GLOBALISATION AND WAGE DIFFERENTIALS:

A SPATIAL ANALYSIS

Michelle Baddeley* and Bernard Fingleton**

September 2008

In this paper, we assess the Fujita, Krugman and Venables (FKV) non-linear model of wage differentials. Using a spatial econometric model incorporating a spatial autoregressive error process, we estimate a quadratic form using cross-sectional data for 98 countries from 1970 to 2000. The evidence suggests no necessary tendency for all countries to converge towards the stable upper root. Polarization is possible. This polarization may be permanent - generating persistent international wage differentials. Our findings suggest that moderating the transmission of shocks across countries should be a key element of international macroeconomic policy co-ordination.

Keywords *Globalisation, convergence, wage differentials, spatial error models*

JEL codes *018, 047, R12, R15*

• Corresponding author. Contact details: Gonville & Caius College, Cambridge CB2 1TA, email: mb150@cam.ac.uk

** University of Strathclyde Business School

GLOBALISATION AND WAGE DIFFERENTIALS:

A SPATIAL ANALYSIS

A key question to emerge from globalisation debates focuses on the extent to which globalisation has fostered national and/or international inequality. Have gains from trade and openness encouraged development in poorer countries? Or has spatial specialisation exacerbated inequality within and between countries. Some argue that trade liberalisation and globalisation have reduced inequality across the North-South divide (e.g. Das, 2005). Others assert that globalisation has accelerated growth and reduced poverty by promoting foreign direct investment (FDI) and by fostering competition, thus allowing poorer countries to exploit their economies of scale (Bhagwati, 2004 and Loungani, 2005). Historically, the globalisation process involves a step-like progression, with rapid development switching from country to country. So if we take a snapshot at any particular time we see certain countries (e.g. Taiwan, South Korea) moving up the GDP per capita ladder quite rapidly, following in the wake of earlier rapid-developers such as Japan, now at high levels of GDP per capita (although also at lower rates of growth).

This historical record can be judged by assessing the impact of globalisation in reducing spatial patterns of wage inequality both within and between countries, e.g. using convergence analyses. Theoretically, mainstream analyses of convergence develop the neoclassical growth theories of Solow (1956) and Swan (1956) in which convergence across countries, whether absolute or conditional, is towards some steady state. By contrast, early versions of endogenous growth theory predict that convergence will not necessarily occur. Important differences in technology and capital (physical or human) are associated with increasing returns and may limit the potential for international convergence (Romer, 1986; Lucas, 1988).

The empirical evidence from the analysis of these convergence models is mixed. Abramovitz (1986) analyses globalisation eras between 1870-1979 and finds evidence of convergence only during the Golden Age of 1944-1973. He argues that, during this period, fixed exchange rates and capital controls limited globalisation. Baddeley (2006) shows, using σ and club convergence models, that key facets of globalisation (e.g. increasing flows of trade and capital) are associated with limited international convergence. Similarly Dowrick and DeLong (2003) present empirical evidence suggesting that globalisation does not necessarily imply convergence. They identify periods of expansion associated with 'club' convergence amongst richer nations but with limited benefits for the poorer nations and argue that benefits do not necessarily spread if demographic and financial constraints limit the opportunities for developing countries to take advantage of expensive new technological innovations.

In this analysis of the net effects of globalisation, we use a different approach to capturing convergence. Our starting point is Fujita, Krugman and Venables' (FKV) model (Fujita, Krugman and Venables 2001; Krugman and Venables 1995). This predicts that there will be initial divergence but followed by convergence in real wages across nations. The advantage of this approach is that it does not embed a binary view of convergence in which countries either converge or diverge. Instead it allows for episodes of divergence and convergence depending on the structural characteristics of different economies.

This paper assesses (theoretically and empirically) the implications of FKV's model for globalisation and wage convergence. In section 1, we present the FKV model; in section 2, we assess its assumptions and implications; in section 3, we develop a quantitative analysis of the interactions between globalisation and inequality in order empirically to test the predictions of the FKV using real-world evidence. Conclusions and policy implications are presented in section 4.

1. The Fujita, Krugman and Venables (FKV) Model

1.1. Fujita, Krugman and Venables on Wage Convergence

In analysing convergence and divergence in spatial patterns of production, FKV focus on the interactions between transport costs[1], economies of scale and factor mobility. In particular, transport costs drive a wedge between effective wage costs on home-produced versus traded goods (depending on whether or not a country is an importer or exporter), they drive up the costs of imports, raise the cost of living and deter immigration, moderating forces for agglomeration (FKV 2001, p. 97).

With very high transport costs, there will be no trade; it will always be cheaper to produce at home. But as transport costs start to fall, countries with marginal industrial advantages (i.e. the 'core' countries in the North) will be able to exploit economies of scale and so will continue to dominate industrial production. This will fuel manufacturing labour demand in these countries, driving-up real wages relative to unindustrialised countries (i.e. the agricultural countries in the Southern periphery) and fostering international divergences in wage differentials. Both labour and capital

[1] In defining trade costs, FKV use Samuleson's (1952) specification of transport costs in iceberg form: costs are represented as the amount of good dispatched per unit received and therefore not solely dependent on direct trade costs. FKV also emphasise that transport costs are only one facet of the costs of doing business across geographical space. They allow that a range of costs are associated with transactions across distances including costs associated with indirect, complex and expensive procedures for communicating and gathering information (FKV 2001, pp. 97-98).

will have incentives to move into manufacturing production in the North. So although falling transport costs *ceteris paribus* encourage two-way trade in manufactures, there will be regional specialization in manufacturing as transport costs first start to fall. Forward and backward linkages will encourage producers to locate in the Northern regions because they already have easy access to large markets and plentiful supplies of inputs. These linkages also make it more efficient to locate intermediate production in existing manufacturing areas, fostering agglomeration in manufacturing activity in countries that are already industrialised.

But continuing falls in transport costs will mean that transport-cost adjusted labour costs in the South will be falling fast relative to wage costs in the North. Location and distance will become less relevant and declines in transport costs will offset the disadvantages of remoteness. So eventually manufacturing firms will have incentives to shift production to the periphery to take advantage of lower labour costs there. Manufacturing will disperse towards the periphery with a concomitant convergence of wage rates and peripheral nations will start to industrialise. The implication is that impoverishment of peripheral nations will be temporary and will be followed by eventual ‘catch-up’. There is some historical evidence in support of this hypothesis, for example Williamson (1998*a*).

1.2. The FKV Model

FKV’s overall theme is that agglomeration effects emerge from distance related tensions between centrifugal and centripetal forces, which (as mentioned above) reflect interactions between economies of scale, factor mobility and transport costs. Core-periphery patterns emerge when symmetric equilibria (in which manufacturing is evenly distributed across regions) are broken by centrifugal forces and/or when agglomeration is sustained by centripetal forces (FKV 2001, p. 23). Centripetal forces emerge because existing manufacturing industries are more able to exploit economics of scale and forward/backward linkages; these encourage agglomeration and core-periphery patterns will emerge as a consequence. Centrifugal forces emerge from factor mobility: capital is mobile in response to profit differentials; labour is occupationally mobile and will move in response to real wage differentials. Both have the potential to break core-periphery patterns. Transport costs will add momentum to either centrifugal or centripetal forces. At very high levels, they will completely discourage trade. At intermediate levels, there will be multiple equilibria and agglomeration may be sustained or symmetry broken, depending on the starting point. At very low levels, core-periphery patterns will again be sustained *ceteris paribus*. FKV focus their analysis of implications on the high and intermediate transport costs cases.

In developing these ideas and following from Krugman and Venables (1995), Fujita, Krugman and Venables (2001) focus their analysis on a number of models of industrial agglomeration including base-multiplier models, applications of Dixit and Stiglitz (1977) to regional dynamics, and bifurcation models. We blend these insights to formulate a quadratic wages function, as is explained below.

Insights from Base Multiplier Models

Base multiplier models rest on the insight that a cumulative process of regional growth generates increased production via multiplier effects, with the basic relationship between income (Y) and exports (X) determined as:

$$Y_t = \frac{1}{1-a_t} X_t \qquad \text{where } a_t = \min\left[\alpha Y_{t-1}, \bar{a}\right] \qquad (1)$$

This shows that export generated income is magnified by the multiplier $(1/(1-a_t)$ and a_t is a variable proportional to Y_{t-1} - up to a maximum value $\bar{a}$ (FKV 2001, pp. 28-9).

Insights from Dixit-Stiglitz Models of Monopolistic Competition

FKV identify a number of limitations with base-multiplier models (ibid, pp. 31-32) but use insights from a Dixit-Stiglitz (1977) to give analytical foundations to the basic result. For two regions producing two kinds of goods (agricultural and manufactured) there are assumed to be no inherent patterns of comparative advantage. Regions are homogenous in terms of endowments, preferences and technology. The agricultural sector is perfectly competitive, exhibiting constant returns to scale and producing an immobile homogenous product.[2] The manufacturing sector is imperfectly competitive, producing differentiated products that are geographically mobile; the manufacturing sector is also responsive to increasing returns (ibid, p. 11). Both intermediate and final goods are produced in the manufacturing sector.

Simplifying this model to a two-country scenario, the link between regional incomes and wages is given by the following relationships (ibid, p. 65):

$$Y_1 = \mu \lambda w_1 + \frac{1-\mu}{2} \qquad (2a)$$

$$Y_2 = \mu (1-\lambda) w_2 + \frac{1-\mu}{2} \qquad (2b)$$

where w_1 and w_2 are wages in regions 1 and 2 respectively, λ is region 1's share in manufacturing and μ is consumers' expenditure share in manufacturing, assuming a

2 Relaxing the assumption of homogenous agriculture eliminates kinks in the break and sustain conditions explained below.

Cobb-Douglas utility function (FKV 2001, p.46)). Wages in each country (w_1 and w_2) are a function of the price index in each country (G_1 and G_2):

$$w_1 = [Y_1(G_1)^{\sigma-1} + Y_2(G_2)^{\sigma-1}(T)^{1-\sigma}]^{1/\sigma} \qquad (3a)$$

$$w_2 = [Y_1(G_1)^{\sigma-1}(T)^{1-\sigma} + Y_2(G_2)^{\sigma-1}]^{1/\sigma} \qquad (3b)$$

(ibid, p.65).

T represents iceberg transport costs, i.e. the factor by which shipments must be multiplied in the exporting country to ensure that one unit of production is received in the importing country. σ is the elasticity of substitution between differentiated manufactured product varieties and given certain assumptions can be shown to be equal and constant for all product varieties, in which case it is also the price elasticity of demand for manufactured products. FKV define this elasticity as $\sigma = 1/(1-\rho)$, where ρ captures the intensity of preference for variety in manufactured goods (FKV 2001, p. 46-7). As $\rho \to 1$, then $\sigma \to \infty$ and differentiated goods will be almost perfect substitutes for each other; individual producers will have no price-setting power. As $\rho \to 0$, then $\sigma \to 1$ and consumers will have increasing preferences to consume a greater variety of manufactured goods. Firms will have price-setting power and will be able to exploit consumer demand for differentiated products, leading to greater product differentiation (ibid, p. 46). The prices faced by manufacturers will respond favourably to increases in product differentiation leading to reductions in manufacturing costs (ibid, p. 48).

Putting together the relationships outlined in the equations above, FKV illustrate (using numerical examples) that tendencies towards agglomeration versus symmetry are determined by 'break' and 'sustain' points which are in turn a function of manufacturing shares (as captured by λ) and transport costs (FKV p.65-67).

When transport costs are sufficiently high (and positive), no trade will take place and a symmetric equilibrium will emerge in which manufacturing production is evenly dispersed.[3]

At the other extreme, with very low transport costs, this symmetric equilibrium will be unstable and a core-periphery pattern of production will emerge with $\lambda=1$; thus all manufacturing production will be concentrated in region 1 (core) and all agricultural production will be in region 2 (periphery). Wage differentials will persist; peripheral countries will concentrate exclusively on agricultural production and core countries will concentrate exclusively on manufacturing production.

At more moderate levels of transport costs, cumulative causation sustains agglomeration reflecting home market effects (increased manufacturing production in a country generates higher manufacturing wages and so manufacturing demand is higher in that country) and price index effects (countries producing manufactured good do not incur as large transport costs on these goods and so manufacturing goods are cheaper in this region) (ibid, pp. 56-7). Initially the agglomeration of manufacturing production will be sustained by these home income and price effects and associated forward and backward linkages but as incomes rise in peripheral nations (e.g. with technological transfer from core to peripheral regions), there will be an expansion in demand for manufactures in poorer peripheral countries and therefore of labour demand by the manufacturing industries in these countries. How the system moves between equilibria can be explained using bifurcation models, as explained below.

---

[3] Given the assumptions of the FKV model (i.e. of equality in factor endowments etc.) this implies that when transport costs are very high, real wages will be equalised across the two regions. In reality however, the high transport cost scenario might instead be associated with persistent wage differentials reflecting productivity differentials, e.g. emerging from differences in factor endowments.

Bifurcation Analysis

Bifurcation analysis (FKV 2001, pp. 34-41) links the Dixit-Stiglitz style model and base-multiplier models (ibid, p. 68) and can be used to illustrate the overall implications of FKV's core-periphery model (ibid, p. 75). FKV argue that the forces generating core-periphery patterns are the outcome of interactions between centripetal forces (sustaining agglomeration and core-periphery patterns) and centrifugal forces (breaking symmetric equilibria). Transport costs play a central role in shifting the balance between these forces. Shifts in manufacturing share as a function of transport costs follow a 'tomahawk pitchfork' bifurcation. At very high transport costs, there is a single symmetric equilibrium in which manufacturing production is evenly dispersed. With intermediate transport costs, multiple equilibrium are generated: there are stable equilibria at $\lambda=0$ and $\lambda=1$; another locally stable symmetric equilibrium at $\lambda=½$; and this is flanked by two unstable equilibria. If λ is outside a central basin of attraction, the symmetric equilibrium will be unstable and when the break point is reached, the even dispersion of manufacturing activity will break down. In this intermediate region wage differentials will emerge (or not) depending on the system's starting point. As transport costs fall further, there will be two stable equilibria and sustain points will be reached in which manufacturing agglomeration takes place in either one or the other region. Overall, the model shows that continuous changes in exogenous variables (such a technology) may have catastrophic consequences, i.e. may generate discontinuous change in actual outcomes.

1.3. Extending the FKV Model

Together, the key elements from base-multiplier, Dixit-Stiglitz and bifurcation models can be used to show that the non-linear relationship between wages, transport costs and agglomeration reflects the fact that initial declines in transport costs will encourage agglomeration but further declines in transport costs will dissolve it. With no manufacturing production in the South, i.e. $\lambda = 1$, a core-periphery pattern will be sustained because Southern manufacturing producers will not be able to compete with the North unless transport costs are zero. So all Southern production will be concentrated in agriculture. But as Southern manufacturing production begins to develop (i.e. as $\lambda < 1$) unit labour costs in the South will start to fall, generating a competitive advantage in Southern manufacturing to some extent compensating for transport costs. As industrial agglomeration proceeds further, real wages in the industrialised core will start to rise relative to wages in the unindustrialised periphery because of rising labour demand relative to supply in the core. Southern wages will be eroded by the decrease in λ. Relative incomes in the North will rise, encouraging further agglomeration. However, as wages in the South fall to sufficiently low levels, producers will be attracted by cheap Southern labour and the South will begin to industrialise. Southern manufacturing producers will start to take advantage of forward and backward linkages with their own intermediate production industries, then they can start to compete more effectively with Northern manufacturing production without eroding Southern manufacturing wages and so North-South wage differentials start to disappear. Overall, this creates a non-linear pattern: initially there will be a decrease in Southern wages (relative to North) as the Southern share in manufacturing rises but before linkages have developed. But in longer term, increased intermediate production and the development of linkages in South will encourage further shifts of manufacturing production towards the South, eventually encouraging a relative rise in Southern manufacturing wages and eroding North-South wage differentials.

In establishing this result, we start by adapting Equation (1) to allow that exports are endogenous and a function of current income, i.e. $X_t = \xi Y_t$ where ξ is the marginal propensity to export.[4] Assuming $\alpha Y_{r,t-1} < \overline{a}$ gives:

$$Y_{r,t} = \frac{1}{1-\alpha Y_{r,t-1}} \xi Y_{r,t} \qquad (4a)$$

Incorporating the equilibrium condition dY=0 gives:

$$dY_r = Y_{r,t} - Y_{r,t-1} = \frac{\xi Y_{r,t}}{1-\alpha Y_{r,t-1}} - Y_{r,t-1} = 0 \rightarrow Y_{r,t} = \frac{(1-\alpha Y_{r,t-1})}{\xi} Y_{r,t-1} = \frac{1}{\xi} Y_{r,t-1} - \frac{\alpha}{\xi} Y_{r,t-1}^2 \qquad (4b)$$

Thus current income is a quadratic function of past income.

Using equations 2*a* and 2*b* by generalising and simplifying to the case of symmetric equilibrium at λ=½, gives a general expression for a country's income at time t as a function of its wages in time t (i.e. $w_{r,t}$):

$$Y_{r,t} = \frac{\mu}{2} w_{r,t} + \frac{1-\mu}{2} \qquad (5)$$

The implications for wages can be shown by substituting the expression for $Y_{r,t}$ (and equivalently for $Y_{r,t-1}$) from equation (5) into equation (4b) to give:

$$Y_{r,t} = \frac{\mu}{2} w_{r,t} + \frac{1-\mu}{2} \text{ and } Y_{r,t} = \frac{1}{\xi} Y_{r,t-1} - \frac{\alpha}{\xi} Y_{r,t-1}^2$$

So:

$$\left[\frac{\mu}{2} w_{r,t} + \frac{1-\mu}{2}\right] = \frac{1}{\xi}\left[\frac{\mu}{2} w_{r,t-1} + \frac{1-\mu}{2}\right] - \frac{\alpha}{\xi}\left[\frac{\mu}{2} w_{r,t-1} + \frac{1-\mu}{2}\right]^2$$

Expanding the right-hand side gives:

---

[4] The export function can be assumed to capture net exports but in the interests of parsimony here we exclude the explicit, separate analysis of imports.

$$\left[\frac{\mu}{2}w_{r,t}+\frac{1-\mu}{2}\right]=\left[\frac{\mu}{2\xi}w_{r,t-1}+\frac{1-\mu}{2\xi}\right]-\frac{\alpha}{\xi}\left[\frac{\mu^2}{4}w^2{}_{r,t-1}+2\left(\frac{1-\mu}{2}\right)\left(\frac{\mu}{2}\right)w_{r,t-1}+\left(\frac{1-\mu}{2}\right)^2\right]$$

Subtracting (1-μ)/2 from both sides, multiplying both sides by 2/μ and rearranging and collecting all terms together (with the constants amalgamated into c for simplicity) gives:

$$\rightarrow\ w_{r,t}=-\frac{\alpha\mu}{2\xi}w_{r,t-1}^2+\frac{1-\alpha(1-\mu)}{\xi}w_{r,t-1}+c \qquad (6a)$$

where $w_{r,t}$ is a region's wages at the end of a period of change, $w_{r,t-1}$ is wages at the beginning and c represents the amalgam of constant parameters. Re-expressing the slope parameters as $a=-\frac{\alpha\mu}{2\xi}$ and $g=\frac{1-\alpha(1-\mu)}{\xi}$ simplifies the expression to:

$$w_{r,t}=aw_{r,t-1}^2+gw_{r,t-1}+c \qquad (6b)$$

Subtracting $w_{r,t-1}$ from both sides gives:

$$\Delta w_r=aw_{r,t-1}^2+bw_{r,t-1}+c \qquad (7)$$

where Δw_r captures wages growth and b=g-1>0 given g>1. The hypotheses a<0, b>0 and g>1 emerge from the plausible assumptions that 0<α<1, 0<ξ<1 and 0<μ<1.

Allowing that wages are themselves a non-linear function of transport costs (as shown in equations 3*a* and 3*b*) and assuming that transport costs are declining over time reflecting technological improvements, this extension of the FKV model generates non-linear patterns in wage differentials with wage differentials at first widening but then narrowing. This is depicted in Figure 1, with the left-hand panel showing the evolution over time of wages in the South versus the North (as described in FKV, pp. 268-9) and the right-hand panel showing the implied North-South wage differentials - these approach the horizontal axis asymptotically.

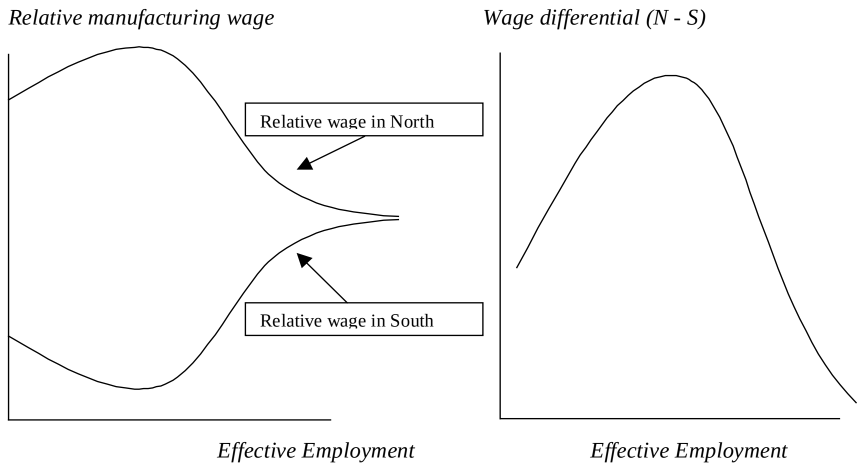

Fig. 1. *The Fujita, Krugman and Venables Model*

2. Assessing the FKV Model

Overall, FKV argue that the spatial dynamics emerging from globalisation are complex and non-linear, with globalisation initially exacerbating world inequality but then reducing it reflecting the fact that technological progress leads to steady increases in the efficiency of labour. Nonetheless, FKV offer a relatively optimistic view. FKV argue that globalisation has brought benefits to developing countries by expanding trade, facilitating access to credit via globalised capital markets and by promoting infrastructural development and export-led growth in poorer economies. But there are some obvious limitations to the FKV model that weaken its attraction. These include the restrictive assumptions made about transport costs, technological progress, industrial structure, labour markets, labour flows and institutional factors.

2.1. Transport Costs

The FKV model embeds iceberg transport costs (ITCs) but the assumptions underlying this specification of transport costs have been subject to criticism particularly in cases where distance is an explicit model variable. McCann (2005) and

Fingleton and McCann (2007) highlight the implausible properties underlying ITCs, maintaining that they do not allow for scale economies associated with the transportation of goods or information. Also distance cost structures (particularly those associated with information transactions costs) will vary according to whether inputs or outputs are being considered.

2.2. Technological Progress

In the FKV model, exogenously determined technological progress drives the path to eventual international convergence in real wages. In further developments of their analysis of the dynamics of globalisation, FKV allow that the non-linear process of divergence followed by convergence emerges in the context of technological change.[5]

But technological change does not necessarily promote such a steady pattern of international convergence. Howitt (2000) and Howitt and Mayer-Foulkes (2005) argue that, rather than encouraging globalisation and convergence, technological change encourages divergence if new technologies are unevenly distributed across countries according to research and development (R&D) strengths. Howitt *et al*'s analysis has some support in the empirical record on globalisation, for example there is little evidence for convergence of manufacturing technologies across countries and substantial technology gaps existed across OECD countries during the most recent era of globalisation (Bernard and Jones, 1996).

---

[5] Aghion (1998) also presents a technological explanation for the non-linear pattern in wage differentials (of first divergent and then convergent wage differentials) in a model that makes similar predictions to the FKV model.

2.3. Industrial structure

FKV assume that monopolistic competition is an appropriate market structure for manufactures. Neary (2003) considers globalisation under a model of oligopoly, arguing that the presence of strategic interaction amongst firms that are relatively large within their sectors is much more realistic than assuming that firms are small, equal in size at equilibrium, and with no power over the market presence or behaviour of others. But the results emerging from a model of oligopoly rather than monopolistic competition are unlikely to be significantly different if the exploitation of market power by oligopolistic firms leads to similar patterns of industrialisation possible within a model of monopolistic competition.

2.4. Labour Markets

The FKV model incorporates an assumption that labour markets always clear, but in reality there are wide discrepancies in both unemployment and wage rates. For example, there are significant differences between unskilled worker wages and unemployment rates. Wage inflexibility with globalisation affects not so much wages rates as unemployment rates because the burden of adjustment falls on quantities rather than prices, particularly in a world of downward wage stickiness. Thus Wood (1998) asserts that globalisation has contributed to widening gaps between skilled and unskilled labour in terms unemployment rates as well as wage differentials.

Feenstra (1998) focuses on another aspect of labour market outcomes – outsourcing. He shows that globalisation has similar impacts on employment and wages as skills-biased technological innovation. It leads to rises in the demand for skilled labour in poorer countries but falls in demand for unskilled labour in richer countries, thus contributing to wage inequality within richer countries. So whilst factor price equalisation has been encouraged by globalisation, the cost has been increasing relative poverty amongst the unskilled workers in developed countries. Workers in peripheral countries are also adversely affected. Williamson (1998*b*) argues that, during earlier eras of globalisation, factor-price convergence and mass migration led to improving conditions for unskilled workers in the North but deteriorating conditions for poor unskilled workers in the South as employers in the South sought to cut costs to maintain competitive advantages.

2.5. Labour Flows

FKV assume that international labour migration is relatively unimportant compared with international trade and the mobility of capital. But empirical evidence suggests that extensive international migration has had important impacts. Peeters and Garretsen (2000) develop a model that introduces international migration in skilled labour showing that the outcome of globalisation is increased regional economic integration rather than global economic integration. Freeman (2006) asserts that immigration is fundamental to the development of the global economy and that it is important to understand the interactions between the flows of people, capital and trade and their impacts on economies.

2.6. Institutional Factors

The FKV model abstracts from the institutional structure; but the argument here is that institutional factors are central determinants not just background noise (Martin 1999). Wages may never be low enough to compensate for structural constraints in peripheral countries; ingrained institutional and infrastructure problems may deter employers thus preventing the elimination of international wage differentials.

3. Empirical Results

As explained in section 1 and depicted in Figure 1, the FKV model implies a quadratic wages function (Equation 7): if a country is below the lower root of the quadratic then wages go to zero. According to FKV, ultimately the wage gap becomes big enough to induce industry to move to poor countries in the South. So falling wage levels do not continue *ad infinitum* and eventually wages in all countries will converge onto the upper root of the quadratic and wage differentials will be eliminated.

In the preceding section, we have presented the FKV model and its limitations. In this section, we will assess empirical predictions from the FKV model about international wage differentials. However a successful empirical model will not emerge purely from any formal links that might be established with FKV's theory. Wage levels in any one country will change due to a multitude of factors, many of which we cannot know. In the interest of realism, we need to represent these additional effects on the change in wages. We assume that they are additive in form and so can be captured by the stochastic error term of our model - ε . So the functional relationship between wage change Δw and wage level w as outlined in Equation 7 is given by the quadratic function (where w_{t-1} from Equation 7 is defined here as a base period value $w_0 = w_{1970}$):

$$\begin{aligned} &\Delta w = a w_0^{\,2} + b w_0 + c + \varepsilon = Xf + \varepsilon \\ &\varepsilon \sim N(0,\sigma^2) \end{aligned} \qquad (8)$$

We also incorporate the plausible scenario of non-negative wages, i.e. $w_0 \geq 0$ and an assumption of weak exogeneity, i.e. $\text{cov}(\varepsilon, Xf) = 0$. The parameters a and b capture the responsiveness of wages growth to w_0^2 and w_0 respectively, c is a constant term. In matrix form, *X* is an n by 3 matrix with columns equal to w_0^2, w_0 and a vector of constants, and *f* is the 3 by 1 vector of parameters. If it were consistent with the FKV globalisation story of rising then diminishing wage differentials, then the FKV model should generate significant regression coefficients with $a<0$ and $b>0$. In addition, the constant term should be insignificantly different from zero. As explained below, we confirm these hypotheses in a spatial error specification of the econometric model.

3.1. Model estimates

The estimation that follows is based on a sample of 98 countries, with data taken from the Penn World Tables Version 6.1 (October 2002). Assuming constant returns to scale and a marginal productivity theory of factor payments, wages (w_0) are proxied by the average labour productivity measured as real GDP per worker. The variable Δw is measured over the period 1970 to 2000, expressed in 1996 constant prices. The start date of 1970 was selected because it just precedes the second contemporary wave of globalisation.

The results from the estimation of Equation 8 are recorded in Table 1, including the parameter estimates for a, b, c and σ together with associated t-ratios and goodness of fit statistics. Interestingly, for these 98 countries, the initial indication is that a quadratic function described in Equation 9 does not seem to describe the relationship between Δw and the initial level of GDP per worker (w_0) in 1970. This simplified model accounts for less than 30% of the variance in Δw but can be effectively adapted to allow for spatial errors, as explained below.

Table 1
OLS estimates of Equation (8)

Parameter	Estimate
$\hat{c}$	-997.0
	t=-0.48
$\hat{b}$	1.022
	t=3.17
$\hat{a}$	-0.00001329
	t=-1.55
σ	10011.0
log likelihood	-1040.2758
R^2	0.2912

When the residuals from the equation (8) model are examined, we see that significant residual spatial autocorrelation extends up to 2000 miles, and it falls to zero between 3000 and 4000 miles. In the analysis that follows, we use a cut-off distance of 3,500 beyond which it is assumed that there is no real long-distance residual spatial autocorrelation. The significant long-distance negative autocorrelation is a logical outcome of significant short-distance positive autocorrelation.

The residual autocorrelation could be due to omitted spatially autocorrelated variables, or it might simply be a spatial error process reflecting the transmission of shocks between 'neighbouring' countries. In other words it may be either substantive, or simply a so-called 'nuisance' effect.

As identified above, equation (8) is incomplete as a model of globalisation because the estimate of the parameter on w_0^2 is small and insignificant. Consequently, the preferred model is given by equation (9) in which we have assumed that wage change will partly be a response to the random shocks ε. In considering globalisation, it is impossible to ignore the fact that shocks are transmitted worldwide: a shock to one economy is also invariably a shock to other countries. We model this interdependence of economies via the so-called spatial error model (see Anselin, 1988), so that:

$$
\begin{aligned}
&\Delta w = Xf + \xi \\
&\xi = \rho W \xi + \varepsilon \qquad (9) \\
&\varepsilon \sim N(0, \sigma^2 I)
\end{aligned}
$$

W is the n-by-n matrix defining the interconnectivity between countries. The simplest possible structure for *W* is as a set of ones and zeros, with ones defining contiguous countries and zeros defining other non-contiguous countries. This seems however to be unnecessarily restrictive. An alternative to the use of distances would be to define the cells of the *W* matrix directly using international trade data and assuming that shock-effects are proportional to the trade links between countries. FKV justify the use of gravity models in estimating the relationship between distance and trade volumes rather than direct trade costs (FKV 2001, p. 98) and this in principle would seem to be a good idea. Trade data has been used in the past, for instance as an indicator of the intensity of R&D spillovers between OECD countries (Coe and Helpman, 1995, Verspagen 1997). However, there are some difficulties with this approach. In the case of a sample of countries that includes underdeveloped countries, obtaining comprehensive and accurate trade data is not easy. Also, trade volumes and directions vary substantially over time, and therefore to convert these into a viable *W* matrix format would require some considerable simplification and numerous assumptions, which may be hard to justify.

The alternative we choose is to examine in more detail the structure of the residuals from fitting a model without any spatial interaction effects, using the residual correlogram (to suggest the range of distances over which the spatial effects may extend) and the shape of the distance decay function. A number of alternative measures of spatial autocorrelation are feasible. Here we employ three: Moran's I, the standardized value (Z) of Moran's I, and the correlation coefficient r (the product moment correlation between residuals and their spatial lags). We use 10 distance bands and assign 1 or zero to the weighting matrix for Moran's I according to whether country pairs fall within each distance band. Thus the spatial lag for a given distance band is the matrix product of the vector of residuals and the appropriate weighting matrix. The outcome is given in Table 2.

Table 2
Spatial correlogram based on residuals from Equation (8)

Band	Mean distance	Z	I	r
1	750	6.423	2.0104	0.3629
2	1898	3.899	1.4578	0.3500
3	3141	0.583	0.1200	0.0258
4	4388	-0.444	-0.3481	-0.0564
5	5609	0.829	0.2639	0.0424
6	6858	-1.525	-0.7518	-0.1662
7	8065	-0.765	-0.3468	-0.0713
8	9324	-3.990	-1.0784	-0.3098
9	10552	-4.649	-1.0940	-0.3512
10	11741	-8.002	-1.2330	-0.4554

In order to define *W* for equation (9), a simple transformation from distance to 'correlation' is used, given by

$$W_{ij} = \left(1 - \frac{d_{ij}^G}{d_{\max}^G}\right)^{\pi} \qquad (10)$$

In equation (10), d_{ij}^G is the great circle distance between countries i and j, with the maximum geographical distance beyond which covariances fall to zero given by $d_{\max}^G$, with $\pi \geq 1$ and $d_{ij}^G \geq 0$. When $\pi = 1$ this is the Bartlett kernel (see Phillips, Sun and Jin, 2003), but π is chosen by minimising the sum of the squared differences between the observed values of r (up to $d_{\max}^G$ = 3500 miles) and the corresponding values of $W(\pi)$. The outcome is that π=2.56650.

Table 3 shows the results of estimating equation (9) via ML and by GMM using this *W* matrix specification. ML estimation of the so-called spatial error model is a standard procedure in spatial econometrics and is well documented in the literature (see for instance Cliff and Ord (1981), Upton and Fingleton (1985), Anselin (1988), Haining (1990). GMM follows Kelejian and Prucha (1999), using a feasible generalized least squares estimator. This has the advantage of not assuming normality for the error distribution. The results are very similar to those obtained via ML, suggesting that the normality assumption is tenable.

Table 3
ML and GMM estimates of equation (9)

	ML	*GMM*
$\hat{c}$	1234.68512814	1619.41933802
t ratio	0.45	0.57
$\hat{b}$	0.95121259	0.94104170
t ratio	2.86	2.81
$\hat{a}$	-0.00001831	-0.00001844
t ratio	-2.23	-2.24
ρ	0.083	0.0899792
t ratio	7.612	…
σ	8866.870169	8822.98
log likelihood	-1031.8235	…

The most notable feature of these estimates is that the existence of the spatial error appreciably improves the level of fit, and allows the non-rejection of the theoretical hypotheses associated with the quadratic function initially outlined in Equation 7, i.e. $a<0$, $b>0$ and $c=0$. The estimated value 0.0899792 obtained via GMM is significant when referred to its Bootstrap distribution, obtained by resampling with replacement the residuals. The Bootstrap estimate is -0.003285 and the Bootstrap variance is 0.002692. The estimate ranks first in the Bootstrap distribution given by Figure 2. The structure of W has implications for the estimate of ρ, which under ML is automatically constrained within upper or lower bounds given by the inverse of its maximum and minimum eigenvalues. In order to satisfy the constraint, which ensures a stable autoregressive error process, the likelihood function includes a term that acts as a penalty or weighting function. This has the effect that the likelihood, which is based on a normality assumption, diminishes sharply as ρ approaches its upper or lower bound. The GMM estimate also falls within the bounds, since the large eigenvalues of W is equal to 10.020.

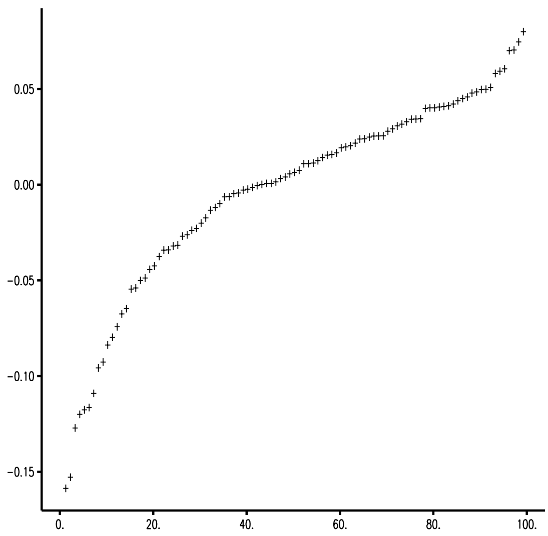

Fig. 2. *Bootstrap Distribution for the GMM estimate* $\hat{\rho}$

3.2. Implications of the model

As explained above, in assessing the long-run implications for globalisation, our starting point is a quadratic wages growth function, such as the one depicted in Figure 3. Figure 3 illustrates graphically what we know mathematically, that there is a solution to the quadratic with two roots (which would be coincident if $\hat{b}^2 = 4\hat{c}\hat{a}$), since $\hat{a} \neq 0$ and $0 \leq \hat{b}^2 - 4\hat{a}\hat{c}$. Using the ML estimates given in Table 3 and solving for the roots using:

$$x_{L,U} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \qquad (11)$$

gives the points, ($\hat{x}_L$ = -1267 ,0) and ($\hat{x}_U$ =53216 ,0).

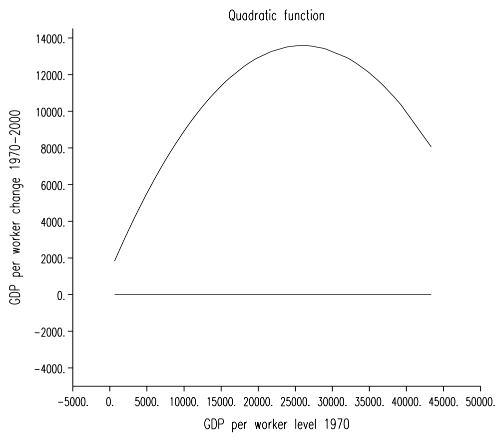

Fig. 3. *Quadratic Wages Growth Function*

On initial inspection, the long-run dynamics implied by the model are that each country will gravitate to the stable upper root, as shown by Figure 4.

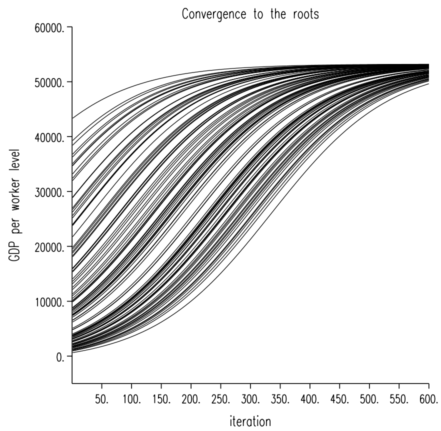

Fig. 4. *Convergence to the Upper Root*

The very simple spatial econometric model that has been estimated has some dynamic implications that are not inconsistent with the FKV analysis of the globalisation process. For instance the functional form and estimated parameters indicate that the low wage economies will see quite sharply rising wage rates at some stage of their development, leading ultimately to a long-run stable equilibrium at which wage rates (or GDP per worker) tend to equalise across countries. Figure 5 shows that wage level dispersion initially increases then falls to zero.

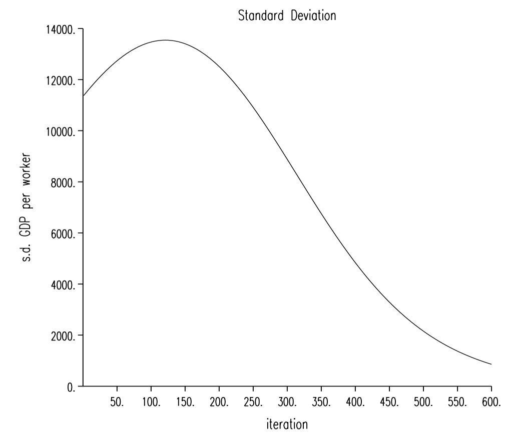

Fig. 5. *Standard Deviation in GDP per worker - Convergence to Upper Root*

Some countries reach the equilibrium level earlier than others, with the poorest countries responding most slowly and only reaching the equilibrium wage level at some distant point in the future. This is suggestive of a globalisation process in which polarization increases but then diminishes, in line with the FKV hypothesis.

But examining the results in more detail, we now explore the implications of alternative parameter values and take account of the uncertainty about the true value of the parameters, as measured by the regression coefficient standard errors. As shown by FKV (explained in section 2) the starting point in bifurcation models is an essential determinant of final outcomes, i.e. of whether or not the system converges. Acknowledging that a, b and c are random variables implies that the roots x are also random variables, the problem now is to measure the uncertainty associated with x, particularly the lower root, since whether or not a country falls lies above the lower root determines whether or not it ultimately converges. We obtain evidence about the distribution and moments of x using simulation methods. The starting point is the vector M with elements E(a), E(b) and E(c), and the symmetric variance-covariance matrix Σ with Var(a), Var(b) and Var(c) on the main diagonal and Cov(a,b), Cov(a,c) and Cov(b,c) as off-diagonal quantities. We use the ML point estimates in

Table 3 for $\hat{a}, \hat{b}$ and $\hat{c}$, and hence $\hat{M}$, and the ML estimation also gives the estimate of the variance-covariance matrix $\hat{\Sigma}$. Since we assume a normal distribution for the likelihood, we assume that the true distribution of *a*, *b* and *c* is a multivariate normal distribution $N(M, \Sigma)$ and we use $\hat{M}$ and $\hat{\Sigma}$ to generate pseudo-random numbers $\tilde{a}, \tilde{b}, \tilde{c}$ and from these we calculate $\tilde{x}_L$ and $\tilde{x}_U$. The method involves initially generating univariate normal random numbers, using the Box-Muller method (Box and Muller 1958), followed by a linear transformation involving *A* where *A* is calculated by a Choleski decomposition[6]; $AA' = \Sigma$, as described by Johnson (1987) and Tong (1990). This process is repeated 1000 times, giving 1000 realizations of $\tilde{a}, \tilde{b}, \tilde{c}$ and $\tilde{x}$.

The implications for convergence are as follows. Assume that the lower root $\tilde{x}_{L,0.95}$ takes a value equal to 2481, which is the 95th sample percentile from the $\tilde{x}_L$ distribution. There are 16 countries with initial GDP per worker below this conjectured lower root, so we infer from this that there is a 0.05 probability that up to 16 countries do not converge. Table 4 gives various conjectured roots, probabilities and numbers of non-convergent countries.

Table 4
Probabilities of non-convergence

Lower root $\tilde{x}_L$	Probability	Number of countries
855	0.20	1
1870	0.10	11
2481	0.05	16
3162	0.025	24

6 This requires that the variance-covariance matrix be positive semi-definite.

From the simulation, we use the parameters $\tilde{a}, \tilde{b}, \tilde{c}$ that generated the lower root closest to $\tilde{x}_{L,0.95}$ = 2481. Figure 6 shows the 16 countries below the unstable lower root, converging to zero. Figure 7 similarly shows that rather than increasing polarization followed by convergence to zero dispersion, polarization is permanent.

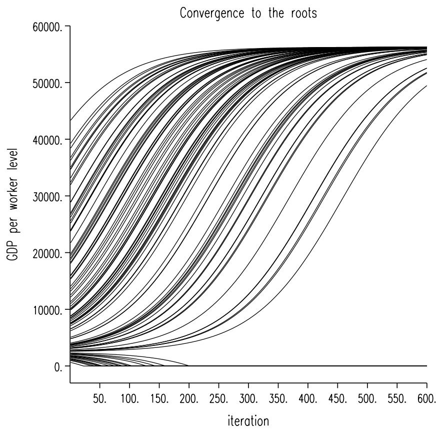

Fig. 6. *Convergence to Upper and Lower Roots*

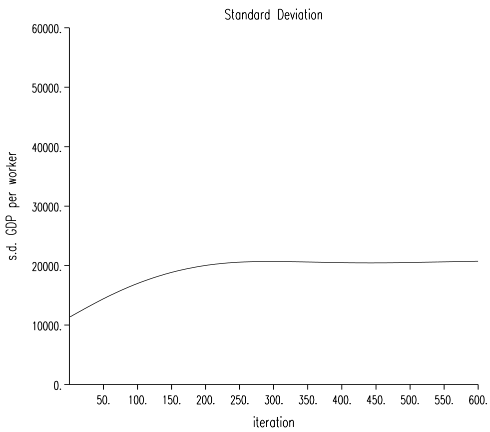

Fig. 7. *Standard Deviation - Convergence to Lower and Upper Roots*

Overall, these results show that FKV's postulated non-linear pattern of divergence then convergence in wage differentials is not necessarily a realistic scenario. As Table 4 shows, the probabilities of non-convergence are relatively high and international wage differentials are not necessarily just a short-term phenomenon. If these differentials persist then international polarization may be permanent.

4. Conclusions and Policy Implications

In this paper we have assessed the baseline model of FKV (1991, 2001) which focuses on the non-linear evolution of North-South wage differentials emerging in the context of globalisation, falling transport costs and technological change. We use FKV's analysis to develop a model in which convergence in wages across nations (given transport costs and technology-driven dynamics) is approximated by a quadratic wages function. The limitations of this approach are assessed.

In the empirical section, econometric evidence is presented to show the likelihood of countries converging to different steady states. We use a spatial error model to capture the transmission of shocks between 'neighbouring' countries, and this specification does support the hypothesis of the quadratic functional form. However, in assessing the equilibrium outcomes from this functional form, two possibilities emerge – first, of all countries converging to a common upper root and second, of a divergence pattern of some countries converging onto the upper root with others converging onto the lower root. We present evidence that the latter scenario is not unlikely. This result confirms previous evidence suggesting international patterns of club convergence (e.g. see Baddeley 2006). The existence of differentials may be explained by institutional and infrastructural constraints. If these are endemic, then wages will never be low enough to encourage labour demand to shift from the modern, industrialised core to the underdeveloped peripheral countries. In this case wages in peripheral countries will head towards the lower root, the minimum value of which is zero (or subsistence level). There will be persistent spatial divergence between countries at the upper versus lower roots and international wage differentials will persist.

Overall, the empirical findings outlined here suggest that the transmission of shocks between different countries is an important cause of wage growth differentials, and it does appear that globalisation and computerisation have speeded-up flows of trade, capital, factors of production and information, thus allowing shocks to be transmitted across national boundaries quickly and easily. The policy implications are that manufacturing linkages in the South should be developed, via support from industrial development, to generate increasing returns via infrastructural development and/or learning by doing. Increasing returns could also be generated via the effective transfer of technology from the Northern to the Southern periphery.

Future research could be focussed on testing competing, non-nested theories that predict international patterns of persistent wage differentials. For example, it would be of interest to compare FKV and Aghion (1998) with the Howitt (2000) and Howitt and Mayer-Foulkes (2005) model of technological change predicting limited club convergence. This suggests that an important focus for research lies in modelling simultaneous inter-country interactions, and simulating/ mapping the impacts of country-specific shocks. For example, following Fingleton (2007), it would be possible to calculate the negative and positive impacts across the globe of a shock of a given magnitude to, say, the US economy, and then to explore alternative counterfactuals and scenarios of shock-effects under different assumptions. This research could usefully inform international policy initiatives aimed at promoting the effective co-ordination of national policies and limiting the negative consequences of the international transmission of macroeconomic shocks.

References

Abramovitz, M. (1986). ‘Catching Up, Forging Ahead, and Falling Behind’, *Journal of Economic History*, vol. 46(2), pp. 385-406.

Aghion, P. (1998). ‘Inequality and Economic Growth’, in P. Aghion and J.G. Williamson (eds), *Growth, Inequality and Globalization*, Cambridge: Cambridge University Press, pp. 5-102.

Anselin, L (1988). *Spatial Econometrics : Methods and Models*, Dordrecht: Kluwer.

Baddeley, M.C. (2006). ‘Convergence or Divergence? The Impacts of Globalisation on Growth and Inequality in Less Developed Countries’, *International Review of Applied Economics*, vol. 20(3), pp. 391-410.

Bernard, A.B. and Jones, C.I. (1996). ‘Technology and Convergence’, *Economic Journal*, vol. 106(437), pp. 1037-1044.

Bhagwati, J. (2004), *In Defense of Globalisation*, Oxford: Oxford University Press.

Box, G.E.P. & Muller, M.E. (1958). ‘A note on generation of normal deviates’, *Annals of Mathematical Statistics*, vol. 28, pp. 610-611.

Cliff, A.D. and Ord, J.K. (1991). *Spatial Processes*, London: Pion.

Coe, D.T. and Helpman, E. (1995). ‘International R&D spillovers’, *European Economic Review*, vol. 39, pp. 859-887.

Das, S.P. (2005). ‘Gradual globalisation and inequality within and between countries’, *Canadian Journal of Economics*, vol. 38(3), pp. 852-869.

Dixit, A.K. and Stiglitz, J.E. (1977). ‘Monopolistic Competition and Optimum Product Diversity’, *American Economic Review*, vol. 63(3), pp. 297-308.

Dowrick, S. and J. Bradford DeLong (2003). ‘Globalisation and Convergence’, in M.D. Bordo, A.M. Taylor and J.G. Williamson (eds), *Globalisation in Historical Perspective*, Chicago: University of Chicago Press.

Feenstra, R.C. (1998). ‘Integration of Trade and Disintegration of Production in the Global Economy’, *Journal of Economic Perspectives,* vol. 12(4), pp.31-50.

Fingleton, B. (2007). 'Modelling globalisation : some spatial econometric issues' in Russel J. Cooper, Kieran P. Donaghy, and Geoffrey J.D. Hewings (eds) *Globalization and Regional Economic Modeling*, Heidelberg: Springer-Verlag (forthcoming).

Fingleton, B. and McCann, P. (2007). ‘Sinking the iceberg? On the treatment of transport costs in new economic geography’, in Fingleton, B. (ed) *New Directions in Economic Geography*, Cheltenham: Edward Elgar, pp 168-203.

Freeman, R.B. (2006). ‘People Flows in Globalization’, *Journal of Economic Perspectives*, vol. 20(2), pp. 145-170.

Fujita M., Krugman P R and A Venables (2001). *The Spatial Economy: Cities, Regions, and International Trade* Cambridge Massachusetts: MIT Press.

Haining R.P. (1990). *Spatial Data Analysis in the Social and Environmental Sciences,* Cambridge: Cambridge University Press.

Howitt, P. (2000). ‘Endogenous growth and cross-country income differences’, *American Economic Review,* vol. 90(4), pp. 829-846.

Howitt, P. and D. Mayer-Foulkes (2005). ‘R&D, Implementation and Stagnation: A Schumpeterian Theory of Convergence Clubs’, *Journal of Money, Credit and Banking,* vol. 37(1), pp. 147-177.

Johnson, M.E. (1987). *Multivariate Statistical Simulation,* New York: John Wiley & Sons.

Kelejian, H.H. and Prucha, I.R. (1999). ‘A Generalized Moments Estimator for the Autoregressive Parameter in a Spatial Model’, *International Economic* Review, vol. 40(2), pp. 509-533.

Krugman, P. and Venables, A.J. (1995). 'Globalisation and the Inequality of Nations', *Quarterly Journal of Economics*, vol. 110(4), pp. 857-880.

Loungani, P. (2005). 'Review of *In Defense of Globalisation* by J. Bhagwati', *Journal of International Economics*, vol. 66(2), pp. 544-548.

Lucas, R.E. (1988). 'On the Mechanics of Economic Development', *Journal of Monetary Economics*, vol. 22(1), pp. 3-42.

Martin, R. (1999). 'The new "geographical turn" in economics: some critical reflections', *Cambridge Journal of Economics*, vol. 23(1), pp. 65-91.

McCann, P. (2005). 'Transport Costs and New Economic Geography', *Journal of Economic Geography*, vol. 5(3), pp. 305-318.

Neary, J.P. (2003). 'Globalisation and Market Structure', *Journal of the European Economic Association*, vol. 1, pp. 245-271.

Obstfeld, M. (1998). 'The Global Capital Market: Benefactor or Menace', *Journal of Economic Perspectives*, vol. 12(4), pp. 9-30.

Peeters, J. and Garretsen, H. (2000). *Globalisation, Wages and Unemployment: An Economic Geography Perspective*, CESifo Working Paper No 256, Munich: Center for Economic Studies.

Phillips, P.C.B., Sun, Y. and Jin, S. (2003). 'Consistent HAC Estimation and Robust Regression Testing Using Sharp Origin Kernels with No Truncation', Cowles Foundation Discussion Papers 1407, Yale: Yale University.

Romer, P.M. (1986). 'Increasing Returns and Long-run Growth', *Journal of Political Economy*, vol. 94(5), pp. 1002-1037.

Samuelson, P.A. (1952). 'The Transfer Problem and Transport Costs: the Terms of Trade when Impediments are Absent', *Economic Journal*, vol. 62(246), pp. 278-304.

Solow, R.M. (1956). 'A Contribution to the Theory of Economic Growth', *Quarterly Journal of Economics*, vol. 70(1), pp.65-94.

Swan, T. (1956). 'Economic Growth and Capital Accumulation', *Economic Record*, vol. 32(2) , pp. 344-361.

Tong, Y.L. (1990). *The Multivariate Normal Distribution*, New York: Springer-Verlag.

Upton, G J G and Fingleton, B (1985). *Spatial Data Analysis by Example*, Vol. 1. Chichester: Wiley

Verspagen, B (1997). 'Estimating international technology spillovers using technology flow matrices', *Weltwirtschaftliches Archiv*, vol. 133, pp. 226-248.

Williamson, J.G. (1998*a*). 'Globalization and the Labor Market: Using History to Inform Policy', in P. Aghion and J.G. Williamson (eds), *Growth, Inequality and Globalization*, Cambridge: Cambridge University Press, pp. 105-200.

Williamson, J.G. (1998*b*). 'Globalisation, Labour Markets and Policy Backlash in the Past', *Journal of Economic Perspectives*, vol. 12(4), pp. 51-72.

Wood, A. (1998). 'Globalisation and the Rise in Labour Market Inequalities', *Economic Journal*, vol. 108(450), pp. 1463-1482.