A GENERALIZED NEG WAGE-TYPE EQUATION[*]

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This chapter discusses several controversial issues of the New Economic Geography (NEG) theory, focusing on some problems of interpretation regarding the estimation results of a *wage equation*. In order to do that, several wage equations found in the literature are encompassed under the derivation of a new generalized wage-type equation, with marginal cost as dependent variable. A testable equation controlling for human and physical capital stocks is also derived.

1. Introduction[1]

The basic form of the so-called *wage equation* of the New Economic Geography (NEG) predicts that "nominal manufacturing wages" depend on the accessibility to markets, as captured by an index of *Market Access* or *Market Potential*. This relationship has been studied in a large empirical literature. However, the NEG "is not easy to test" (Head and Mayer, 2006). For reasons of tractability the theory uses strong simplifying assumptions. More generally, the *Marshallian* or *observational equivalence* of the NEG refers to the difficulty in discerning between alternative theories of location. It seems that this situation has created several common misunderstandings about the NEG.

This chapter discusses various reasons that hinder the connection between the estimation results of a wage equation and the specific explanation offered by the NEG. In particular, it is emphasized that the "wage" equation is the result of imposing a market clearing condition on a profit equation. The dependent variable is actually marginal costs. Redding and Venables (2004) concluded that it is more accurately an equation for the price of the composite immobile factor of production. They interpreted that factor as labour. However, going from marginal costs to wages requires additional assumptions (Head and Mayer, 2004b; Combes *et al.*, 2008, chap. 12) that might have not been sufficiently highlighted.

The "wage equation" has been viewed as an explanation of the spatial distribution of different phenomena: "manufacturing wages", under a literal interpretation of the basic model, or "economic activity" (Redding, 2011), in a broader sense. These alternative views imply different options when measuring the variable on the left-hand side of the testable equation. Redding and Venables (2004), as well as other authors, have chosen income per person. From a literal interpretation of the wage equation, income per capita would be a measure of welfare rather of factor prices. However, the robustness analysis of Redding and Venables (2004) using manufacturing wages per worker shows an extremely similar pattern of estimation results. Tests carried out by the author of this chapter (not shown) using regional European data also prove that the estimation of a wage equation is robust to alternative dependent variables related with income or wages for the aggregate economy, manufacturing or services.

The correlations between these variables are very high because cross-sectional analysis is extremely sensitive to the relative levels of "development". The higher sample heterogeneity, the higher the correlations are. In other words, all these measures are affected by the level of total factor productivity. Of course, the NEG avoids explaining agglomeration through exogenous technological differences (Krugman, 2011). However, "technology", and its spatial distribution, is always underlying any measure of factor prices, income or Market Potential[2].

These issues are discussed here in the context of a new *generalized wage-type equation* encompassing other wage equations found in the literature. Additionally, the derivation of a wage-type equation including human and physical capital is used to illustrate the difficulties when interpreting the estimation results. The model sketched here[3] is mainly based on Redding and Venables's (2004) model and its subsequent by Head and Mayer (2004b), Breinlich (2006) and Head

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and Mayer (2006). NEG models have been described many times but a contribution of this paper is to accommodate different derivations under a common notation.

The rest of the chapter is organized as follows. Section 2 presents the demand side of the NEG basic model. Section 3 introduces the generalized form of the wage equation. Using this framework, the inclusion of human and physical capital is derived in section 4. Section 5 concludes.

2. The Demand Side of the NEG Basic Model

The NEG distinguishes two sectors. A perfect competitive sector produces a single homogeneous good under constant returns to scale (CRS). The second sector produces a large variety of differentiated goods and is composed of firms exhibiting internal increasing returns to scale (IRS) and operating under a market structure of monopolistic competition. Here these two sectors are noted C and M, respectively (Fingleton, 2006; Fingleton and Fischer, 2010).

In the basic NEG model the two sectors are termed "agriculture" and "manufacturing". As Fujita *et al.* (1999, p. 58) point out, "agriculture" can be interpreted as the "'residual', perfectly competitive sector that is the counterpart to the action taking place in the increasing-returns, imperfectly competitive manufacturing sector". For Redding and Venables (2004) the M sector can be interpreted as a composite of manufacturing and service activities while Fingleton and Fischer (2010) define it as services. Alternatively, Baldwin *et al.* (2003, p. 13) argue that the key distinction in the basic core-periphery model is that the C sector uses intensively the internationally immobile factor. Indeed, in some models C is identified with a nontraded good (housing sector). However, the possible presence of nontraded goods affects the selection of the appropriate proxy for the dependent variable of the "wage" equation -see equations (21) and (22) below-.

Some researchers seem to interpret the dependent variable of the "wage" equation as the level of "nominal manufacturing" wages. However, on the one hand, an assumption of sectoral factor mobility guarantees factor equalization across sectors, justifying to proxy the dependent variable by measures for the aggregate economy. On the other hand, the "nominal wage" of the M workers refers to their wage in terms of the C numeraire sector (Baldwin *et al.*, 2003, chap. 2). Therefore, the C and M notation for the two sectors, according to their market structure, is a reminder that we are not sure about what the two NEG sectors are.

The model presented here focuses on the M sector but is introduced with the demand side for both sectors. The basic model assumes that every consumer shares the same Cobb-Douglas tastes for the two types of goods. Alternatively, though it is not essential for later arguments, it is useful to assume a different $0 < \mu_j < 1$ parameter of preferences for each type of good in each region j. The upper-level step of the problem of the representative consumer in region j is to divide her total income Y_j between the consumption of the two aggregated goods:

$$\max_{M_j, C_j} U_j = M_j^{\mu_j} C_j^{1-\mu_j} \quad \text{s.t. } G_j^M M_j + P_j^C C_j = Y_j \tag{1}$$

where P_j^C is the price of the C goods and G_j^M is a "price index" of M goods. Therefore, the amount of consumption of region j in M goods is:

$$M_j = \mu_j Y_j / G_j^M = E_j^M / G_j^M \tag{2}$$

E_j^M is the expenditure of region j in all the varieties of the M good. $\mu_j = E_j^M / Y_j = E_j^M / E_j$. is the share of M consumption in income. Here total income, Y_j, is the same than total expenditure, E_j, because the model does not include intermediate goods. Considering heterogeneous preferences (μ_j), as Combes *et al.* (2008b, chap. 12), allows for what in a model with intermediate goods (Fujita *et al.*, 1999, chap. 14) would be different sectoral shares of costs in intermediate goods, or different sectoral composition. The intermediate inputs are included in Table 1 below.

After deciding the optimal consumption of the composite index of M goods, the representative consumer of region j decides the quantity of consumption for each M variety. The demand of M goods in any region j is derived from the maximization of a Dixit-Stiglitz CES subutility function for the consumption $x(v)_j$ of each M variety $v = 1, \dots, V$. Given that the utility function M_j embodies a preference for diversity and there are IRS in the M sector, each firm produces a distinct variety. If the "world" is composed by R regions ($i = 1, \ldots, R$), the number of varieties potentially available (V) in region j is the number of firms and varieties (n_i) produced in all the regions: $V = \sum_{i=1}^{R} n_i$. In equilibrium all goods produced in each region i are demanded by j in the same quantity. Therefore, the representative consumer in j solves the following problem:

$$\max_{x_{ij}} M_j = \left[\sum_{i=1}^{R}\sum_{v=1}^{n_i} x(v)_{ij}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} = \left[\sum_{i=1}^{R} n_i x_{ij}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \quad (3)$$
$$\text{s.t.} \sum_{i=1}^{R} n_i\, p_{ij} x_{ij} = E_j^M$$

where $\sigma > 1$ is the elasticity of substitution between any pair of varieties, x_{ij} is the amount of consumption in j of the variety produced in i and p_{ij} is the delivery price of that variety. The first-order conditions of this problem for a representative variety from region i and a variety g produced anywhere give equality of marginal rates of substitution to price ratios:

$$\frac{{x_{ij}}^{1/\sigma}}{{x_{gj}}^{1/\sigma}} = \frac{p_{gj}}{p_{ij}} \quad (4)$$

The j-market optimum consumption level (x_{gj}^c) of the good produced by a g-firm is obtained by plugging the value of x_{ij} from equation (4) into the expenditure constraint:

$$x_{gj}^c = p_{gj}^{-\sigma} \frac{E_j^M}{\sum_{i=1}^{R} n_i p_{ij}^{1-\sigma}} \quad (5)$$

This relation is also true for the representative variety from region i. Therefore, keeping the denominator as a sum across i varieties, j-consumption of a variety produced by an i-region firm is:

$$x_{ij}^c = p_{ij}^{-\sigma} \frac{E_j^M}{\sum_{i=1}^{R} n_i p_{ij}^{1-\sigma}} = p_{ij}^{-\sigma} \frac{E_j^M}{S_j^M} \quad (6)$$

Redding and Venables (2004) calls "market capacity" to the term E_j^M / S_j^M. It gives the position of the demand curve facing each firm in market j. Equation (6) says that the consumption of a variety i in j market, x_{ij}^c, is inversely related to the delivery price of that variety, p_{ij}, and to the index, $S_j^M = \sum_{i=1}^{R} n_i p_{ij}^{1-\sigma}$. This latter index is called "supplier access" by Redding and Venables (2004). Here it is termed "supply" (Head and Mayer, 2006) or "competition" index. S_j^M measures the level of competition between M varieties in j market given the characteristic tastes of consumers. The assumption $\sigma_i = \sigma > 1$ implies negative exponents in the $p_i^{1-\sigma}$ terms. Therefore, through equation (6), it will be difficult to obtain a high market share in a location j served by a large number of low-price sources.

Plugging equation (6) into j's subutility function, the optimal utility level is $M_j = E_j^M {S_j^M}^{\frac{1}{\sigma-1}}$, which can be re-written as $M_j = E_j^M / G_j^M$ after defining $G_j^M \equiv {S_j^M}^{1/(1-\sigma)}$. This allows the interpretation of G_j^M as an aggregate "price index" of M. Fujita *et al.* (1999, chap. 4) obtain this index through the dual problem of the restricted maximization in equation (3). The minimum cost of attaining M_j results to be $G_j^M M_j$, where:

$$G_j^M = \left[\sum_{i=1}^{R}\sum_{v=1}^{n_i} p(v)_{ij}^{1-\sigma}\right]^{\frac{1}{1-\sigma}} = \left[\sum_{i=1}^{R} n_i p_{ij}^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \quad (7)$$

Head and Mayer's (2006) S_j^M notation is preferred here to the traditional G_j^M because makes more transparent the negative exponents of p_i and avoids defining G_j^M as a nonobservable price. G_j^M is a price because is the unit cost of utility derived from the consumption of M goods. "(...) just as M can be thought of as a utility function, G can be thought of as an expenditure function" (Fujita *et al.*, 1999, p. 47). Brakman *et al.* (2009, chap. 3) call G_j^M a consumption-based or exact price index. Baldwin *et* *al.* (2003, chap. 2) label it "perfect" price index. The original adjectives used by Krugman (1992) were "true" or "ideal" price index.

Firms of the same region are assumed to have the same *free-on-board* price. Trade costs are assumed to be borne by consumers, so firms follow a mill pricing policy. If p_i is the mill price of a good produced in region i, the delivered price in market j is assumed to be $p_{ij} = T_{ij}p_i$, where $T_{ij} \geq 1$ are "iceberg" transport or trade costs: for every unit shipped only $1/T_{ij}$ units arrive to destiny while the rest melts during transport. Therefore, for every unit consumed in j at a price p_{ij}, T_{ij} units must be shipped. From equation (6), j effective demand to i becomes:

$$x_{ij} = T_{ij}x_{ij}^d = T_{ij}{}^{1-\sigma}p_i^{-\sigma}\frac{E_j^M}{S_j^M} \tag{8}$$

When $i \neq j$, these sales are the exports from region i to region j. $\phi_{ij} \equiv T_{ij}{}^{1-\sigma}$ is what Baldwin *et al.* (2003, chap. 2) call "phi-ness" of trade. It ranges from $\phi_{ij} = 0$, where T_{ij} and σ are high enough to eliminate all trade, to $\phi_{ij} = 1$, for full economic integration.

In order to get the value of total exports from region i to j, Redding and Venables (2004) express in values the volume of export in equation (8) and aggregate it across all the varieties produced in region i. The resulting "trade equation" reflects bilateral trade flows in an Anderson and van Wincoop's gravity-type equation:

$$n_i p_i x_{ij} = \phi_{ij} n_i p_i^{1-\sigma}\frac{E_j^M}{S_j^M} \tag{9}$$

where the term $n_i p_i^{1-\sigma}$ measures the "supply capacity" of the exporting region. Redding and Venables (2004) proxy market capacities, E_j^M/S_j^M, with the estimates for importing region dummies in the gravity equation (9). Therefore the crucial role of S_i^M in NEG theory is measured by an unobservable and constant individual effect for the importing region in an equation of bilateral trade. With those estimates, the authors construct the key variable of the model, Market Potential.

Given the effective demand from j-market in equation (8), total demand to a representative M firm in region i will be the sum of what it sells to the world markets[1]:

$$x_i \equiv \sum_j^R x_{ij} = p_i^{-\sigma}\sum_j^R T_{ij}{}^{1-\sigma}\frac{E_j^M}{S_j^M} = p_i^{-\sigma}RMP_i \tag{10}$$

where RMP_i stands for Real Market Potential (RMP_i). In summary, using alternative notations, the Market Potential of a firm/region i is:

$$RMP_i = \sum_j^R \phi_{ij}\frac{E_j^M}{S_j^M} = \sum_j^R \mu_j T_{ij}{}^{1-\sigma}E_j G_j^{M\,\sigma-1} \tag{11}$$

where the competition index is $S_j^M = G_j^{M\,1-\sigma} = \sum_{i=1}^R \phi_{ij} n_i p_i^{1-\sigma}$. It is assumed that $\phi_{ij} = T_{ij}{}^{1-\sigma} = 1$ for the domestic sales ($i = j$), although research with areal data needs to consider a proxy for internal trade costs.

"Krugman Market Potential" (Head and Mayer, 2004a) in equation (11) is a phi-ness of trade weighted sum of market capacities. This term is relabelled as "Real Market Potential" (RMP_i) by Head and Mayer (2006). These authors reserve the adjective "nominal" for a Harris's (1954) index such as $\sum_j^R \phi_{ij}E_j$, because is a pure measure of the size of the available market, equivalent to assume $S_j^M = S^M = 1$. The adjective "real" underlines the importance of discounting expenditures by the supply index S_j^M.

However, Head and Mayer's (2006) adjective "real" may be a misleading analogy with the deflation of nominal monetary values, because the $p_i^{1-\sigma}$ terms in S_j^M have a negative exponent. "Real" becomes more confusing when expenditure is measured in deflated monetary units, as it is common in empirical research. Therefore, the competition effects of S_j^M seem to be better described by the expression "Market Access" (Redding and Venables, 2004). Despite this, the name "Real

Market Potential" has two virtues. On one side, it stresses the continuity from the old-style Regional Science to the NEG, as commented by Fujita *et al.* (1999, chap. 3). On the other hand, it avoids the confusion with WTO definition of "market access" (Head and Mayer, 2011).

Empirical works using Harris's (1954) measure of Market Potential are frequently criticised because that measure does not allow interpreting the estimating results of a wage equation in terms of the structural parameters. When proxying trade costs by distances, Harris's index implies an *ad hoc* assumption of -1 for the distance exponent, instead of estimating it through equation (9). However, a trade elasticity to distance of -1 is an extremely robust empirical finding (Head and Mayer, 2014). Moreover, the different measures of Market Potential share the same crucial features (Bruna, Lopez-Rodriguez, *et al.*, 2014) and are highly correlated (Breinlich, 2006; Head and Mayer, 2006). Additionally, with distance exponents close to -1 any of them overweighs the nearest neighbours. The meaning of geographical distances as trade cost also remain unclear and measuring internal distances is a serious challenge (Bruna, Faíña, *et al.*, 2014). In any case, for any proxy variable of Market Potential, the main argument of the present paper is that the empirical results of a wage equation do not enable unambiguous interpretation in terms of structural parameters of the model.

3. Supply Side and Generalized Wage-Type Equation

Krugman's (1980) classic assumptions for the M sector are the following: labour is the only production factor; there are no economies of scope; and there are CRS during production, which involves a marginal input requirement. Production also involves a fixed input, inducing IRS. Because of that, consumer's preference for variety and the unlimited number of potential varieties, no firm will choose to produce the same variety supplied by another firm. This means that each variety is produced in only one location by a single specialized firm, so the number of firms in operation is the same as the number of available varieties (Fujita *et al.*, 1999).

Keeping the x_i notation of the demand equation (10), the production function considered here for the M firm in region i is:

$$x_i = -f + A_i I_i = A_i \left(-\frac{f}{A_i} + I_i\right) \tag{12}$$

where I_i is a compound input. A_i is a Ricardian technology, which means that the marginal input requirement is $c_i = 1/A_i$. f is a fixed cost defined in units of output. Therefore, $I_i = c_i(f + x_i)$ and the fixed input requirement, $c_i f$, is allowed to vary across regions. If, for now, q_i is the price index of I_i, the cost of producing x_i is $q_i c_i (f + x_i)$. Marginal cost, the price of the compound input in efficiency units, is $m_i = q_i c_i$.

Firm's total output is given by the sum of what it sells to the world markets, $x_i = \sum_j^R x_{ij}$, and its total income is $\sum_{j=1}^R p_i x_{ij} = p_i x_i$. Therefore, firms of the M sector, facing given factor prices in m_i, maximize the following profit function with respect to their mill prices p_i:

$$\pi_i = p_i x_i - m_i(f + x_i) \tag{13}$$

where the effective demand (x_i) is taken from equation (10). If each firm takes the competition index S_j^M in RMP_i as given[4], profit maximization implies that firms choose price as a mark-up over marginal costs:

$$p_i = \frac{\sigma}{\sigma - 1} m_i \tag{14}$$

At these optimum mill prices, profits are:

$$\pi_i = m_i \left(\frac{1}{\sigma - 1} x_i - f\right) \tag{15}$$

The demand function in equation (10) at optimum prices is: $x_i = \left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} m_i^{-\sigma} RMP_i$. Therefore, the profits of i become a function of its Real Market Potential:

$$\pi_i = \frac{(\sigma - 1)^{\sigma - 1}}{\sigma^\sigma} m_i^{1-\sigma} RMP_i - f m_i \tag{16}$$

Equation (16) is similar to the "profit equation" derived by Combes *et al.* (2008, chap. 12). It is at the origin of the "wage equations" derived below. When a market equilibrium condition is imposed in equation (16), the wage-type equation gives a relationship between marginal costs and the spatial distribution of expenditure, as captured by RMP_i[5]. Free entry and exit in response to profits or losses ensures that the long-run profits are zero. Therefore, Redding and Venables (2004) use the production level at which firms break even to calculate the maximum remuneration that firms afford to paid to factors.

In order to get rid of f, equation (10) allows calculating the production level at which profits are zero: $x_i = (\sigma - 1)f = \bar{x}$. Therefore, from the effective demand, active firms at location i attain this level of output and break even if and only if the mill price they charge satisfies:

$$p_i^{\sigma} = \frac{1}{\bar{x}} RMP_i \qquad (17)$$

Through the mark-up pricing rule (14), equation (17) can be expressed with marginal cost as the dependent variable:

$$m_i = \frac{\sigma - 1}{\sigma}\left(\frac{1}{\bar{x}} RMP_i\right)^{\frac{1}{\sigma}} = \frac{\sigma - 1}{\sigma}\left(\frac{1}{\bar{x}}\sum_j^R \mu_j {T_{ij}}^{1-\sigma}\frac{E_j}{S_j^M}\right)^{\frac{1}{\sigma}} \qquad (18)$$

Equation (18) is called here "generalized wage-type equation". It reveals a relation between Real Market Potential and the maximum marginal cost that a firm can afford to pay. The word "generalized" is used to emphasize that the dependent variable is marginal cost. "Wage-type" equation makes reference to the name "wage equation" [6] used by Fujita *et al.*'s (1999, chap. 4) in a model in which labour is the only production factor. Baldwin *et al.* (2003, p. 19) prefer the expression "market-clearing condition" in order to emphasize the assumption of zero profits.

The presence of Real Market Potential, $RMP_i = \sum_j^R {T_{ij}}^{1-\sigma} E_j^M / S_j^M$, in the profit equation (16) captures the two typical NEG effects. As summarized by Redding (2011), IRS imply that firms want to concentrate production while transport costs imply that they want to be close to large markets. This is called "home market effect" and provides a "backward linkage". Therefore, firms close to large markets can pay higher marginal costs.

On the other hand, the counteracting force promoting M sector dispersion is the "market crowding" or "competition" effect derived from discounting expenditures by S_j^M in RMP_i. The supply index S_j^M is a trade cost weighted sum of supply capacities and measures the degree of competition in j market. As more firms choose one region, the market there becomes more crowded, lowering the Real Market Potential, until another region is more profitable (Head and Mayer, 2004a).

Head and Mayer (2006) discussed two paths to equilibrium. Spatial equilibrium requires that markets clear and no mobile agent has a unilateral incentive to relocate. In a spatial equilibrium firms have the same profits in all regions, so if c_i is considered as given, any shock in the demand to a region will be followed by an adjustment in their use of factors and/or by an adjustment in its factor prices. Therefore, the relative magnitudes of price or quantity adjustment to cross-regional variation in demand depend chiefly on the mobility of factors. One strand of the literature makes the polar assumption of factor price equalization. Redding and Venables (2004) pioneered what Head and Mayer (2006) call the second polar path towards spatial equilibrium, that loads all the response to demand differences into factor prices.

When labour is not the only production factor, as in Redding and Venables's (2004) model, the assumptions about factor mobility determine which factor prices are not equalized across regions. Therefore, the left-hand side variable of equation (18) becomes a function of the price of immobile factors. Redding and Venables interpret these factors as labour. The full general equilibrium explored in Fujita *et al.* (1999) involves specifying factor endowments. Alternatively, Redding and Venables "take expenditure and output in each country as exogenous and ask "what wages can manufacturing firms in each location afford to pay?".

Accommodating the notation to distinguish two inputs, now q_i designates the price of an internationally immobile factor with input share θ. z_i is the price of a mobile factor with input share ψ. If there are CRS during production, $\psi = 1 - \theta$. Alternatively, θ and ψ can be viewed as parameters describing the degree of mobility of the underlying production factors. Therefore, similarly to Breinlich's (2006) specification, marginal costs are:

$$m_i = q_i^{\theta} z_i^{\psi} c_i \qquad (19)$$

And the generalized wage-type equation takes the form:

$$q_i = \left[\frac{\sigma - 1}{\sigma} \frac{1}{\bar{x}^{1/\sigma}} RMP_i^{\,1/\sigma} \frac{1}{z_i^{\psi}} \frac{1}{c_i}\right]^{1/\theta} \tag{20}$$

Given that z_i is the price of a mobile factor, Redding and Venables (2004) assume that it is equalized across regions, so $z_i = z$. These authors seem to be thinking of the Footloose Capital model (Baldwin *et al.*, 2003, chap. 3). In this model each M firm requires just one unit of mobile capital. Capital owners spend their income locally, so a long-run spatial equilibrium implies the international nominal equalization of the return on capital. The following section provides an alternative assumption.

Under Redding and Venables's (2004) interpretation, the price of the immobile factor is the wage level: $q_i = w_i$. Simplifying $c_i = A_i^{-1}$ and taking logarithms in equation (20), their testable cross-sectional wage equation including an intercept (C) becomes:

$$\ln w_i = C + \frac{1}{\theta\sigma} \ln RMP_i + \frac{1}{\theta} \ln A_i \tag{21}$$

Assuming also $q_i = w_i$, Head and Mayer (2004b) provide an alternative version of equation (20). In equation (19), labour is distinguished from other primary factors without reference to their geographical mobility. Now, the wage-type equation takes the following form:

$$\theta \ln w_i + \psi \ln z_i = C + \frac{1}{\sigma} \ln RMP_i + \ln A_i \tag{22}$$

where z might the prize of nontrade factors, for instance. The left-hand side of equation (22) is a cost-share weighted sum of logged primary factor prices. Head and Mayer (2004b) interpret that a natural proxy for this dependent variable is the log of GDP per capita. Similarly, despite the appearance of equation (21), it seems that Redding and Venables (2004) considered that the assumption $q_i = w_i$ was restrictive and their empirical analysis recovered the meaning of q_i in equation (20). They proxied q_i by GDP per capita, because GDP includes the income of all immobile factors. In other words, under both approaches the proxy variable to measure the left-hand side of these wage-type equations is not the wage level.

This assessment of the "wage" equation has an important consequence when trying to interpret the empirical estimations in terms of structural parameters. The estimate of $\ln RMP_i$ in equation (21) cannot be interpreted as an estimate of $1/\sigma$ anymore. It would be necessary to measure A_i in order to deduce a value for σ from the estimation. On the contrary, equation (22) allows the direct estimation of σ. However, as mentioned in section 1, the high correlation between alternative dependent variables make it observationally equivalent to equation (21).

Table 1: The Generalized Wage Equation in Several NEG Models

$$\boldsymbol{m_i = q_i^{\theta} z_i^{\psi} c_i} \;\Rightarrow \text{If } q_i = w_i\text{: } \boldsymbol{w_i = \left[\frac{\sigma-1}{\sigma} \frac{1}{\bar{x}^{1/\sigma}} RMP_i^{\,1/\sigma} \frac{1}{z_i^{\psi}} \frac{1}{c_i}\right]^{1/\theta}}$$

Authors, model	$\boldsymbol{\theta}$	$\boldsymbol{z_i^{\psi}}$	$\boldsymbol{1/c_i}$
Fujita *et al.* (1999, c. 4)	1	1	A
Fujita *et al.* (1999, c. 15)	1	1	A_t
Fujita *et al.* (1999, c. 14); Puga (1999)	θ	$G_i^{M\,1-\theta}$	A
Redding and Venables (2004)	θ	$z^{\gamma} G_i^{M\,1-\theta-\gamma}$	A_i
Head and Mayer (2004a)	θ	$z_i^{1-\theta}$	A_i
Breinlich (2006)	θ	z^{ψ}	A_i
Head and Mayer (2006)	1	1	$A\exp(\beta h_i)$
Fingleton (2006); Fingleton and Fischer (2010)	1	1	A_i; h_i^{β}
Redding and Schott (2003), if $w_i^u = w_i/h_i$	1	1	h_i^{β}
Bruna (2015)	θ	z^{ψ}	$\left(Ak_i^{\alpha} h_i^{\beta}\right)^{\theta}$

Table 1 summarizes how some NEG models can be interpreted under the specification of marginal costs in equation (19). Starting from the 1999 book by Fujita, Krugman and Venables, the table presents some models with different emphasis in theory and in econometrics. The distinction about what is noted as q_i^{θ} and z_i^{ψ} in Table 1 is a matter of convenience. w_i is chosen as the dependent variable of the generalized wage-type equation in order to encompass the models under a common framework. The derivation of each specification from the generalized wage-type equation is available from the author upon request.

The last column in Table 1 translates the marginal input requirement, c_i, into productivity parameters of the M sector. A few models in the table consider an empirical wage equation with control variables proxying for total factor productivity (A_i). Several of those models consider human capital (h_i) and one of them distinguishes the wages of unskilled labour (w_i^u). G_i^M, defined in equation (7), appears in the models with "forward linkages", where the M consumption varieties are also intermediate inputs and their true price index is included in equation (19). The following section presents the wage-type equation in the last row of the Table 1.

4. Inclusion of Human and Physical Capital

In order to consider the role of capital stock as an immobile factor, it is convenient to disaggregate q_i in equation (20) as $q_i = r_i^{\alpha} w_i^{1-\alpha}$, with r_i being the user cost of capital in region i. If this last price is not equalized across countries, and being difficult to obtain data about it, the dependent variable of the generalized wage-type equation get close to the one in equation (22). Under this latter interpretation the testable equation would not be affected by the inclusion of physical capital stock. However, as might be expected, the estimates of Market Potential change dramatically when a wage equation is controlled for physical and human capital (Breinlich, 2006; Bruna, Faíña, *et al.*, 2014).

Alternatively, it is natural to wonder about the interpretation of Redding and Venables's (2004) wage equation when capital adopts the form of capital stock, as in the constructed capital model (Baldwin *et al.*, 2003, chap. 6) or, particularly, in Li's (2012) model with immobile specific capital. The international trade literature considers investment as a produced commodity subject to trade. Once installed as an addition to the capital stock, investment becomes immobile. If capital is considered as mobile *ex-ante*, in some degree or another, but immobile *ex-post*, then past decisions about the location of capital goods are going to condition firm's productivity during long time horizons. However, the time horizon of the NEG model is empirically ambiguous. Cross-sectional regressions with variables in levels are usually considered to represent "long-term" relationships. This may mean that we are taking current data to study remote forces originating a particular spatial distribution of economic activity. Indeed, Krugman (2011) recognized that NEG models were talking about the past, not so much about the current forces of agglomeration. This might not be what many researchers try to test, as evidenced by their discussion about the estimates of σ in terms of current industries.

The time horizon of the model is related to the problem of endogeneity. It might be said that the NEG is concerned with fundamental determinants of income (Redding and Venables, 2004) while developing accounting searches for proximate ones (Caselli, 2005). Under a "long-term" perspective, human and physical capital are endogenous and dependent on forces such as institutions and government policies, which are also endogenous. All these relationships are shaped by Geography through historical processes and it is not easy to disentangle the causal channels. For instance, the spatial distribution of human capital (Redding and Schott, 2003), as well as other variables, can be correlated with Market Potential. However, a distance exponent close to -1 makes any proxy variable for Market Potential to capture neighbouring effects or similarities. Therefore, the whole empirical debate is about the compromise between endogeneity and omission of relevant variables, the selection of the proper exogenous instruments and the unambiguous statistical information captured by each empirical variable. These issues are part of the problem of interpreting the estimation results of a wage equation.

Similarly to Head and Mayer's (2006) approach to human capital, the alternative proposed here is to include human and physical capital stock in the productivity parameter as immobile and exogenous factors. Per capita capital stock could be viewed as embodied in the firms paying immobile workers. Including exogenous human and physical capital in the model does not solve the problems identified above. However, the resulting testable wage-type equation presents several advantages. It permits evaluating a possible upward bias in the estimate of Market Potential due to the omission of relevant variables (Fingleton, 2006) and ascertaining the “direct effects” of Market Potential (Breinlich, 2006). Additionally, the specification can help to capture the effects of exogenous education, infrastructure and transport policies (Bruna, Faíña, *et al.*, 2014). Finally, the similarity of the resulting equation to an expanded production function is an useful reminder of the problem of measuring our ignorance in development accounting, particularly in the context of the discussion in section 1 about the empirical dependent variable of the wage-type equation.

The starting point is to replace equation (12) by a Jones’s (1997) production function, but omitting any reference to Minceranian regressions:

$$x_i = -f + K_i^{\alpha}(B_i h_i L_i)^{1-\alpha} \tag{23}$$

where B_i is a labour-augmenting technological index, while K_i, L_i and h_i are physical capital, raw labor and the average level of human capital, respectively. Then, if physical capital stock per worker is noted as k_i, firm’s production function becomes:

$$x_i = -f + B_i^{1-\alpha} k_i^{\alpha} h_i^{1-\alpha} L_i = -f + A_i k_i^{\alpha} h_i^{1-\alpha} L_i \tag{24}$$

where $A_i = B_i^{1-\alpha} = A$ is a common marginal labour requirement in “effective” labour units ($L_i/k_i^{\alpha}h_i^{1-\alpha}$). Therefore, marginal costs take the form $m_i = w_i^{\theta} z_i^{\psi} c_i = w_i c_i = w_i/Ak_i^{\alpha}h_i^{1-\alpha}$, with $z_i = \theta = \psi = 1$. However, even if k_i and h_i are considered as determinants of the productivity of labour, the possible presence of other production factors makes relevant the θ parameter. The following three examples show why this issue is pertinent to the interpretation of empirical results.
The first case is a generalization of equation (24), such as:

$$x_i = -f + \left[Ak_i^{\alpha} {h_i}^{1-\alpha} L_i\right]^{\theta} Z_i^{\psi} \tag{25}$$

where Z_i is a factor with price z_i, and $z_i = z$. From this production function, the last row of Table 1 shows the proposed version of the generalized wage-type equation (20):

$$w_i = A\left(\frac{\sigma - 1}{\sigma}\bar{x}^{-1/\sigma} z^{-\psi}\right)^{1/\theta} RMP_i^{1/\theta\sigma} k_i^{\alpha} h_i^{\beta} \tag{26}$$

which it is supposed to verify $\alpha + \beta = 1$. The exponent of RMP_i is $1/\theta\sigma$.
A second example with a different interpretation of h_i is based on Mankiw-Romer-Weil’s (1992) production function, in which human capital is considered to be h_i times more productive than raw labour:

$$x_i = -f + AK_i^{\alpha}(h_i L_i)^{\beta} {L_i}^{1-\alpha-\beta} = -f + Ak_i^{\alpha} h_i^{\beta} L_i \tag{27}$$

Unlike the previous example, the wage equation derived from here verifies $\alpha + \beta < 1$ and the exponent of RMP_i is $1/\sigma$:

$$w_i = A\frac{\sigma - 1}{\sigma}\bar{x}^{-1/\sigma} RMP_i^{1/\sigma} k_i^{\alpha} h_i^{\beta} \tag{28}$$

The third example starts with a CRS production function in per capita units, such as $y_i = A_i k_i^{\alpha} h_i^{1-\alpha}$. In the spirit of models with spillovers (Baldwin *et al.*, 2003, chap. 7), now the productivity parameter depends on neighbours productivity or “scale”. From the empirical point of view, this is equivalent to assume $A_i = A\,RMP_i^{\chi}$ for $\chi > 0$ and the estimation results are identical to those of equation (26). Variants of this approach have been used in different strands of the literature by Clemente *et al.* (2009), Fischer (2011) or Holl (2012), among others. This example illustrates once more the difficulty in interpreting the estimation results of a wage-type equation in terms of specific NEG interactions.

5. Conclusions

This chapter discusses some controversial issues of the NEG basic model and derives a new generalized wage-type equation with marginal costs as dependent variable. This equation is used to encompass many previous wage equations found in the literature and to derive a testable equation including human and physical capital as explanatory variables.

The NEG model is difficult to test and presents problems of observational equivalence. The estimation results of a wage-type equation can be interpreted in several ways. These are probably the reasons why some misunderstandings are frequent. In terms of a testable equation and real data, doubts remain about issues such as: the definition of the NEG sectors; the selection of the proper dependent variable; the measurement of the competition index; the production function of the agglomeration sector; the degree of geographical mobility of the production factors; or the time horizon studied by each researcher. Examples of other problematic issues are the following: the influence of the distance decay parameter when measuring Market Potential; the measurement of internal markets; the selection of control variables and exogenous instruments; or the role of technological differences and remote history in cross-sectional regressions with variables in levels.

This discussion is a reminder of the lessons learned by Head and Mayer (2004b) from past work. On the one hand, methods should be connected closely to the theory but should not depend on features of models that were included for tractability. On the other hand we do not want to confirm the validity of NEG based on results that are also consistent with alternative theories.

Notes

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[2] See Duranton and Puga (2004), Head and Mayer (2004b) or Brakman *et al.* (2009, chap. 5).

[3] Estimations carried out by Head and Mayer (2011) or the author of this chapter reveal that the "wage equation" is robust to fixed effects panel data. However, discussing the interpretation of panel data estimations and the role of different rates of technological progress is beyond the scope of this paper, which only refers to the abundant cross-sectional literature.

[4] Many variants of the NEG models are isomorphic irrespective of the agglomeration mechanism they assume (Robert-Nicoud, 2005). Additionally, Head and Mayer (2011) show that the wage equation prediction arises under diverse conditions. However, the interpretation of the empirical results may be different.

[5] See the discussion about a possible variable elasticity of demand in Baldwin *et al.* (2003, chap. 5).

[6] This nonstrategic behaviour is innocuous. (Fujita *et al.*, 1999, chap. 4; Combes *et al.*, 2008, chap. 9).

References

Baldwin R.E., Forslid R., Martin P., Ottaviano G. and Robert-Nicoud F. (2003). "Economic Geography and Public Policy", Princeton University Press.

Brakman S., Garretsen H. and van Marrewijk C. (2009). "The New Introduction to Geographical Economics", Cambridge University Press.

Breinlich, H. (2006). "The spatial income structure in the European Union—what role for Economic Geography?", *Journal of Economic Geography* 6(5), 593–617.

Bruna F., Faíña A. and Lopez-Rodriguez J. (2014). "*Market Potential and the curse of distance in European regions*", MPRA Paper 56747, University Library of Munich.

Bruna F., Lopez-Rodriguez J. and Faíña A. (2014). "Market Potential and Spatial Dependencies in the European Regions", *Regional Studies* (resubmitted).

Caselli, F. (2005). "Accounting for Cross-Country Income Differences", in Aghion P. and Durlauf S. (eds.): *Handbook of Economic Growth*, pp. 679-741, Elsevier.

Clemente J., Pueyo F. and Sanz F. (2009). "Market potential, European Union and growth", *Journal of Policy Modeling* 31(5), 719–730.

Combes P.-P., Mayer T. and Thisse J.-F. (2008). "Economic geography: the integration of regions and nations", Princeton University Press.

Duranton G. and Puga D. (2004). "Micro-foundations of urban agglomeration economies", in Henderson J.V. and Thisse J.-F. (eds.): *Handbook of Regional and Urban Economics* 4, pp. 2063–2117, North Holland.

Fingleton, B. (2006). "The new economic geography versus urban economics: an evaluation using local wage rates in Great Britain", *Oxford Economic Papers* 58(3), 501–530.

Fingleton B. and Fischer M.M. (2010). "Neoclassical theory versus new economic geography: competing explanations of cross-regional variation in economic development", *The Annals of Regional Science* 44(3), 467–491.

Fischer, M.M. (2011). "A spatial Mankiw–Romer–Weil model: theory and evidence", *The Annals of Regional Science* 47(2), 419–436.

Fujita M., Krugman P. and Venables A.J. (1999): “The spatial economy: cities, regions and international trade”, The MIT Press.
Harris, C.D. (1954). “The Market as a Factor in the Localization of Industry in the United States”, *Annals of the Association of American Geographers* 44(4), 315–348.
Head K. and Mayer T. (2004a). “Market potential and the location of Japanese investment in the European Union”, *Review of Economics and Statistics* 86(4), 959–972.
Head K. and Mayer T. (2004b). “The empirics of agglomeration and trade”, in Henderson J.V. and Thisse J.-F. (eds.): *Handbook of regional and urban economics* 4, pp. 2609–2669, North Holland.
Head K. and Mayer T. (2006). “Regional wage and employment responses to market potential in the EU”, *Regional Science and Urban Economics* 36(5), 573–594.
Head K. and Mayer T. (2011). “Gravity, market potential and economic development”, *Journal of Economic Geography* 11(2), 281–294.
Head K. and Mayer T. (2014). “Gravity Equations: Workhorse, Toolkit, and Cookbook”, in Helpman E., Rogoff K. and Gopinath G. (eds.): *Handbook of International Economics* 4, pp. 131–195, Elsevier.
Holl, A. (2012). “Market potential and firm-level productivity in Spain”, *Journal of Economic Geography* 12(6), 1191–1215.
Jones, C.I. (1997): “Convergence revisited”, *Journal of economic Growth* 2(2), 131–153.
Krugman, P. (1980). "Scale economies, product differentiation, and the pattern of trade", *American Economic Review* 70(5), 950–959.
Krugman, P. (1992). “*A Dynamic Spatial Model*”, NBER Working Paper 4219, National Bureau of Economic Research.
Krugman, P. (2011). “The New Economic Geography, Now Middle-aged”, *Regional Studies* 45(1), 1–7.
Li, Y. (2012). “Capital mobility, diminishing returns and wage inequality”, *Journal of International Trade and Economic Development* 21(3), 321–345.
Mankiw N.G., Romer D. and Weil D.N. (1992). “A Contribution to the Empirics of Economic Growth”, *The Quarterly Journal of Economics* 107(2), 407–437.
Puga, D. (1999). “The rise and fall of regional inequalities”, *European Economic Review* 43(2), 303–334.
Redding, S.J. (2011). “Economic Geography: A Review of the Theoretical and Empirical Literature”, in Bernhofen D., Falvey R., Greenaway D. and Kreickemeier U. (eds.). *Palgrave Handbook of International Trade*, pp. 497–531, Palgrave Macmillan.
Redding S.J. and Schott P.K. (2003). “Distance, skill deepening and development: will peripheral countries ever get rich?”, *Journal of Development Economics* 72(2), 515–541.
Redding S.J. and Venables A.J. (2004). “Economic geography and international inequality”, *Journal of International Economics* 62(1), 53–82.
Robert-Nicoud, F. (2005). “The structure of simple ‘New Economic Geography’ models (or, On identical twins)”, *Journal of Economic Geography* 5(2), 201–234.