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Urban Economic Growth in Europe: Testing Theory and Policy Prescriptions

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Summary. A quite robust model of differential growth rates of per capita income in the major functional urban regions of the European Union is presented and tested for the 1980s. The results underline the important role of purely spatial economic processes in differential regional growth and suggest that the pattern of European urbanisation tends itself to generate systematic divergence of mean per capita incomes between neighbouring city-regions, even though the mechanism generating this divergence of mean incomes is not inconsistent with converging incomes for comparable individuals. In addition, the evidence is supportive of a spatial adaptation of Romer's endogenous technical progress model. The model is formulated in a way which tests policy concerns. In general, the results are supportive of European regional policy although the systematic spatial effects of European integration seem to be fading and extending outwards to near-peripheral urban regions.

There recently has been increasing interest amongst economists in developing new approaches to explaining economic growth (Lucas, 1988; Romer, 1986, 1990). Another comparatively recent area of activity has been the debate about 'convergence' and 'divergence' in national and regional growth rates (Barro, 1991; Barro and Sala-i-Martin, 1991, 1992; Sala-i-Martin, 1994). It would seem to be partly as a result of these developments that a number of economists, previously active in other areas of the subject, have been attracted to work on spatial economics and on urban and regional growth (Glaeser *et al.*, 1992; Krugman, 1991, 1993). With the exception of Krugman, most of these contributions, however—despite Blanchard's (1991) claim that macroeconomists had rediscovered regional economics—have remained curiously aspatial: that is they have not sought to take account of how frictions and adjustment mechanisms, or the spatial specialisation of activities, condition what we observe or influence local growth rates.

While it is hoped that this paper is informed by these developments, it has a different purpose from either of the two main strands of recent literature identified: the new growth theory or convergence–divergence debates. Our focus is on regional growth differentials themselves, on whether European structural policy is aimed at categories of problem that evidence shows exist,

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and on identifying and testing for spatial factors involved in regional growth processes. Spatial factors, such as the role of agglomeration economies and congestion, the differential impact of European integration, or the differential impact on measured per capita incomes of adjustment processes, have received very little attention in the mainstream economic growth literature.

Balanced growth models, for example, focus on the supply side and are definitionally long-run. Actual observation of growth experiences are at best medium-run, subject to important demand-side shocks and—the evidence of this paper suggests—specifically spatial factors. Unless these are fully accounted for, it is not possible to provide an appropriate test of underlying growth theory. And, since it is the actual observed growth differentials which condition peoples' lives and to which European policy-makers respond, a reasonable case can be made that a model which tries to account for actual growth is both more relevant to real-life concerns and more appropriate for evaluating theory.

The concern for regional economic disparities and the view that steps towards European integration tend to increase these differentials, do, after all, consume non-trivial quantities of resources. European regional policy, operated through the European Regional Development Fund (ERDF), cost 12.9bn ECU at 1988 prices in 1992 (CEC, 1993) or about $11.2bn. The European Union (EU) is committed to increase the resources available to the Structural Funds from 20.1bn ECU ($16.8bn) to 27.4bn ECU ($22.9bn) by 1999 measured at 1992 prices (CEC, 1993).

European regional policy has traditionally placed great emphasis on the problems of 'peripheral' regions. Integration has been seen as further reinforcing growth in 'core' regions. As a consequence, each step towards integration has been accompanied by an increase in regional assistance mainly directed to peripheral regions (Cheshire *et al.*, 1991); 70 per cent of Structural Fund spending is to be directed to 'peripheral' regions between 1994 and 1999 (CEC, 1993). Since the reform of the Structural Funds in 1988, regions for assistance have been designated on the basis of two main objectives: to assist the development of poor and backward, largely agricultural regions; and to alleviate the problems of declining industrial regions. Most recently (Millan, 1993), the Commission has begun to argue that the traditional dichotomy of core and peripheral regions was becoming oversimplified, even outmoded:

> Dramatic contrasts such as those between the centre and the outlying regions are being overtaken by a more complex pattern of territorial organisation...This diversification of disparities is generating a patchwork in which privileged areas border directly on depressed areas. (Millan, 1993, p.7)

The empirical work reported here attempts directly to test some of these policy concerns. Is the diagnosis of regional growth processes implicit in European regional policy concerns, consistent with the data? Does the process of European integration tend to assist core regions at the expense of peripheral ones? Given spatial adjustment mechanisms, how can we reconcile increasing mobility within Europe with an increasing "patchwork in which privileged areas border directly on depressed areas"?

In the US, the assumption with respect to spatial adjustment processes tends to be made that labour mobility is so strong between regions ('regions' used in the sense of spatial sub-divisions of national economies) that characteristic-specific income or unemployment differentials are equalised on the margin. Glaeser *et al.* (1992) explicitly assume that in the US migration equalises marginal real wages to skill-specific labour across US city-regions and the implicit assumption of such a strong definition of spatial equilibrium is common to much US analysis (e.g. Blomquist *et al.*, 1988; Gyourko and Tracy, 1991). A comparable assumption is usually made with respect to the inter-regional equalisation of characteristic-specific unemployment differentials (Marston, 1985).

In Europe, both policy-makers and academics tend to assume that barriers to mobility mean that inter-regional equalisation will be far from the norm even within countries, and certainly between regions in different countries. Even in a broadly neo-classical perspective 'equilibrium differentials' are the expected outcome (Gordon, 1985; Evans, 1990). At an intra-regional level, however, positions are broadly reversed. Europeans, analysing compact city-regions which, socio-economically and ethnically are, by US standards, comparatively homogeneous, argue for equalisation on the margin (Cheshire, 1979; Evans and Richardson, 1981; Gordon and Lamont, 1982). Americans, however, express continuing concern for implicit disequilibrium at the intra-regional level (Wilson, 1987; Hughes, 1993).

The position adopted in this paper is that although both the US and European views of spatial adjustment involve strong assumptions, each view is more appropriate to its continental context. There are very significant barriers to inter-regional migration in Europe, but intra-regional adjustment to demand shocks is speedy and complete because of induced adjustments to commuting patterns. In the context of densely urbanised regions, such as the Randstad, Ruhr, the English Midlands or South East, this mechanism of spatial adjustment extends to inter-regional adjustment, helping systematically to generate Millan's "patchwork of privileged areas (bordering) directly on depressed areas".

The Definition of Region

An appropriate model can only be constructed in the context of a specific dependent variable. Models to explain rates of change of total regional income should contain endogenous explanations of labour and capital flows; this is not the case if growth in per capita income is the object of interest unless a significant contribution is expected to be made by general forms of increasing or decreasing returns. Growth models are not generally couched in terms of employment growth.

The focus of attention in this paper is growth in regional per capita income.[1] Regions, however, are not defined as administrative units[2] but as Functional Urban Regions (FURs). For reasons explained in previous contributions to this journal (Cheshire *et al.*, 1986; Cheshire, 1990) and at greater length in Cheshire and Hay (1989), regions so defined are economically coherent, being as relatively self-contained as spatial sub-divisions of a single open economy can be; they are representative measures of local economies (not, for example, excluding poor industrial zones) and they are appropriate for policy analysis since—because of their relative self-containment—the effects of policy interventions within them are likely to be largely contained; in contrast to interventions at a more local level which will spill over into surrounding areas (Gordon and Lamont, 1982).

FURS are defined in terms of concentrations of employment. To each concentration of employment—or core—are added all spatial units from which more workers commute to the core in question than to some other core. This set of spatial units forms the hinterland of each core, so that each FUR consists of a city-core and its labour-market sphere of influence. FURS are typically more self-contained than travel-to-work areas (which have fixed levels of self-containment), but the precise degree of self-containment will vary according to how closely they are clustered. Cities such as Madrid, Toulouse or Plymouth have very extensive hinterlands and are highly self-contained because they do not compete with other employment centres. Cities such as Essen, Coventry or Brussels, close to other large cities, are less self-contained.

No official data are published for FURS except in the UK (and then on boundaries not identical to those used here). Demographic and some other data have been collected from national sources for the smallest administrative units of each country and aggregated to the FUR boundaries originally defined by Hall and Hay (1980). From these, weights can be derived to apply to official Eurostat data for the smallest (Level 3) European administrative regions which allow reasonably accurate estimates of comparably defined FUR data such as GDP or unemployment rates. For more detail as to the methods used, see Cheshire and Hay (1989). The data analysed here relate only to the (EU's) largest FURs, those with a core city of 200 000 or more and a total population of a third of a million or more. There are 122 such urban regions in the EU but 4, those of Greece and Portugal, have had to be excluded because of lack of data.

The Model

As was noted above, European regional policy identifies two main categories of region for assistance; the so-called Objective 1 regions are the backward agricultural regions, mainly of southern Europe. That Objective 1 regions have per capita income levels well below the EU average is self-evident since that is a criterion for their designation. Not self-evident, however, is whether a heavy representation of agriculture and low income is associated with slow growth of per capita income. This is particularly pertinent given the rapid trend towards industrial decentralisation observed since the 1970s. There is a longstanding view that industrial decentralisation has systematically been directed to more rural regions (Fothergill and Gudgin, 1982; Keeble *et al.*, 1983). The regional growth model of von Böventer (1975), indeed, stresses both intra- and inter-urban agglomeration economies and implies that the fastest rates of growth will, through time, move from the largest, metropolitan centres to successively smaller and more distant urban centres. In the context of all the largest urban regions in the EU, the most appropriate expectation should be for the relationship between FUR growth in per capita income and specialisation in agriculture in the wider surrounding region to be quadratic. FURs in the most urbanised regions would have slower growth but—because of decentralisation to relatively close and more rural areas—more agricultural employment in the wider region would initially be associated with faster growth. This effect would tend to fall away and in FURs surrounded by very agricultural regions—the backward peasant agriculture of much of southern Europe—growth in per capita incomes would be slower. They are too remote from advanced metropolitan centres to receive significant decentralisation and rural–urban migration of unskilled workers from the countryside would be associated with population increasing faster than output and falling average levels of human capital.

The ERDF also identifies so-called Objective 2 regions—old industrial regions experiencing industrial decline and employment loss—as suffering from problems. These are identified in 1988 on the basis of three criteria:

(1) that the unemployment rate in the three years prior to 1988 exceeded the Community mean;
(2) that in some year(s) since 1975 the proportion of industrial employment had exceeded the Community mean; and that
(3) there had been an observable fall in industrial employment in the region compared to the year(s) selected for (2).

Not all industries are declining—particularly in value-added terms—and data permitting the systematic identification of particular industries, even for the largest administrative units, NUTS Level 1 regions, are not easily obtained,[3] certainly not for FURS. In addition, it is reasonable to argue that the influence of some industries, especially coal, continues adversely to affect local growth prospects for a considerable period after they have ceased to account for a substantial share of local employment and output. In the case of coal, other industries which have developed because of its local availability tend to decline or disappear; land has to be reclaimed if it is to be redeveloped; the environment has been damaged; local skills are inappropriate and perceived industrial relations problems may act as a disincentive for inward investment. By 1979, the first date for which the data on GDP per capita can be calculated, the coal industry had entirely disappeared from Belgium and the Netherlands and all but disappeared from north-eastern France and the Ruhr. The historic influence of the coal industry is measured in this model, therefore, by a dummy variable related to the physical coincidence with the area of FURs; if the whole of a FUR was located within the area of a coalfield (as defined in the *Oxford Regional Economic Atlas*, 1971) it had a value of 2; if a part was within a coalfield area it had a value of 1; and otherwise it had a value of 0.

The local effects of the port industry have had much less attention than many traditional declining industries such as coal, steel or shipbuilding, but the dynamic effects of the transformation of the port industry on local economies may well have been more important. The introduction of containerisation and roll-on-roll-off ferries did not just result in a loss of employment and a reduction of value added in port activity but it meant that quite rapidly port cities ceased to exercise a locational attraction for processing industries[4] and even, to some extent, for distribution. Again the historic influence of port activity would seem to be the appropriate variable. It is measured as a dummy variable scaled from 0 to 4 strictly according to the value of seaborne port traffic in 1966 (*Oxford Regional Economic Atlas*, 1971). The largest inland port on the Rhine is also included. These two variables—the influence of the coal and port industries—might be seen as proxies for traditional resource-based industrial specialisation which, in as far as it was associated with human capital, was associated with very industry-specific skills.

Forces for economic integration are global but in Europe they have been given an explicit policy-directed boost. At least since the work of Clark *et al.* (1969), the potential effects of European integration on regional incomes and output have been on the agenda. Empirical evidence for its influence is relatively scarce but a fact of policy-making in Europe is that steps towards integration are believed to strengthen ‘core’ regions at the expense of ‘peripheral’ regions. That is why each step towards further integration since 1970 has been accompanied by a strengthening of structural policies to reduce ‘spatial disparities’. If only for policy reasons, therefore, it is important to test for the impact of European integration on regional growth differentials. The Single European Market was one more marker on a path towards integration established by the Treaty of Rome in 1957.

The concept of economic potential (defined as the accessibility to total income at any location allowing for distance, transport costs and tariffs) as put forward by Clark *et al.* (1969) is an *ad hoc* one in theoretical terms. Various theoretical reasons why it might be associated with regional growth differentials and justifications for the use of changes in it as a measure of the spatial impact of European integration are possible (Cheshire, 1992). It remains a fact that there is no alternative measure of the systematic effects of integration. Since the object of the present analysis is growth, the appropriate indicator is change in economic potential brought about by tariff reductions, falling transport costs and EU enlargements. This is calculated from Clark *et al.* (1969) (who considered the regions of a Europe of 10, including Norway but excluding Greece) supplemented with estimates derived from Keeble *et al.* (1988) for the regions of Spain. These have been scaled to Clark’s values. The theoretical arguments as to why integration should favour core regions do not imply that that relationship measured for the 1980s should be linear. Clark’s calculations are for different hypothetical states of the world but with data for 1966. Induced growth may have been fastest where economic potential increased most in the initial stages of integration and falling transport costs. But this growth would tend to bid-up land and labour costs and produce additional congestion. In turn this would tend, over time, to produce deconcentration from the core to surrounding regions, so by the 1980s the relationship in terms of Clark *et al.*'s (1969) estimates should be quadratic. That would also be consistent with the more abstract representation of inter-and intra-urban agglomeration economies in von Böventer's model of regional growth processes (1975).

The variables discussed so far all relate to European policy concerns. There is considerably more theoretical interest in the role of specifically spatial economic factors. The first two are relatively straightforward. Different activities tend to concentrate in cities of different sizes, as the size at which diseconomies of agglomeration offset the economies of agglomeration varies between types of activity. Those activities which were fastest growing in the 1980s, such as business services, finance and information-intensive activities, tend to be concentrated in larger cities. It has been widely suggested that small and medium-sized cities grew fastest during the 1970s and 1980s (though this has usually not been tested in a multivariate context and it is not clear whether the implied dependent variable is total population, total income or per capital income). However, the size of cities in the present analysis has been necessarily truncated; only large FURs are included because of the high cost of acquiring and adjusting data collected by national agencies. In 1981, the FURs which are the object of the present analysis accounted for just over 50 per cent of EU population.

Thus we might expect city size to be positively associated with income growth but, given the evidence on the distribution of city sizes, this would be more appropriately entered as the log of population. After standardising, so far as possible, for other factors influencing the rate of income growth, we might also expect a measure of density to be negatively associated with growth. There are two possible but not mutually exclusive reasons for this. The first is that higher density, other things being equal, is likely to be associated with greater unit congestion and infrastructure costs; the second is that it is likely to be a reasonable proxy for land rents. The higher these are, other things being equal, the lower income growth (both absolute and per capita) is likely to be. This is not to deny that other factors, such as natural or policy-created restrictions on urban land supply, will also influence land prices. Density is calculated for the area of the FUR as a whole in 1981.

The final variable reflects the spatial adjustment process. As was noted above, the tendency in the US is to assume that real wages for characteristic-specific (that is skill, experience, etc.) labour equalise on the margin between city-regions. In Europe, with its much higher costs associated with migration, this is not a reasonable assumption. Equilibrium differentials are likely to remain even in marginal returns (Gordon, 1985) and greater ones are possible with respect to average returns. As was pointed out in Cheshire (1979), however, two forms of spatial adjustment process exist in the labour market; migration, involving a change of both workplace and residence—or discontinuous mobility—and alterations to commuting patterns—or continuous mobility. Since the potential for continuous spatial mobility exists every time an individual changes jobs, and the flow of job changes is very large (see Bowers *et al.*, 1972), continuous mobility represents a low-cost adjustment mechanism in densely urbanised regions. It should be noted that this is a fact of the European settlement pattern and therefore of its spatial adjustment mechanisms. City regions in the US tend to be much more isolated, so adjustment via induced commuting-pattern changes between (but not within) city regions is unlikely to be very significant except in some specific areas. Thus the closer FURs are clustered, the more induced commuting changes will be produced for a given change in income differentials and the more likely it will be that characteristic-specific incomes (or unemployment probabilities) will equalise on the margin.

The effect of this mechanism will, however, be paradoxical with respect to measured per capita income growth. There will be two effects. The first will be that the

FUR in which incomes grow faster will attract in commuters from its neighbouring FUR(s)[5]—thus increasing its workforce and total GDP, but not its measured resident population. Measured per capita income will grow even faster than income per worker, therefore, as a purely statistical artefact since GDP is measured at the workplace. There is likely, however, to be a real effect too. There is a strong positive relationship between length of commuting trip and income and measures of human capital. There is also such a relationship between area of search and measures of human capital. Thus the FUR in which per capita incomes grow faster will tend systematically to attract more productive and highly paid workers from its neighbouring FUR(s), increasing the differential in mean per capita incomes further by a form of composition effect. Thus we should expect that, other things being equal, per capita income will grow faster in a faster-growing FUR the nearer it is to other, less rapidly growing FUR(s); and that, conversely, in the FURs where per capita income grows more slowly, it will grow more slowly still the closer the FUR is to other FUR(s) where income is growing more rapidly. It should be expected that there will be some lag in this process since commuting patterns do not adjust instantaneously so the variable is measured over the period 1979–86. This also removes any plausible reasons for fearing definitional correlation. Differences in per capita income growth were measured for all FURs within 80 km of each other and this differential was divided by distance to reflect a likely distance-decay effect. Some FURs within 80 km of each other are divided by a national boundary. Later experiment showed that in these cases there was no measurable effect whatsoever; but the variable on which the results reported here were estimated was calculated doubling linear distance if a national boundary intervened.

The seminal contribution of Romer (1990) is to formulate a consistent model of economic growth which makes technological progress endogenous and respond to market incentives in a believable way. A key result is that since there are increasing returns to human capital employed in research, because of the non-rival and partially non-excludable nature of a part of the output of knowledge generation (the ‘blueprints’ or designs), larger markets can induce more knowledge generation and so not just create static increasing returns to scale but dynamic increasing returns to scale in the form of a faster growth rate. The mechanism which produces this result is the rate of growth of A, the number of new designs, ideas or blueprints. This is a function of human capital employed in research. Thus in a Romer-style model the quantity of human capital available, and the proportion devoted to research, drives economic growth. This derives from his equation (3):

$$\dot{A} = \delta H_A A \tag{1}$$

where:

$\dot{A}$ is the rate of growth of non-rival knowledge; H_A is total human capital employed in research; and A is stock of knowledge.

Although he acknowledges that other assumptions are possible, he assumes “anyone engaged on research has free access to the entire stock of knowledge” (Romer, 1990, p. S83). A more plausible assumption to an urban economist, used to thinking about the source of agglomeration economies, industrial districts and the like, is that there is both a distance-decay function associated with access to knowledge[6] and economies of scale and concentration. The more opportunities there are of meeting someone working on a related problem or with useful, incremental knowledge, the more knowledge-productive the individual worker is likely to be.

This idea can easily be incorporated within a modified version of Romer’s equation (3):

$$\dot{\mathrm{A}}_{\mathrm{r}} = \delta H_{Ar} \cdot A \cdot \phi_r \tag{2}$$

and

$$\phi = H^{\alpha}_{Ar} \tag{3}$$

where: r denotes the region; ϕ denotes knowledge spillovers; and α is a parameter describing the concentration of human capital within a region and the resulting opportunities for productive contacts.

This reduces to

$$\frac{\dot{A}_r}{A} = \delta H_{Ar}^{1+\alpha} \qquad (4)$$

A reasonable argument may be made that this will capture both differential spillover effects of knowledge within regions and between regions. The chances of accessing useful knowledge available in another region will increase as opportunities of meeting someone who has recently visited that region, or is networked into that region, rise. Lone researchers have the same probability of accessing knowledge wherever they are (the Romer assumption) but the more concentrated they are, the greater their probability of accessing knowledge both existing within the region and in other regions. This suggests that there will be dynamic increasing returns to the spatial concentration of human capital via accelerated knowledge generation. H_{Ar} will be raised to a power of $1+\alpha$ and $\alpha > 0$.

This is strictly only an explanation of disequilibrium growth differentials since it would imply that all research and development would ultimately end up in one region and this region would have the fastest rate of growth. There are various plausible mechanisms that would prevent all human capital engaged in research and development concentrating in a single region. One such would be if there were human-capital-generating institutions located in every region and only a small probability of any human capital element moving to another region within any given time-period (an individual's working life). Another possible mechanism would be that research and development is sector-specific and that there is some positive probability of a new sector emerging in any given region in each time-period. A model such as this would be in the spirit of that suggested by Brezis and Krugman (1993) to explain the relationship between technology and the life-cycle of cities. Mechanisms such as these would, however, greatly complicate the Romer model and are beyond the scope of the present paper to explore. It might also be argued that the period analysed here is short enough (in the context of R&D facilities and personnel) to be consistent with a disequilibrium view anyway.

Other spatial formulations are, of course, possible but this suggests that if a regional measure of human capital employed in economically applicable knowledge generation can be found, then the prior expectation is that the influence that that would have on differential FUR growth rates would be raised to a power greater than 1.

As an example of localised knowledge spillovers, when working on this problem the authors were in a department which has long been interested in multinational firms and had collected a database on all research and development establishments in Europe of Fortune top 500 firms, including their addresses. These have been allocated to FURs and—to represent concentration of human capital employed in knowledge generation—expressed per unit population. While it is a crude measure—it would be more appropriate if the number of qualified researchers at each establishment were also known—it is a crude measure of the theoretically appropriate variable. That the data relate to 1988 does, in principle, raise the possibility of simultaneity bias: a significant result could be at least partly because R&D establishments moved to fast-growing regions. The practical importance of this is likely to be negligible, however. R&D establishments of major companies are highly immobile and the correlation between the 1988 value and that for 1979 (if that were known) would be very close to 1. A follow-up study by Casson (1993) found only 39 new R&D facilities belonging to multinationals of any size located within the EU between 1989 and 1993: and these new establishments were highly concentrated in existing R&D-specialised regions.

The final set of variables reflects national factors. FURs are not isolated from the rest of the economies of which they are a part. National macroeconomic policy, education and training policies, national culture, legal and social institutions all influence rates of economic growth of both national economies and of their component city-regions. These are not directly measured, but are entered as the growth in per capita income in the national remainder (that is, excluding the FURs that are the object of the analysis) over the 1979/82 to 1987/90 period. This has the advantage of entirely avoiding any definitional correlation while entirely capturing the policy, cultural and institutional context (except in so far as those systematically differ between large city-regions and the rest of their nations).

The second national factor was entered because of the expectation that German cities were influenced by the influx of refugees from eastern and central Europe, notably from the former DDR, in the period under study (only FURs of the former West Germany are included in this analysis for reasons of data availability). It is well documented that these flows were substantial (see, for example, Burda, 1993). Other work (Cheshire, 1995) has shown that German FURs displayed substantial population growth in their cores over the 1980s as a whole, reversing a decade or more of population loss. Although this was part of a wider pattern of partial urban population recentralisation in northern European city-regions during the 1980s, elsewhere there was mainly relative, rather than absolute, recentralisation. The explanation seems likely to be the influx of refugees/migrants in 1989 and 1990. Just as this raised population, so it would have tended to lower per capita income growth, other things being equal, because the new migrants remained mainly unemployed. The German border with Belgium is virtually open and other evidence suggests that lower living costs in Belgium have induced a movement of population working in north-west Germany to live in Belgium. Independently of this, there has been extensive immigration to Brussels. The four major city-regions of Belgium were therefore included with those of Germany in this dummy variable.

The final variable is a dummy for Northern Italian FURs (including Rome). The rate of growth of the national remainders acts as a proxy for national, institutional, social and cultural factors, but the difference between northern and southern Italy in these respects is exceptional. This dummy is to allow for the possibility of two Italies, therefore.

The full model, then, has the following form:

$$\begin{aligned}\dot{Y}_F = a &+ b_1 A_{75} + b_2 A_{75}{}^2 + b_3 I_{75} + b_4 C + b_5 P \\ &+ b_6 \Delta PT + b_7 \Delta PT^{\,2} + b_8 \ln S + b_9 L \\ &\quad b_{10} \sum \left(\frac{\dot{Y}_i - \dot{Y}_j}{D_{ij}} \right) + b_{11} \left(\frac{R}{S} \right)^n \\ &+ b_{12} \dot{Y}_{\mathrm{N}} + b_{13} C_{BG} + b_{14} C_{NI}\end{aligned}$$

where:

$\dot{Y}_F$ = percentage growth in FUR GDP per capita, converted at purchasing-power parity to US dollars;

A_{75} = proportion of total labour force in agriculture in the wider Level 2 region in 1975;

I_{75} = proportion of total labour force in industry in the wider Level 2 region in 1975;

C = dummy variable measuring physical coincidence of FUR territory to coalfield: C = 2 if whole area of FUR coincident with area of coalfield; C = 1 if part of area of FUR coincides with area of coalfield;

P = dummy variable ranging from 0 to 4 scaled strictly to volume of seaborne trade through port in 1966, except for inland part of Duisberg, the largest on the Rhine;

ΔPT = change in economic potential resulting from abolition of tariffs, EC/EU enlargement and reduced transport costs: calculated from Clark *et al.* (1969) and Keeble *et al.* (1988);

S = size of FUR measured as population in 1981;

L = density of development within

FUR measured as population density in 1981;

$\sum\left(\frac{\dot{Y}_i - \dot{Y}_j}{D_{ij}}\right)$ = sum of difference between growth rate of per capita income in FUR i and growth rate of per capita income in other FUR(s) j within 80km, divided by D, distance between FUR and other FUR(s) in km. If a national boundary lies between FURs, actual distance is doubled;

R = number of research and development establishments of 500 largest world industrial enterprises (Fortune listings) per million population: n to be determined by investigation;

$\dot{Y}_N$ = percentage growth in GDP per capita in area of nation excluding major FURs, converted at purchasing power parity to US dollars;

C_{BG} = dummy variable taking value of 1 for all major FURs of Belgium and former Western Germany: 0 elsewhere;

C_{NI} = dummy variable taking value of 1 for all major FURs of northern Italy south to and including Rome;

$\dot{Y}_F$ and $\dot{Y}_N$ were measured as percentage increase in income between the mean of 1979–82 and the mean of 1987–90. $\dot{Y}_i - \dot{Y}_j$—the difference between the percentage change of income within a FUR and each of its neighbours—was measured between the mean of 1979–82 and the mean of 1983–86.

The Results

This model was estimated using OLS for the 118 FURs for which there were data. The results are shown in Table 1 which also shows the effects of adding particular groups of variables. The diagnostics of the full model were satisfactory with no indicated problems of functional form, non-normal residuals, heteroscedasticity or spatial autocorrelation of residuals. Contiguity, linear, road and time distance measures of spatial interdependence were tested. Of these, that conforming to the most obvious measure—the inverse of time-distance—proved the most sensitive to changes in model specification. The model with spatial interdependence specified *a priori*—that is, with dummies for northern Italian FURs and for FURs in Belgium and Germany (model 4 in Table 1)—performed best. The implication was that significant, but difficult to measure, independent variables, affecting all FURs in those areas equally, were omitted. Using the Spacestat package, the value for the Lagrange Multiplier test for a spatial lag (Burridge, 1980) in this model was 0.6151 which was not significant. An alternative model, omitting the spatial dummies and including a generalised spatial-lag variable performed almost but not quite as well. If, however, either or both of the spatial dummies was omitted, there was clear evidence of spatial autocorrelation in the residuals of the estimated model.

The adjusted R^2 for the full model, at 0.60 ($R^2 = 0.65$), was satisfactory for a large cross-sectional data set and all coefficients had the expected sign, most were significant at the 1 per cent level and all but for ΔPT^2 was significant at the 10 per cent level (that for ΔPT^2 was significant at 10.3 per cent). A large number of experiments were conducted with alternative models and specifications and re-estimation on sub-samples. The estimates for most variable parameters proved extremely robust and no sign ever changed. The general conclusion from these experiments was that the model performed well and that there were few underlying statistical or specification problems. In the four models presented in Table 1, the only coefficients changing by more than one standard error are those for the historic influence of the coal industry and for the constant term; but the latter is non-significant in all formulations.

Table 1. Income growth, 1979–90: regression results

	Dependent variable: percentage change in FUR GDP per capita, 1979–90							
	Model 1		Model 2		Model 3		Model 4	
Independent variable	$\hat{b}$	t	$\hat{b}$	t	$\hat{b}$	t	$\hat{b}$	t
1 Constant	7.7738 (12.0799)	0.64	8.1028 (11.5820)	0.70	−16.5276 (13.3238)	−1.24	−13.9615 (12.3198)	−1.13
Objective 1 type variables								
2. Percentage of L.F. in agriculture in 1975 in NUTS 2 region	0.4802* (0.2755)	1.74	0.5677* (0.2656)	2.14	0.5604* (0.2621)	2.14	0.6121* (0.2424)	2.53
3. Percentage of L.F. in agriculture in 1975 in NUTS 2 region squared	−0.0187* (0.0077)	−2.44	−0.0202** (0.0074)	−2.75	−0.0189** (0.0071)	−2.66	−0.0202** (0.0066)	−3.09
Objective 2 type variables								
4. Percentage of L.F. in industry in 1975 in NUTS 2 region	−0.1665 (0.1171)	−1.42	−0.1929* (0.1125)	−1.71	−0.1615 (0.1054)	−1.53	−0.1708* (0.0974)	−1.75
5. Historic influence of coal industry	−5.1695** (1.3053)	−3.96	−4.6697** (1.2610)	−3.70	−3.8537** (1.1940)	−3.23	−3.1862** (1.1133)	−2.86
6. Historic influence of port activity	−1.3535* (0.5678)	−2.38	−1.4630** (0.5454)	−2.68	−1.7920** (0.5170)	−3.47	−1.6193** (0.4791)	−3.38
European integration								
7. Change in economic potential resulting from European integration	9.1176 (7.4383)	1.23	9.8110 (7.1347)	1.38	10.3441 (6.6728)	1.55	10.2756* (6.1629)	1.67
8. Change in economic potential resulting from European integration squared	−4.6244 (4.0763)	−1.13	−4.7687 (3.9084)	−1.22	−5.5207 (3.6563)	−1.51	−5.5536 (3.3769)	−1.64
Spatial processes								
9. Log of total population 1981					3.7260** (0.9751)	3.82	3.3726** (0.9042)	3.73
10. Population density 1981					−0.0021* (0.0010)	−2.16	−0.0016* (0.0009)	−1.78
11. Growth differential with neighbouring FURs 1979–86 divided by distance							6.3141** (1.4516)	4.35
Dynamic knowledge-spillover effects								
12. R&D establishments per million, 1988 raised to power of 4			0.0035** (0.0011)	3.23	0.0040** (0.0010)	3.83	0.0038** (0.0010)	3.92
National factors								
13. Percentage income growth 1979–90 in national remainders	0.7716** (0.1250)	6.17	0.7610** (0.1199)	6.35	0.7465** (0.1135)	6.58	0.7382** (0.1048)	7.04
14. Dummy for Belgium and Germany	−5.1179* (2.0849)	−2.45	−4.6266* (2.0047)	−2.31	−4.8597* (1.9574)	−2.48	−4.7718** (1.8079)	−2.64
15. Dummy for northern Italy	4.5096 (2.8615)	1.58	5.1100* (2.7498)	1.86	3.9974 (2.6100)	1.53	4.3731* (2.4121)	1.81
N	118		118		118		118	
Adjusted R^2	0.41		0.46		0.53		0.60	
Max log likelihood	−395.20		−389.67		−380.50		−370.55	

Standard errors in parenthesis.
*significant at 10 per cent.
**significant at 1 per cent.

The results on the research and development variable are particularly noteworthy and were subject to considerable investigation. The performance of the variable when raised to a power of four was superior to any alternative although the *t* value never fell below 3 when the variable was raised to any power between 1 and 4. Nevertheless a power of 4 is a higher value than might have been expected. Investigation showed there was a very high leverage on one observation, which had the highest value on the R&D variable. To check that this was not conditioning the results, the model was re-estimated excluding that observation. The form of the influence of the R&D variable was sensitive to this. The best performance was still obtained with the variable raised to a power greater than 1, but squared rather than to the power of 4. Omitting the outlying observation only trivially affected the overall performance of the model as a whole in terms of *t*-statistics for other coefficients, log-likelihood or adjusted R^2. The significance of the R&D variable, however, fell quite sharply. This implies that the particular result reported in Table 1 is significantly conditioned by the outlying observation but that the best fit, even excluding that information, is still obtained with the R&D variable raised to a power of two.

Discussion

A quite full and robust model of differential income growth rates in the EU's major city-regions is, therefore, possible. It has interesting implications both in policy terms, in terms of understanding the significant role and form of purely spatial factors and adjustment processes, and as providing evidence consistent with a spatial application of Romer's ideas (1990) in relation to dynamic increasing returns to human capital employed in knowledge production. In addition, the form of the spatial adjustment mechanism posited, itself has significant welfare implications which policy should take into account.

First, the traditional regional policy concerns of the EU are mainly consistent with the results reported here. City-regions located in backward agricultural regions did grow less rapidly, as did those still influenced by the historic inheritance of old resource-based industries. This result is entirely consistent with results previously reported (Cheshire, 1990) using an entirely independently calculated dependent variable designed to reflect changes in a more widely defined 'urban problem' index. Two points to note, however, are first the quadratic form of the influence of agricultural specialisation in the wider region; up to a point, increasing agricultural specialisation was associated with a rising growth rate. It was only after the proportion of the labour force in agriculture in the wider region exceeded the level found in all but the extreme cases in southern Italy and Spain that a further increase was associated with slower FUR growth. These results, furthermore, are wholly consistent with the slower growth being concentrated in the urban regions themselves not in their agricultural surrounding areas. A second point to note is the strong association of historic specialisation in port activity with slower growth in per capita incomes during the 1990s.

The result on the measure of the spatial effects of European integration is also of interest, not only in itself and the interpretation it has for the impact of European integration on 'core' compared to 'peripheral' regions, but in the context of previous results. Clark *et al.* (1969) calculated regional economic potential on four assumptions; for the regions of the European Economic Community (EEC) of six before the Treaty of Rome; as it was for the EEC of six with tariff reductions following the Treaty of Rome; as it would be for the EEC of ten after the first enlargement; and as it would be following that enlargement and a fall in transport costs associated with containerisation and roll-on-roll-off ferries. Each value of regional economic potential used the same GDP data—those estimated by Clark and his associates for 1966. Thus the values were for different hypothetical states of a static world of fixed distribution of population and activity.

Seven studies using four unrelated dependent variables have now been undertaken. As the database has been enlarged, it has been possible to increase the range of dependent variables from simple percentage population change, to change in unemployment rate, to change in the value of the urban problem index for three periods between 1971 and 1988 and, now, for the percentage change in GDP per capita from 1979 to 1990. The results of a total of seven separate models are summarised in Table 2. In each case, experiments were undertaken to get the best performance.

The pattern of these results is striking. Not only did a plausible relationship emerge for each model, but for each period studied, irrespective of which growth variable (inverse growth in the case of change in unemployment rate) was the focus of analysis, the most appropriate form of the change in economic potential variable performed best. For the 1960s, the estimated change associated only with tariff-barrier reductions between the original six member states performed best. For later periods, the estimated change associated with tariff reductions, transport-cost reductions and enlargement performed best. Not only that, but the relationship moved from being linear, with the greatest gains being associated with the highest values right at the centre of economic gravity of the EU, to being quadratic, for the two most recent periods, suggesting deconcentration and spread effects.

Figure 1 shows the form of the net impact of changing economic potential from the models for the two most recent time-periods for which the quadratic forms were estimated. Figure 2 maps the changing pattern of regions receiving maximum benefits from the impact of integration estimated from the models relating to successive time-periods. In interpreting these results, it may be worth repeating two points. Clark *et al.*'s (1969) calculations of the impact on regional economic potential for different states of European integration and levels of transport costs used GDP data for a single date, 1966; in addition, the change in economic potential predicted tended to fall away with distance from the 'core' of the EU, that is from the Benelux countries and north-western parts of Germany. What the results shown in Table 2 and Figures 1 and 2 suggest, therefore, is that the initial impact of integration was systematically to favour city-regions the closer they were to the core (the period from 1960 to 1975, when all estimated relationships were linear). These gains, however, tended over time to produce rising costs. In addition, there were continuing falls in transport costs unanticipated by Clark which extended the area of greatest gains from integration. Over time, therefore, the maximum favourable impact of the change in economic potential as estimated by Clark extended outwards from the core (to regions with changes in economic potential less than the highest estimated by Clark *et al.* on the basis of 1966 data) and the impact of changes in economic potential as calculated by Clark *et al.* became less important in determining regional growth differentials. For the latest period analysed (1979/82 to 1987/90), not only had changes in regional economic potential become only marginally significant, but the greatest gains had spread out far beyond the traditional 'core' regions to areas previously considered 'peripheral'.

The coefficient on the spatial adjustment mechanism is also worthy of note. As can be seen from a comparison of the performance of model 3 with that of model 4 (Table 1), this variable contributes substantially to the performance of the full model and suggests that the observation of Bruce Millan, the Commissioner for Regional Policy, quoted above, does not relate to a chance factor but to a process which is wholly systematic and integral to the pattern of relatively dense urbanisation common in Europe (but not in the US).[7] It also has interesting welfare implications which it is beyond the scope of the present paper to explore. The implication has to be considered, however, that since quite low-cost adjustment is possible via commuting-pattern changes between closely clus-

Table 2. The role of changing economic potential: estimated coefficients for different models

	Period over which dependent variable was measured						
	1961–71	1971–81	1977/81–1985/7	1971–78[a]	1975–83[a]	1975–88[a]	1979–1990
	Dependent variable of model						
Measure of European integration effect	% Population change[b]		Change in unemployment[c]	Change in urban welfare index[d,e]			% Change in GDP p.c.[f]
Change in economic potential following:							
Treaty of Rome	+ 0.0038*						
All changes		+ 0.0038**	− 1.1621*	+ 1.0780*	+ 1.3291*	+ 5.6145**	+ 10.2756
All changes squared						− 2.6290**	− 5.5536

*Significant at 5 per cent.

**Significant at 1 per cent.

[a] Calculated as a moving average so periods are not precise and overlap.

[b] Reported in Cheshire and Hay, 1989.

[c] Reported in Cheshire, 1991.

[d] Reported in Cheshire, 1992.

[e] A linear form was reported for the whole period 1971–88 in Cheshire, 1990.

[f] Reported in Table 1.

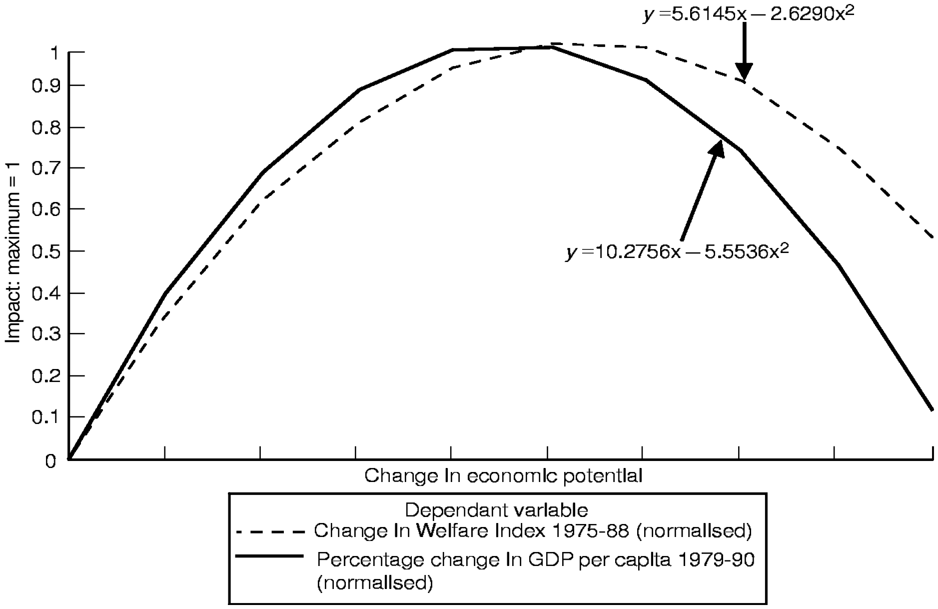

Figure 1. The changing regional impact of European integration.

tered FURs with divergent growth rates, economic opportunities for characteristic-specific groups in such cities tend to converge even while mean GDP per capita diverges. This would not be true for divergences in growth rates for more isolated city-regions (except in as far as, in the very long run, migration and capital movements may produce convergence).

Any conclusion that there will be long-run convergence, however, is made less plausible by the results which are consistent with Romer's growth model (Romer, 1990). Some caution is appropriate given the evidence that the leverage of one outlying observation plays a non-trivial part in the specific result reported in Table 1. But, as was noted above, if that observation is dropped, the R&D variable still works best when squared. Not only are these results consistent with the central mechanism of Romer's model, therefore, but they also support a spatial interpretation of it; that there are increasing returns to the concentration of human capital employed in R&D. This is a specific type of agglomeration factor affecting the productivity of human capital in research.

Alone this would suggest that per capita income growth rates might persistently diverge because of localised knowledge spillovers and dynamic increasing returns to knowledge. However, since the determination of net changes in GDP per capita is a multivariate process, this does not necessarily imply that observed per capita incomes would diverge in any given time-period. The conclusion of the model reported here is that there are some forces producing convergence and others producing divergence and the actual outcome over time is determined by the net effect of those forces; a conclusion which is consistent with Quah's (1993) analysis which showed that, for countries at least, there was little correlation in growth rates between successive time-periods. If, in fact, the log of the initial level of FUR per capita income is entered as an additional independent variable, we find evidence for neither

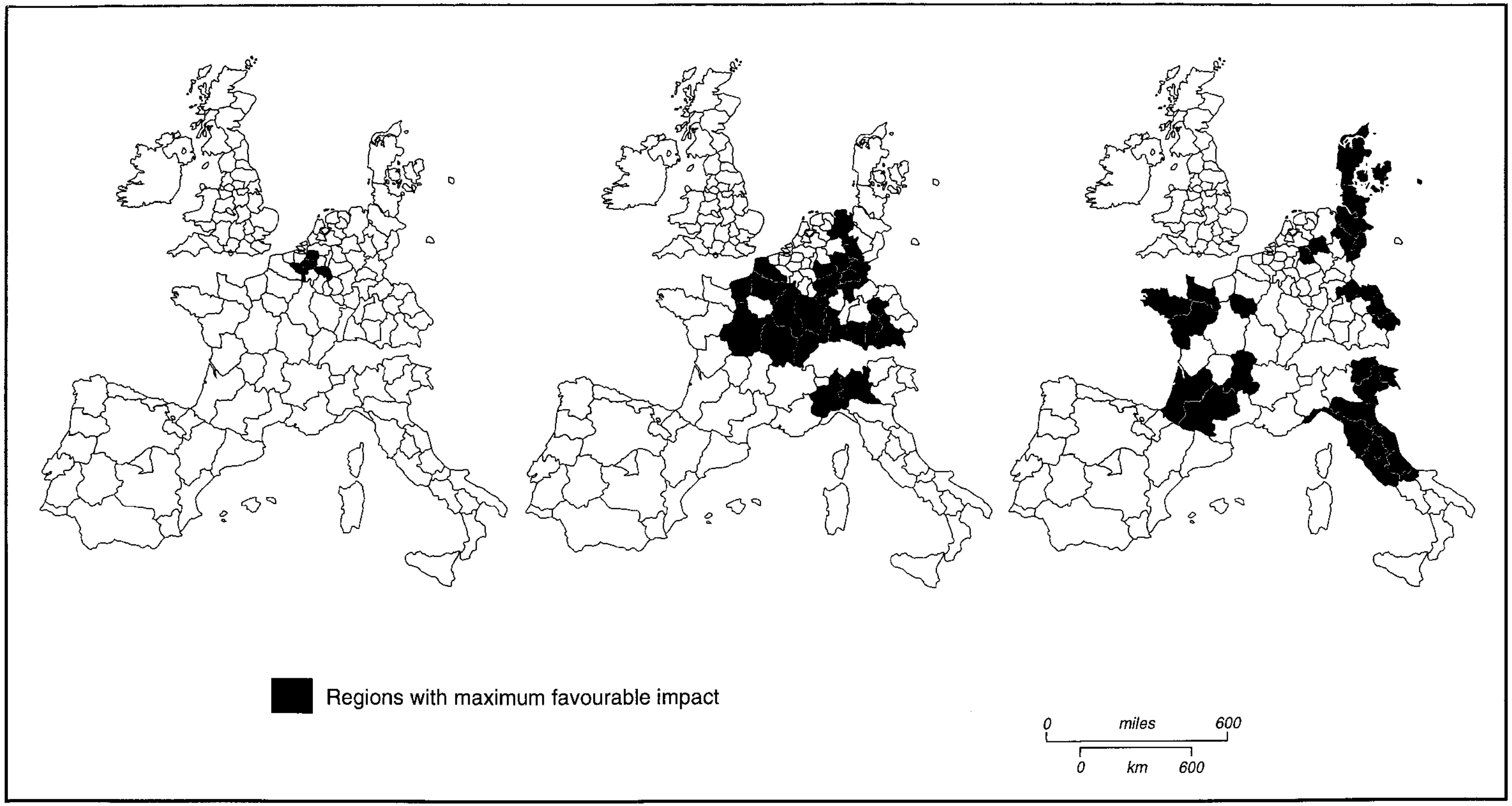

Figure 2. Maximum favourable impact of change in economic potential variable on regional development: 1961–81 (left); 1975–87 (centre); 1979–90 (right).
Source: Table 2.

convergence nor divergence from initial income level alone. The coefficient is negatively signed (convergence) but the '*t*' value is less than 1. All other coefficients and '*t*' values remain virtually as those reported for the full model in Table 1.

Notes

1. Converted at OECD purchasing power parities into $US. This eliminates the effects of relative but not absolute price changes.
2. These are the NUTS (Nomenclature des Unités Territoriales Statistiques) of EU data and policy—in Britain, for example, the Counties or Standard Planning Regions. In the US, the nearest equivalent would be counties, states and regions.
3. It might be thought that employment by sector would be readily available, but different national classification systems and simple non-availability (in Italy before 1981, for example) mean that unless very large numbers of observations are dropped, only a three-sector classification—agriculture, industry and services—can be calculated for any date before about 1986.
4. See Alonso (1964) for a discussion of the historic locational attractions of ports for processing industries in their capacity as trans-shipment points.
5. Thus extending its boundaries—if these could be perfectly and continuously measured—but the units analysed in this paper have boundaries defined with respect to 1971 data and frozen.
6. Universities are themselves embodiments of this phenomenon. Access to the knowledge of colleagues is strongly associated with the number to whom one has easy access: the nature of coffee-room discussion is knowledge spillovers. In the present case, we would like heartily to acknowledge the contribution of a graduate student—Stefano Magrini—with whom we have enjoyed many hours discussing ways of applying Romer-type models in a spatial context.
7. Given the arguments advanced in the text, as to the processes of adjustment underlying this result, it also suggests more detailed and direct tests that could be performed given the availability of time-series data on commuting, unemployment rates by skill level and employment by workplace, for areas small enough to be reconstituted into FURs. Such data exist for a number of European countries, but would have to be collected from national sources and subject to significant further adjustment to give adequate comparability. Such a task would require resources approximately equal to those needed to collect all Census data to update FUR population data to 1990/91; that is, resources on approximately the same scale again.

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