. For the RMA term this means that in the long run real market access, and the regional demand differences which it reflects, cannot be taken as given. In particular, neither income Y_s nor the price index I_s can be considered to be fixed in the long run from a NEG perspective. Ideally, we would like to be able for the case n (=1….s) EU regions to analytically derive what the

[10] Inspection of wage equation (4.42) in Fujita, Krugman, and Venables (1999) immediately reveals that in principle both elements are important: wage as well as employment (here, RMA) adjustments.

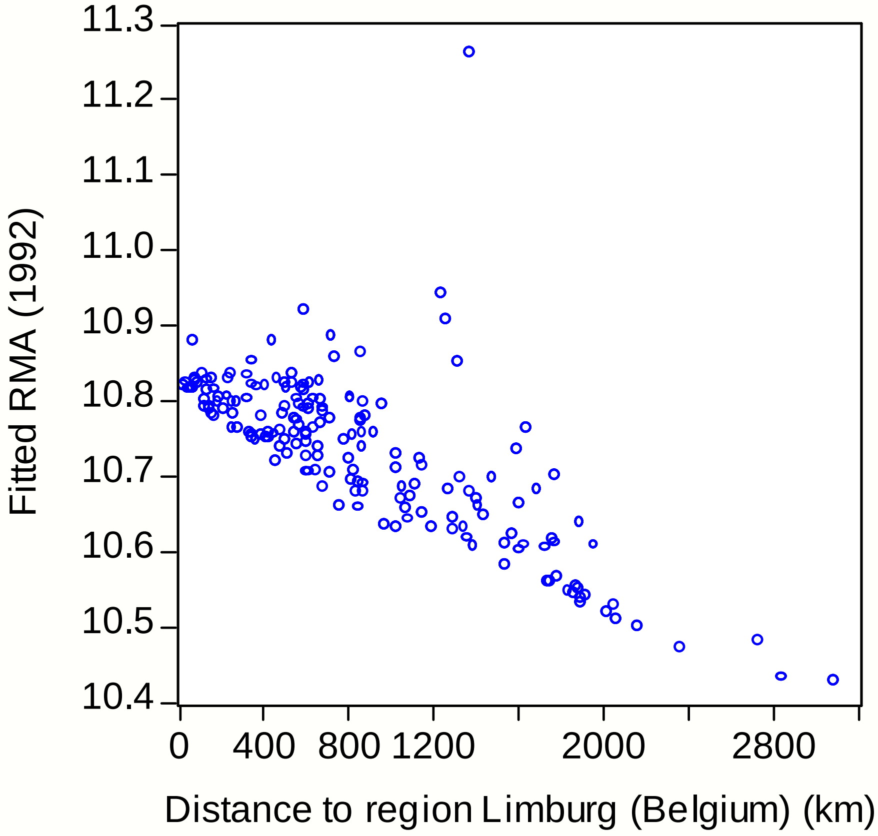
[11] As explained above, the inclusion of both the supplier access (SA) term and the real market access (RMA) term in our estimation of (7') is troublesome a priori, because of the expected degree of multicollinearity between SA and RMA. Because of lack of data we cannot directly compute SA but we can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

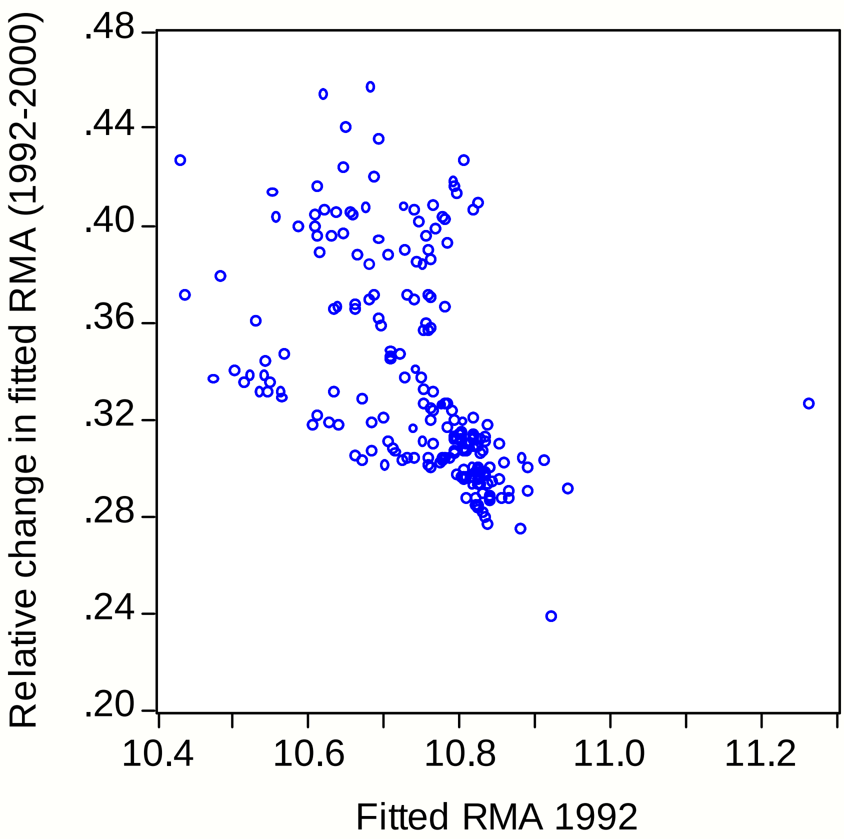
relationship between the free-ness of trade and the degree of agglomeration. And in doing so we would like to allow both factor prices and factor movements to function as adjustment mechanisms to determine the equilibrium spatial allocation across regions.[12] At present, NEG simply is not able to do this for the case of more than 2 regions.

In terms of our wage equation, a first option would be to assume that *either* mobile workers and hence the RMA term *or* wages do all of the adjustment (Head and Mayer, 2004b and Fujita et al, 1999, Chapter 4). The former is for instance assumed in home market effect studies (Davis and Weinstein, 1999), with the result that regional wages do not differ. Whereas the latter boils to down to assuming that RMA is exogenous, that is the location of firms and workers is given. In our view both of these extreme options are not very appealing for our present purposes since in reality one may expect that the equilibrium spatial allocation is the result of both price and quantity adjustments. In important contributions to the empirics of NEG, Redding and Venables (2004) and Head and Mayer (2004b) for instance estimate an equivalent of wage equation (7') and assume that wages do all of the adjustment keeping the RMA (and SA) term fixed. Our estimation results in Table 1 do indeed lend support to a spatial wage structure and thereby the idea that real market access and supplier access are higher in or near centre regions. Based on Head and Mayer (2004b, their Figure 2) for our sample of EU regions, it is indeed the case that the RMA term is higher for regions that are close the centre of the EU, see the top panel of Figure 3**.** The top panel shows for each EU region the real market access (fitted values based on Table 1 for 1992 data) and the distance of the region to the NUTSII region of Limburg in Belgium which is the most central region in our EU sample. It is clear that RMA is *higher* for regions that are *closer* the centre of the EU. At the same time, however, the data and our estimation results for the EU regions indicate, see the bottom panel of Figure 3**,** that the spatial distribution of RMA is not constant over time indicating *that the degree of agglomeration cannot be taken as fixed a priori.* During the period 1992-2000 some regions experienced quite a substantial change in their RMA. To be clear on this, this is not a criticism of Head and Mayer (2004b) or Redding and Venables (2004) since they are not concerned with the question as to how the degree of agglomeration might change when key model parameters change, but it merely points out that their strategy will not do for our purposes.

[12] Or in model terms, we would like to take equation (4.42) in Fujita, Krugman, and Venables (1999) seriously.

Figure 3 Real Market Access (RMA) across regions and over time





When we want to investigate the relationship between the free-ness of trade and the degree of agglomeration, we thus must go back to NEG models that allow both RMA and hence the degree of agglomeration to be endogenous and to be subject to change to when the free-ness of trade changes. And this is, of course, precisely what the NEG models like Puga (1999) set out to do, recall Figures 1 and 2. But if we do so a different problem arises. We would like to confront the empirically grounded estimate of the free-ness of trade with the analytical break points from of section 3 so as to be able to say where, given the free-ness of trade estimate, the various EU regions are on the Tomahawk or Bell Shaped curve depending on which of these 2 core NEG models versions is preferred. Below, following *inter alia* Crozet (2004), we will show the results of this thought experiment. But this analytical clarity has its price, analytical solutions like the break-point conditions (8) and (9) have only been derived in a meaningful sense for a *2 region* model. This strategy thus creates a problem when, as is the case here, the sample consists of many regions.[13] To tackle this problem, we will also address the relationship between our empirically grounded free-ness of trade and the degree of agglomeration using numerical simulations based on (a version) of the NEG model that includes all NUTSII regions while, in line with our estimations of the wage equation, controlling for the actual geography of Europe.

Before we turn to these multi-region simulations, we will first restrict ourselves to our NEG model where for the case of 2 regions the break-points φ^B 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 NUTSII 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 transport 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

[13] In section 6, we use bilateral sector trade data for various country pairs to answer the same question.

agglomeration just like Figure 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, p. 454 for a similar approach) and this holds for the break points in both the model with and without interregional labor mobility:

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

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 Figure 2, and provided that equation (9) gives us 2 real solutions (φ^B_{low} and φ^B_{high} denote the 1st and 2nd breakpoint in Figure 2). 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 transport 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 substitute 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 information as to the spatial reach of agglomeration forces for any pair of regions r and s: if we position ourselves in region r we want to know at what distance a region s still falls within the agglomeration reach of region r. It is important to keep in mind that we conduct this thought experiment under the stringent and crucial assumption that we are dealing with a 2 region world! For regional policy makers this thought experiment might be important as they are often interested in the position of their region versus *the rest of the world.* In the last part of this section we will drop this assumption when we turn to our multi-region simulations.

To be able to confront our estimation results with the break-point conditions (8) and (9), while taking into account 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). For the first three parameters we simply 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.

Generally speaking it is true in both versions of the NEG model of sections 2 and 3 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). Given these benchmark values and break-conditions (8) and (9), we thus arrive at values for the 3 break-points. From equations (8) and (9) we get thus values for the 3 break points φ^B and we also know, see equation (10), that $\phi^B = \left[\left[\frac{D_{rs}}{D_{rr}} \right]^{\gamma(1-\varepsilon)} \right]^B$. Given our estimates from Table 1 for the distance parameter γ (0.34) and the substitution elasticity ε (3.85) we finally arrive at the hypothetical relative distance that corresponds with the break point.

The results of this experiment imply that the agglomeration does not extend further than a few times the internal distance of a region. To see this, note that the average internal distance for the *NUTSII* 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 about 200 km. for φ^B_{low} and 100 km. for φ^B_{high}. This means that for any actual D_{rs}>200 km we are in Figure 2 to the left of the first break-point where spreading rules (the average distance between a pair of NUTS II regions is 620 km). Along similar lines, it is only when the actual D_{rs}<100 km. that spreading rules again. In between, that is for 100 km<D_{rs}<200 km, we are on the part of Figure 2 with (partial) agglomeration. For the Tomahawk model the range or radius of agglomeration forces is 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 *NUTSII* regions is thus often much larger than 161 km.[14]

To put our results based on this 2 region thought experiment 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. For these 39 centre regions, the average distance to each other is 309 km. (of these regions, the region Limburg in Belgium, see also Figure 3, has the lowest average distance to the other 38 regions: 220 km.). Set against our thought experiment, these distances

[14] 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).

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 limited number of the other 38 regions are affected. For the core NEG model (Krugman, 1991) we can use equation (8) with $\mu=\eta=0$ and here we find, compared to other NEG models nested by Puga (1999) that the corresponding break point is reached for relatively low values of D_{rs}, that is to say for the Krugman 1991 model the agglomeration forces and based on our estimations the critical external distance below which we are in the agglomeration part of the Tomahawk is about 100 km. We will use this result (that agglomeration occurs relatively (!) easy in the Krugman 1991 model) to opt for the Krugman 1991 model in our multi-region simulations below.

To understand what we do and do not want to claim, it is important to be clear as to what we have done so far in our attempt to go back from empirics to NEG theory. For our sample of NUTSII regions, we estimated 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 clearly not when n>2 because it means assuming equidistant regions). [15] Using our estimates for the substitution elasticity and the distance parameter from Table 1 we can calculate the implied threshold distances between regions r and s at which a break point occurs. Or in other words, our experiment "indicates how far the agglomeration forces emanating from a region extend across space" (Crozet,

[15] 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 II 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.

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 for any region r for both NEG models the radius (measured by D_{rs}) within which agglomeration or spreading forces dominate.

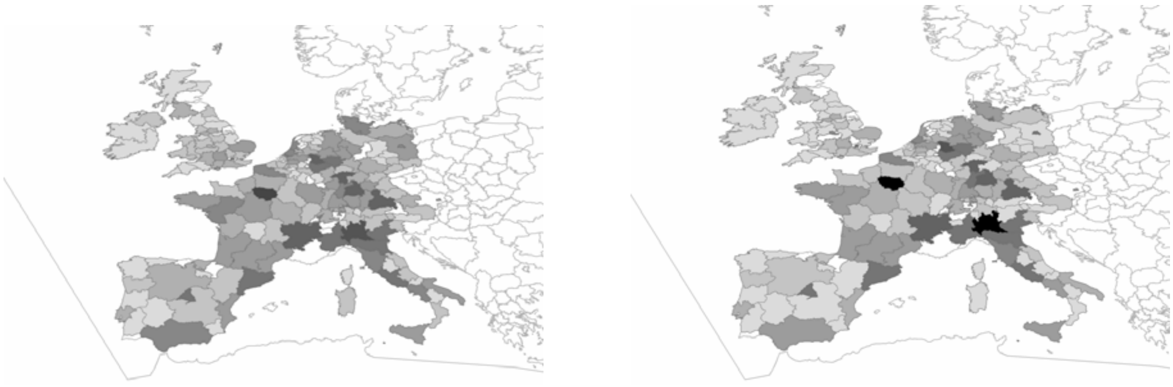
The above experiment, though interesting in our view, has a severe shortcoming. It confronts the empirics of a multi-region EU with the analytics of the 2 region model. An alternative approach would be to confront our estimation from Table 1 with a NEG model for n regions, where n is the number of NUTSII 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. To illustrate such a simulation exercise we use the methodology of Stelder (2005) who applied the Krugman (1991) model to the regions of Europe.[16] The essence of this method is that it uses the actual geography of Europe and calculates the shortest distance between grid points on the map of Europe (in our case the grid consists of the NUTSII regions in our sample). In this way one is able to deal with mountains, seas, islands etc. Physical obstacles like these increase the distance between NUTSII regions. Applying this non-neutral space simulation experiment to Krugman (1991) has a number of advantages in our view. First, in wage equation we use the physical geography of Europe as a control variable and we are able to do the same with our simulations. The use of the actual geography of Europe also means that our simulations are more "realistic" than for instance the well-known (12 region) race track simulations or seamless world analysis in Fujita, Krugman and Venables (1999, see chapters 6 and 17 respectively). Our simulation experiment includes all NUTSII regions. The reason to use the Krugman (1991) NEG model is also grounded on the fact, see above, that the previous experiment suggested that, if anything, for this model agglomeration forces are relatively strong.

Starting with the initial distribution of regional gross value added across the regions and given our preferred estimates of γ and ε, one can simulate the long-run equilibrium situation in Europe, that is, an outcome where real wages across regions are equalized. Figure 4 below shows the outcome of such a simulation exercise (gross value added for the European regions

[16] See Brakman, Garretsen and van Marrewijk (2001), pp. 171-174, for a brief explanation of this simulation method, see Stelder (2005) for more details. The distance between 2 locations is calculated as the shortest path, on the assumption that each location on the grid is connected with its direct and horizontal and vertical neighbours with distance 1 and with diagonal neighbours with distance $\sqrt{2}$. Non-neutral space is then introduced by making "holes" in the grid.

is normalized to 1, regions where activity is concentrated are darker compared to more peripheral regions).

Figure 4. Agglomeration in Europe in Multi-Region Model



A = initial distribution B = final distribution

Figure 4A depicts the initial (here, 1992) distribution. Darker areas thus denote that such a region has a relatively larger share of European gross value added. Agglomerations are to be found roughly along the lines of the so called European banana ranging from London to Belgium and the south part of the Netherlands via west and south-west Germany to northern Italy, the central position of Paris is also noteworthy. Based on our parameter estimations Figure 4B calculates the long run equilibrium for the European region to which the initial, 1992 distribution would give rise based on our estimations of the free-ness of trade. When compared to the initial distribution, the region around Paris and the region around Milan are for instance able to attract more economic activity. The same holds for other initially larger regions. In general, when comparing Figure 4A and 4B, core regions gain at the expense of nearby regions. This is in line with our previous finding that the reach of agglomeration is limited in space. Overall, when comparing these Figures 4A and 4B, and notwithstanding some re-distribution, the long run equilibrium does, however, not look very different from the initial situation. In particular, the long run equilibrium is not one in which the European regions have collapsed into a strong core-periphery pattern whereby one or just a few regions have attracted all of the economic activity. To investigate this further, we have also simulated long-run equilibria for larger values of the free-ness of trade than those implied by our estimations for the substitution elasticity and the distance parameter in Table 1, **see Figure 4C** for just one example. These additional simulations reinforce the above conclusions. Larger regions increase in economic importance and smaller regions in the vicinity of those larger regions lose out. But also for increased values of the free-ness of trade, the overall equilibrium distribution remains rather similar to the one shown in Figure 4B.

To sum up, following the estimation of the equilibrium wage equation in the previous section we started this section by asking if this wage equation could be used to learn more about the equilibrium spatial distribution of economic activity, in particular as to the relationship between the free-ness of trade and the degree of agglomeration. It turned out that that merely sticking to the wage equation would not do for our purposes. We had to go back to our NEG model where the degree of agglomeration and hence the locations of footloose firms and workers is allowed to change when key parameters like the free-ness of trade change. Sticking to the 2 region model has the advantage that our estimation results can be confronted with analytical solutions as to whether and how the free-ness of trade impact on the degree of agglomeration. When doing so, agglomeration appears to be a rather localized phenomenon for the European regions. Though interesting in our view, in the end we must dismiss this strategy of linking the empirics of the NUTS II regions with the 2 region NEG model for the basic difficulty of analysing the case of multiple regions by means of 2 region model. It is therefore that we ultimately have to rely on multi-region simulations.

6 Bilateral country trade flows and sector φ's

Our estimations and the subsequent analysis in section 5 are based on aggregate data for each *NUTSII* 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 II 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 and as a complement to our analysis in sections 4 and 5, 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:

$$\varphi_{\text{trade}} = \sqrt{\frac{m_{ij} m_{ji}}{m_{ii} m_{jj}}}$$

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/USA 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 pairs of countries most industries are still to the left of the bell-part: that is, $\varphi_{trade}<\varphi^{B}_{low}$.

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).

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 2 gives the computed free-

[17] For the data-sets and the actual values used to come up with industry specific measures for the intermediate input share, the labour 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).

ness of trade parameter φ_{trade} and compares this implied degree of economic integration with the two break-points φ^B_{low} (equation (8), the bell-curve model) as well as with φ_{labmob} (equation (9), 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]

Table 2 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

* $\varphi_{bell\text{-}top}$=0.545; ** $\varphi_{bell\text{-}top}$=0.50; **** $\varphi_{bell\text{-}top}$=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.

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

In our view the results in Table 2 with a free-ness of trade parameter based on bilateral trade data on the country level are in line with the conclusions in the previous section based on regional data. The bilateral trade data n which Table 2 is based suggest the spatial reach of agglomeration forces is probably rather limited.[19]

7 Conclusions

The estimation of the equilibrium wage equation from a model by Puga (1999) for the EU *NUTSII* 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 spatial reach of agglomeration forces is rather limited. Both in our 2 region setting and multi-regions simulations, agglomeration seems to be a rather localized phenomenon. This last conclusion was substantiated by free-ness of trade estimations based on bilateral trade data on the EU country level. At the same time, we emphasized that the usefulness of the 2 region model and its underlying analytics is rather limited when one is dealing with multiple regions like in the case of the NUTSII EU regions. We therefore also ran multi-region simulations while taking the actual geography of Europe into account.

Where does this leave us? In our view the main findings of this paper are consistent 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 Crozet (2004). The relevance of the proximity of agglomeration effects is also underlined by Brülhart, Crozet, and Koenig (2004) with respect to the impact of the EU enlargement and its impact on incumbent EU regions. In their survey Head and Mayer (2004a) also conclude that it seems that agglomeration forces are rather localized.

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 and these results

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19 Compared to our calculations for the 3 break points in our 2 region thought experiment in sect ion 5, 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 δ=0.1 that we used in the previous section (a lower δ ceteris paribus means weaker agglomeration forces).

point also to the (current) limitations of confronting NEG empirics with NEG theory. How should NEG research proceed from here? 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, our 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 changes in the free-ness of trade 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. Three 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, 2004). The third, and perhaps most pressing, issue that needs to be taken up in future research is the tension between NEG empirics based on multiple regions and large size asymmetries on the one hand and the NEG theory where analytical results are too often only available for 2 regions on the other hand. Until more progress has been made on this issue, numerical simulations will remain a vital (and very useful) element of NEG.

APPENDIX

Data Description

Nominal wage is defined as compensation of employees per worker (NUTS 2-level, except for Germany –NUTS I). 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 euros of 1995, and the price deflator of national GDP (AMECO-database).
In the real market term RMA in the wage equation, we included the NUTS I-regions of EU14 (=EU15 excluding Luxembourg) + Norway, Czech Republic, Poland, Hungary, Switzerland; . For wages we used the EU14 only. All wage, income and production data are taken from The European Regional Database (summer 2002 version) from Cambridge Econometrics.
Distance D_{rs} is in km.
A set of additional control variables for each NUTS II 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).

How to Approximate the Price Index I?

For the model without intermediate inputs (μ=0), we proceeded 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 *NUTSII* 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**	20	Zeeland
1	Nordrhein-Westfalen	21	Nord-Pas de Calais
2	Limburg	22	Saarland
3	Limburg(B)	23	Luxembourg(B)
4	Luik	24	West-Vlaanderen
5	Noord-Brabant	25	Picardie
6	Vlaams-Brabant	26	Champagne-Ard.
7	Baden-Württemberg	27	Alsace
8	Rheinland-Pfalz	28	Noord-Holland
9	Gelderland	29	Overijssel
10	Antwerpen	30	Flevoland
11	Waals-Brabant	31	Niedersachsen
12	Brussel	32	Lorraine
13	Namen	33	Vorarlberg
14	Utrecht	34	Ostschweiz
15	Ile de France	35	Zurich
16	Oost-Vlaanderen	36	N_W Schweiz
17	Hainaut	37	London
18	Bayern	38	Kent
19	Zuid-Holland	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 *NUTSII* regions, see Table A1) gives us $T_{r,\text{ center}}$ 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)).

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

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

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

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

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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