Population Growth in European Cities: weather matters – but only nationally

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Abstract

This paper investigates differences in the rate of growth of population across the large city-regions of the EU12 between 1980 and 2000. The US model which assumes perfect factor mobility does not seem well adapted to European conditions. There is evidence strongly suggesting that equilibrating migration flows between cities in different countries are highly constrained in the EU. However, quality of life motives do seem to be a significant and important feature of differential population growth rates if measured relative to national rather than EU12 values. Once other factors are allowed for, a systematic and highly significant factor determining rates of urban population growth is climatic variation. Cities with better weather than that of their countries have systematically tended to gain population over the past 20 years once other factors – including natural rates of increase in the areas of each country outside the major cities - are allowed for: there is no such effect for climate variables if expressed relative to the value of the EU12 as a whole. On the other hand, there is evidence that the systematic spatial gains from European integration are reflected in a city's population growth. The results are tested for spatial dependence and remain robust.

Key words: growth; cities; quality of life differences; mobility; migration

JEL Codes: H41; H73; O18; R11; R50

1. Introduction[1]

This paper sets out to explore the determinants of population growth in European cities and how those forces differ and coincide with findings for the USA. The results illuminate both the extent to which European integration has been having an impact on population movements and also suggest important differences between the situation in Europe and that in the US. In Europe urban population growth seems likely to be a rather imperfect signal of changes in welfare in cities. This is apparently much less true within countries within Europe despite the notorious geographical stickiness of people in Europe. Once one has controlled for other systematic influences, urban population growth is not affected at all by a city having a better climate than the EU12 as a whole – that is the 12 countries that formed the European Union until its enlargement in 1996 to include Austria, Finland and Sweden - but is strongly influenced by it having a better climate than its country.

The results strongly suggest that the model widely used in the US - both in the quality of life literature (Roback, 1982; Blomquist *et al*, 1988; Gyourko and Tracey, 1991; Gyourko *et al.,* 1999) and in the analysis of urban growth (Glaeser *et al*, 1995; Rappaport, 1999) – has application but has to be fundamentally modified for a European context. The evidence presented here suggests that labour in Europe is geographically immobile and, in as far as there is mobility in search of quality of life, it is a within country phenomenon. The central assumption of perfectly mobile factors and the equalisation of real marginal returns across cities explicit in the US models cannot reasonably be maintained in the European context, therefore. That said, however, it is interesting how significant climatic differences between cities within countries in Europe appear to have been in determining differential patterns of population urban growth over the past 20 years. In this sense the results reported here can be seen as complementing those reported for Germany in Rehdanz and Maddison (2004) and making more precise those reported previously for the EU12 in Cheshire and Magrini (2002)

The impact of climatic variables is analysed within a wider examination of rates of urban population growth. There are other influential regional fixed effects that have to be allowed for. These have been modelled explicitly, however, since some of them are of interest in their own right. In the context of our findings with respect to quality of life differences, the most interesting is the impact of systematic regional differences in a measure of the economic gains from European integration. Here we find that changes in a city's economic potential – a measure of the accessibility of incomes at any point - associated with the integration of the EU and falling transport costs, have had a statistically significant influence on differential rates of population growth across the whole space of the EU of 12. This influence on the spatial pattern of incomes, therefore, does appear to operate at an EU level although in statistical terms it is not so influential or so significant as climatic variation within countries.

The idea that differences in climate might influence long run population movement has a long history. One of the first to investigate it was Graves 1976; 1980 and 1983; 2003a & b; Graves and Linneman, 1979. His interest was in the influence of climatic differences on migration flows, however, and it was not until the work of Roback (1982) that climatic differences were put into the more general framework of a compensating differentials model from which inferences might hope to be made about regional and urban differences in the quality of life. If

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[1] The authors have benefited from many discussions with colleagues as this work has developed. This paper draws on work undertaken for a project within the ESRC's Cities Initiative under Award L 130251015. This support is gratefully acknowledged. Thanks to a colleague Giles Atkinson for pointing us to a usable source of climatic data and to Vassilis Monastiriotis for downloading the data and putting it into a usable format.

people are perfectly mobile and vote with their feet, then it follows that in equilibrium no one could move without being worse off. In such a model, differences in climate will be just one source of differences in quality of life. Other features of the natural environment such as topography, scenery and major natural attractions including ski slopes and access to large bodies of water will also have an influence. So too will features of the manmade environment such as conserved open space, the quality of the housing stock, the quality of local public goods and of course jobs, wages and job opportunities. Such differences will be capitalised into land values (and hence house prices) and reflected in labour markets. There they may appear as differences in wages for given occupations, jobs and qualities of labour and/or into expected earnings, allowing for the probability of an individual with a given stock of human capital not being employed. One may chose to live in a nice place accepting that one will have lower expected money earnings – whether because wages are lower or it is harder to find a job for given skills.

In the US, there seems to be significant power in this model. Various studies (for example, Hoehn *et al.,* 1987; Blomquist *et al.,* 1988; or Gyourko and Tracy, 1991) have found convincing evidence that interregional environmental differences are valued and capitalised in the way predicted by the compensating differentials model. However, as Gyourko *et al*., 1999 conclude:

> '…recent work….reports the presence of large city-specific error components in the underlying….estimated …local trait prices….it turns out that….the level of imprecision is such that much better descriptions of local amenity and fiscal conditions, plus superior controls for housing, worker and job quality are needed….' (page 1415)

The authors concluded on a rather pessimistic note. Collecting the additional and better data needed to get better estimates of the underlying hedonic models to obtain more accurate estimates of the relevant local trait prices, would be exceedingly time consuming and expensive. So further progress was unlikely for the foreseeable future.

In a European context the data demands for the estimation of quality of life models are, as was noted in Cheshire (1990), wholly impossible to meet. There is not even systematic data available on house prices that would allow the estimation of hedonic house price models for European cities across countries. Internationally comparable data on individual workers, their locations, the jobs they do and their remuneration are also absent. The position with respect to local fiscal regimes and the supply of local public goods is even worse. There is thus no prospect of estimating 'compensating differentials' models for the cities of Europe.

In the quality of life literature, however, differences in climate have been found to be the most important single environmental variable in explaining difference between cities. The work of Graves (and most recently Rappaport, 2004) has produced conclusive evidence that once other factors have been standardised for, such climate differences are a highly significant explanatory variable in migration patterns. It does seem well worth exploring the role of such differences in the context of Europe, especially given the popular perceptions that it is increasingly relevant to view Europe as a single integrated economic space. It is in this spirit that we approach the question. Given data limitations, we cannot measure migration flows between the major city regions of the EU12 but we can measure population growth. We can also measure natural population change at the regional level and so measure a surrogate net migration effect.

We focus therefore on patterns of urban population growth over an extended twenty-year period with an open mind. Does the evidence support the view that climate differences in Western Europe are influential factors in urban population growth once natural increase has been allowed for? Does the evidence suggest that the EU12 is a single integrated space? Depending on the answers we may then draw some conclusions as to whether people in the EU12 respond to quality of life differences in making locational choices as they appear to in the US and whether they trade off more obviously economic factors, such as employment prospects and house price differences, against such factors as climate.

3. The data and estimation

All the analysis is performed on a data set built up over a 25 year period relating to Functional Urban Regions (FURs) defined[2] so far as possible according to common criteria across the EU of 12. Such FURs correspond to the economic spheres of influence of significant employment concentrations and so are relatively self-contained in economic terms. The analysis is conducted only for FURs with a population of more than one third of a million and a core city which exceeded 200 000 at some date between 1951 and 1981. Cities of the former eastern Länder of Germany and Berlin have to be excluded because of lack of data. The variables used are defined in Appendix 1, which also provides a brief description of how they were measured and the sources used. All data are defined to common statistical concepts either weighting data available from the Eurostat REGIO database to estimate values for FURs or collected directly from national statistical offices or common data providers and adjusted where necessary to common definitions. The data on climate are taken from the Climate Research Unit (University of East Anglia) database and for each city relate to the 30 km square which contains the geographical centroid of the FUR. In a very few cases, such as Portsmouth and Southampton, the FURs are so close together they fall in the same square but there is nevertheless considerable climatic variation within most countries. Even within the Randstat cities of the Netherlands there is a 10 percent variation on most climate measures.

Since the focus of this paper is regional fixed effects, the analysis employs OLS. Our estimation strategy is to find the ‘best’ base model in terms of differences in economic structure and gains from integration and then to explore the impact of climatic differences and alternative functional forms. The models are estimated using robust standard errors. Having chosen a set of best models, we then subject these to extensive tests for specification and econometric problems. The only evidence of any such estimation problems is that there are signs of some multicollinearity and of spatial dependence. The indications are that the multicollinearity which is present does not imply that there is a serious problem of bias in the estimation. It results mainly from the collinearity of the climatic variables, especially in the quadratic form, but also from the functional form selected for some of the economic structure variables. For these, however, there are strong reasons of economic logic. Above all the estimated parameters show considerable stability and are always statistically significant. The tests for spatial dependence mainly suggest the specifications are satisfactory but do indicate that there is a degree of spatial dependence. We therefore also provide the results from a spatial lag model. Although suggesting that perhaps it is useful to include a spatial lag, these results confirm the main findings. Incidentally, and relevant to our focus on the effects and

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[2] For a detailed discussion of the definition of the FURs used throughout this paper see Cheshire and Hay (1989). They are defined on the basis of core cities identified by concentrations of employment and hinterlands from which more commuters flow to the employment core than to any other, subject to a minimum cut off. They were defined on the basis of data for 1971. They are broadly similar in concept to the (Standard) Metropolitan Statistical Areas used in the US.

extent of economic integration within Europe, they also suggest that on average a national border imposed an equivalent time distance cost of two hours.

4. Some practical and theoretical considerations

Within the EU, geographic labour mobility is an order of magnitude less than in the US. If, for example, we measure net interregional population mobility, using similarly sized regions in both the US and the EU, then the incidence of mobility is higher by a factor of 15 in the US. Taking the weighted mean net migration flows between the 51 US states over the decade of the 1990s and expressing that per resident in 1992 yields a mobility rate of 0.005255 – or about 0.5%. Data on net migration at an interregional level are not available for all the EU12 countries so we have to exclude Italy and Portugal. But if the remaining large countries – France, Germany, Spain and the UK are divided into their Level 1 regions (in Germany the Länder or in Britain the Standard Regions) and the smaller countries are treated as single units then for the resulting 47 territorial units the weighted mean net migration flow over the 1990s was 0.000382 per person – or about 0.04%. Since the EU is substantially smaller in geographic terms and has larger regional differences in mean incomes one would have expected that net migration flows between units of roughly equal size would have been greater rather than smaller.

Thus, we should not expect necessarily to find that either the patterns of population growth or their determinants were the same in European and US contexts. Equally we should have a degree of scepticism as to whether such population movement as does occur is sufficient to equilibriate spatial differences in opportunities and welfare within any reasonable timeframe in the EU.

Glaeser *et al.,* (1995) argue that if we assume perfectly mobile factors, a common Cobb-Douglas production function (and factors receiving the value of their marginal product) and quality of life decreasing in city size then it follows that population growth is the most useful indicator for growth in urban prosperity or welfare. People vote with their feet and if the combination of the real wage and quality of life they could receive in some other city is higher then they will move to it. This will be an equilibrating process, however, with equalisation of the combined real wage and quality of life on the margin. Population growth thus reflects both productivity growth and growth in a city's quality of life.

Between countries, however, there is not free factor mobility and it may be less reasonable to assume a common production technology, so it is more appropriate to adjust for exchange rate and price differences and analyse (rates of growth of) GDP p.c. if the researcher wishes to investigate differences in economic well being or rates of growth thereof. As noted above, on one reasonable measure, rates of net interregional migration in the US are some 15 times greater than those in the EU. It is also possible that linguistic, cultural and institutional difference between European regions mean that they do not fully share a common production technology and that there are differences in regional rates of technical progress (Rodriguez-Pose, 1998). These considerations suggest the model of urban growth processes frequently applied in the US may be inappropriate in a European context and that in Europe the most relevant variable is growth in real GDP p.c. Thus a further point to the present paper is to investigate what variable is most appropriate if one wishes to investigate spatial differences in welfare or welfare change in a European context: is it population growth or the rate of growth of incomes? It is to this we now turn.

5. The results: the basic model

Table 1 shows the results obtained in deriving our base model. The dependent variable here, as elsewhere, is the annualised rate of population growth for 121 major EU FURs over the period 1980 to 2000. All variables are defined in Appendix 1. Agricultural and Industrial Employment ’75 measure the proportion of the labour force in industry and agriculture respectively in the encompassing level 2 region in 1975. The variable to reflect the influence of the coal industry is measured as a dummy to indicate whether the FUR core or hinterland coincided with a physical coal measure. The port size is a measure of the tons of traffic through each port in 1969. Employment even by such broad sectors as agriculture, industry and services is only available for all relevant regions of the EU12 for one year before 1980. The more specific resource based industries – coal mining and port activity – have had negative environmental and local economic effects. As a result they are likely to have had a more influential negative effect on a FURs' growth than the broader sector – industry.

Table 1 : Dependent Variable: FUR Population Growth Rate 1980 to 2000: the Base Model

Model	1	2	3	4	5	6	7 **‘Base’**
R-squared	0.2460	0.3101	0.3830	0.4046	0.4818	0.5014	0.5180
constant	0.0068865	0.0066006	0.0084915	0.0080842	0.0055553	0.0053513	0.005074
std. err.	0.0016594	0.0016423	0.0017794	0.0017393	0.0014765	0.0015266	0.0015308
t	4.15	4.02	4.77	4.65	3.76	3.51	3.31
Agric Emp.’75	0.0003431	0.0002432	*0.0001806*	0.0002023	0.0003818	0.0003966	0.0004102
std. err.	0.0000956	0.0000945	0.0000937	0.0000912	0.0000946	0.0000975	0.0000974
t	3.59	2.57	1.93	2.22	4.04	4.07	4.21
Agric Emp.’75^2	-0.000009	-0.0000065	-0.000005	-0.0000057	-0.0000092	-0.0000092	-0.0000094
std. err.	0.00000261	0.00000262	0.00000263	0.00000259	0.00000255	0.0000026	0.0000026
t	-3.50	-2.47	-2.04	-2.22	-3.62	-3.52	-3.61
Ind. Emp.’75	-0.0001456	-0.0001123	-0.000134	-0.0001318	-0.0001564	-0.0001716	-0.0001693
std. err.	0.000037	0.0000403	0.0000413	0.000041	0.0000411	0.0000417	0.0000416
t	-3.93	-2.78	-3.25	-3.22	-3.81	-4.11	-4.07
Coalfield: core		-0.0026591	-0.0029095	-0.002535	-0.0028371	-0.0024507	-0.0021143
std. err.		0.0009654	0.0008784	0.0008874	0.0008671	0.0008449	0.0008684
t		-2.75	-3.31	-2.86	-3.27	-2.90	-2.43
Coalfield: hint’land		-0.0020922	-0.0023182	*-0.0015429*	-0.0022892	-0.0027245	-0.0020548
std. err.		0.0005813	0.0008054	0.0008996	0.00073	0.0007467	0.0008282
t		-3.60	-2.88	-1.72	-3.14	-3.65	-2.48
Port size ’69			-0.0010267	-0.0009157	-0.0008617	-0.0008216	-0.0007278
std. err.			0.0003332	0.000337	0.0002967	0.0002753	0.0002844
t			-3.08	-2.72	-2.90	-2.98	-2.56
Port size ’69^2			0.0000569	0.0000515	0.0000478	0.0000412	0.0000366
std. err.			0.0000169	0.0000172	0.0000149	0.0000142	0.0000146
t			3.36	3.00	3.21	2.91	2.51
Nat Ex-FUR Pop Grow ’80-’00					0.4731661	0.4559771	0.4417852
std. err.					0.1080538	0.109942	0.1117606
t					4.38	4.15	3.95
Integration Gain^2						0.0011008	0.0011278
std. err.						0.0004778	0.0004542
t						2.30	2.48
Interaction ’79-’91				0.0501691			0.0440806
std. err.				0.0241136			0.0209222
t				2.08			2.11

Parameter estimates shown in *italics* are significant only at 10%: all other parameter estimates are significant at 5% or better

If quality of life differences are a significant influence on the rate of population growth then since both the coal industry and port activity have had negative impacts on the physical environment of cities and their regions - and perhaps also on their social environment - as well as leaving a poor endowment of human capital, we should expect to find lower rates of population growth in FURs in which coal and port activity were concentrated. That is cities concentrated on these activities not only had a relative decline in economic opportunities but also, even allowing for this, a worse quality of life. It is partly because of the environmental effect that it leaves behind that the influence of the coal industry is measured in terms of the physical co-incidence with coal measures of the FUR core city and its hinterland; the influence of a past specialisation in coal mining would endure after the industry itself had disappeared as a source of employment. Even by 1979, a significant number of the traditional mining areas of Europe had nil or negligible employment left in mining. Thus, the coal variable is, and was intended to be, independent of when mining employment declined.

Ports have received little attention in the literature as sources of disadvantage for urban economies. Given their historic importance as locations for processing industries (see, for example, Alonso, 1964), however, and the way in which the technological transformation of port activity over the period from the mid-1960s to the early 1980s ended this role by eliminating their function as transhipment locations, the legacy of problems ports have left their host cities seems likely to be significant. A further aspect of the transformation of port activity is that it has involved a very substantial increase in capital : labour ratios. An industry which was labour intensive has become capital intensive. Therefore, it is reasonable to expect that while the general effect of having specialised in port activity for a city's economy would have been negative over the period of the analysis, some of the very largest ports might have benefited from the concentration of port activity in few locations. As a result, we might expect the functional form relating port size with city growth to be quadratic with the very largest ports having a less negative effect than medium sized ones.

In understanding urban population growth, therefore, it would seem that these more precise measures of industrial structure, which capture not just declining economic opportunity but also aspects of quality of life differences, should provide more explanatory power than a broad measure of specialisation in industry. The results confirm this.

The base model, model 7, reported in the final column of Table 1, contains two additional economic variables related to systematic differences between cities. These are explicitly measures of spatial economic variables. At least since the 1960s there have been arguments that (European) integration would have systematic spatial effects, economically favouring core regions. An early empirical attempt to quantify such effects was embodied in the work of Clark *et al.,* (1969). More recently work by Krugman and Venables has produced formal theoretical models with essentially the same conclusions (see Fujita *et al.,* 1999 for a survey). The Integration Gain variable is calculated directly from the work of Clark *et al.,* (1969) supplemented with the estimates for the regions of Spain and Portugal provided by Keeble *et al.,* (1988) and scaled to Clark *et al.*'s values. Values for Athens, Lisboa, Porto and Saliniki have been interpolated to provide coverage of all the regions of the EU of 12. Since our interest is in growth, we have calculated the *change* in the values of regional 'economic potential'[3] from Clark *et al.*'s estimates of the pre-Treaty of Rome values to those estimated as being associated with an elimination of tariffs, the EU's enlargement of the 1980s and a

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[3] Economic potential is a measure of the accessibility at any location to total GDP allowing for costs of distance including tariffs. For further discussion see Clark *et al.,* 1969

reduction in transport costs following the introduction of roll-on roll-off ferries and containerisation.

As was discussed in Cheshire (1999) the theoretical arguments as to why integration should favour core regions do not imply that the relationship measured for the 1980s or the 1990s should necessarily be linear with respect to the variable used here. Clark's calculations are for different hypothetical states of the world but with regional GDP data estimated for, and fixed at, 1966. Any differential spatial growth induced by integration might have been fastest where economic potential increased most in the initial stages. But such growth would tend to bid up local factor costs and produce additional congestion, other things equal. In turn, if there were a fixed and single integration shock, this would tend to produce deconcentration over time from the core to surrounding regions. Therefore, in the absence of further integration shocks, by the 1980s the relationship between differential urban growth and Clark *et al.*'s (1969) estimates of the change in economic potential might be expected to be quadratic, with the greatest gains no longer in the core regions but in the outer core or near periphery. In the 20 years from 1980, however, there were a series of integration shocks: the enlargement to include Portugal and Spain; the introduction of the Single European Market; further enlargement and then monetary union. Thus, since our population growth rate is the average over 20 years we might expect the best approximation for the relationship between population growth and the influence of our measure of the spatial impact of Integration Gain to be linear, implying that the greatest gains from integration over the period as a whole were in the core regions in which there were the largest expected increases in 'economic potential'. This is the result reported in Model 7 where the variable is significant and the best statistical results are obtained if the square of the gain in economic potential is used as the independent variable[4].

As has already been shown, interregional migration in the EU is very restricted. However there are alternative forms of labour mobility, likely to be particularly important in Europe, because of both the dense nature of urbanisation and the relatively effective transport systems and the long distance commuting these render feasible. In the EU, there are swathes of densely urbanised territory where FURs are not just tightly clustered but their boundaries are contiguous. In such conditions, if the economic attractions of a FUR increase relative to its neighbours it will attract in additional commuters. Since changes in commuting patterns are cheap relative to migration, the major adjustment mechanism would be expected to be changes in the former in response to changes in the spatial distribution of economic opportunities between neighbouring FURs. This assumes that conditions influencing the quality of life are constant over time between neighbouring FURs.

If changes in commuting patterns act in this way as spatial adjustment mechanisms between neighbouring FURs, then we should expect a 'growth shadow effect'. A FUR growing economically faster will initially suck in additional workers from neighbouring FURs. Over time these long distance commuters attracted to work in the faster growing FUR may move residence and become short distance inter-FUR migrants leading to population growth in the subsequent period in the economically more dynamic FUR. Moreover, since long distance commuters (and perhaps those reacting to changes in the pattern of spatial economic opportunities) have higher human capital and perhaps favourable unmeasured productivity characteristics then there would also be a composition effect. The productivity of the labour force of the FUR attracting

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[4] Compared to the set of result reported in Cheshire (1999), relating to various dependent variables and sub periods since 1971 which found that for certain shorter periods the best fit was, as hypothesised, quadratic: consistent with an outward spread of each successive integration shock from the core. A quadratic form was tried in the present data set but the linear form outperformed it.

additional commuters would grow relative to that of its neighbours. Finally, there might also be dynamic agglomeration effects favouring productivity growth in the faster growing FUR.[5]

This is tested by means of the Interaction variable, measured as the sum of the differences in the growth rate of employment in the FUR and in all FURs within 100 minutes travelling time weighted by distance over the period 1979-1991. It thus proxies for net commuters attracted to employment in each FUR over the first half of the period. Differential employment is discounted by distance measured in minutes since the impact of employment growth in a FUR on the attraction of commuters from neighbouring FURs has been shown to be distance sensitive (see Cheshire *et al.,* 2004). The estimated parameter for the variable is significant and positive, supporting the interpretation that commuters attracted in one period reinforce the dynamism of the more successful FUR relative to its neighbours and generate differential population growth in it over the period as a whole.

It would seem obvious that a control should be introduced for background differences in net fertility rates. Two possibilities suggest themselves: country dummies and the rate of natural increase in population in the area of each country outside the area of its major FURs. Because of small numbers of observations in small countries, these would have to be grouped to construct dummies. In addition, by using the measured rate of natural increase of population outside the areas of the major FURs one is not only constructing a continuous variable and minimising potential problems of endogeneity but also, in effect, creating a surrogate for net migration. Since the underlying interest is in the drivers of population change resulting from net migration this is a clear advantage. The variable has the expected sign and is highly significant[6].

Table 2 reports the results of adding to this base model variables to reflect climate differences between FURs. The results in the first three columns show the impact of geographical position: ‘west’ and ‘south’ measure how far west or south the centroid of the FUR is from its national capital and ‘euwest’ and 'eusouth’ measure how far west and south the FUR is relative to Brussels. How far south a FUR is, is related to its climate. This is not so obviously true of how far west a FUR is although in a European context this will usually be related to a milder but damper climate. What we observe is that south within country is highly significant and the coefficient is stable whether west within country is included or not. Westness is not really significant although it has a negative sign suggesting that dampness is less attractive. This is in strong contrast to the position of the FUR relative to the EU as a whole. Both these measures are completely non-significant. Adding just the ‘south within country variable’ to the base model, however, increases the R^2 from 0.518 to 0.60.

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[5] In an ESRC Cities Initiative project, we addressed these issues directly. Changes in commuter flows between a set of 114 EU FURs with cores within 100 minutes travel distance were modelled. It was found that with appropriate lags inward commuting increased as GDP p.c. increased in a FUR, outward commuting increased as unemployment increased in any FUR and the responsiveness of all inter FUR commuting to changes in economic variables declined with time-distance (Cheshire *et al.,* 2004)

[6] There are two further issues of interest: these are the impact of the unemployment rate in the FUR at the start of the period and population density. Including the mean FUR unemployment rate for the period 1977 to 1981 in the base model instead of the measure of concentration on industrial activity in the wider region reduces the R^2 significantly and although the parameter associated with unemployment has the expected sign, it is not significant. Population density might be expected to be relevant since if all other things are constant, higher density should be associated with more congestion and higher costs of land. Including it as an additional variable in the ‘base model’ it has the expected negative sign and increases the R^2 slightly but it is only significant at about the 20 percent level.

Table 2: Dependent Variable: FUR Population Growth Rate 1980 to 2000: the Base Model plus Geographic and Climate Variables

	Base + geographical variables				Base model + climate (linear)					Base model + climate (quadratic)		
	West or South within Country	South within Country	West or South within EU		Cloud cover ratio: country	Minimum temperature ratio: country	Mean temperature ratio: country	Maximum Temperature ratio: country	Wet day frequency ratio: country	Mean temperature ratio: country	Maximum Temperature ratio: country	Wet day frequency ratio: country
Model	8	9	10		11	12	13	14	15	16	17	18
R^2	0.6012	0.5951	0.5258		0.5508	0.5418	0.5547	0.5613	0.5940	0.5863	0.5946	0.6090
west	*-0.000002*			$\hat{\beta}_1 x$	-0.00823	0.003154	0.00666	0.009099	-0.00789	-0.048056	-0.076058	-0.02615
std. err.	*0.000001*			std. err.	0.00251	0.001548	0.00285	0.00355	0.00168	0.02027	0.033282	0.006567
t	*-1.44*			t	-3.28	2.04	2.34	2.56	-4.70	-2.37	-2.29	-3.98
south	0.000005	0.000005		$\hat{\beta}_2 x^2$						0.026076	0.041133	0.009387
std. err.	0.000001	0.000001		std. err.						0.009533	0.015919	0.003228
t	4.02	4.69		t						2.74	2.58	2.91
EUwest			*0.0000008*									
std. err.			*0.0000008*									
t			*0.99*									
EUsouth			*0.0000004*									
std. err.			*0.0000006*									
t			*0.66*									

Parameter estimates shown in *italics* are not significant at 10%

Table 3: Dependent Variable: FUR Population Growth Rate 1980 to 2000: Best Models

Model	**19**	**20**	**21**
R-squared	0.6325	0.6326	0.6405
Constant plus:			
Agric Emp.’75	0.0003127	0.0004266	0.0004079
std. err.	0.0001034	0.0000987	0.0000923
t	3.02	4.32	4.42
Agric Emp.’75^2	-0.00000563	-0.00000826	-0.00000753
std. err.	0.0000027	0.00000249	0.00000246
t	-2.09	-3.31	-3.06
Industrial Emp.’75	-0.0000962	-0.0001457	-0.0001213
std. err.	0.0000377	0.0000393	0.0000341
t	-2.55	-3.71	-3.55
Coalfield: core	-0.0015896	-0.001655	-0.001812
std. err.	0.0007185	0.0007881	0.000748
t	-2.21	-2.10	-2.42
Coalfield: hint’land	-0.0020415	-0.001682	-0.0018028
std. err.	0.000826	0.0007934	0.0007607
t	-2.47	-2.12	-2.37
Port size ’69	-0.0005831	-0.0006274	-0.0006521
std. err.	0.0002533	0.0002422	0.0002469
t	-2.30	-2.59	-2.64
Port size ’69^2	0.0000291	0.0000294	0.0000315
std. err.	0.0000126	0.0000123	0.0000124
t	2.31	2.39	2.55
Nat Ex-FUR Pop Grow ’80-’00	0.3029144	0.5536141	0.4710524
std. err.	0.1255056	0.1127851	0.1075922
t	2.41	4.91	4.38
Integration Gain^2	0.0015988	0.0020954	0.0020679
std. err.	0.0004693	0.0004612	0.0004593
t	3.41	4.54	4.50
Interaction ’79-’91	0.0539774	0.0532723	0.0519908
std. err.	0.0200782	0.0197226	0.0190658
t	2.69	2.70	2.73
South within EU	0.0000032		
std. err.	0.00000114		
t	2.80		
Frost frequency ratio : country		-0.0039281	
std. err.		0.001571	
t		-2.50	
Frost frequency ratio^2 : country		0.0020628	
std. err.		0.0006133	
t		3.36	
Maximum temperature ratio : country			-0.0752656
std. err.			0.0322676
t			-2.33
Maximum temperature ratio^2 : country			0.0379645
std. err.			0.0151008
t			2.51
Wet day frequency ratio : country	-0.0214449	-0.0247	-0.0202854
std. err.	0.0056818	0.0065655	0.0056615
t	-3.77	-3.76	-3.58
Wet day frequency ratio^2 : country	0.0082249	0.008621	0.0069708
std. err.	0.0029544	0.0030658	0.0029409
t	2.78	2.81	2.37

All parameter estimates significant at 5% or better

The next four models in Table 2 include a range of climate variables, each measured relative to the mean value for the country, with a linear specification while the final three models (16 to 18) include climate relative to country variables but use a quadratic functional form. We do not have priors about which specific climate variables should be significant although from US studies we might expect more sunshine and warmer weather to be preferred. Nor can one have priors about the functional form. It would seem most reasonable to expect the relationship (if there is one) to be asymptotic to some upper value of heat, dryness and sunshine. All possible climate variables were tried and we just report some of the more successful here in Table 2. We should emphasise that the climate variables when expressed as a ratio to the value for the EU as a whole were never significant. The highest t value for any such variable was –1.11 for frost frequency relative to the EU mean.

As expected, we find that cloud cover and wet day frequency are associated with slower, and warmth is associated with faster, population growth. Comparing the results for models 13 and 16, 14 and 17 and 15 and 18 suggests that the quadratic functional form performs systematically better and inspection shows that the relationship is effectively asymptotic to an upper value of dryness and heat as anticipated.

Table 3 reports what might be thought of as the best models. In all such models, a quadratic form for the climate variables performs best. The linear estimates for each independent climate variable reported in Table 2 provide a simple guide to the overall impact of the climate variable on population growth: thus more cloud cover and wetness have a negative impact on growth and the variables reflecting a warmer climate have a positive impact. Model 19 includes a direct measure of wetness and the 'south within country' variable. The R^2 increases relative to the comparable models: 8 (which includes the south and west variable but not wetness) and 18 (which includes the ratio of wet days to the country mean but not the south variable). Models 20 and 21 include combinations of climate variables: frost frequency, maximum temperature and wet day frequency all calculated as ratios of the county values. It will be seen that these models appear to perform well and provide striking evidence that climatic differences are strongly and significantly associated with differential rates of urban population growth but only when measured as differences within countries. There is no evidence to suggest that differences in climate across the EU as a whole were relevant although, of course, this is not inconsistent with a degree of international population mobility associated with climatic differences. It suggests rather that in so far as people do make such moves, they select the country first and then, in choosing locations within countries, choose cities with better weather.

6. Spatial dependence

Table 4 reports the critical results of a series of diagnostics tests for specification and spatial dependence. For illustrative purposes, the results are shown for the so-called base model and for two of the best models, Models 20 and 21. Full results are available from the authors but these show the significant results. As is well known the major problem in testing for problems of spatial dependence is the choice of measures of 'distance'. Past experience (see, for example, Cheshire and Magrini, 2000) has shown that the most sensitive measure of distance when analysing growth differences between European FURs is the inverse of time distance between pairs of FURs (measured as transit time by road including any ferry crossings and using the standard commercial software for road freight). In the present case, we tested for both the inverse of time distance and the inverse of time distance squared and, in addition, experimented with an added time distance for all FURs separated by a national border. 'Time' effects tested for national borders varied from zero to 120 minutes. We found that the greatest sensitivity in the tests for spatial dependence was achieved if the time cost of a national border was set at 120 minutes. In addition, the most sensitive measure of total distance was if the distance between each pair of FURs was represented as the inverse of time distance (including the 120 minutes for a national border) squared. The loglikelihood and information criterion values are included so that the fit of these models can be directly compared with the spatial lagged models reported in Table 5.

The diagnostic tests suggest that there are no problems of either heteroskedasticity or non-normality of errors. The value of the multicollinearity condition number is relatively high in most of the models in which climate variables are included in quadratic form but since the parameter estimates are stable and the functional form (effectively suggesting that it is asymptotic to an upper value) seems sensible, we are not concerned with this. The highest value for the multicollinearity condition was found for Model 21 but as can be seen from the results of the equivalent model with a spatial lag (see Table 5) this may be because the functional form is very close to linear. Of more concern are the results for the tests for spatial dependence. In the models in which 'south within country' or climate variables were included the LM error test – the most reliable and appropriate – suggests no problems of autocorrelation in errors but the results of the LM lag tests (again the most appropriate and reliable) suggest there could be estimation bias because of the omission of a spatial lag variable. This seems likely to be a minor problem, however, only showing up as significant at all when distance is represented in the most sensitive form as the inverse of time distance squared including the 120 minute national border effect: and even then, in Model 21, it is on the margins of significance at 10%. Table 5 reports the results of fitting a spatial lag model using maximum likelihood estimation. The results are shown for the base model and three other good models including Models 20 and 21.

As suggested by the tests for spatial dependence, the spatially lagged value of population growth is significant. However all signs remain appropriate and – except for the spatial effects of EU integration in the 'base' model - all variables are significant at at least 10%. A few variables however, cease to significant at 5%. All other variables are significant at 5% or better, however, and the diagnostics remain reassuring. Perhaps most reassuring of all, and again consistent with the conclusion that problems of spatial dependence are for practical purposes very minor, the coefficient estimates for equivalent models hardly change numerically in the spatially lagged estimates (Table 5) compared to the robust standard errors, OLS estimates reported in Table 3.

7. Conclusions

The results reported in this paper provide strong evidence that there are some systematic EU-wide spatial adjustment effects influencing the rate of growth of city populations. These EU-wide effects, however, are only related to economic conditions. Using the predicted value of the change in economic potential associated with EU integration (as reported in Clark *et al.*, 1969) as our measure of the spatial impact of integration, we find a significant positive effect on a FUR's rate of population growth over the whole period 1980 to 2000. We cannot test a full compensating differentials model of population movement but the results strongly support the conclusion that population movement does respond to climatic differences but only within countries. When climatic variables are included relative to EU values, the results are totally non-significant. When they are expressed relative to national mean values, however, they are highly significant and the results appear stable and robust. Not only that but including climatic variables directly rather than the proxy of 'south within country' produces rather better result. This is further evidence that climatic differences themselves influence patterns of population mobility (remembering that since the rate of natural growth of population in the area of each country outside its major cities, represented by FURs, is included, we have a surrogate model for population movement not just population growth).

Table 4 Diagnostics for the 'Base' Model, Models 7, 20 and 21

	Model 7 Base			Model 20			Model 21		
R^2-adj		0.4741			0.5841			0.5930	
LogLikelihood		550.3160			566.7440			568.063	
F-test		11.8200			13.0361			13.4905	
F-test (prob)		0.0000			0.0000			0.0000	
Regression Diagnostics									
Multicollinearity Condition Number	19.7911			143.0190			487.77		
Test On Normality Of Errors									
Test	DF	Value	Prob	DF	Value	Prob			
Jarque-Bera	2	4.4466	0.1083	2	2.4107	0.2996	2	1.3645	0.5055
Diagnostics For Heteroskedasticity									
Random Coefficients									
Test	DF	Value	Prob	DF	Value	Prob	DF	Value	Prob
Breusch-Pagan Test	10	9.4059	0.4941	14	15.3892	0.3521	14	15.7706	0.3276
Diagnostics For Spatial Dependence									
For Weight Matrix 120 mins borders +Inverse time distance									
Test	MI/DF	Value	Prob	MI/DF	Value	Prob	MI/DF	Value	
Moran's I (Error)	0.0245	3.1722	0.0015**	0.0175	2.9603	0.0031**	0.0124	2.5297	0.0114**
Lagrange Multiplier (Error)	1	1.4695	0.2254	1	0.7497	0.3866	1	0.3764	0.5395
Robust LM (Error)	1	0.0250	0.8745	1	0.1820	0.6697	1	0.1768	0.6741
Kelejian-Robinson (Error)	11	2.8226	0.9929	15	4.0319	0.9976	15	4.1273	0.9973
Lagrange Multiplier (Lag)	1	3.1892	0.0741*	1	2.6616	0.1028	1	1.6872	0.1940
Robust LM (Lag)	1	1.7447	0.1865	1	2.0939	0.1479	1	1.4875	0.2226
Lagrange Multiplier (Sarma)	2	3.2142	0.2005	2	2.8436	0.2413	2	1.8640	0.3938
For Weight Matrix 120 mins borders +Inverse time distance^2									
Moran's I (Error)	0.1248	3.2825	0.0010**	0.0797	2.5592	0.0105**	0.0726	2.3999	
Lagrange Multiplier (Error)	1	5.7734	0.0163**	1	2.3529	0.1250	1	1.9511	0.0164**
Robust LM (Error)	1	0.0022	0.9624	1	0.0004	0.9840	1	0.0421	0.1625
Kelejian-Robinson (Error)	11	2.8226	0.9929	15	4.0319	0.9976	15	4.1273	0.8373
Lagrange Multiplier (Lag)	1	8.8033	0.0030**	1	4.1270	0.0422**	1	2.8366	0.9973
Robust LM (Lag)	1	3.0321	0.0816*	1	1.7744	0.1828	1	0.9277	0.0921*
Lagrange Multiplier (Sarma)	2	8.8055	0.0122**	2	4.1274	0.1270	2	2.8788	0.3355

* Significant at 10% **Significant at 5%

Table 5: Inclusion of Spatially Lagged Population Growth 1980 to 2000

	Model 7 Base	**Model 20**		**Model 21**	**Model 22**	**Model 23**
R-squared	0.5416	0.6418		0.6468	0.6079	0.6192
Loglikelihood	554.986	568.97		569.604	563.785	565.306
Spatially lagged pop growth 1980-‘00	0.37939	0.25415		0.21369	0.299399	0.26290
z-value	3.5567	2.3337		1.9270	2.7417	2.3990
prob	0.0004	0.0196		0.0540	0.0061	0.0164
Agric Emp.’75	0.00033	0.00037		0.00036	0.000321	0.00036
z-value	3.5452	4.2355		4.1561	3.6445	4.0421
prob	0.0003	0.0000		0.0000	0.0003	0.0001
Agric Emp.’75^2	-0.00001	-0.00001		-6.6E-06	-0.00001	-0.00001
z-value	-3.1172	-2.9951		-2.7727	-2.2868	-2.7301
prob	0.0018	0.0027		0.0056	0.0222	0.0063
Industrial Emp.’75	-0.00013	-0.00013		-0.00011	-0.000091	-0.00010
z-value	-3.9706	-3.6612		-3.2185	-2.7249	-2.9060
prob	0.0001	0.0003		0.0013	0.0064	0.0037
Coalfield: core	-0.00169	-0.00141		-0.0016	-0.001845	-0.00174
z-value	-2.3008	-2.1002		-2.4219	-2.7027	-2.5603
prob	0.0214	0.0357		0.0154	0.0069	0.0105
Coalfield: hint’land	-0.00177*	-0.00150*		-0.00165*	-0.001864	-0.00181
z-value	-1.7657*	-1.6525*		-1.8329*	-1.9942	-1.9602
prob	0.0774*	0.0984*		0.0668*	0.0461	0.0450
Port size ’69	-0.00069	-0.00061		-0.00064	-0.000679	-0.00065
z-value	-2.9492	-2.8072		-3.0374	-3.0887	-2.9775
prob	0.0032	0.0050		0.0024	0.0020	0.0029
Port size ’69^2	0.00003	0.00003		3.04E-05	0.000032	0.00003
z-value	2.2643	2.0266		2.2679	2.2962	2.1991
prob	0.0236	0.0427		0.0233	0.0217	0.0279
Integration Gain^2	*0.00077*	0.00175		0.00178	0.001475	0.00165
z-value	*1.5776*	3.6897		3.7686	3.0612	3.3943
prob	*0.1146*	0.0002		0.0002	0.0022	0.0007
Interaction ’79-’91	0.04829	0.05532		0.05378	0.050558	0.05238
z-value	2.3383	2.9730		2.8986	2.6177	2.7378
prob	0.0194	0.0029		0.0037	0.0089	0.0062
Nat Ex-FUR Pop Grow ’80-’00	0.37956	0.50526		0.43847	0.376769	0.41429
z-value	4.0927	5.5174		4.8258	4.3636	4.7167
prob	0.0000	0.0000		0.0000	0.0000	0.0000
Wet day frequency ratio : country		-0.02122		-0.01743	-0.007074	-0.02194
z-value		-2.4836		-2.0635	-4.3253	-2.5547
prob		0.0130		0.0391	0.0000	0.0106
Wet day frequency ratio^2 : country		0.00715*		*0.00563*		0.00759*
z-value		1.6761*		*1.3245*		1.7609*
prob		0.0937*		*0.1853*		0.0783*
Frost frequency ratio : country		-0.00350	Max. Temp	-0.07122		
z-value		-2.0524	z-value	-2.7491		
prob		0.0401	prob	0.0060		
Frost frequency ratio^2 : country		0.00193	Max.Temp^2	0.03555		
z-value		2.5848	z-value	2.8591		
prob		0.0097	prob	0.0042		

* Estimated parameters significant at 10%. All other estimates significant at 5% or better except those in italics which are not significant at 10%.

These results have significant implications because they suggest that even with the geographically comparatively sticky population observed in Europe, where interregional net migration flows are several orders of magnitude lower than in the USA, still the idea that people vote with their feet and to some extent trade-off quality of life for income is valid. This is consistent with the single country results recently reported for Germany (Rehdanz and Maddison, 2004) All other things equal we should expect that unemployment rates would be somewhat higher and incomes and income growth somewhat lower where the climate is drier, sunnier and warmer. That we only find climatic differences are significant within countries, not over the EU as a whole, in models of population growth does not imply there is no quality of life driven migration in Europe. Rather it would seem to imply that people when they move chose their country first but, having chosen their country, are then influenced by better weather. This has considerable significance for the interpretation of the welfare implications of measured differences in income or unemployment between cities or regions. A further point of interest is the finding that measures of the spatial lags between cities in their rates of growth of population are most sensitive if national borders are represented as equivalent to a two hour increase in time distance. It may be forcing the results somewhat but it is perhaps suggestive of the continuing impact of national borders on population mobility in Europe.

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Appendix 1: Variable Definitions and data

Table A1: The dependent variable was in all cases the annualised rate of FUR population growth between 1980 and 2000.

Industrial Emp.'75	Percentage of labour force in industry in surrounding level 2 region in 1975: source Eurostat
Coalfield: core	A dummy=1 if the core of the FUR is located within a coalfield
Coalfield: hinterland	A dummy=1 if the hinterland of the FUR is located within a coalfield
Port size '69	Volume of port trade in 1969 in tons
Agric Emp.'75	Percentage of labour force in agriculture in surrounding Level 2 region in 1975
Integration Gain	Change in economic potential for FUR resulting from movement from individual nation-states to post enlargement EU with reduced transport costs (estimated from Clark *et al* 1969 and Keeble *et al* 1988)
West	Distance west of centre of FUR from national capital city (Amsterdam taken as capital of Netherlands; Bonn of Germany)
South	Distance south of centre of FUR from national capital city (Amsterdam taken as capital of Netherlands; Bonn of Germany)
EUwest	Distance west of centre of FUR from Bruxelles/Brussel
EUsouth	Distance south of centre of FUR from Bruxelles/Brussel
Nat Ex-FUR Pop Grow '80-'00	Annualised rate of growth of population in territory of country outside major FURs between 1980 and 2000
Wet day frequency ratio : country	Ratio of wet day frequency between FUR and national average (1970s and 1980s)
Frost frequency ratio : country	Ratio of ground frost frequency between FUR and national average (1970s and 1980s)
Maximum temperature ratio : country	maximum temperature percentage difference between FUR and national average (1970s and 1980s)
Cloud cover ratio: country	Ratio of cloud cover days between FUR and national averages (1970s and 1980s)
Minimum temperature ratio: country	Ratio of minimum temperatures between FUR and national average (1970s and 1980s)
Mean temperature ratio: country	Ratio of mean temperature between FUR and national average (1970s and 1980s)
Max temperature ratio: country	Ratio of maximum temperature between FUR and national average (1970s and 1980s)

All climate variables were also expressed as the ratio of the FUR value to the EU mean.