Oxford Economic Papers Advance Access published April 3, 2006

Oxford Economic Papers 1 of 30
doi:10.1093/oep/gpl006

The new economic geography versus urban economics: an evaluation using local wage rates in Great Britain

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This paper tests two major competing theories explaining the spatial concentration of economic activity, namely new economic geography theory (NEG) which emphasizes varying market potential, and urban economics theory (UE) in which the main emphasis is on producer service linkages. Using wage rate variations across small regions of Great Britain, the paper finds that it is UE theory rather than NEG theory that has most explanatory power. Evidence for this comes from encompassing both models within an artificial nesting model. Despite the popularity of NEG theory, this paper shows that although NEG works well using regional data, there is evidence that it does not necessarily provide the best explanation of local wage variations, since producer services inputs associated with UE theory and labour efficiency variations are important effects at a local level, and these are excluded from the formal NEG model.

JEL classification: C21, C52, J30, O18, R11, R12.

1. Introduction

There have been major advances in the theory of economic geography and urban economics (Fujita *et al.*, 1999; Huriot and Thisse, 2000; Brakman *et al.*, 2001) which strengthen the integration of these fields within mainstream economics by providing formal, general equilibrium, solutions with each agent solving a clearly defined economic problem within the context of a monopolistic competition market structure (Dixit and Stiglitz, 1977). One of the most striking aspects of the new theory is the presence of increasing returns to scale, which hitherto restricted integration with mainstream economic theory, despite the insistence of many researchers that increasing returns were fundamental to a proper understanding of spatial disparities in economic development. However in order to achieve this, a formal theoretical framework had to be constructed which was based on fairly unrealistic assumptions and excluding many factors known to be relevant in the real world. It was only quite recently that economists began to confront models with a basis in the new theory with real data, but now there is a deluge of work which takes the new theory as its starting point, striving to estimate some of the fundamental parameters, or in various ways to operationalize various versions and extensions of the new theory (Combes and Lafourcade, 2001, 2004; Forslid *et al.* 2002; Combes and Overman, 2003; Head and Mayer, 2003; Brakman *et al.*, 2004; Combes *et al.*, 2004; Mion, 2004; Redding and Venables, 2004).

Much of this work focuses around the concepts of the wage equation and market potential, and as acknowledged by Head and Mayer (2003), the wage equation is one of the most successful equations deriving from the new economic geography (NEG). The wage equation formally links nominal wage levels to market potential, which is a long-established concept that goes right back to the work of Harris (1954), but it has been given a new lease of life as a fundamental part of NEG theory. The key element is that firms have differing levels of market potential according to their level of access to their own and neighbouring markets, with access depending on trade costs, the size of the markets, and the competition within markets, with good market access associated with higher wage levels. At the international level the empirical NEG literature provides strong support for NEG theory. Redding and Venables (2004), who consider both market and supplier access, maintain that these 'can explain much of the cross-country variation in *per capita* income', and even after controlling for a variety of other determinants of *per capita* income, they continue to find highly statistically significant and quantitatively important effects. The current understanding coming from the NEG literature is that market and supplier access go a long way to explaining the emergence and persistence of different levels of economic development worldwide. Although the literature is less extensive, within-country regional variations also seem to be accounted for by NEG theory. There is evidence from some studies, such as the often-cited papers by Hanson (1997, 1998), that wages increase in market potential or access, in line with the theoretical predictions set out in the standard NEG literature (Fujita *et al.*, 1999). Among others, Davis and Weinstein (2001), Roos (2001), and Mion (2004) provide further evidence at the level of regions. Rice and Venables (2003) set out a formal general equilibrium model and simulations explaining differentials for UK cities and regions, but this somewhat more elaborate than the wage equation of basic NEG theory.

The main aim of this paper is to test whether the success of NEG and its wage equation is replicated in data for very small regions in the UK, under the challenge of a competing theory and the need to control for additional effects. The paper thus estimates an NEG-motivated wage equation and compares the results with the alternative but related urban economics (UE) model which denies any role for market potential, attributing a primary cause of wage variation to the pecuniary externalities deriving from the presence of service sector linkages which are particularly evident in urban areas, so that in this UE set-up wages increase with the density of productive activity (Rivera-Batiz, 1988; Abdel Rahman and Fujita, 1990; Ciccone and Hall, 1996; Fingleton, 2003). Generally there is empirical support in the literature for UE theory linking urban size or density with wages or productivity. Ciccone (2002) estimates an elasticity of approximately 0.045 for productivity with respect to the density of economic activity using data on European regions, and according to the literature survey by

Rosenthal and Strange (2004), ‘doubling city size seems to increase productivity by an amount that ranges from roughly 3–8%’. From our knowledge of the significance of urban density or size effects, it appears that UE theory may be a credible alternative to NEG as a way of explaining local productivity/wage variations.

Currently there are rarely any UE-style links in NEG theory, although there is a growing recognition that they are likely to be relevant. For instance Venables (1996) and Krugman and Venables (1995) explicitly model intersectoral linkages, de Vaal and van den Berg (1999) develop a hybrid model in which producer service linkages are incorporated into an NEG model, and Redding and Venables (2004) and Amiti and Cameron (2004) give theory and estimates embodying intermediate inputs. Despite this, in this paper a clear distinction between UE and NEG theory is retained, with empirical models derived from UE theory that omit the market potential effects that are at the core of NEG theory, and with NEG-based empirical models that exclude UE-style linkages. However, the paper does bring the two perspectives together as a single empirical model, in the form of an artificial nesting model[1] (ANM) (Davidson and MacKinnon, 1993, Hendry, 1995), in order to evaluate their comparative significance.

To summarize, the paper is divided into the following Sections. Section 2 briefly sketches the two theoretical models. Section 3 is dedicated to issues relating to Data and Assumptions. Section 4 details the empirical models and their estimation. Section 5 give the results, first of fitting the NEG-based model and the UE model, and then the results of fitting the ANM which encompasses both. Section 6 concludes.

2. The theoretical models

2.1 The NEG model

The relationship between nominal wage levels and market access is as set out in Fujita *et al.* (1999). They assume that the economy is divided into competitive (C) and monopolistically competitive (M) sectors, so that the (short-run) equilibrium M wages occasioned by the fast entry and exit of firms driving profits to zero are

$$w_i^M = \frac{\bar{W}_i^M}{E_i^M} = \left[\sum_r Y_r \left(G_r^M\right)^{\sigma-1} \left(\bar{T}_{ir}\right)^{1-\sigma} \right]^{1/\sigma} = P^{1/\sigma} \tag{1}$$

in which i denotes region, $\bar{W}_i^M$ is area i’s total M wage bill, E_i^M is the M workforce, and the summation is over the set of regions including i. The transport cost is $\bar{T}_{ir}$, G_r^M denotes M prices, Y_r denotes income and σ is the elasticity of substitution for M varieties. In contrast, since in this set up C goods are freely transported and

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[1] I use the term artificial since the model does not derive explicitly from a single extant theory but is a hybrid of the two competing theories.

produced under constant returns, C wages w_i^C are constant across regions. Following Fujita *et al.* (1999), the price index is given by (2)

$$G_i^M = \left[\sum_r \lambda_r \left(w_r^M \bar{T}_{ir}\right)^{1-\sigma}\right]^{1/(1-\sigma)} \tag{2}$$

in which the number of varieties produced in region r is represented by λ, which is equal to the share in region r of the total supply of M workers. Income is given by

$$Y_r = \theta\lambda_r w_r^M + (1-\theta)\phi_r w_r^C \tag{3}$$

The basic wage equation is therefore

$$\ln w_i^M = \frac{1}{\sigma}\ln P_i \tag{4}$$

2.2 The UE model

In contrast to NEG theory, UE theory accounts for the spatial concentration of economic activity by emphasizing the varying supply across cities and regions of non-traded producer services. Transport costs, and hence market potential or access, are not relevant. However both approaches have much in common because of their use of Dixit-Stiglitz monopolistic competition theory, and their embodiment of increasing returns to scale within a general equilibrium framework. The core of UE theory is that the monopolistically competitive service sector provides inputs to the production (Q) of competitive industry, in other words

$$Q = \left((E^C \cdot A)^{\beta} I^{1-\beta}\right)^{\alpha} \tag{5}$$

in which $E^C \cdot A$ is the number of C labour efficiency units, and I is the level of composite services based on a CES production function for producer services under monopolistic competition. The presence of $\alpha < 1$ indicates diminishing returns due to congestion effects (Ciccone and Hall, 1996), so that the variables are measured per unit of land. Since I depends only on $E^M \cdot A$ and $N = A\ (E^C + E^M)$, it is possible to show[2] that

$$Q = \left((E^C \cdot A)^{\beta} I^{1-\beta}\right)^{\alpha} = \phi N^{\gamma} \tag{6}$$

with constants ϕ and $\gamma = \alpha[1 + (1-\beta)(\mu - 1)]$ where $[\mu/(\mu-1)]$ is the elasticity of substitution for different services. So long as $\gamma > 1$ this indicates that there

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[2] See for example Fingleton and López-Bazo (2003).

are increasing returns with employment density. It follows, using standard equilibrium theory giving the equilibrium allocation of labour efficiency units to final production Q so that

$$\frac{w^o N}{Q} = \alpha \tag{7}$$

(see the Appendix and Fingleton, 2003), that this results in a wage equation thus

$$\ln(w^o) = \ln(Q) + \ln(\alpha) - \ln(N) \tag{8}$$

and substituting for Q and for labour efficiency units $N = E \cdot A$ in which E is the total employment level per square km and A is each area's level of efficiency, gives

$$\ln(w^o) = \ln(\phi) + \gamma \ln(A \cdot E) + \ln(\alpha) - \ln(A \cdot E) \tag{9}$$

It then follows that

$$\ln(w^o) = k_1 + (\gamma - 1)\ln(E) + (\gamma - 1)\ln(A) \tag{10}$$

in which k_1 denotes a constant. Assuming no efficiency variations, the model becomes

$$\ln(w^o) = k_1 + (\gamma - 1)\ln(E) \tag{11}$$

3. Data and assumptions

3.1 Assumptions about sectors

In the paper I assume that the M sector is equivalent to a subset of service sectors, while all other sectors are C activities. I define the producer services (M activities) as the Banking, Finance and Insurance, etc., subgroup of the UK's 1992 Standard Industrial Classification (see Appendix Table A2). Under UE theory these provide inputs to competitive 'industry' and there is approximate equivalence of firms in these sectors to the theoretical assumptions of monopolistic competition. It is also based on the precedence set in the earlier UE literature. In contrast, it is common in the NEG[3] literature to assume that manufacturing is the M sector, while

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[3] Assuming that M activities are equivalent to Manufacturing, while all other sectors (agriculture) are C activities, follows Fujita *et al.* (1999). Manufacturing is assumed to have increasing returns to scale in many theoretical and applied papers, for example Forslid *et al.* (2002) use evidence from the presence of scale economies in different industrial sectors provided by Pratten (1988). However Redding and Venables (2004) use a composite of manufacturing and service activities.

agriculture (a catch-all for all other activities) is competitive. To show that the choice of M sector is not somehow biasing the results in favour of UE, I also give in Appendix Table A1 estimates of the ANM that result from using manufacturing as the M sector, with manufacturing defined in Appendix Table A3. This means changing θ, λ and ϕ in eq. (3), and λ in eq. (2) so that G and Y are altered in eq. (1).

The assumption made here is that producer services are, broadly, provided by numerous small firms producing differentiated services in which there are often appreciable internal scale economies, perhaps due fixed costs associated with the business start-up and the small equilibrium size of such firms. With a sole input of labour and each firm's total cost function linear, so that $L = s + am(t)$ with fixed labour requirement s and marginal labour requirement a for typical firm or variety t, then as the equilibrium output $m(t)$ increases, returns to scale (defined as average cost divided by marginal cost) fall asymptotically to 1. Hence it seems reasonable to choose a 'sector' typified by small firms using labour as a predominant input, firms freely entering and leaving the market, and competitive pressure giving a zero profit equilibrium. Similar assumptions that services can be characterized as monopolistically competitive are made by Rivera-Batiz (1988) and Abdel-Rahman and Fujita (1990), among others.

3.2 Trade costs

For trade costs I assume an exponential function of the natural logarithm of distance, in other words a power function of the form

$$\bar{T}_{ir} = e^{\tau \ln D_{ir}} = D_{ir}^{\tau} \tag{12}$$

in which D_{ir} is the distance[4] between regions i and r, using the often-used convention (Head and Mayer, 2003, Redding and Venables, 2004) that $D_{ii} = (2/3)\sqrt{A_i'/\pi}$ in which A_i' is region i's area in square miles.[5] The natural logarithm of distance is preferred to distance per se because of it seems to work better when used in gravity model estimates of trade flows. Ideally the parameter τ should be obtained from trade data, but these are unavailable at this very local level. I assume that $\tau = 0.1$, which implies that if $D_{ir} = 100$ miles, the delivered price increases by a factor of 1.58. In contrast, if I were to assume for example that $\tau = 0.25$, this would cause the multiplicative factor to rise to 3.16. It is noticeable that the market potential P that results from an assumption that $\tau = 0.25$ is very similar to the employment density E that is at the core of the competing UE model, with the correlation between P_i and E_i increasing from 0.6373 to 0.8328 as τ goes from 0.1 to 0.25.

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[4] These are simply straight-line distances in miles, since it is considered unnecessary to use great circle distances within a small area such as Great Britain.

[5] The assumption is that within-region distance is equal to a fraction of the radius of a circle with area equal to that of the region.

So using $\tau = 0.25$ means that both the competing reduced forms are in a sense the 'same', although the NEG model with $\tau = 0.25$ means that P is dominated by internal demand which is a function of D_{ii}, and therefore P will depend very much on the arbitrary assumptions used to calculate D_{ii}.

3.3 Market potential, prices, and wages

The right hand side of eq. (1) within brackets can be referred to as the level of market access or market potential P, which depends on incomes Y_r, prices G_r^M, trade costs $\bar{T}_r$, and on σ, and is illustrated by Fig. 1. If for simplicity we were to assume a nominal market potential measure in the spirit of Harris (1954), so that prices are constant across regions, wage levels will be high in regions with low transport costs to high income regions, while isolated regions will tend to have low wage levels. Allowing price variation gives us real market potential but adds

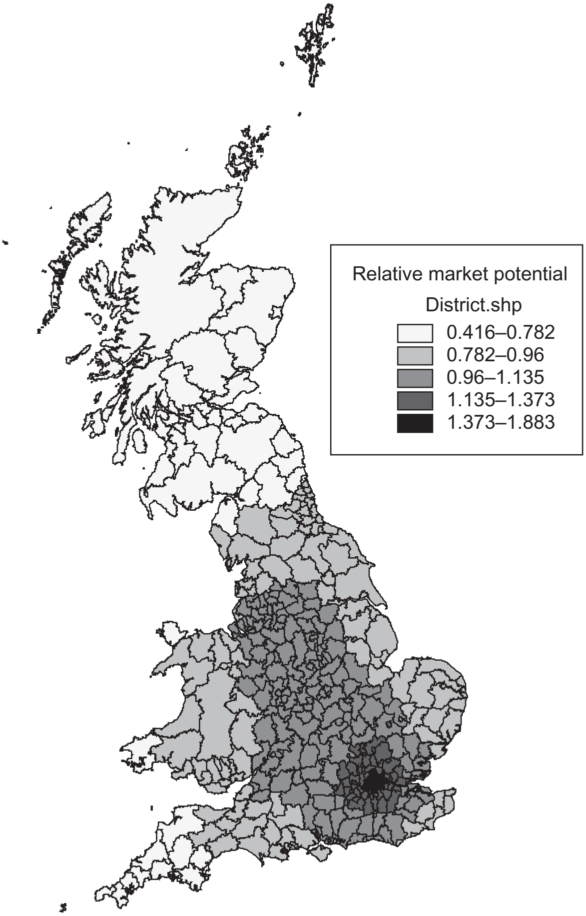

Fig. 1. Real market potential (relative to the mean)

a complication, with high prices (low competition) raising wages, and low prices (strong competition) lowering wages. The price index decreases in the number of varieties, so competition effects will be stronger in larger (more varied) regions. In this paper the real market potential variable is used in the empirical modelling.

Given the assumptions detailed below, we see in Fig. 1 that real market potential reaches a peak in and around London, despite the fact that this is where competition effects are at their strongest, as revealed by the price ratios. The ratio of the M price indices for the areas in Central London and the Shetland Islands is about 1.22, while prices are 8% higher in mid-Devon, and 1% higher in inner Manchester.

An important feature of Fig. 1 is the focus on London and the smooth decline away from this focal point in all directions. However alternative values allotted to σ produce different surfaces. If we choose large values for σ (eg 20), the main cities, but especially London, stand out also as peaks on the P surface, while small σs (eg 2) create an almost flat plain. The value for σ is therefore of great significance for the explanatory power of NEG theory. In eqs (1) and (2), σ is set equal to a value for elasticity of substitution typical of the published literature. Hence we assume that $\sigma = 6.25$ (the mid-point of the published range given by Head and Mayer, 2003). This then allows estimation of σ, with covariates necessary to ensure that the estimated and assumed σ are similar to each other.

This approach to P estimation differs from gravity model based estimates that make use of trade flows (for example Redding and Venables[6], 2004). Unfortunately trade flows are not available at the level of spatial resolution adopted here. One possible limitation of the method used here is that it ignores differences in access to EU markets, which are treated as effectively constant across all GB regions. However, as indicated later, there is empirical evidence that supports this simplifying assumption.

Unfortunately, we do not have data for M wage rates, but only for the overall wage rate[7] w_i^o in each UALAD, as described by Fig. 2. In the NEG model I therefore use the overall wage rate as a proxy for w_i^M and include an error term in the model to capture this measurement error. This also means that measurement error is incorporated into the market potential P_i, and in the price index G_i, which depend on w_i^M. Partly because of the measurement errors, we routinely use an instrument for P_i^M as part of a 2sls estimation routine (see below).

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[6] Redding and Venables (2004) focus on the equivalent to the wage equation in an international setting using a related but different theoretical set up to the one underpinning NEG in this paper. In their model, wages are a function of market access and access to suppliers of intermediate goods, and they measure market (and supplier) access via an auxiliary gravity model fitted to international trade data.

[7] The observed wages are taken from the year 2000 results of the Office for National Statistics' New Earnings Survey, which is carried out annually by the UK's Office of National Statistics. These are workplace based survey data of gross weekly pay for male and female full time workers irrespective of occupation, so are not directly comparable with the C wages and M wages produced by the model. These are available on the NOMIS website (the Office for National Statistics' on-line labour market statistics database). There are no data for Scilly isles, so the data for the nearest mainland area of Penwith have been used in this case.

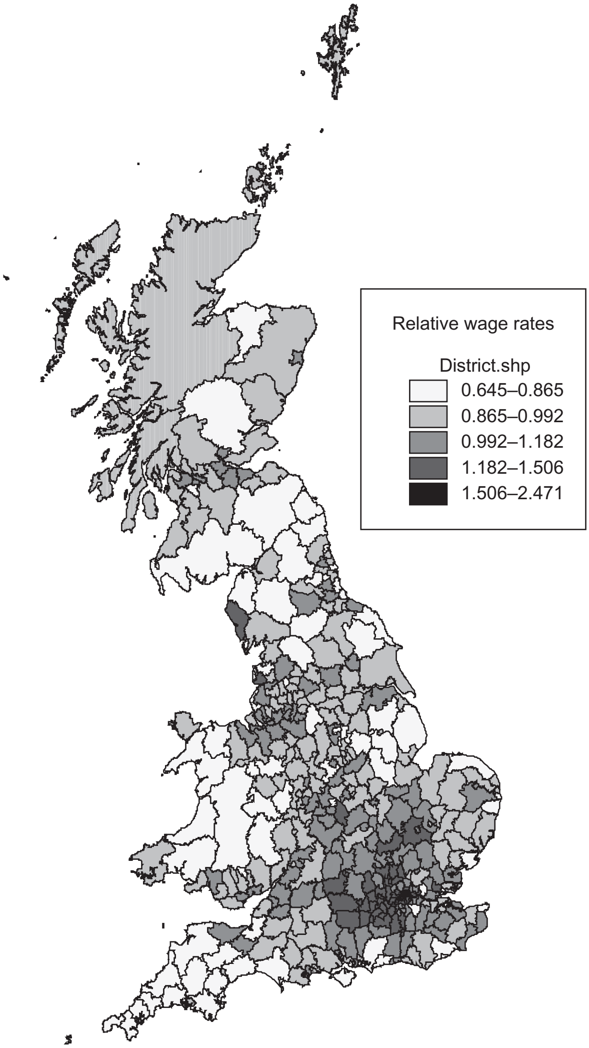

Fig. 2. Wage rates (relative to the mean)

Incomes, given by eq. (3), are estimated using the share of C workers[8] in each region (ϕ_i), the share of M workers (λ_r), and the expenditure share of M goods (θ) which is taken as the overall share of total employment in 2000 that is engaged in M activities, assuming that θ is also the total M workers and $1-\theta$ is the total C workers using a suitable metric that equates the overall number of workers to 1. Again we use the proxy w_i^o for w_i^M and assume that $w^C = MEAN(w_r^o)$.

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[8] Employment levels are given by the annual business enquiry employee analysis, also carried out by the Office of National Statistics and available on the NOMIS database.

3.4 Labour efficiency

Wage rates w_i^M and w_i^o are also assumed to depend on factors other than market potential, in the case of NEG, or employment density in the case of UE. We assume that an important factor is the level of efficiency of workers (A_i), both within each local area and within commuting distance. Given that we are analysing small area data within the UK, the variation in efficiency level between areas is attributed to differences between workers in their ability to make use of the common technology that is available. We therefore assume that technology is homogeneous across the areas but differences exist between areas in terms of the ability to apply that technology in production. As a first approximation, the assumption is that efficiency depends on local levels of schooling (S) and on workplace acquired skills (T).

Introducing these extra variables contradicts somewhat the theory underlying the basic NEG wage equation which is based on the existence of pecuniary externalities, while other effects are excluded from the formal structural model. However in the real world a range of factors will play a part in determining observed wage rates, and excluding them would severely bias our estimates, as will be shown below. In fact we are making a shift in the definition normally applied in NEG theory, which in its basic form (Fujita *et al.*, 1999) does not distinguish between efficiency wages (earnings per efficiency unit) and earnings per worker. In other words, we are extending the wage equation by writing

$$\begin{aligned} w_i^{\prime M} &= \frac{\bar{W}_i^M}{E_i^M \cdot A_i} = P_i^{1/\sigma} \\ w_i^M &= \frac{\bar{W}_i^M}{E_i^M} = P_i^{1/\sigma} \cdot A_i \end{aligned} \tag{13}$$

Recognizing this distinction opens the door to some additional variables. Interestingly, other researchers have recognized the need to consider efficiency or skills variations, for example Combes *et al.* (2004).

The variable S is the percentage of residents with no qualifications, as given[9] by the UK's 2001 Census. The rationale for this variable is the widely recognized link between labour inefficiency and inadequate schooling. The focus is no qualifications, since this is considered to be a more transparent measure than the various levels of qualification indicators that are available, eliminating the problem of determining which level of schooling one should focus on, maintaining the same intrinsic meaning across cultures and time, and being an important focus for policy initiatives. Although S postdates w^o by one year, I assume that S is exogenous for the purposes of estimation. It is unlikely that we would see feedback from w^o to S

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[9] Available from the website Casweb, which is a web interface to statistics and related information from the United Kingdom Census of Population.

on this time scale, and S is undoubtedly affected by factors other than wage differentials, such as Government and EU policy initiatives, institutions and social and cultural differences, and so is in effect predetermined.[10]

The technical 'workplace oriented' knowledge (T) of the workforce is approximated by the relative concentration of employees in the computing and research and development sectors. Therefore T is the location quotient for each area giving the workforce specialization in computing and related activities (1992 SIC 72) and in research and development (1992 SIC 73), calculated from data taken from the annual business enquiry employee analysis (available through NOMIS).[11] This therefore measures the relative concentration by area of employees with work-related skills in hardware consultancy, software consultancy and supply, data processing, data base activities, computer and office machinery maintenance and repair, and in other unspecified computer related activities. In addition it includes workers involved in research in the natural sciences and engineering, and in the social sciences and humanities.

3.5 Commuting

The wage data are based on employer surveys and therefore relate to the place of work not the place of residence. This means that we should consider the effect of commuting, since while we know the wages paid to local workers and commuters at the place of employment, we cannot base our estimation of their efficiency simply on the level of efficiency pertaining to workers living within the local area, but should also consider the added effect of the efficiency of workers living in areas within commuting distance. In other words the efficiency of the labour force employed within an area will, it is hypothesized, in part be determined by commuting, the frequency of which falls as distance increases. The rate at which this fall-off in commuting frequency occurs is embodied within the matrix W, which is determined by the varying rate of decline-with-distance of commuting in each individual area. Written in general matrix notation, the vector of efficiency levels is

$$\begin{gathered} \ln(A) = Xb + \rho W \ln(A) + \xi \\ \xi \sim N(0, \Omega^2) \end{gathered} \tag{14}$$

in which X is an n by k matrix of exogenous variables (with columns equal to 1, S and T), b is a k by 1 vector of coefficients, the matrix product $W\ln(A)$ is an

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[10] Comparing the 1991 and 2001 shares with no qualifications for the 408 unitary authority and local authority districts in Great Britain, I find that while the average population share with no qualifications has fallen dramatically, there exists a strong linear correlation ($r = 0.872$) between the 1991 and 2001 census data sets, so using the 1991 data gives similar results.

[11] The location quotient is the share of local employment in these sectors divided by national share.

n by 1 vector with scalar coefficient ρ, and vector ξ represents excluded variables which behave as random shocks. The endogenous variable $W\ln(A)$ represents the contribution to efficiency which is assumed to be due to commuting, as defined by the matrix W, where the definition of W is

$$\begin{aligned} W_{ir} &= \exp(-\delta_i D_{ir}) \quad i \neq r \\ W_{ir} &= 0 \quad i = r \\ W_{ir} &= 0 \quad D_{ir} > 100\,km \end{aligned}$$

This shows that the value allotted to cell (i, r) of the W matrix is a function of the (straight line) distance (D_{ij}) between areas and an exponent δ_i that reflects the area-specific distance decay. The choice of exponent δ_i is based on empirical comparisons with observed census data on travel to work patterns,[12] following the calibration method given in Fingleton (2003).

Presented in more detail, the log level of efficiency in area i is

$$\ln(A_i) = b_0 + b_1 S_i + b_2 T_i + \rho \sum_r \exp(-\delta_i D_{ir}) \ln(A_r) + \xi; \quad r \neq i, \quad D_{ir} \leq 100$$

so that provided $\rho > 0$, area i's efficiency level will be higher if the commuting frequencies fall less steeply with distance (δ_i is small) and be mostly influenced by efficiency levels in nearby areas (D_{ij} small). In fact the Leontief expansion shows that this means that the efficiency level of area i depends on the schooling (S) and technology (S) levels in all other areas. Reverting to the matrix notation of eq. (14), and assuming $|\rho| < 1$, the expansion is given by

$$\begin{aligned} \ln(A) &= (I - \rho W)^{-1}(Xb + \xi) \\ \ln(A) &= (I - \rho W)^{-1}(Xb) + (I - \rho W)^{-1}\xi \\ \ln(A) &= \left(\sum_{i=0\ldots\infty} \rho^i W^i \right) Xb + \left(\sum_{i=0\ldots\infty} \rho^i W^i \right) \xi \\ \ln(A) &= Xb + \rho WXb + \rho^2 W^2 Xb + \rho^3 W^3 Xb + \ldots \end{aligned}$$

in which W^0 equals the identity matrix I, W^2 is the matrix product of W and W, W^3 is the matrix product of W^2 and W, and so on. This means that an area's level of efficiency A depends on the exogenous variables S and T (and the shocks) to infinite spatial lags, but, depending on ρ, will be mainly determined by the levels of S, T and ξ within the area (Xb), and by the levels of S, T and ξ in other nearby areas (WXb) with weights determined by the 'commuting' matrix W.

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[12] 1991 Census of Population – Special Workplace Statistics, available from NOMIS.

Note that the efficiency term A is not measured directly, but enters (due to substitutions elaborated upon in the appendix) on the right hand side of the estimating equation through S, T, and $W \ln w^o$, as indicated below.

4. The empirical models and estimation

4.1 The empirical NEG model

Combining eqs (14) and (4), it can be shown (see the Appendix) that

$$\begin{gathered}\ln w^o = \rho W \ln w^o + a_1(\ln P - \rho W \ln P) + b_0 + b_1 S + b_2 T + \xi + (I - \rho W)\omega \\ \xi \sim N(0, \Omega^2) \quad \omega \sim N(0, \Pi^2)\end{gathered} \tag{15}$$

in which ω represents measurement error caused by using $\ln w^o$ to represent $\ln w_i^M$. This equation has some special features that should be noted for estimation purposes. First, directly as a result of the way we have modelled each labour force's efficiency, it contains an endogenous lag $W \ln w^o$. Therefore there is an autoregressive interdependence of the wage rate on wage rates within commuting distance, so the right hand side wage variable is endogenous, picking up spatial autocorrelation in the wage rate. In addition and the variable P is endogenous because it too depends on w^o, and it is subject to measurement error. Secondly there are parameter constraints[13] involving ρ which exist because of the hypothesis that the spatial autocorrelation in wages is caused by the spillover of labour efficiency levels between areas. Third it contains a spatial moving average error $(I - \rho W)\omega$, which as noted by Anselin (2003), implies a local range for the induced spatial covariance, as opposed to the global range that would be induced by the covariance structure that would be given by a Leontief expansion of a spatial autoregressive structure $(I - \rho W)^{-1}\omega$, assuming $|\rho| < 1$ and $W_{ij} < 1$ for all i, j. Because this adds further complication, I have disregarded the moving average errors in the model, but I test for residual autocorrelation in the model to check whether this leads to any specification error. This also tests whether there is unmodelled spatial dependence in the wage rate due to nuisance spatial autocorrelation effects. The equation estimated is therefore

$$\begin{gathered}\ln w^o = \rho W \ln w^o + a_1(\ln P - \rho W \ln P) + b_0 + b_1 S + b_2 T + \xi \\ \xi \sim N(0, \Omega^2)\end{gathered} \tag{16}$$

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[13] One is that ρ appears twice. The other is that $1/e_L = -1.021 < \rho < 1/e_U = 0.04164$ where e_U is the largest positive eigenvalue of W, and e_L is the largest negative eigenvalue. This constraint avoids an 'explosive' model at these and other singular points similar to the presence of unit roots in time series, as discussed in Fingleton (2003). This latter constraint is satisfied without any intervention in the estimation process.

The question of endogeneity is carefully considered by Mion (2004), who exploits the time dimension and possibly slow adjustment to equilibrium to avoid fully contemporaneous simultaneity. In this paper I primarily use iterated 2sls to estimate the equation, with each iteration giving an updated ρ from $W\ln w^o$ term which is then used to update $\rho W\ln P$ and $\ln P - \rho W\ln P$ for the subsequent iteration, until ρ reaches a steady state, as in Fingleton and McCombie (1998) and Fingleton (2003). The endogenous right hand side terms $W\ln w^o$ and $\ln P - \rho W\ln P$ are replaced in each iteration by instruments equal to the fitted values of first stage regressions. In the case of $W\ln w^o$ the regressors are the instrumental variable I^P, as explained below, and the exogenous and spatially lagged exogenous variables (ie *S, T, WS, WT*).[14] Likewise for $\ln P - \rho W\ln P$ we use the same regressors I^P, *S*, *T*, *WS*, and *WT*. With regard to the instrumental variable I^P, the method used is based loosely on the 3 group method (described in Kennedy, 2003 and Johnston, 1984) in which I^P takes values 1, 0 or -1 according to whether $\ln P - \rho W\ln P$ is in the top, middle or bottom third of its ranking, which ranged from 1 up to 408.[15] Note that since $\ln P - \rho W\ln P$ changes in each iteration, so in principle does I^P.

Additionally maximum likelihood estimation is used to provide an informal comparison with the 2sls estimates. The likelihood function[16] and covariance matrix given in Cliff and Ord (1981), Upton and Fingleton (1985), and Anselin (1988) allows for the presence of the endogenous right hand side term $W\ln w^o$ in eq. (16), and estimation is by an iterative bisection search routine, which is embedded within the iterations necessary to ensure that the parameter constraint involving ρ is also satisfied. Hence the bisection search provides a ML estimate ρ from the $W\ln w^o$ term which is then used to update $\ln P - \rho W\ln P$, and the bisection search is repeated until ρ converges. The additional constraint that $1/e_L < \rho < 1/e_U$ is automatically satisfied by the likelihood function.

Because of the comparative complexity of the estimation method, we also give the results of a simpler model in which there is no ‘commuting’ effect, simply to highlight its necessity. The estimating equation is as eq. (16) but with ρ set to zero, hence

$$\begin{gathered} \ln w^o = + a_1 \ln P + b_0 + b_1 S + b_2 T + \zeta \\ \zeta \sim N(0, \Omega^2 + \Pi^2) \end{gathered} \tag{17}$$

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[14] See Kelejian and Robinson (1993) and Kelejian and Prucha (1998) for a discussion of the efficacy of the use of low order spatial lags. While the use of spatial lags is seen as an effective way to generate instruments, these authors warn against including high order spatial lags to avoid linear dependence.

[15] This method is described in the context of variables subject to measurement error, but is intended here to have the same effect of eliminating correlation between the instrument and the error term.

[16] Strictly this is invalidated by endogeneity and measurement error within right hand side variables.

in which the error term ζ combines the errors associated with $\ln w^o$ and $\ln(A)$. This is estimated by 2sls using simply I^P in the first stage regression of $\ln P$, with values $-1, 0, 1$ from the ranking of $\ln P$.

4.2 The empirical UE model

Combining eqs (10) and (14), it can be shown (see the Appendix) that

$$\begin{aligned} \ln w^o &= \rho W \ln w^o + (I - \rho W)\ln(k_1) + (\gamma - 1)(\ln E - \rho W \ln E) \\ &\quad + c_0 + c_1 S + c_2 T + \Psi \\ &\quad \Psi \sim N(0, (1-\gamma)^2 \Omega^2) \end{aligned} \tag{18}$$

in which $E = E^C + E^M$ is the employment level per sq. km (see Fig. 3).

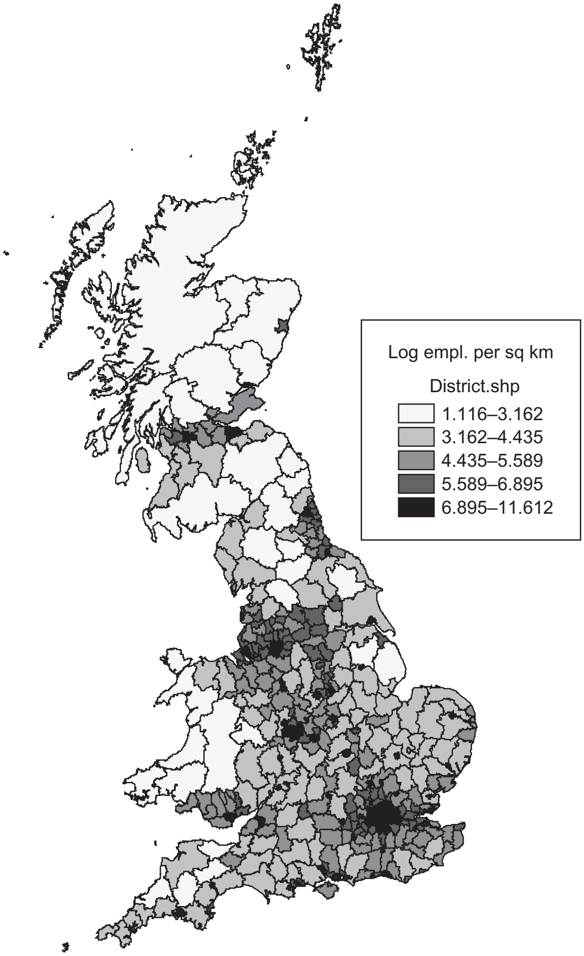

Fig. 3. Employment density

Unfortunately, we do not know $k_1 = \ln(\alpha\phi)$ so the variable $(I - \rho W)k_1$ is of necessity omitted from the estimating equation, which is therefore

$$\ln w^o = \rho W \ln w^o + (\gamma - 1)(\ln E - \rho W \ln E) + c_0 + c_1 S + c_2 T + \Psi \qquad (19)$$

However the test for residual spatial autocorrelation below shows that this omission is evidently not a problem. Estimation of eq. (19) presents the same problems as eq. (16), since we have an endogenous variable E (employment density will depend on wage rates), an endogenous spatial lag $W \ln w^o$, a constraint involving ρ, and an omitted variable. The method of estimation is again iterated 2sls, which is carried out in precisely the same way as for the NEG model, except that among the set of regressors for the first stage 2sls regressions of each iteration, I^P is replaced by I^E, which is the $-1, 0, 1$ variable from the ranking in each iteration of $\ln E - \rho W \ln E$. This is supplemented by the results of ML estimation, carried out in the same way as for the NEG model.

The simpler alternative model (20) resulting from nullifying spatial effects by constraining $\rho = 0$ in eq. (19) is

$$w^o = (\gamma - 1)\ln E + c_0 + c_1 S + c_2 T + \Psi \qquad (20)$$

In this case estimation is via 2sls with the single first stage regressor a $-1, 0, 1$ variable using the ranking of $\ln E$.

4.3 The artificial nesting model

The focus of the paper is whether it is possibly to falsify one, both or neither of these two 'competing' theories. The problem with this assessment is that here we are dealing with non-nested hypotheses, H_0: NEG and H_1: UE. By non-nested I mean that the explanatory variables of one are not a subset of the explanatory variables of the other, with the hypotheses representing conflicting theories and the standard inferential tool-kit which is available for nested hypotheses inapplicable. For example, in the context of likelihoods, if H_0 is nested in H_1, so that the two are identical apart from restrictions placed on one or more parameters under H_0, then it is well known that the twice the difference in log likelihoods is distributed as χ^2_k under the null that H_0 is true, where k is the number of restricted parameters. With non-nested models this asymptotic distributional theory breaks down, leading to the work of Cox (1961, 1962) and subsequently Pesaran (1974) and Pesaran and Deaton (1978) who considered the appropriate null distribution. However Anselin (1986, 1988) points out that with the presence of an endogenous spatial lag, Cox-type tests resulting from the comparison of likelihoods are fairly impracticable because of the absence of simple analytical derivations, unlike Pesaran (1974) and Walker (1967) who worked in the context of serial correlation.

However non-nested does not mean 'non-nestable'. Hendry (1995) sheds light on the question by invoking the existence of an assumed Data Generating

Process[17] which has the property that even though the rival models are non-nested relative to each other, they are nested within the DGP. Both rivals are special cases of the DGP even though they are not special cases of each other. The problem of deciding between the rivals then amounts to considering whether any one rival encompasses the DGP. By encompass we mean that one model can explain the results of another. If the UE model encompasses the DGP, since the DGP nests the NEG model, we can infer that the UE model explains the results from the NEG model.

We build on these ideas using an ANM, which by construction encompasses both of the nested empirical models, by testing whether there is a loss of information in restricting the ANM and reducing to either of the UE and NEG models. Rather than theoretically distinct hypotheses, with the ANM I assume that wage rates depend not only on market potential and labour efficiency, but also on the market services input linkages (density of employment E_i) in an area, anticipating the further development of formal theory combining these two separate perspectives. The resulting ANM specification falls out from the same arguments as earlier (see the Appendix), so that

$$\begin{aligned}\ln w^o = {} & (I-\rho W)k_2 + \rho W \ln w^o + d_0[(I-\rho W)\ln E] + d_1[(I-\rho W)\ln P] \\ & + g_0 + g_1 S + g_2 T + \zeta + (I-\rho W)\eta\end{aligned} \qquad (21)$$

Note that $(I-\rho W)k_2$ is unknown and omitted, and I also omit the moving average error process $(I-\rho W)\eta$. Neither omission results in significantly spatially autocorrelated residuals. This gives the equation

$$\ln w^o = \rho W \ln w^o + d_0[(I-\rho W)\ln E] + d_1[(I-\rho W)\ln P] + g_0 + g_1 S + g_2 T + \zeta \qquad (22)$$

Estimation proceeds exactly in the same way as for the NEG and UE models per se, by means of iterated 2sls (and iterated ML) until successive ρ estimates reach a steady-state, and with 2sls instrumental variables I^E, S, WS, T, WT for, I^P, S, WS, T, WT for $(I-\rho W)\ln E$, I^P, S, WS, T, WT for $(I-\rho W)\ln P$, and I^E,I^P, S, WS, T, WT for $\rho W \ln w^o$.

Again, for purposes of comparison, we also eliminate spatial effects by restricting ρ to 0, so that in this case the estimating equation is

$$\ln w^o = d_0 \ln E + d_1 \ln P + g_0 + g_1 S + g_2 T + \zeta \qquad (23)$$

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[17] This does not mean that the assumed DGP is the true mechanism generating the data, which remains unknown.

5. Results

5.1 The NEG model

Table 1 gives the results of fitting the NEG model.[18] The second column contains the 2sls estimates of eq. (4) (plus a constant which is an empirical necessity), which corresponds to the very basic, purest, NEG specification. This equation is clearly misspecified, with residual autocorrelation very evident which, if caused by omitted spatially autocorrelated regressors, would induce significant bias in the estimated value of σ, which is assumed to be 6.25 for the purpose of constructing G_i^M and hence P_i^M. The test statistic for residual autocorrelation is equal to 22.03 is quite an

Table 1 Estimates of empirical models motivated by NEG theory

Regressors	Parameter estimates†*			
	2sls eq. (4)	2sls eq. (17)	2sls eq. (16)	ML eq. (16)
constant	−15.20	−7.846279	0.225841	2.556047
(b_0)	(−11.30)	(−5.66)	(0.11)	(2.18)
Market potential:				
$\ln P_i - \rho W \ln P_i$ ($a_1 = 1/\sigma$)	0.576237	0.377006	0.150611	0.086316
	(15.60)	(9.90)	(2.70)	(2.67)
Labour efficiency (A) variation due to:				
local schooling	0	−0.005007	−0.000802	−0.001032
S_i (b_1)		(−4.62)	(−0.87)	(−1.15)
local technical knowledge	0	0.050442	0.045874	0.051718
T_i (b_2)		(6.85)	(6.66)	(8.96)
commuting	0	0	0.017412	0.002960
$W\ln(w^o)$ (ρ)			(2.97)	(5.73)
error variance	0.01632	0.01292	0.008754	0.008326
R-squared*	0.4851	0.5475	0.7269	
Correlation†	0.4342	0.5531	0.6983	0.7092
Degrees of freedom	406	404	403	403
Residual autocorrelation‡	22.03	10.91	1.784	2.939
Log likelihood				397.871271

Notes: *Given by $\mathrm{Var}(\hat{Y})/\mathrm{Var}(Y)$, where Y is the dependent variable.

†The square of the Pearson product moment correlation between observed and fitted values of the dependent variable.

‡For 2sls, the Anselin and Kelejian (1997) test for residual correlation with endogenous variables either with or without endogenous lag. The test statistic should be referred to $N(0,1)$. For ML, the LM test which should be referred to the Chi-squared distribution with 1 degree of freedom, each using the commuting matrix.

†*t ratios given in brackets beneath estimates.

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[18] As a matter of interest, since they do not rely on instruments, the results of ML estimation, again iterated to preserve the constraints, are also given. However these cannot be relied on for statistical inference because they are obtained assuming that all the variables, apart from $W\ln(w)$, are exogenous and measured without error, hence discussion is confined to the 2sls estimates.

extreme value in the N (0, 1) reference distribution, and is incompatible with a null hypothesis of no residual spatial autocorrelation. The results of fitting eq. (17) are summarized in column 3, which shows the impact of introducing the labour efficiency variables, which are evidently not orthogonal to market potential since the estimated coefficient $1/\sigma$ changes, although the evidence still points in the direction of a very significant market potential effect. From column 3 we have that $\sigma = 2.652$, but there are some issues created by this specification. For instance the approximate 90% confidence interval for σ is 2.28 to 3.18, which excludes the assumed value of $\sigma = 6.25$ which was used to construct P_i^M. In addition, significant residual autocorrelation remains in evidence, pointing to some misspecification error possibly created by one or more omitted spatially autocorrelated variables inducing residual dependence.

Allowing also for commuting by estimating eq. (16) gives the preferred 2sls estimates in Table 1 column 4, which are the result of iterations to ensure the constraints in eq. (16) are satisfied. The 2sls point estimate of $1/\sigma$ is 0.17 standard errors from the assumed value ($1/\sigma = 0.16$) used to construct P_i, which is central to a range of estimates in the empirical literature. Note that this specification eliminates significant residual autocorrelation. Finally there is no significant effect from a proxy for differential access to EU markets, in the form of an additional regressor equal to the natural log of straight-line distance from Dover (estimating distance from Dover to itself in the same way as before). The iterated 2sls parameter estimates are nearly identical to those of column 4 and the t ratio is equal to -0.18.

It appears that the NEG-based model, in the form of eq. (16), with the simplifying assumption that market potential is determined primarily by access to GB markets, provides a plausible explanation of wage variation and generally supports NEG theory as an explanation of the spatial concentration of economic activity. It appears that access to markets and suppliers, as measured by market potential variations described by Fig. 1, is indeed a cause, and a consequence, of wage rate variation between local areas. Up until now much work in geographical economics has focussed at the international level and shown this type of effect. These data add to the evidence that market potential is also an important cause of within-country wage variations. However it is apparent that market potential alone is insufficient to explain wage rate variations; considerable effects due to local skill variations are also evident, in line with ongoing research which is also tending to now incorporate this as an aspect of NEG-based models. The negative coefficient on schooling is precisely what one would anticipate given its definition as a lack of qualifications, while the technical knowledge indicator is significantly positive, as expected. In addition, a very strong residual autocorrelation effect has been seen, which has been attributed to the effects of commuting to centres of employment, so that both within-area skill levels and efficiency variations among commuters living outside the area of employment make a significant additional contribution to explaining wage level variation between areas.

5.2 The UE model

The ‘competing’ UE model estimates are summarized in Table 2. The estimates given in Table 2 column 2 shows that employment density (*E*) is a highly significant variable (Fig. 3) although again there is also a very high level of residual autocorrelation associated with this simplest specification, which corresponds to eq. (11). Allowing for efficiency variations, column 3 summarizes estimates of the eq. (20) specification, and while this does reduce the autocorrelation to some extent, it remains a significant feature pointing to ongoing misspecification error, probably again as a by-product of one or more omitted variables. Interestingly, the elasticity of wages with respect to employment density is approximately 0.04, which is close to that found by Ciccone (2002).

In order to eliminate what is hypothesized as the source of this misspecification error, the commuting effect is introduced, according to the eq. (19) specification. The results of 2sls estimation, iterated in order to satisfy the constraints in eq. (19), are summarized by column 3, which shows that the quantitative impact of *E* is moderated somewhat with the introduction of the significant commuting term. The elasticity with respect to employment density is only about 0.014. Therefore as in the case of the NEG model, commuting is again considered to be a significant factor in explaining wage rate variation between areas, causing levels of labour efficiency to be enhanced in central city areas with extensive commuting links to

Table 2 Estimates of empirical models motivated by UE theory

	Parameter estimates†*			
Regressors	**2sls eq. (11)**	**2sls eq. (20)**	**2sls eq. (19)**	**ML eq. (19)**
constant	5.525702	5.726596	5.644819	5.635621
(c_0)	(211.25)	(151.68)	(186.09)	(189.01)
Density				
$\ln E_i - \rho W \ln E_i$ ($\gamma - 1$)	0.048651	0.039727	0.013978	0.018051
	(10.21)	(9.97)	(3.64)	(5.29)
Labour efficiency (A) variation due to:				
local schooling	0	−0.007407	−0.001751	−0.002046
S_i (c_1)		(−6.75)	(−1.90)	(−2.26)
local technical knowledge	0	0.062147	0.052693	0.051613
T_i (c_2)		(8.95)	(9.60)	(9.52)
commuting	0	0	0.001422	0.001365
$W\ln(w^o)$ (ρ)			(16.40)	(16.45)
error variance	0.02004	0.01293	0.008053	0.007927
R-squared*	0.2180	0.5285	0.7175	
Correlation†	0.3119	0.5533	0.7222	0.850
Degrees of freedom	406	404	403	403
Residual autocorrelation‡	62.80	19.64	1.331	2.013
Log likelihood				407.915215

Notes: See Table 1.

well-educated and highly skilled residents of the suburbs. And again, the labour efficiency level within each local area is a significant factor with both variables *S* and *T* correctly signed and significant. Technical knowledge of the labour force in the local area is highly significant, while local schooling is marginally significant.

Despite these significant effects and the low elasticity, it is nevertheless the case that the estimated value of $\gamma - 1$ from the eq. (19) specification is significantly above zero, pointing to increasing returns to employment density within the local area. It appears that the pecuniary externalities, as envisaged in the underlying UE theory, are a separate source of high levels of productivity and wages additional to local and in-commuting labour efficiency effects. The level of fit of the UE model, as summarized by eq. (19), is about equivalent to that of the NEG model summarized by eq. (16), suggesting informally that neither model is quantitatively superior to the other. The analysis below attempts to cast more light on which might be the preferred specification from an econometric perspective.

5.3 The artificial nesting model

The resulting estimates of the restricted eq. (23) model are given in column 2 of Table 3, and these suggest that wage rates are dependent both of market potential *P* and on producer service inputs *E*. In addition the significance of schooling *S*

Table 3 ANM estimates

	Parameter estimates†*		
Regressors	**2sls eq. (23)**	**2sls eq. (22)**	**ML eq. (22)**
constant	−3.929388	4.246565	4.654684
(g_0)	(−2.75)	(1.68)	(3.73)
Market potential:			
$\ln P_i - \rho W \ln P_i$ (d_1)	0.266563	0.038654	0.027192
	(6.76)	(0.55)	(0.79)
Density:			
$\ln E_i - \rho W \ln E_i$ (d_0)	0.028356	0.013934	0.016873
	(6.87)	(3.63)	(4.53)
Labour efficiency (A) variation due to:			
schooling	−0.006467	−0.001860	−0.002044
S_i (g_1)	(−6.17)	(−1.98)	(−2.26)
technical knowledge	0.045770	0.050505	0.050396
T_i (g_2)	(6.54)	(7.49)	(8.95)
commuting	0	0.001776	0.001600
$W\ln(w^o)\ \rho$ (ρ)	(2.79)	(5.28)	
error variance	0.01157	0.008047	0.007916
R-squared*	0.6430	0.7213	
Correlation†	0.6015	0.7231	0.7235
Degrees of freedom	403	402	402
Residual autocorrelation‡	4.048	1.278	2.294
Log likelihood			408.193566

Notes: See Table 1.

and knowledge T is again evident, with appropriate signs. However this model is misspecified, as shown by the significant residual spatial autocorrelation. The eq. (22) model introduces spatial dependence assumed to be due to commuting, and the iterated 2sls estimates in column 3 of Table 3 show that this has significant effect on wage rates, supplementing the effects of the efficiency variables S and T. The coefficient on the employment density variable E is also significantly above zero, but it is apparent that market potential is insignificant, since the null $d_0 = 0$ cannot be rejected. Reducing from the ANM to the UE model entails no loss of information, but it is evident that reducing from the ANM to the NEG model by restricting the coefficient d_1 to zero is not feasible, since Table 3 shows that d_1 is significantly different from zero. When confronted directly by the UE model, the market access kernel of the NEG-motivated model loses it explanatory power, but the opposite is not true. These results are also supported by bootstrap J tests (Fan and Li, 1995; Godfrey, 1998; Davidson and MacKinnon, 2002a,b; MacKinnon, 2002), although because of space limitations they are unreported in this paper. They are however given in a more extended version of the paper available from the author.

On the face of it the superior explanatory power of the UE model is quite a singular conclusion, given that NEG theory has become increasingly popular in recent years, although we therefore need to be very cautious in our interpretation since up to now there have been practically no studies that directly compare NEG with a competing theory. Most applications of NEG (for example Fingleton, 2005a) are concerned with showing that NEG is capable of simulating real data in a realistic fashion. This paper is one of the few to take the extra step of evaluating its performance *vis-à-vis* a competing theory. In a related paper (Fingleton, 2005b) which also confronts the two theories considered here, but uses models based on 186 EU NUTS 2 regions, I also conclude that both employment density and market potential have some explanatory power, but this is without considering spatial (commuting) effects which as we have seen in this paper tend to nullify the impact of market potential in the ANM specification. To summarize the empirical results, at the very least it appears that with regional data, it is quite hard to discriminate between the two theories, although UE seems to outperform NEG on this evidence, and it is certainly the case that NEG theory need enhancing by also considering labour efficiency variations in order to produce an acceptable level of fit to the data.

6. Conclusions

In this paper two competing hypotheses have been compared, one based on NEG theory and the well-known relation between wage rates and market potential, the other based on UE theory with wages dependent on employment density *qua* producer services linkages. Considered alone the NEG-based specification, modified to allow for labour efficiency variations, but without any allowance for producer service linkages, is seemingly adequate. Likewise the UE model evidently fits the data well, even though it does not incorporate any effect due to market potential. These are seen as different theories seeking to account for the same phenomenon, the variation in wage levels across small areas within Great Britain, although in reality hybrid models combining both can be envisaged, even if formal models have yet to be fully developed.

To provide evidence regarding the relative explanatory power of the competing theories, I invoke the existence of an ANM which nests both of these 'non-nested' hypotheses. The evidence from fitting the ANM is that it is itself encompassed by the UE model, so I infer that that the results from the NEG model, elaborated to allow for labour efficiency variations, are also explained by the UE model.

The paper shows that when considered in isolation it is quite easy to produce evidence supporting NEG theory as a valid basis for understanding the spatial concentration of economic activity, but when it is confronted with the competing UE theory it is seen to be inferior. This does not mean that we have evidence by which to reject NEG theory outright, since it is capable of reformulation and modification in the light of empirical evidence, but it is clear that market potential alone will not explain local wage variations and that modifications allowing for labour efficiency variations are necessary. What the analysis in this paper calls for is further theoretical development to capture the ideas coming both from NEG theory and from UE theory.

Acknowledgements

I am very grateful to the referees and to a Managing Editor of *Oxford Economic Papers* for their helpful comments and suggestions on the earlier versions of the paper.

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Appendix

The labour efficiency submodel

Equation (14) shows that log labour efficiency is assumed to depend on local exogenous variables (S, T) embodied in the n by k matrix X, on log labour efficiency in ‘nearby’ areas ($W \ln A$), and on random disturbances (ξ), hence

$$\ln A = Xb + \rho W \ln A + \xi$$
$$\xi \sim N(0, \Omega^2)$$

It is convenient to specify this with the exogenous variables on the right hand side, by rearranging the equation and then multiplying by $(I - \rho W)^{-1}$ as follows

$$(I - \rho W)\ln A = Xb + \xi$$
$$\ln A = (I - \rho W)^{-1}(Xb + \xi).$$

Derivation of the empirical NEG wage equation

The derivation of eq. (15) commences with eq. (13), which is

$$w_i^M = P_i^{1/\sigma} A_i$$

On taking logs, ignoring subscripts and writing $a_1 = 1/\sigma$, and adding ω to allow for measurement error, we obtain

$$\ln w^o = a_1 \ln P + \ln A + \omega$$
$$\omega \sim N(0, \Pi^2)$$

Substituting for $\ln A$ gives

$$\ln w^o = a_1 \ln P + (I - \rho W)^{-1}(Xb + \xi) + \omega$$

and multiplying by $(I - \rho W)$ we obtain

$$(I-\rho W)\ln w^o = (I-\rho W)(a_1 \ln P) + Xb + \xi + (I-\rho W)\omega$$

which when rearranged is equal to

$$\begin{aligned}\ln w^o &= \rho W \ln w^o + a_1(\ln P - \rho W \ln P) + Xb + \xi + (I-\rho W)\omega\\ &\quad \xi \sim N(0, \Omega^2)\end{aligned}$$

Derivation of the empirical UE wage equation

The derivation of the empirical UE model commences with eq. (10),

$$\ln w^o = k_1 + (\gamma - 1)\ln E + (\gamma - 1)\ln A$$

and substituting for $\ln A$, I obtain

$$\ln w^o = k_1 + (\gamma - 1)\ln E + (\gamma - 1)(I - \rho W)^{-1}(Xb + \xi)$$

Multiplying by $(I - \rho W)$ gives

$$(I-\rho W)\ln w^o = (I-\rho W)k_1 + (\gamma - 1)(I-\rho W)\ln E + (\gamma - 1)(Xb + \xi)$$

and on rearranging I obtain

$$\begin{aligned}\ln w^o &= \rho W \ln w^o + (I-\rho W)k_1 + (\gamma - 1)(\ln E - \rho W \ln E) + Xc + \Psi\\ &\quad \Psi \sim N(0, (\gamma - 1)^2\Omega^2)\end{aligned}$$

using the rule that var(aX) = a^2 var(X).

Derivation of the ANM

In order to derive eq. (21), I commence with a specification that combines eqs (4) and (10) thus

$$\begin{aligned}\ln w^o &= k_2 + d_0 \ln E + d_1 \ln P + d_2 \ln A + \eta\\ &\quad \eta \sim N(0, \Gamma^2)\end{aligned}$$

in which k_2 is a constant term. Substituting for $\ln A$ gives

$$\ln w^o = k_2 + d_0 \ln E + d_1 \ln P + d_2(I - \rho W)^{-1}(Xb + \xi) + \eta$$

and on multiplying by $(I - \rho W)$ I obtain

$$\begin{aligned}(I-\rho W)\ln w^o &= (I-\rho W)k_2 + (I-\rho W)(d_0 \ln E + d_1 \ln P) + Xg + \zeta + (I-\rho W)\eta\\ &\quad \zeta \sim N(0, d_2^2\Omega^2)\end{aligned}$$

which can then be rearranged to give

$$\ln w^o = (I - \rho W)k_2 + \rho W \ln w^o + d_0[\ln E - \rho W \ln E] + d_1[\ln P - \rho W \ln P] \\ + Xg + \zeta + (I - \rho W)\eta$$

Data Sources for the variables used in the empirical modelling

The *wage rate* w^o The wage rate w^o is that recorded for the year 2000 in each of the 408 unitary authority and local authority districts (UALADs) within Great Britain (see Fig. 3). The data come from the UK's Office for National Statistics' (ONS) New Earnings Survey, and are the gross weekly pay for full time workers irrespective of occupation. These are available on the NOMIS website (the ONS on-line labour market statistics database).

Market *potential P* Market Potential is real market potential defined by eq. (1). In order to quantify P, I have assumed that the parameter σ is equal to 6.25, and calculated income, prices and transport costs.

Income is defined by eq. (3), and depends on the share of the M sector and the share of the C sector employment in each UALAD, the assumed M and C sector wage rates across areas, and the assumed share of M sector employment in total employment

Table A1 ANM estimates (with *M* defined as manufacturing)

	Parameter estimates†*		
Regressors	**2sls eq. (23)**	**2sls eq. (22)**	**ML eq. (22)**
constant	−2.736977	3.345843	5.010876
(g_0)	(−1.96)	(1.31)	(4.16)
Market potential:			
$\ln P_i - \rho W \ln P_i$ (d_1)	0.236066	0.064182	0.017494
	(6.06)	(0.90)	(0.52)
Density:			
$\ln E_i - \rho W \ln E_i$ (d_0)	0.029113	0.013868	0.017340
	(7.00)	(3.61)	(4.66)
Labour efficiency (A) variation due to:			
schooling	−0.006407	−0.001871	−0.002039
S_i (g_1)	(−6.08)	(−2.01)	(−2.25)
technical knowledge	0.046113	0.048786	0.050776
T_i (g_2)	(6.50)	(6.97)	(8.97)
commuting	0	0.001991	0.001500
$W\ln(w^o)$ (ρ)		(3.14)	(5.50)
error variance	0.01160	0.008075	0.007919
R-squared*	0.6243	0.7252	
Correlation†	0.6000	0.7221	0.7234
Degrees of freedom	403	402	402
Residual autocorrelation‡	4.344	1.428	2.176
Log likelihood			408.097194

Notes: See Table 1.

($\theta = 0.1964$ for services as the M sector, and $\theta = 0.15024$ for manufacturing as the M sector). Services are banking, finance and insurance, etc (Appendix Table A2) and manufacturing is defined by Appendix Table A3, and both variables were obtained from the Annual Business Inquiry employee analysis provided by the ONS and NOMIS. The data are for all employees by sector and by UALAD for the year 2000.

Prices are defined by eq. (2), and again these are quantified using the M employment shares in each UALAD, the assumed M wage rate (equal to w^o) for each area, and the transport cost from each area.

Transport costs (eq. 12) are a power function of distances between assumed centres of each UALAD. Distances are straight line in miles and the power is equal to 0.1 (see Section 3.2). Internal distances are a fraction of the radius of a circle with area (in square miles) equal to the UALAD.

Employment *density* E this is total employees per square km in each UALAD. The number of employees was obtained from the Annual Business Inquiry employee analysis provided by the ONS and NOMIS. The data are all employees by UALAD for the year 2000.

Table A2 Service subsectors defined as *M* activities

1992 SIC code (3 digit)	Subsector
651	Monetary intermediation
652	Other financial intermediation
660	Insurance and pension funding
671	Activities auxiliary to financial intermediation
672	Activities auxiliary to insurance/pension funding
701	Real estate activities with own property
702	Letting of own property
703	Real estate activities
711	Renting of automobiles
712	Renting of other transport equipment
713	Renting of other machinery and equipment
714	Renting of personal/household goods nec
721	Hardware consultancy
722	Software consultancy and supply
723	Data processing
724	Data base activities
725	Maintenance/repair office machinery etc
726	Other computer related activities
731	Research: natural sciences/engineering
732	Research: social sciences/humanities
741	Accounting/book-keeping activities etc
742	Architectural/engineering activities etc
743	Technical testing and analysis
744	Advertising
745	Labour recruitment etc
746	Investigation and security activities
747	Industrial cleaning
748	Miscellaneous business activities nec

Table A3 Manufacturing subsectors defined as *M* activities

1992 SIC code (2 digit)	Subsector
15	Manuf food products and beverages
16	Manuf tobacco products
17	Manuf textiles
18	Manuf apparel; dressing/dyeing fur
19	Tanning/dressing of leather, etc
20	Manuf wood/products/cork, etc
21	Manuf pulp, paper and paper products
22	Publishing, printing, repro recorded media
23	Manuf coke, refined petroleum products
24	Manuf chemicals and chemical products
25	Manuf rubber and plastic goods
26	Manuf other non-metallic products
27	Manuf basic metals
28	Manuf fabricated metal products, etc
29	Manuf machinery and equipment nec
30	Manuf office machinery and computers
31	Manuf electrical machinery/apparatus nec
32	Manuf radio, tv/communications equipment
33	Manuf medical, precision instruments, etc
34	Manuf motor vehicles, trailers, etc
35	Manuf other transport equipment
36	Manuf furniture; manufacturing nec
37	Recycling

Schooling *S* This is the % of residents in each UALAD without formal qualifications. The data are from the UK's 2001 Census. This was obtained from the CASWEB website via the variables ks0130002 and ks0130001.

Local *technical knowledge T* Location quotients by UALAD for SICS 72 and 73, from the Annual Business Inquiry employee analysis for 1999.

The *matrix W* A negative exponential function of distance with the distance decay for each UALAD controlled by a set of parameters δ, one for each UALAD, obtained by calibration of 1991 Census commuting data (see Section 3.5).