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East-West Integration and the Economic Geography of Europe

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Contents

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- *Entry barriers and sunk costs in foreign trade, e.g. in the IT sector.*
- *International income distribution and inequality.*

In most fields, theoretical as well as empirical work has been undertaken. Melchior has experience as an advisor domestically and for international institutions, and from teaching at various universities. For selected publications, see http://www.nupi.no/IPS/?module=Articles;action=Article.publicShow;ID=259.

Abstract

Implementation of the European internal market and East-West integration has been accompanied by a dramatic change in the spatial distribution of economic activity, with higher growth west and east of a longitude degree through Germany and Italy. In the east, income growth has been accompanied by increasing regional disparities within countries. We examine theoretically and empirically whether European integration as such can explain these developments. Using a numerical simulation model with 9 countries and 90 regions, theoretical predictions are derived about how various patterns of integration may affect the income distribution. Comparing with reality, we find that a reduction in distance-related trade costs combined with east-west integration is best able to explain the actual changes in Europe's economic geography. This suggests that the implementation of the European internal market or the Euro has "made Europe smaller". In Central Europe, capital regions grow faster and there are few east-west growth differences inside countries. There is no convincing support for the hypothesis that European integration had adverse effects on non-members.

1. Introduction*

Since the fall of the iron curtain, Europe has been subject to a number of profound reforms and changes. During the early 1990s, the European internal market was established, and the process of East-West European integration started – eventually leading up to the recent enlargement of the EU in 2004 and 2007. From integration within a club of rich countries in Western Europe during the 1960's and 1970's, integration has expanded to the south and east. The implementation of reforms takes time and Europe is still in a period of change. Nevertheless, almost two decades have passed since the process started and we now have data to examine whether the reforms have caused dramatic changes in the economic landscape of Europe.

In the former "rich man's club", there was a belt of agglomeration, popularised in the concept of the so-called "blue banana" stretching from London to Milano (Brunet 2002). This pattern of agglomeration mainly survived the enlargement of the EEC from 6 to 15 members. During the period before 1990, enlargement to the south contributed to economic convergence across countries, and little change – or modest increase – in regional disparities within countries (see e.g. Combes and Overman 2005, Cappelen et al. 1999, and also Ben David 1996). For the post-1990 period, recent evidence similarly suggests that there has been convergence across countries in the wider Europe, but regional inequality has increased considerably in new member states (see e.g. World Bank 2000, Römisch 2003, Landesmann and Römisch 2006, Melchior 2008a).

A better understanding of regional dynamics is urgent not only for those affected but also for policy: regional support constitutes a main component of the common policies of the European Union. Some research suggests that EU regional policies are effective in some cases but not always (see e.g. Ederveen et al. 2006). According to Baldrin and Canova (2001), these policies mainly have a redistributive role with little impact on growth. For understanding when such policies are effective and when they are not, it is crucial to understand the dynamics of regional change as well as the impact of other policies. In particular, we should understand the impact of integration itself: Does European integration as such contribute to regional convergence or more disparities? In the light of growing

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regional disparities in Central and Eastern Europe, the issue is even more "burning". In the context of the EU Neighbourhood Policy (see e.g. Dodini and Fantini 2006), an urgent issue is whether there is an "agglomeration shadow" whereby regions outside the enlarged EU are worse off.

As argued by Puga (1999, 2002), new theories of industrial location may add to this understanding, and this paper represents an effort to add to our knowledge about integration and the economic geography of Europe. The purpose of this paper is to examine how European integration has affected the income distribution across countries and regions. We start by showing that there has recently been a sharp change along Europe's East-West axis; with higher growth to the east and west of a longitude degree passing through Italy and Germany. The further away from this longitude, the higher is regional growth. During the period covered, there is a gradual switch from western growth (Ireland, Portugal, Spain) to eastern growth (in the new EU member states). As an attempt to understand this development, we use a large-scale numerical simulation model as a basis for econometric analysis. We show that in Western-Europe, the east-west gradient of growth differences applies within countries as well as between them. In Central Europe, however, capital regions dominate and wipe out the east-west growth differences within countries, so here the east-west growth pattern (with higher growth in the east) is driven by differences across countries. Comparing to results from the simulation model, we tentatively conclude that in Western Europe, this development is driven by reductions in the "cost of distance" due to the EU internal market. In Central Europe, the impact of wider European integration dominates; jointly with transition that may explain the dominating role of capital regions. For Eastern Europe, we do not find evidence confirming the presence of an "agglomeration shadow".

In the new economic geography literature, numerical simulation models with many regions have been used for theoretical purposes. Fujita et al. (1999, Chapter 18) analyse patterns of agglomeration across regions spread out along the circumference of a circle and show that lower trade costs can lead to fewer and larger agglomerations. Venables (1999) examine the location of different industries in a setting with many regions on a circular plain. Approaching the real-world economic geography in Europe, Stelder (2005) uses a large-scale simulation model in order to study the location of cities in Europe. In the current paper, we use a stylised model with a two-dimensional space (a rectangular plain) in the theoretical part in order to capture some features of the European landscape. Based on this we derive predictions and hypotheses for empirical analysis, and then revert to the model in the light of the empirical findings. However we do not attempt to construct a numerically realistic or calibrated model fitted to actual data. Hence the simulation model is used for theoretical purposes and not a computable equilibrium (CGE) approach, as in e.g. Bröcker and Schneider (2002). In the paper, we attempt to develop "geographical economics", by using quasi-realistic numerical modelling in order to understand true spatial effects. The purpose of the theory is not to derive universal predictions, e.g. that "globalisation promotes regional inequality" or the like. We maintain that such universal predictions do not exist; the effects depend on the specific reforms undertaken as well as the initial income distribution.

The paper proceeds as follows: In section 2, a descriptive account of economic growth patterns in Europe is presented, using data at the regional level for 1995-2005 covering 29 countries and 1410 regions. In Section 3, we explain the numerical simulation model with nine countries and 90 regions that is used to derive predictions about spatial change. We then compare different scenarios with actual empirical trends and draw tentative conclusions about the forces driving the substantial changes in Europe's economic geography. In section 4, we analyse empirically whether the observed east-west pattern of growth differentials is driven mainly by differences across countries, or whether it is also reflected across regions within countries (as suggested by the numerical simulation model). In this way, we arrive at tentative but nevertheless relatively clear conclusions about the driving forces behind the changes in Europe's economic geography. In section 5, we revert to the theoretical model and show a revised scenario which is close to the observed pattern. In section 6, we sum up some of the results and present some concluding comments as well as ideas for future research.

2. The economic geography of Europe: Major changes 1995-2005

In Melchior (2008a), trends in within-country regional inequality are analysed using a similar but extended data set. Based on this study, Figure 1 summarises some results for the EU-27 plus Croatia, Norway and Ukraine.[1] Darker colour indicates a higher increase in domestic regional inequality. For the brightest areas (except white=missing), there was little change or even some reduction in domestic regional inequality. The diagram is based on population-weighted Gini coefficients for domestic regional inequality during 1995-2005. Using annual estimates for the Ginis, a predicted trend over time has been derived for each country by means of regression analysis.[2] The results from this are shown in the diagram.

[1] Denmark and Switzerland are missing and therefore white areas.

[2] By using this method, we also correct for variations in the number of years covered for each country, cf. Appendix Table A1. In Figure 1, Russia is not included due to limitations in the map data available (using the SAS system version 9.1.3).

Figure 1: Changes in domestic regional inequality in Europe, 1995-2005.

In the whole eastern part and with no exceptions among the countries covered, there was a substantial increase in regional disparities. In the central areas from Italy to Norway, there was little change or even some reduction in regional inequality. Moving westward, we find modest changes but some increase in e.g. the UK and Ireland. These changes in regional inequality are correlated with income levels as well as growth: Relatively poor countries had faster growth but also increasing regional inequality. At the European level, income convergence across countries is quantitatively more important than income divergence within some countries. On the whole, therefore, there was income convergence in Europe (ibid.).

This is the point of departure for the analysis to be undertaken here. Given our interest in the impact of east-west integration, we are particularly interested in the spatial east-west dimension of European economic development. In addition, we focus on the interaction between international changes (between countries) and regional changes within countries: How does international integration affect domestic regions?

In the economic growth literature, the North-South dimension has sometimes been explored, e.g. with the underlying motivation that climatic differences may affect growth. On such grounds, latitudes have been used as explanatory variables in the analysis (see e.g. Rodrigues-Pose and Telios 2008 for a recent contribution using latitudes, focusing on Western European regions). In our analysis, we will also include latitudes, since we are interested in tracing spatial patterns of change generally. However our core focus will be on the east-west aspect and therefore *longitudes*.

In the empirical analysis, we use regional data on real GDP and population for 28 countries: 23 countries among EU-27 (Denmark, Cyprus, Luxembourg and Malta are dropped due to missing data or limited regional subdivisions), plus Norway, Croatia, Russia, Turkey and Ukraine. Information about data and sources is provided in Appendix A. In parts of the analysis, we also report results where Germany is split into East and West. In order to obtain a more detailed spatial subdivision, and in order to have a sufficiently large number of regions in the smaller countries, we mostly use regional data at the more detailed NUTS 3 classification level. The data set therefore contains 1410 regions.

For all countries except Russia and Ukraine, we use income data in purchasing power parities (PPPs) and constant prices, so figures are comparable across countries and over time. Observe, however, that PPPs are national and not regional, so income comparisons across regions within a country may be biased to the extent that price levels or inflation rates differ across regions within this country. This also applies to the non-PPP countries Russia and Ukraine. For Russia, inflation rates may differ substantially across regions and the lack of satisfactory regional price data is a limitation (Gluschenko 2006, see also Melchior 2008a). Given the large number of countries covered by the analysis here we do not attempt to correct for within-country differences in price levels or inflation rates, but leave this as a task for future research.

Data on income and population are supplemented with data on latitude and longitude for each region. For NUTS 3 regions, we use coordinates for centre points used by Eurostat for labelling maps.[3] For Poland, Russia and Ukraine we use coordinates for regional administrative centres from the Geocities database.

Figure 2 shows income averages in 1995 and 2005 for all regions at each longitude degree, for 1204 regions in our sample (excluding Croatia, Russia, Turkey and Ukraine due to limited time series or lack of comparable income data).[4]

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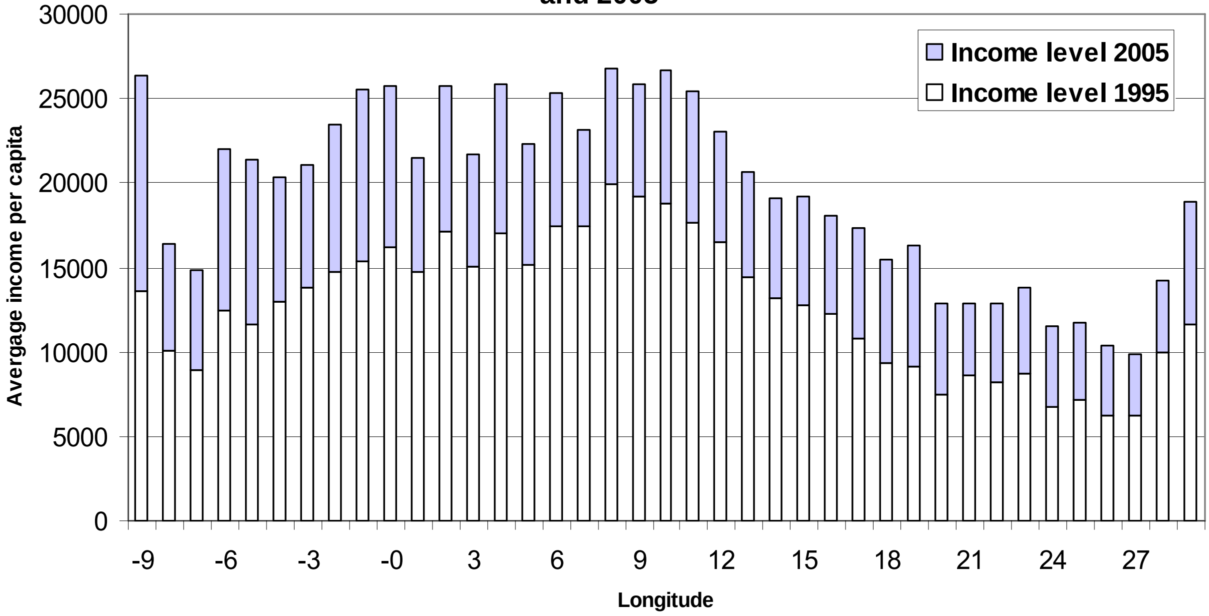
[3] For explanation of the NUTS classification of regions, see Eurostat (2007).
[4] For some countries with a shorter time span covered (Bulgaria, Latvia, Estonia, Romania) the first year covered differs from 1995.

Figure 2: Average income levels in EU-27/EEA regions by longitude, 1995 and 2005

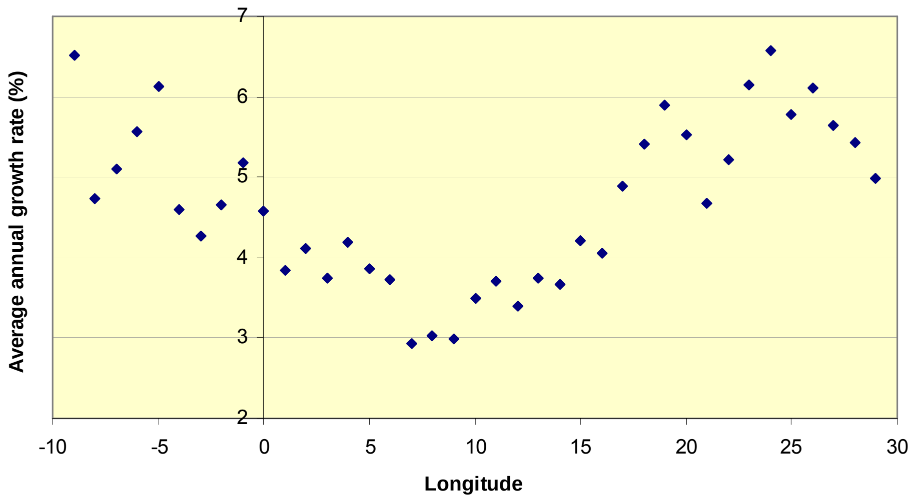


In order to facilitate the interpretation of the graph, Figure A1 in the Appendix shows the range of longitudes spanned by the regions of each country in the graph.[5] To the far west we find Portugal, Ireland, Spain and then the UK. At the centre we find e.g. Western Germany (longitude range 9.4-13.5), Italy (12.2-18.1) and others. Estonia, Finland, Bulgaria and Romania are located furthest east.

In both periods, there is a distinct W-shaped distribution, with peak income levels in the central areas with longitudes around 8-10. Comparing levels in the two periods, we observe that absolute increases are slightly larger in the western half of the diagram. The *relative* increase is however larger towards the east. In order to see this more clearly, Figure 3 shows average annual growth rates by longitude, using the same data set.

[5] We use centre point for regions so regional border areas are not covered.

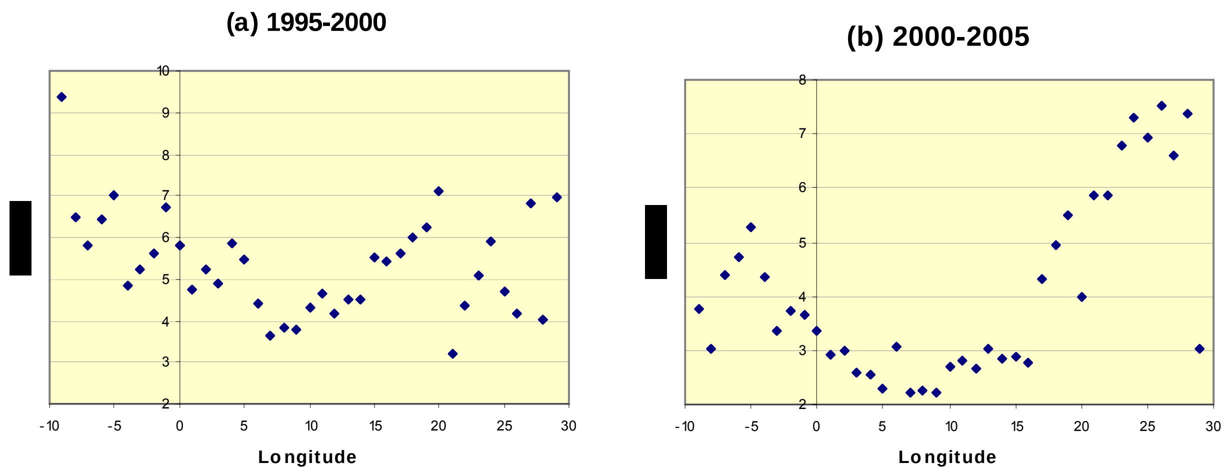
Figure 3: Per capita income growth rate averages



Now the W is inverted, approaching an M. The pattern of growth differentials is quite characteristic, especially in the mid-range where a sharp V is present. Hence the pattern of growth differences across European regions has an easily discernible and distinct spatial dimension during the period. Observe that this applies to the east-west dimension – a similar pattern is not present in the North-South direction.

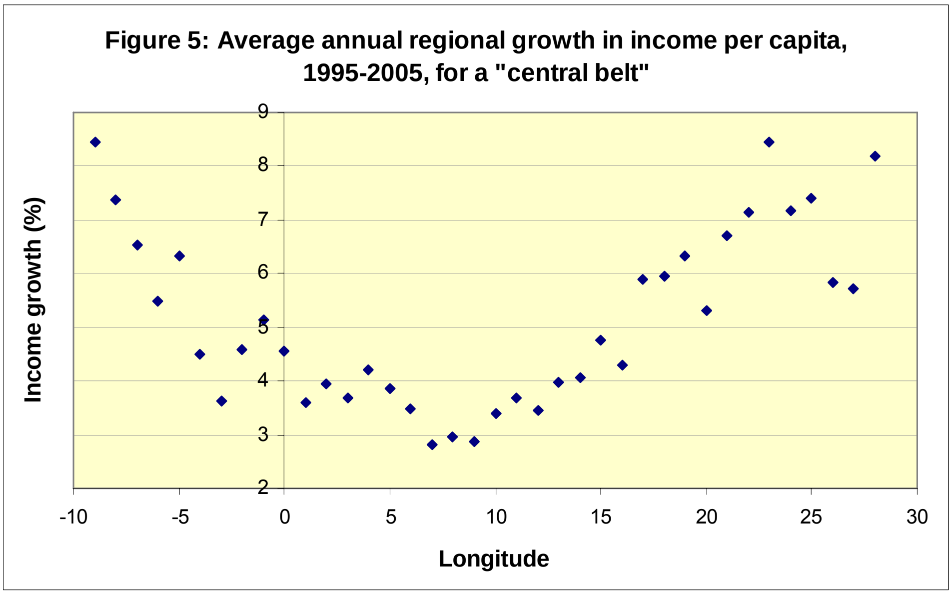
Comparing Figures 2 and 3, it is evident that there is an inverse relationship between initial income and growth. Melchior (2008a, Appendix E) presents simple growth regressions that confirm the trend towards convergence. The analysis also shows that growth in eastern EU-27 countries was higher and European convergence more pronounced after 2000. In order to check how this affects the pattern above, we split the period into two halves; shown in Figures 4a (1995-2000) and 4b (2000-2005).

Figure 4: East-West patterns of growth, by time period



In the most recent period, growth in Western Europe was slower and growth in Central/Eastern Europe higher. For 2000-2005, the pattern approaches a U-shape with higher growth in the east. Figure 3 represents an average of the two periods; but its shape is considerably influenced by period two since growth differences were greater then.

Figures 3 and 4 include countries with widely varying latitudes, from the Mediterranean to the Nordics. Hence there is a risk that the patterns not only represent east-west dimensions, but also north-south patterns of development. For example, Finland and Greece are included in the group of countries to the far east and these are also extremes along the north-south scale in Europe. In the west, Spain and Portugal are mixed with the UK and Ireland, and in the middle, Mezzogiorno in Italy and the regions of Norway or Sweden all contribute to the average. As an attempt to "purify" the central east-west dimension, we drop regions with a latitude below 45 or above 55 degrees. In the south; we drop Portugal, Spain, Greece, Bulgaria and parts of Italy and Romania. In the north, we drop the Nordic and partly the Baltic area, and a small part of the UK. In this way, we make the east poorer and the west richer than in the former sample. The cut-off points are evidently arbitrary but the exercise serves to illustrate that the east-west gradient is even clearer in this "central belt". In Figures 5, we replicate Figure 3, showing growth rates by longitude for this more restricted sample over the whole period.



Within this central belt from west to east in Europe, the W-shape observed in Figure 3 disappears and we approach a clean V or U or W pattern, with a minimum at a longitude of 7-9. In our sample, this is mainly an average for the regions in Western Germany and Italy. This visualisation of European growth demonstrates that it has a clear spatial dimension.

One possible continuation of the story would be to undertake growth regression analysis; analysing whether growth depends on initial income. With our focus on spatial effects, this is however a secondary issue. We will also see later that when we control for spatial effects, initial income actually plays a limited role.

In order to illustrate some methodological issues for the statistical analysis, we regress growth rates on longitudes with a dummy that allows for a break point at some intermediate longitude: i.e. an equation of the form

$$g_i = \alpha + \alpha_{east} * D_{east} + \beta * LON_i + \beta_{east} * D_{east\text{-}i} * LON_i + \varepsilon_i \qquad (1)$$

where g is the growth rate, D_{east} is a dummy for observations with longitudes above some critical value, LON is the longitude, ε is the residual, and i refers to an individual observation (region). Hence we allow the constant term as well as the slope to be different for higher longitudes, as measured by the “deviation parameters” α_{east} (for the intercept) and β_{east} (for the slope). We experiment with different break points and chose LON=8 which gives the highest adjusted R^2. This gives the following results:

Table 1: East-west gradients of regional growth in Europe

Sample	Period	α	α_{east}	β	β_{east}	Adj. R^2	N
Regions in 23 EU countries plus Norway	1995-2005	4.37	-2.87	-0.13	0.30	0.27	1204
	1995-2000	5.49	-2.07	-0.15	0.22	0.09	1162
	2000-2005	3.28	-3.84	-0.11	0.40	0.36	1204
"Central belt"	1995-2005	4.47	-3.82	-0.18	0.43	0.40	846
	1995-2000	5.78	-4.25	-0.23	0.46	0.22	817
	2000-2005	3.20	-4.58	-0.12	0.50	0.46	846

Note: Results from OLS regressions. P values were below 0.0001 in all cases.

The results confirm the patterns shown above: Growth is significantly related to longitude. The fit is better for the second period compared to the first, and for the central belt compared to the whole sample. For the central belt, adjusted R^2 in the second half of the period was 0.46. All parameter estimates are highly significant, with P values below 0.0001.

These estimates could however suffer from an omitted variable bias as well as other aspects that may render the assumption of normally and independently distributed residuals invalid. In particular, the regressions neglect any country-specific spatial effects. There could be a distinct core-periphery pattern inside countries, or there could be east-west gradients at the country level that differ from those that apply to Europe as a whole. If such features are present, the residuals could be spatially correlated at the country level. We will revert to such issues in Section 4, after discussing potential explanations of the V-shaped growth pattern observed in the analysis above.

3. U-shapes revisited: A numerical simulation analysis

In the new economic geography literature, the "U-curve" has become a standard term (see e.g. Forslid et al. 2002). Demonstrated in NEG models such as Krugman (1991), a common theme is that agglomeration is stronger at intermediate levels of trade costs. The presence of trade costs creates a disadvantage for the peripheral regions, but with very high trade costs trade is limited so the better located regions may not exploit their locational advantage. With intermediate barriers this becomes possible. But when barriers become low enough, the disadvantage of the periphery disappears and a more dispersed pattern of production, with less inequality, is again possible. Hence when trade costs are gradually lowered from initially high levels, it is expected that agglomeration first increase and thereafter decrease when trade costs become low enough.

While this theoretical result is plausible, it is formulated in models with few regions and limited spatial structure. In the European context, it dos not tell us much about where the core actually is located geographically, or how this might change. Will the so-called "blue banana" from London to Milan (Brunet 2002) remain the core of the European economy, or will it be weakened and replaced by something else? Europe is affected by a number of different processes that affect trade costs: Initial EU integration, wider European integration, EU enlargement, a number of free trade agreements, multilateral liberalisation through the WTO (the World Trade Organization), and reduction in transport costs and other trade costs. It would be implausible to assume that all these have a similar impact. For assessing the spatial impact of such changes, we therefore need a model with sufficient dimensionality and an explicit modelling of spatial characteristics. In their survey of the NEG, Fujita and Mori (2005) consider the development of higher-dimensional spatial models as one of the top priorities for future research in the field. In order to examine what may explain the U-patterns observed in Figures 2-5, we therefore develop a numerical simulation model. Another contribution in this direction is Stelder (2005), who study the location of European cities using a NEG model with labour migration. Various computable general equilibrium (CGE) models (see e.g. Forslid et al. 2002) may also be relevant, although they do not explicitly focus on the spatial dimension that is the focus here.

In standard NEG models as well as new trade theory models in the footsteps of Krugman (1980), results often depend on strong inter-sectoral specialisation or trade effects: Large countries or core regions become exporters of scale-based goods, as illustrated by the so-called home market effect. In their survey of agglomeration and trade, Head and Mayer (2004, p. 2663) however conclude that in empirical work, the relationship between agglomeration and income levels is more strongly supported than the relationship between agglomeration and trade specialisation. For Europe, one finds a variety of patterns at the industry level (see e.g. Forslid et al. 2002, and the survey in Combes and Overman 2004). Comparing Western Europe and the USA, one finds less industrial concentration in Europe, and one might therefore expect a more even income distribution across regions. The opposite is however the case (Puga 2002, Melchior 2008a), and this casts some doubt about the predictions of NEG models with strong net trade effects.[6]

This evidence is one reason why in this paper, we try another approach to agglomeration and income differences. Krugman (1980) showed that differences in market access may show up in two ways; either as inter-sectoral net trade effects or, alternatively, as wage effects. As an alternative to the models with net trade effects, we therefore try out a

[6] The net trade effects normally also depend on strong asymmetries across sectors; for example that there are trade costs for one sector and not the other, and when these asymmetries are dropped, the net trade effects may disappear (see Davis 1998).

model where the whole economy is collapsed into a single sector, producing differentiated goods with economies of scale. While the volume of trade varies across scenarios, there are no net trade effects, and differences in market access show up only in differences in nominal and real wages. We will therefore call it *the wage gap model*. In the following, we explain the structure of the model.

3.1. The wage gap model

There are N regions. Each region, indexed *i* or *j*, has a single factor of production; labour, with endowment L_i and wage w_i. The total income of the economy is therefore $Y_i=w_iL_i$. Following a standard Dixit-Stiglitz approach, labour can be used in the production of individual varieties of manufactured goods under increasing returns to scale. For an individual variety x_i produced in region *i*, there is, measured in labour units, a fixed production cost *f*, constant marginal costs *c* and trade costs t_{ij} for sales in market *j*. For a good produced in region *i* and sold in market *j*, the cost in value terms is equal to $w_i\ (f+ct_{ij}x_{ij})$. Trade costs are expressed as a mark-up on marginal costs so $t_{ij}\geq 1$, e.g. a trade cost of 10% implies $t_{ij}=1.1$. [7]

We assume standard CES (constant elasticity of substitution) demand functions, so demand for a variety from region *i* in market *j* is equal to $x_{ij} = p_{ij}^{-\varepsilon}P_j^{\varepsilon-1}Y_j$ where p_{ij} is the price of a variety from region i in market *j*, ε is the elasticity of substitution between varieties (with the standard assumption $\varepsilon>1$), P_j is the CES price index in region *j*. With monopolistic competition, firms maximise profits $\pi_i=-fw_i+ \Sigma_j\ (p_{ij}-w_ict_{ij})x_{ij}$, and we obtain the standard pricing condition $p_{ij}=[\varepsilon/(\varepsilon-1)]\ w_i\ ct_{ij}$. Furthermore, free entry and exit imply that total profits for a firm have to equal sunk costs f, and as a consequence the total value of sales for a firm in region *i* will be εfw_i.

Now write $v_{ij} = x_{ij}p_{ij}$ for the value of sales of an individual firm from region i in some market j. Dividing v_{ij} by v_{jj}, we can express the sales v_{ij} in some market *j* as a function of the home market sales v_{jj} of firms in that market: Using the demand functions and the pricing condition, we obtain $v_{ij} = v_{jj} * (w_i/w_j)^{1-\varepsilon}\ (t_{ij}/t_{jj})^{1-\varepsilon}$. Using this, the total sales of a firm in region *i*, $\sum_j v_{ij}=\varepsilon fw_i$, can be written as

$$\sum_j v_{jj}\ (w_i/w_j)^{1-\varepsilon}\ (t_{ij}/t_{jj})^{1-\varepsilon}= \varepsilon fw_i$$

or, moving the common term w_i to the right hand side,

$$\sum_j v_{jj}\ w_j^{\varepsilon-1}\ (t_{ij}/t_{jj})^{1-\varepsilon}= \varepsilon f{*}w_i^{\varepsilon}.$$

[7] We consider it simpler in terms of notation to express trade costs as a mark-up on marginal costs rather than the usual iceberg formulation where goods melt away in transport. The results are similar.

For the N regions, we have N equations with 2N unknowns (v_{ii}, w_i). In order to express this in matrix form, we define

$$T_{N\times N}=\begin{bmatrix} 1 & t_{12}{}^{1-\varepsilon} & \dots & \dots & t_{1N}{}^{1-\varepsilon} \\ t_{21}{}^{1-\varepsilon} & 1 & \dots & \dots & t_{2N}{}^{1-\varepsilon} \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ t_{N1}{}^{1-\varepsilon} & t_{N2}{}^{1-\varepsilon} & \dots & \dots & 1 \end{bmatrix}$$

T expresses the relative trade costs in all markets, relative to domestic supply. Using this, the equation system above can be written as

$$T_{N\times N} \times Diag\ (w_i^{\varepsilon-1})_{\ N\times N} \times [v_{ii}]_{\ N\times 1} = \varepsilon f \times [w_i^{\varepsilon}]_{N\times 1} \qquad (1)$$

where $Diag\ (w_i^{\varepsilon-1})_{\ N\times N}$ is the diagonal matrix with $w_i^{\varepsilon-1}$ as diagonal elements, $[v_{ii}]_{\ N\times 1}$ is a vector with v_{ii} (i.e. the home market sales of firms in each region) as elements, and $[w_i^{\varepsilon}]_{N\times 1}$ is a vector with w_i^{ε} as diagonal elements.

Since manufacturing is the only sector in the economy, the sales of all firms in market j must add up to Y_j; i.e. $\sum_i n_i v_{ij}=Y_j$. n_i is the number of manufacturing firms in region i, and since there is no firm heterogeneity, and no sunk exports costs, all firms will sell a (large or small) positive amount in any market. Expressing all v_{ij}'s in terms of home market sales as above, we can put w_i and v_{ii} on the right hand side and obtain the system of N equations

$$T_{N\times N}{}' \times Diag\ (w_i^{1-\varepsilon})_{\ N\times N} \times [n_i]_{\ N\times 1} = Diag\ (v_{ii}^{-1})_{\ N\times N} \times Diag\ (w_i^{1-\varepsilon})_{\ N\times N} \times [Y_i]_{N\times 1} \qquad (2)$$

Given that firm size is determined (see above) and assuming full employment, the number of manufacturing firms must be $n_i= w_iL_i/(\varepsilon f w_i)= L_i/(\varepsilon f)$. Thereby eliminating the unknowns n_i, we obtain a system with 2N unknowns that may be solved. Equation (2) then simplifies to:

$$T_{N\times N}{}' \times Diag\ (w_i^{1-\varepsilon})_{\ N\times N} \times [L_i]_{\ N\times 1} = \varepsilon f \times Diag\ (v_{ii}^{-1})_{\ N\times N} \times Diag\ (w_i^{2-\varepsilon})_{\ N\times N} \times [L_i]_{N\times 1} \qquad (2a)$$

This is however a non-linear system where no explicit analytical solution can be found.[8] We therefore use numerical simulation in order to determine the outcome. As noted, we call this *the wage gap model* since differences in market access show up in different

[8] In Melchior (2008b) we show that the equation can be solved in some special cases but the results are not very user-friendly so we have to rely mainly on simulation.

nominal wages. In addition, real wages or welfare will be affected by the price level of each region, and welfare can be simply expressed as w_i/P_i.

In the following, we will use this model as a tool to derive predictions about how European integration and other changes in trade costs may affect the income distribution in Europe. In Melchior (2008b), the model and the calculations are explained and discussed in greater detail, and the model is compared to a model with strong trade effects (the home market effect model of Krugman 1980). The latter may be considered as an extreme "representative" of a broader class of models, including NEG models, that rely on net trade or specialisation effects. It turns out that the welfare results in the two models are closely correlated but the specialisation or net trade effects in the latter sometimes differ considerably from other results. The nominal wage effects in the wage gap model are more closely correlated with the welfare results. This was checked for a variety of scenarios and especially for the reduction in spatially related trade costs (such as transport costs), the two models may give rather different predictions. The welfare results are however still similar, and this may suggest that the nominal and real wage effects in the wage gap model are of a more general nature than some of the net trade effects in the home market effect model.

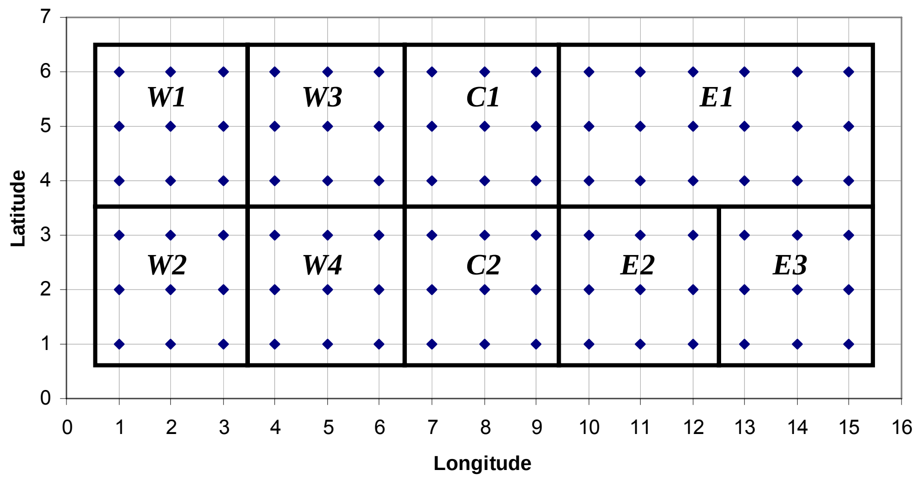
The wage gap model has the property that wage differences are reduced monotonically when trade barriers come down. Hence there is no U-shape in the sense that differences first increase and then fall as barriers are reduced. Furthermore, there are no "bifurcations" or multiple equilibria; the model has a determinate solution. This is a deliberate choice for two reasons: First, we are to solve a highly non-linear model with many unknowns, so we need a tractable model. Analysis of bifurcations and break points can be demanding even with two regions, and with 90 regions (the number we use) the number of potential equilibria could be daunting. Secondly, we have seen from Figure 2 that the economic geography of Europe is a relatively smooth surface and we want a model with a continuous scale of outcomes rather than catastrophic agglomeration in a few regions.

For model simulations with many regions, it is important that the model is well-behaved in the sense that it has a positive and economically meaningful solution. The home market effect model can easily be generalised to many regions, but there is positive production of manufactured goods in all regions only for a range of parameter values (see e.g. Helpman and Krugman 1985, Chapter 10). In a setting with many regions, this range is quite limited, since some region will be "deindustrialised" even for quite high levels of trade costs. The wage gap model is much better in this sense, and in the simulations undertaken, we obtain positive and economically meaningful outcomes in all cases.

3.2. Some simulation results

In order to create a stylised spatial pattern where computations are technically manageable and results are easy to interpret, we chose to use a rectangular grid with 9 countries and 90 regions.[9] This is shown in Figure 6, where the solid-line squares and rectangles represent countries and each dot inside represents a region. Each region is assumed to have the same population size.

Figure 6: A stylised European space with 90 regions



While the map is highly stylized, the idea is to capture aspects of the true European space. The four countries W1-W4 to the left represent the "old EU" or Western Europe whereas C1-C2 represent the "new members" or Central Europe. Eastern Europe is represented by E1-E3, of which one (E1) is a large, long and narrow country which is meant to capture some dimensions of Russia. E2 could in terms of geographic position resemble Turkey or Ukraine and E3 might represent Eurasian countries further east. The 90-region landscape has distinct North-South and even more East-West dimensions; there is a sufficiently rich regional structure inside each country, and we have a sufficient number of countries to study different integration scenarios, and their impact on insiders and outsiders.

The map in Figure 6 captures some aspects of the true European space but we should nevertheless be aware of its limitations:

- There is no outside world so the model will tend to overestimate the isolation of regions at the borders of the landscape. Given that e.g. regions in the Russian Far East are now benefiting from more intensive trade with China, USA and others, this is a limitation.

[9] It was tried with true regional coordinates but the number of regions in the wider Europe is then more than 400 at the NUTS2 level of classification. This creates more technical difficulties and this option was left as a possibility in future research.

- The landscape is stylized and misses many features of true geography, which has more countries, oceans, lakes, mountains, climatic differences and so on. Especially the North-South dimension is limited and allows limited analysis of e.g. EU enlargement towards the South and North. This is however deliberate since our focus here is particularly on the East-West dimension; in the lights of the patterns of change we have shown earlier.

A core feature of the approach used here is that we include some trade costs that are a function of distance, and others that are independent of distance. We call the first *spatial* or *distance-dependent* trade costs, and the second *non-spatial* or *distance-independent*. As shown by Melchior (2000), see also Behrens et al. (2007); when the two types are present simultaneously one obtains qualitatively new effects on the spatial distribution of activity or incomes that are not present when each is considered in isolation. In the model simulations, trade costs always include a spatial as well as a non-spatial component.

We may think of spatial trade costs as transport costs, and non-spatial trade costs as "trade policy". This is however not fully clear and it could also be the case that policy-shaped barriers or regulations have a spatial dimension. In the European context, the European internal market is a large-scale project containing thousands of reforms, of which some may be spatial and others non-spatial. For example, if geographical distance also reflects institutional similarity, standards and regulations could be more similar in countries and regions that are close to each other. The relationship between transport costs and distance is also not straightforward: while e.g. the costs of road transportation in Europe may be monotonously increasing with distance, this may not be so clear for long-distance sea freight. In the analysis, trade costs represent distribution costs in general, and it is an empirical issue which trade costs are spatial and non-spatial, and which are politically determined and which are not.

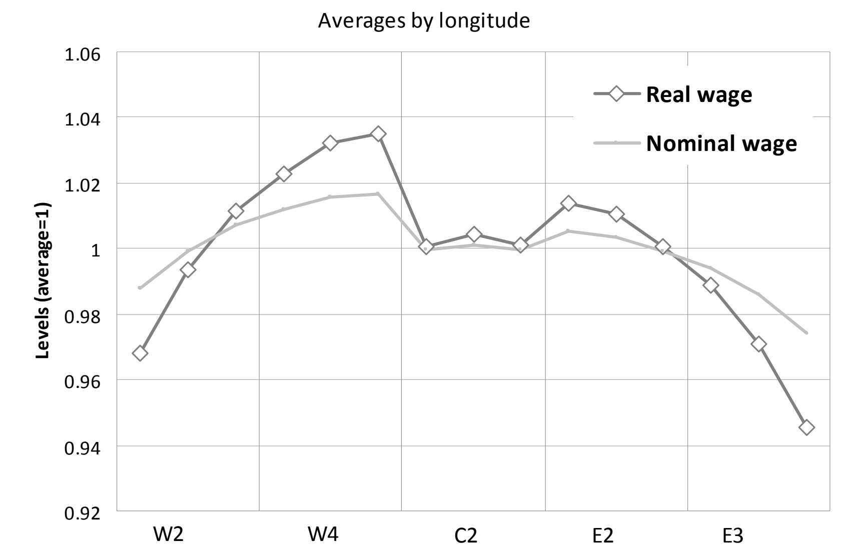
In the model simulations, trade costs always include a spatial as well as a non-spatial component. Spatial trade costs are present within as well as between nations. We simply use distances in the rectangular grid (Figur 6) and scale it with some factor. Next, we assume that there are non-spatial trade costs present between all regions, also within nations. We use three levels; within nations ($t_{domestic}$), between regions in different nations but within the same trade bloc (t_{rta}, where the rta subscript refers to some regional trade agreement), and between regions in different nations that have made no special integration agreement (t_{mfn}, where mfn refers to Most Favoured Nation). We assume $t_{domestic}<t_{rta}<t_{mfn}$ and for simplicity we let the level for regional integration be mid-way between the domestic and MFN barriers. If we had allowed $t_{domestic}=t_{rta}$ countries would not exist any more. Since international trade costs are always higher than the domestic ones, countries continue to matter in all scenarios.

We run simulations with different levels of trade costs in order to check whether levels matter. But since there is no "U-effect" in the NEG sense described above, the level does not matter too much for the qualitative results. We therefore report here results only for simulations with medium-level trade costs. In this case, non-spatial trade costs are 10% (domestically), 20% (in regional trade agreements) and 30% (between countries without RTA's). In addition, there are distance-related trade costs ranging from 3.5% (to the neighbour region) to 50% (for the maximum distance). In this case, average trade costs of all kinds, spatial and non-spatial, is about 45%. Considering that Anderson and van Wijnkoop (2003) found that total trade costs broadly defined, including distribution costs, could be as high as 170% of the production price, this is not very high.

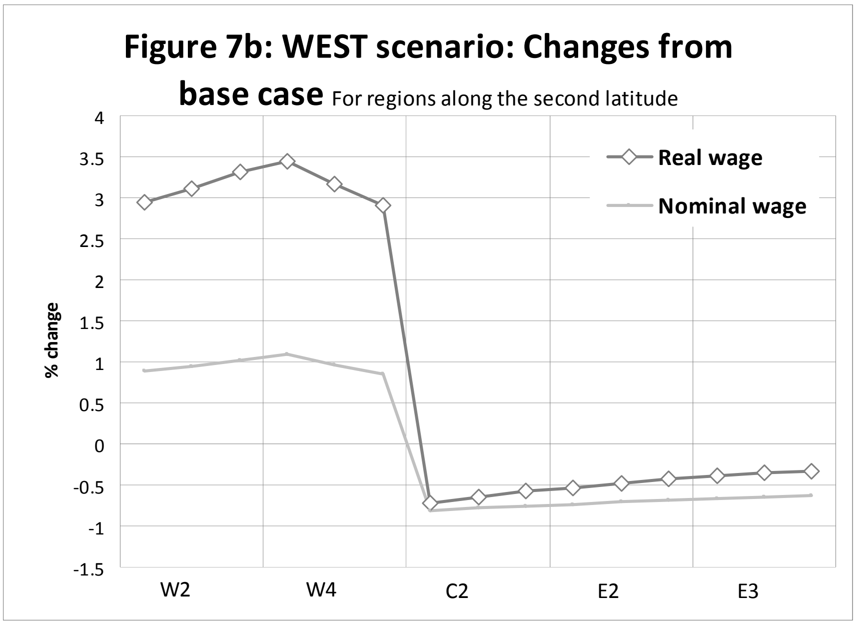
We start with a base case with no regional integration, and then proceed to a scenario with Western integration (WEST), where the countries W1-W4 reduce non-spatial trade costs between them from 30 to 20%. In order to present the results in a compact and easily accessible way, we report results along the 2nd latitude, i.e. along the line running through the centre of countries W2, W4, C2, E2 and E3; including 15 of the 90 regions in our landscape. More details and a richer picture are shown in Melchior (2008b), including tables with the numbers involved as well as sensitivity analysis.

In Figures 7a and 7b, we show income/welfare levels and changes in the WEST scenario. In order to illustrate to what extent the simulated income distribution matches the real-world pattern observed in Figure 2, Figure 7a shows nominal and real wage averages by longitude in the simulation model. Hence each data point is an average of six observations at each longitude.

Figure 7a: Income levels in WEST scenario



Hence the simulated income distribution is inverse U-shaped, as in Figure 2, and it also matches by predicting a higher income level in the western countries. Observe the "agglomeration shadow" in country C2: being outside but close to the integrated bloc is a disadvantage. This is demonstrated even more clearly in Figure 7b which shows the income changes compared to the base case without integration.



Hence Western integration creates a welfare gain for the integrating countries and a slight loss for those outside. This "agglomeration shadow" aspect of integration is well known from new trade theory models of regional integration; see e.g. the survey of Baldwin and Venables (1995). In such models, however, this discrimination effect corresponds to a net trade effect; there is "production shifting" whereby the trade bloc increases its net exports of manufactured goods. In the wage gap model, there is only one sector so there is no export surplus, and no net trade effects (although the trade volume is affected). The "welfare shifting", as we may call it, is therefore caused by changes in nominal wages and price levels, due to lower trade costs. For the integrating countries, there is an increase in trade.

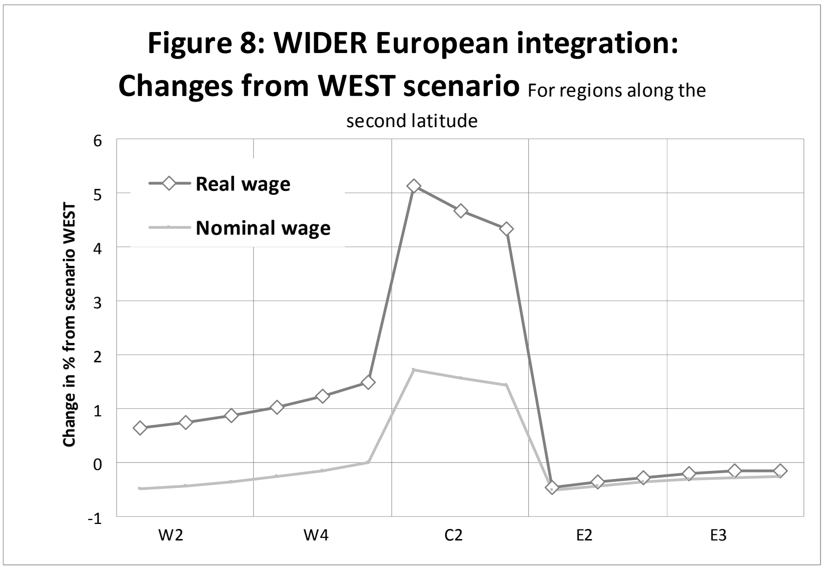
Another new feature of the results shown here is due to the disaggregation of countries into regions: The impact of integration varies across regions within each country. Integration creates centralisation in the new trade bloc, and central regions gain more than the peripheries. Outside the trade bloc, the "agglomeration shadow" bites harder for regions close to the border of the new bloc.

The WEST scenario is intended to represent the pre-1990 situation with integration in Western Europe. Later, the EU internal market has been established; Western and Central Europe have been integrated through the Europe Agreements between EU and Central European countries, other free trade agreements (e.g. between EFTA and Central Europe), and recently EU enlargement. Furthermore, there was liberalisation within the WTO and unilateral liberalisation by some Eastern European countries (e.g. Ukraine). According to our terminology, these reforms would reduce non-spatial trade costs. In addition, there could have been a reduction of spatial trade costs, either as a consequence of the European internal market or because of improved transport supply. EU monetary integration could also have had an impact.

In order to capture the spatial impact of these reforms, we show three different scenarios:

- WIDER is the extension of the western trade bloc to include Central Europe.
- WTO represents multilateral liberalisation, reducing t_{mfn} from 30 to 25%. Observe that t_{rta} in this case stays unchanged at 20% so there is "preference erosion" by which the margin of preference for the trade bloc is reduced.
- SPATIAL represents a reduction in spatial trade costs by half. We assume that this applies between all regions in Figure 6.[10] Hence the maximum level of distance-related trade costs is now 25%.

In all the three cases, we show changes in nominal and real income from scenario WEST. The results are presented in Figures 8-10. When interpreting the results, observe that the scale of each reform is not comparable: the percentage-point reduction in trade costs is largest in SPATIAL and smallest in WTO. Hence since we have not corrected for the "size of the shock", one should look at the patterns rather than the absolute magnitude of the effects.



[10] Later, we revert to a scenario where the reduction in spatial trade costs is higher in Western Europe.

Figure 9: General trade liberalisation (WTO scenario): Changes from WEST

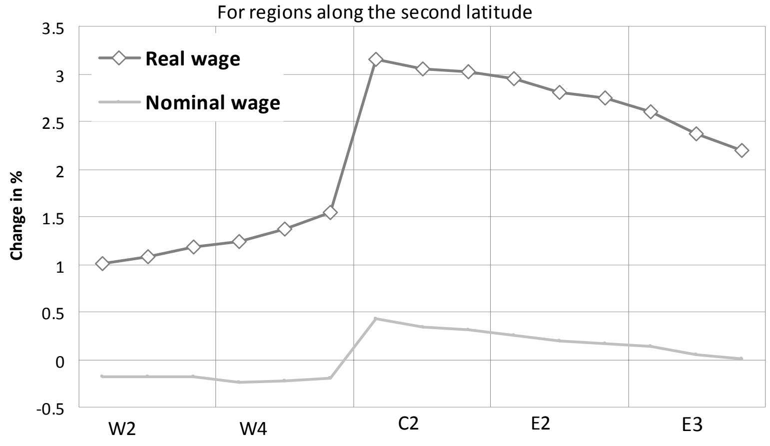
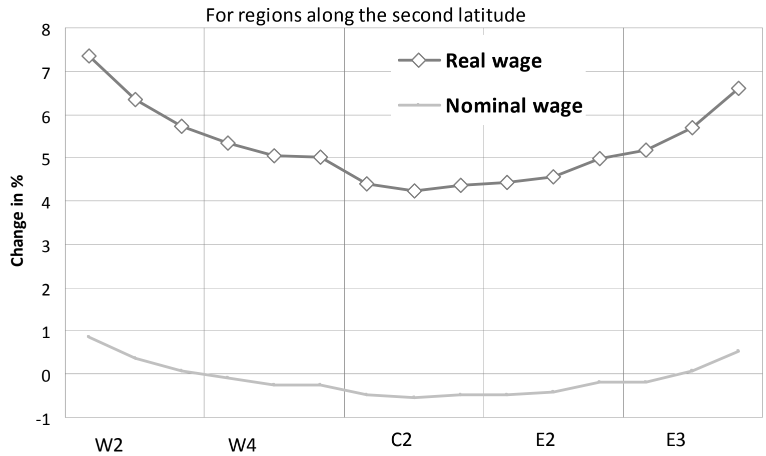


Figure 10: Reduced distance costs (SPATIAL): Changes from WEST



An important message from these results is that *different forms of trade liberalisation have quite distinct and different spatial effects*. Hence there is no unambiguous rule telling how international integration affects domestic regions: this varies across scenarios. Whether it creates more or less regional inequality inside countries also depends on the initial situation. For example, western regions in W2 were initially worse off and therefore regional inequality in W2 increases in Figures 8 and 9 while it is reduced in Figure 10.

Turning to the results, we observe:

- In the WIDER scenario, the results for WEST are just moved one step eastward: The Central European countries obtain a large gain by being taken from the "agglomeration shadow" into the trade bloc, and the shadow is moved one step further east. The former WEST bloc also gains from widening. Interestingly, the gain is larger for regions close to the new members, so there is no reason for incumbents to fear the competition from the newcomers.[11] Eastern Europe however loses from WIDER, but quite modestly.

- All countries and regions gain welfare from general trade liberalisation (WTO), but countries and regions outside the existing WEST bloc gain more. The reason is the "preference erosion" that eliminates some of the integration advantages obtained by the western countries. For this reason, the gain from WTO is also larger for Central Europe, which is more harmed by being excluded from WEST. There is a modest nominal wage reduction for the western countries, but this is more than compensated for by lower prices so there is a welfare gain.
- When distance-related trade costs are reduced in SPATIAL, it is generally to the benefit of the peripheries, so the change has indeed a U-shape; although the story behind is quite different from the NEG version. SPATIAL weakens the impact of geography. In real Europe as well as the simulations, there is a gravity-like central agglomeration with higher income in central areas. When the disadvantage of being peripheral is reduced, this centralisation pattern is reversed. In the central areas of the rectangular plain, there is even a nominal wage reduction.

Since the spatial patterns vary strongly across scenarios, there are no universal predictions. Hence one may not assume generally that "western regions in Central Europe will gain more from integration" or that "regions with a greater market potential will gain more". While such expectations have been used as a platform for research, our results suggest that the appropriate hypothesis depends on the specific integration scenario as well as the initial income of regions. As noted above, general predictions about how international integration will affect domestic regional inequality are not warranted, for similar reasons.

Do any of the scenarios help us understand the U-shaped pattern of growth shown in Figures 3-5? Considering the shape, our first bet would be SPATIAL, given the similar U shape in Figure 9. A caveat is that the minimum of the U-curve for SPATIAL is in Central Europe, while in real Europe (as in Figure 5) it is in Western Europe, corresponding to W3-W4 in our model. This is however only a technical issue and not a strong objection: The location of the minimum point in the simulation could easily be changed by technical adjustments to the model (we will show this later).

Therefore, the SPATIAL scenario is a candidate explanation for the observed change in Europe's east-west geography. This is however only a suggestion; more specific evidence is needed to draw a conclusion. This tentative suggestion is nevertheless surprising, given that we would expect wider European integration to be a more dominating force during the time period studied. The WIDER scenario however captures only reductions in non-spatial

[11] As seen from the Appendix, Figure A2, there is a nominal wage reduction for all the former members, but the price level reduction is sufficient to secure a welfare gain, as shown in Figure 8.

trade costs, and it could be the case that the EU internal market actually also changes the distance-related costs. Institutional convergence, improved infrastructure and scale economies in the transport sector are potential explanations. The EU internal market is a massive institutional reform, creating institutional convergence across European countries. It contains thousands of reforms and regulations. If geographically not-too-distant countries initially had more similar institutions (e.g. the Nordic countries), institutional harmonisation could reduce the impact of distance (by making e.g. the Nordic countries and Italy more similar). While the internal market was established in 1992, it is plausible to believe that the implementation takes time and the full effects could appear during the period studied here, i.e. 1995-2005. According to Herderschee and Qiao (2007) the impact of the Europe Agreements between the EU and Central Europe, which were established in the early 1990s, would take 15 years to materialise. Given the complexity of the internal market reform, it would be plausible to expect that its impact would materialise over a long period. Regional transfers could also matter; if the magnitude of such transfers is inversely related to income levels (and these have a spatial profile as in Figure 2). For Western Europe, monetary integration could also be a candidate explanation.

One path towards obtaining more decisive evidence would be to undertake more research on the spatial characteristics of economic activity (trade, investment, budget transfers etc.) (see e.g. Anderson and Yotov 2008 for an interesting recent contribution on gravity and border effects). Another research option, which we shall pursue here, is to derive more detailed but still macro-level predictions from the model scenarios and check if they are supported by the data. In Section 4, we therefore examine whether growth differences and changes in inequality across regions within countries are in line with the model predictions.

In the analysis, we will examine all three scenarios presented in Figures 8-10. Even if it would turn out that SPATIAL is relevant, we still know that widening of European integration as well as some WTO liberalisation have actually happened, so in real life we would expect to observe a pattern affected by various reforms that have occurred in the 1995-2005 period.

4. Spatial inequality and growth differences across regions within European countries

Is the spatial pattern of growth observed in Figures 2-5 driven by differences across countries only, or does it also apply *within* countries? It is evident that the pattern is to a large extent driven by cross-country differences, as shown in Melchior (2008a). Especially after 2000, Central and Eastern European countries have on average grown faster, and this contributes to convergence. But are there also domestic growth differences within each country with a similar east-west gradient? For example; do growth differences across regions in France have an east-west gradient so that western regions grow faster? According to the simulation model, this should indeed be the case and if it is supported empirically, it could bring us one step further. We therefore proceed by deriving some of these implications, and check whether they are supported by the evidence.

We therefore proceed to an analysis where we test econometrically whether regional growth within each country has an east-west or north-south gradient, but also controlling for other types of spatial income or growth differences. As a point of departure, Table 2 shows the model predictions about whether real income growth will have an eastward or westward bias.

Table 2: Will real income growth be higher in the east or west of a country? Predictions from model simulations

Scenario	Countries in simulation			
	W1-W2	W3-W4	C1-C2	E1-E2
WEST	East	West	East	East
WIDER	East	East	West	East
WTO	East/Neutral	East	West	West
SPATIAL	West	West	U-shaped	East

Explanatory note: "East" e.g. indicates that income growth is expected to be higher in the eastern parts of the relevant countries (shown in the column headings).

As noted above, minimum growth in the SPATIAL scenario is obtained for Central European countries but we consider that an outcome where the U-shaped outcome occurs for W3-W4 would also be technically possible.

As seen from Table 2, the predicted effects again vary across scenarios. If the SPATIAL scenario is to receive further support, we should find western gradients of income growth in western countries, and eastern gradients inside eastern countries, with a neutral/ U-shaped pattern in some intermediate range.

One possible method for analysing these country-level spatial effects would be to pool the data and allow constant terms and slopes to vary also across countries. Determinants of spatial patterns however vary considerably across countries and this variation is difficult to handle properly in pooled regressions.[12] Furthermore; there is no common pan-European prediction about the signs of parameters so in one sense the pooled regression is inconsistent unless we have specific methods to address heterogeneity. Indeed heterogeneity is our research focus and not something that we want to "correct for" in order to derive "general law" about spatial change, for example by some econometric approach with general assumptions about the pattern of spatial autocorrelation. Since our model predicts heterogeneous outcomes rather than some general law about spatial change, we address the issues by means of country-level regressions.

The number of observations at the country level is on average 49 but varies from 5 to 348, and for five countries it is 10 or below. We therefore drop six countries with 12 regional observations or less. For some other countries with more but still few observations, regressions are not that reliable but we nevertheless include them in the analysis. Hence we will examine spatial gradients of regional growth in 22 countries. For Germany, we also report results for West and East separately. Given our interest in the east-west gradient of growth, we include longitude (LON) in the analysis, and also latitude (LAT) in order to examine north-south effects.

In addition to our examination of causes of spatial income change, the analysis also adds to the descriptive accounting of European regional inequality, by quantifying changes that are not captured by standard measures of regional inequality such as the Gini or Theil indexes. These indexes measure overall inequality without addressing geographical redistribution of income. For example; if there is a relative increase in the west and a relative decline east in some country, the Gini may be unchanged even if there has been a substantial change in the spatial income distribution. The analysis here therefore adds a new dimension compared to earlier analysis of regional inequality in Europe, such as Förster et al. (2003), Römisch (2003) or Melchior (2008a).[13]

Analysing east-west and north-south gradients of the growth pattern would however be too limited since spatial growth inequality could be caused by other factors. In the empirical analysis, we therefore try to control for such aspects.

[12] Also in a growth regression framework, there is a parallel problem with convergence across the EU (i.e. poor countries or regions grow faster), but variable outcomes within countries, with divergence between regions in a majority of countries (see Melchior 2008a). This variation is difficult to capture accurately in pooled regressions.

[13] Landesmann and Römisch (2006, 5) maintain that income per capita levels are relatively higher in the western border regions of the Czech Republic, Hungary, Poland and Slovakia, and to some extent Romania, and the authors attribute this to market potential (proximity to the EU-15 market) as well as foreign direct investment. More analysis of the issue is however not presented.

In Central and Eastern Europe, higher income levels and growth in capital regions is a common feature (see e.g. Brülhart and Koenig 2006, Landesmann and Römisch 2006, Melchior 2008a). Countries with high regional inequality also have agglomeration in capital regions, so there may be a core-peripery pattern that is quite distinct from the east-west or north-south geographical patterns that we have examined. Melchior (2008b) shows model simulations with a hub-and-spoke pattern inside countries, where capital regions act as hubs for the foreign trade of peripheral regions. In this case, east-west growth differences tend to be modified since the peripheral regions cannot exploit their proximity to foreign markets. For example, according to this regions in western Poland cannot exploit their proximity to the EU-15 market so they remain peripheral and gains from integration accrue disproportionately to the capital region. In order to capture capital region dominance in the empirical analysis, we include the distance of each region to the capital (CAP) as a variable.

In the economic geography literature, a common theme is also that market potential or the proximity to markets can be a determinant of growth. Regarding international markets, the idea here is to capture that indirectly through the longitude and latitude variables. Domestically, there may however also be such a market potential effect. We capture this through the variable CORE, which is the distance from each region to an economic centre point. This is calculated as the GDP-weighted average of coordinates (longitude and latitude) for all regions in each country.[14]

In some countries, the capital of a country is also close to the economic centre point so that CAP and CORE are highly correlated. This is however not always the case, and in some cases the correlation is 0.5 or lower. This is the case for e.g. Poland and Ukraine. Furthermore, capitals or economic centre points may be located to the east, west, north or south of a country and in that case they will be correlated with LON or LAT. For example, Austria, Ireland, Lithuania and Poland have eastern capitals and CAP is then highly (and negatively) correlated with LON. Similarly, high positive correlations between CAP and LON are observed for Bulgaria, Czech Republic, Western Germany (where we use Bonn as the capital), Norway, Russia and Turkey, due to their western capitals. Unless we take this into account, we may mix up geographical east-west effects with the growth of capital regions. For example, it is commonly assumed that there is a strong capital city effect in Russia, but when the east-west dimension is taken into account, we will see from later results that this is not such a robust result any more.

In Table A2 in the Appendix, we show the most relevant correlations between the four variables LON, LAT, CAP and CORE. Table A2 provides a guide for the regressions, by indicating where correlations are high and collinearity may represent a problem.

[14] We also calculated population-weighted centre points but these are highly correlated with the GDP-weighted measure and give similar results. Results using the population-weighted measure are therefore not reported.

An issue is whether we should include initial income, as in growth regressions. For example, one might argue that growth in some region is due to its capital endowment and not its geographical location, and if we omit the initial income variable or some other variable reflecting the capital-labour ratio, the estimates would be biased. Against this, it could be argued that LON and LAT are not as such causes and we are not looking for causality in a standard sense: According to the model, LON and LAT are macro-level indicator variables reflecting a more complex underlying pattern driven by scale economies, imperfect competition and differences in trade costs. Hence we use LAT and LON to describe the spatial pattern of growth and check whether this spatial pattern conforms to the model. We start by using this latter approach; running regressions without the income variable. However, we also undertake regressions with initial income y_0 included (in logs) in order to see how this affects the results.

LON, LAT and CAP do not change over time and CORE changes only a little. For this reason, there is little to gain from a panel approach and we start by running country-level OLS regressions of the form

$$g_i = \alpha + \gamma_1 * LON_i + \gamma_2 * LAT_i + \gamma_3 * CAP_i + \gamma_4 * CORE_i + \varepsilon_i \qquad (2)$$

and later with $\ln(y_0)$ added on the right hand side. This specification is linear in all variables. For LON and LAT a linear approximation seems plausible, since the range covered for each country is limited. For CAP and CORE it is less clear that a linear specification is the appropriate choice, and this is an empirical issue with little à priori guidance. The shape of spatial agglomeration around capitals or economic centres may not be a “pyramid” – as we assume in equation (2) – but bell-shaped or inverse U-shaped. If that is the case, equation (2) is mis-specified and the estimates may be biased. We try to avoid this by using, alternatively, the following two other specifications:

$$g_i = \alpha + \gamma_1 * LON_i + \gamma_2 * LAT_i + \gamma_3 * \ln(CAP_i) + \gamma_4 * \ln(CORE_i) + \varepsilon_i \qquad (3)$$

$$g_i = \alpha + \gamma_1 * LON_i + \gamma_2 * LAT_i + \gamma_3 * CAP_i + \gamma_5 * CAP_i^2 + \gamma_4 * CORE_i + \gamma_6 * CORE_i^2 + \varepsilon_i \qquad (4)$$

Equation (3) is in logs while equation (4) adds quadratic terms for CAP and CORE in order to better capture the curvature of the core-periphery dimension.[15] In the analysis, we try the three specifications above and report the specification with the highest adjusted R^2. If some parameters are insignificant due to collinearity, we rerun the equations with some variables excluded. If different specifications give different results for LON and CAP, which

[15] Since the capital region has CAP=0 and ln(0) is not defined we actually use ln(1+CAP) in equation (3).

we consider as variables of particular importance, we take this into account in the reporting of results. Hence if e.g. LON obtains a particular result only in one specification but not others, we examine further the reasons behind.[16]

The number of observations is low in some cases even if we have dropped some smaller countries. Especially for such countries, results may be unduly affected by outliers. We therefore also run robust regressions in all cases in order to check whether outliers unduly affect the results.[17] In some cases where robust regression lead to a change in the conclusions, e.g. that a significant estimate becomes insignificant in the robust regressions, we report this. In some cases where the number of observations is small, this type of robust regression may not capture underlying problems with "leverage points". We revert to this when reporting the results.

As noted, we also undertake regressions where the log of initial income is included as a right hand side variable. In Appendix Table A3, we report correlations between initial income and the four spatial variables used (LON, LAT, CAP, CORE). In general, these correlations are lower than between the spatial variables, but in some cases, income levels have a strong spatial pattern. By using Tables A2 and A3, the interested reader may trace the economic geography of each country; i.e. where income is higher, where the economic mass is concentrated, the role of the capital, east-west and north-south dimensions. For each country we could tell a little story, but with the paper long already we leave that to the interested reader who may find information about specific countries of interest.

In Appendix Tables A4 and A5, we report the results when average annual growth in GDP per capita is the dependent variable, without and with the initial income level ($\ln(y_0)$) included, respectively.[18]

As an alternative or supplement to per capita income growth as the dependent variable, other variables could be considered, such as wages, employment or prices. Such data are however generally not available at the NUTS3 level which we use in order to have a sufficient number of observations. We do however have population data, and these may be of interest due to migration and also since GDP per capita is affected by population change. Here we could imagine various mechanisms; e.g. that migration exceeds job growth so GDP per capita declines in spite of a growing economy; or economic decline causing population

[16] The CAP and CORE variables may capture agglomeration related to one or two reference points in each country, depending on whether the two variables are highly correlated or not. If the two variables are highly correlated, we are essentially controlling for a "monocentric" pattern of agglomeration with one central location. This may not be appropriate since countries may have a hierarchy of agglomerations. Especially for larger countries such as Russia, this monocentricity may be a limitation of the analysis. It is however beyond the scope of this analysis to provide an in-depth analysis of "multicentric" patterns of agglomeration in each country. This is left as a task for future research.

[17] We use standard robust regressions as suggested by Huber (1973) and discussed in e.g. Maddala (1988); so-called M regressions. Such regressions use iterative procedures and adjusted R^2 is not appropriate as test statistics. R^2 is reported by the SAS software output and is used instead, in the Appendix tables.

[18] We also tried the log of income per capita growth but this did not improve the fit so the growth rate was used.

decline and this adds to income per capita. As a check on whether such aspects matter, we run regressions with equation (3) using population growth as dependent variable. Here we also include initial income per capita in order to examine whether higher income drives population growth or migration. These results are reported in Table A6 in the Appendix.

Tables A4-A6 contain many results and in order to facilitate the interpretation, Table 3 sums up the main qualitative results, by indicating where results for each parameter were significantly positive or negative (blank cells indicating non-significant results). These concluding results are obtained after checking different specifications as well as robust regressions. While this problem is certainly present, it was nevertheless not as severe as we would expect from the correlations in Table A2. In some cases we nevertheless chose to drop one of the two variables, as shown in Tables A4 and A5.

In Table 3, some borderline cases are marked with an asterisk, indicating some remaining uncertainty about the reliability of the estimates. There are also cases with high collinearity, for example when CAP and CORE are highly correlated, where it is hard to say whether one or the other is true, or which one of the two variables that should be dropped. For some countries with a low number of observations, results remain significant in spite of repeated checking, but we maintain some scepticism due to extreme results. This is especially the case for the Czech Republic, with a modest 14 observations. Visual inspection of the data suggests that there is a remaining problem with outliers that is not taken into account through the type of robust regressions used.

In order to see how the results relate to our theoretical framework as well as earlier empirical results, Table 3 ranks countries according to longitude as in Figure A1 in the Appendix. As an exception, the Nordic countries are reported separately at the bottom of the table, since they are located far from the central east-west axis of Europe and have few significant spatial patterns. In the table, some of the most important results are marked with shaded areas.

Table 3: Summary of regressions on spatial determinants of income and population growth in European countries

Explanatory notes:

- For LON, LAT: E.g. "West" indicates higher growth in the west, equivalent to a significant negative estimate for LON, and "South" indicates higher growth in the south i.e. a significant negative estimate for LAT.
- For CAP, CORE: "Yes" indicates an agglomeration effect with lower growth further away from the capital or economic centre point; i.e. a significantly negative parameter estimate. "Reverse" indicates a positive estimate which reflects higher growth further away from the capital or centre point.
- For Y_0: "Converge" indicates a significant negative estimates so poor regions grow faster; "Diverge" the opposite.

Countries (ranked by longitude)	Income per capita growth					Population growth		N
	LON	LAT	CAP	CORE	Y_0	LON	LAT	
Portugal						West		28
UK			Yes				South	126
Spain	West	South		Reverse		East	South	47
France	West	South		Reverse			South	99
Belgium				Yes		East		42
Netherlands	West	North		Yes				38
Germany	East	South*	Reverse*	Yes	Converge			414
W. Germany	East	South		Yes	Converge	West	South	348
Italy	East			Yes	Converge		North	99
E. Germany			Reverse	Yes		West		66
Austria		South		Yes		West		35
Czech Rep.	East*	South*	Yes*	Reverse *		West*		14
Croatia		South						21
Poland			Yes					16
Hungary			Yes					20
Greece	West*	North*	Yes	Reverse *	Converge			51
Romania	West		Yes			East		42
Bulgaria			Yes		Converge	East		28
Ukraine		South*	Yes*		Diverge	West		27
Turkey	East	North			Converge		South	79
Russia				Reverse *		West	South	79
Nordic countries								
Norway								19
Sweden			Yes				South	21
Finland					Converge			19

Note: Details are found in Tables A4-A6 in the Appendix. An asterisk indicates some remaining uncertainty about the reliability of estimates.

From the Appendixes we observe that the average value of adjusted R^2 is 0.20 for the regressions with per capita income growth as dependent variable but without initial income included. When initial income included, this average increases to 0.25. Including initial income however does not change the results very much, and most of the results in Table 3 are supported in both cases. When population is the dependent variable, average adjusted R^2 is 0.28; indicating that population has even stronger spatial gradients than income change.

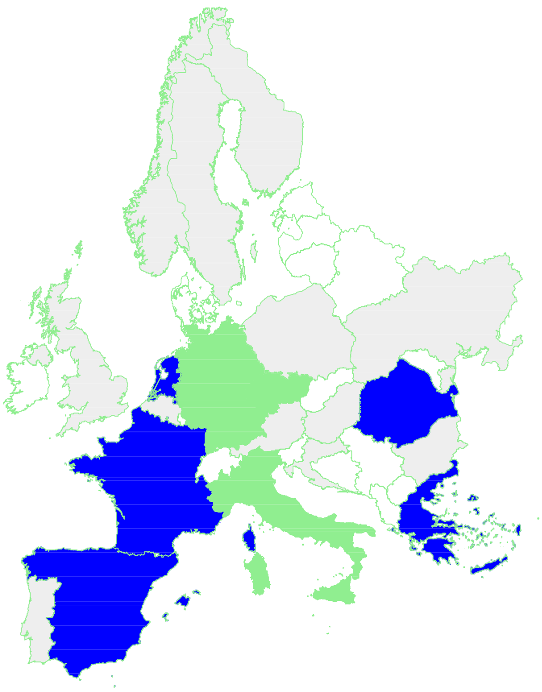
From Table 3, it is evident that we find significant spatial gradients in slightly less than half of the possible cases. The lack of a pattern in some countries is however also a relevant result, and in many cases there are plausible explanations why results may be insignificant.

For Western Europe from Spain to Italy, the results for LON are in conformity with our earlier results in Figures 3-5: Corresponding to this U-shape, there is a western gradient of regional growth within Spain, France and the Netherlands, and an Eastern gradient for West Germany (and Germany as a whole) and Italy.[19] In the latter family, we also find the Czech Republic as a borderline case. Figure 11 summarises this pattern.[20]

Figure 11: East-west gradients of income growth

Summary of results from country-level regressions

Blue/dark=western, green/intermediate=eastern, light grey=not significant, white=not covered by analysis



The North-South gradients summarised in Table 3 may suggest there is also decentralisation in the North-South direction; with a Northern gradient for the Netherlands and a southern gradient for Spain, France, West Germany, Austria and the Czech Republic. The results indicate that the "blue banana" is weakened and there is decentralisation

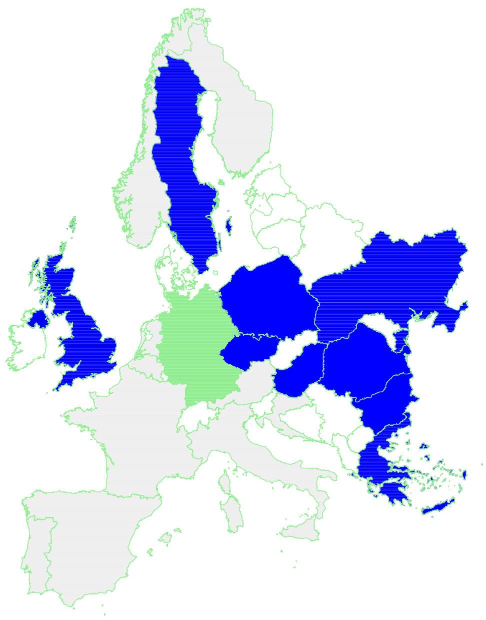
[19] Redding and Sturm (2005) analysed Germany and concluded that unification promoted growth in the border regions between West and East Germany. We find an eastern gradient for West Germany but no western gradient for East Germany. Potentially, the unification effect observed could be linked to the alternative mechanism discussed here and not the impact of unification.

[20] Russia is not included in the graph but the results were insignificant. This also applies to Figure 12.

compared to the formerly inverse U-shaped income distribution shown in Figure 2. Interestingly, this is combined with a systematic pattern of results for the CORE variables: Proximity to the domestic market potential is a driver for regional growth in Belgium, Netherland, Germany, Italy and Austria; whereas further west (in Spain and France) and east (in the Czech Republic) growth is higher away from the economic centres of gravity. Hence in the low-growth area of Figure 2, including Germany and Italy, domestic market potential plays an increasing role. This mechanism is not reflected in the model simulations, and we leave for further research to sort out the mechanisms behind this effect.

Moving one step further east, or one step down in Table 3, to Central Europe, the pattern of results is completely changed: Now we find few east-west or north-south gradients of growth, and few significant results for CORE. On the other hand there are significant capital region effects for all countries covered in this range. This is shown in Figure 12.

Figure 12: CAPITAL effects
Summary of results from country-level regressions
Blue/dark=CAPITAL effect, green/intermediate=reversed effect, light grey=not significant, white=not covered by analysis



For the Czech Republic, Poland, Hungary, Greece, Romania, Bulgaria and Ukraine, there are significant negative estimates for CAP, indicating that regions further away from the capital have lower growth. Evidence on the role of capitals in Central Europe was also provided by Brülhart and Koenig (2006). Similar to our results, they find that capital region dominance is more important than proximity to EU markets.

For Western Europe, the geographical pattern between and within countries are similar, but in Central Europe, the east-west gradient is driven by cross-country changes and not reflected in the domestic pattern of growth in these countries. As noted, this is in conformity with the predictions when a hub-and-spoke effect within countries is introduced in the simulation model. For Central Europe, one possibility is that capital region effects eliminate the east-west patterns of growth observed in Figures 3-5, and expected according to the SPATIAL scenario. If this is true, the story is that integration drives growth in Central Europe, but the benefits accrue disproportionately to the capitals, due to the hub-and-spoke pattern.

Another possible interpretation of the results for Central Europe is that different reforms have opposite impact on east-west trends so in sum, these cancel out. In Table 2, two of the scenarios (WIDER and WTO) predict a western gradient of growth across regions in Central Europe, whereas SPATIAL predicts an eastern gradient. The relative strength of either mechanism will then determine the outcome. In this perspective it may not be surprising that the east-west effects are weak and varying. In addition to the non-significant results in most cases, we find one border case with an eastern gradient (the Czech Republic), and two with a western gradient (Greece and Romania).

For Romania, this is in line with the results of Crozet and Koenig-Soubeyran (2004) who interpreted their results as indicating that proximity to the EU market would promote growth. In our framework, this corresponds to the WIDER scenario. Observe however that for Romania, there is an eastern gradient for population change and this seems to be driving the differences in GDP per capita growth. Hence higher income per capita growth in western Romania is not mainly because of high GDP growth, but because of more population decline in Western Romania. This suggests that the western gradient for income per capita in Romania may be explained by features not captured by our models.[21] Hence it is possible that the trend in Romania is due to transition rather than integration.

Turning finally to the eastern countries, we observe

- a north-eastern gradient of growth in Turkey;
- a capital region effect and a southern growth gradient for Ukraine; and
- growth away from the economic central point in Russia.

For Russia and Ukraine, the results on population growth are however stronger than results with per capita income as dependent variable, increasing adjusted R^2 from 0.10 to 0.48 for Russia, and from 0.27 to 0.51-0.59 for Ukraine. In Russia, population decline is lower in the south-west direction. Along with Andrienko and Guriev (2004), we find that population development in Russia is more favourable for regions with a higher initial income level (see Table A6). For Russia, it is also evident that the growth pattern is affected by the

[21] East-west gradients for income per capita and population growth have opposite signs also for Spain, West Germany and the Czech Republic. For West Germany and Spain, there was higher population growth rather than less decline in areas with more income growth. From Table A6 in the Appendix, we find that population growth was higher in regions with initially higher income in the following cases: Czech Republic, Spain, France, Italy, Russia and Turkey. Hence in these countries, there was migration driven by income gaps.

natural resources and oil prices.[22] It is also likely that for a vast country like Russia, testing for a monocentric agglomeration around the capital and the economic gravity point is a too simple approach and that more complex patterns of agglomeration should be considered. In Ukraine, there is a western gradient for population growth, due to faster population decline in the east of the country.

The results for Eastern Europe do not provide convincing support for any of our model scenarios, and a possible interpretation is that in Eastern Europe, transition effects still dominate so the “invisible hand” of economic geography is still weak. One might interpret the north-east gradient of per capita growth in Turkey as evidence of an “agglomeration shadow” but we consider this as quite uncertain unless we obtain more systematic evidence to this effect. Hence on the whole, the results do not confirm the presence of an “agglomeration shadow” to the east.

5. Summing up: A revised model scenario

Throughout the empirical analysis, the model scenarios have helped us interpret the results. We have found evidence providing some support for the model predictions, but the pattern is complex, varying and we cannot declare a clear “winner”. This is to be expected: the world is complex, and economics should address this complexity rather than search for simple “universal laws” that may turn out to be evasive.

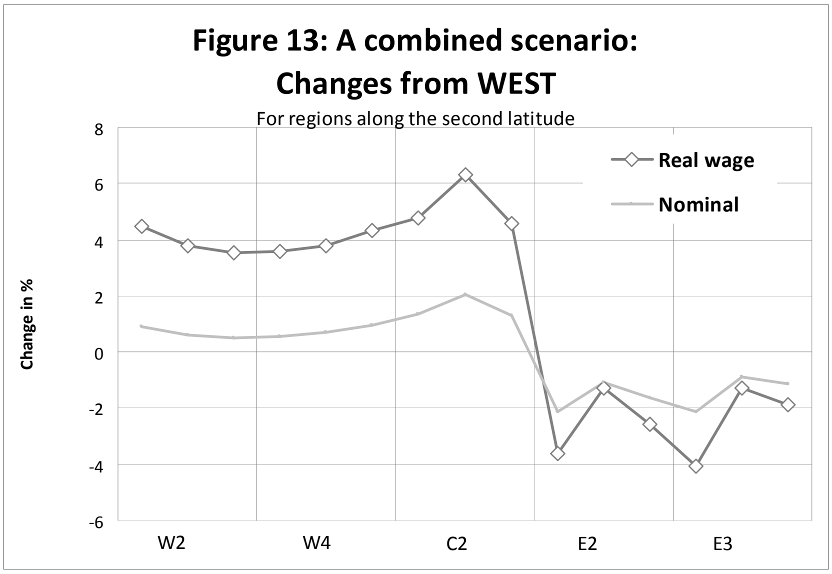
The empirical results suggest that elements from different model scenarios are relevant: the SPATIAL predictions are supported for Western Europe but for Central Europe, the pattern is more ambiguous. As a tentative summing-up of the analysis, we construct a “hybrid” model scenario which captures some of the observed empirical regularities. Departing from the WEST scenario, we add the following elements:

- East-West integration as before, according to the WIDER scenario.
- Hub-and-spoke patterns in all Central and Eastern European countries: Half the trade of each region has to be shipped via the capitals. This creates a “capital effect” in each country, in line with the regression results.
- A reduction in spatial trade costs that is different in the three areas: 50% reduction within W1-W4, and 25% reduction for the trade within C1-C2, and their trade with the western countries. For the eastern countries, there is no reduction in the cost of distance. The

[22] It would be appropriate to take this into account in the econometric analysis but in order to limit the length of this paper we leave this task for further research.

motivation for this pattern is that such a reduction is caused by the internal market, and integration is therefore deeper in the Western area. Monetary integration could also add to this effect.

Combining these elements, Figure 13 shows the result, measured by the change from the WEST scenario. As before, we show the outcome along the 2nd latitude.



Here we have reproduced

- the U-shape in Western Europe, due to deeper "spatial liberalisation" in the west;
- the "skewed U-shape" from the real-world Figure 4b, with higher growth in Central Europe, due to the impact of wider integration;
- a strong capital effect in Central and Eastern Europe, but no clear East-West difference inside the countries, due to the hub-and-spoke effects.

Hence for West and Central Europe, this hybrid scenario reproduces the main observed pattern.

As noted above, the empirical evidence for Ukraine, Turkey and Russia is more mixed so we cannot draw a clear conclusion concerning the relevance of the model predictions. However, correcting for natural resource income is necessary before we can draw firm conclusions about spatial effects in Russia. An extended analysis, beyond the scope of this paper, is required for this purpose.

6. Concluding comments

In the paper, we have shown that along the east-west axis in Europe, there has been a sharp U- or V-shaped pattern of growth differentials across European regions, with the lowest growth at a longitude through West Germany and Italy, and higher growth to the west and to the east of this. We have used numerical model simulation and econometric analysis in order to explain this pattern, and our tentative assessment of the results is as follows:

- In Western Europe, the east-west gradients of growth apply similarly inside as well as across countries, in line with the observed U-pattern. A possible explanation is that the implementation of the EU internal market during the period has implied institutional harmonisation across European countries in a way that has reduced the "cost of distance" and made Europe smaller. Given the complexity of the internal market reform, we expect that its strongest effect should be in Western Europe. After 2000, stronger growth in eastern parts of the EU-15 could also be driven by east-west integration. Monetary integration could also be a driving force for Western Europe.
- For Central Europe, the U-pattern of growth differences applies across countries but not within them, and we find spatial east-west gradients of regional growth within countries only in a few cases. On the other hand there are strong capital region effects in all the countries covered by the analysis. Hence one possible explanation is that gains from integration accrue disproportionately to capitals, and this wipes out any east-west impact inside Central European countries. Another possible explanation is that reduced distance costs and wider regional integration have opposite impacts on regional growth, and this is why the net impact is weak or missing.
- The Eastern European countries Ukraine and Russia are more remote and this may be a reason we do not find strong east-west gradients of income growth in these countries. We find a westward gradient of population change (due to less population decline in the west), but we interpret this as an effect of transition and not linked to the mechanisms studied in the model approach we have used. A north-east gradient of per capita income growth in Turkey could in principle be interpreted as evidence on an "agglomeration shadow" or even reduced distance costs, but with so limited evidence we are not able to draw clear conclusions on this.

In the paper, we have combined descriptive analysis, model simulation and econometrics in order to shed light on the economic geography of Europe. Many of the results, theoretically as well as empirically, are new.

- To our knowledge, the U-shaped pattern of growth along Europe’s east-west axis has not been fully examined by earlier research.
- Through model simulations, we have shown that different trade reforms may have very different effects on the spatial distribution of income. Using higher-dimensional numerical modelling, we have developed tools for examining such reforms and deriving more precise hypotheses for empirical work and interpretation of the results. Instead of looking for “general laws” about spatial change, predictions are specific and not universal.
- Using the Harris (1954) concept of market potential, it has often been assumed that proximity to markets is an advantage for growth. We have shown, theoretically and empirically, that this is the case sometimes but not generally. A possible extension of the analysis could be to derive these implications for the market potential concept.
- The EU internal market was established during the early 1990s but its implementation is gradual and its full impact has not been measured. Our results suggest, as one possible explanation which should be examined further with more specific evidence, that the internal market has had a massive impact on the economic geography of Europe, especially Western Europe, by “making Europe smaller”.
- It is not new that European integration has promoted growth in Central Europe, but the analysis sheds new light on the (partly missing) regional impact of this inside countries as well as the role of capital regions in Central and Eastern Europe; comprehensively for most of the countries involved.
- While earlier research has analysed the extent of overall regional inequality within countries, inequality measures such as Gini or Theil indexes, or growth regressions, are insensitive to the geographical dimensions of inequality. The results here provide a mapping of east-west and north-south gradients of economic growth and population change across European countries.

In the theoretical as well as the empirical work undertaken in the paper, a limitation is that the impact of global competition has not been accounted for. The relative economic decline of the former powerhouses of Europe, in Germany and Italy, could also be affected by competition from e.g. Asia, and in further research this should be examined further. In the analysis, we have also drawn tentative conclusions based on resemblance of macro-simulations and empirical results. For example, we have shown that the pattern of growth in Western Europe conforms with the SPATIAL scenario (halving the distance-related trade costs) but we have presented no direct evidence showing that the cost of distance has actually been reduced. Because of this, all our main conclusions are tentative and should be underpinned by further research providing more specific evidence. Nevertheless, we believe that such a macro-based approach is necessary, at least as a starting point, if we are to capture the “invisible hands” operating on the economic geography of Europe. European integration is the sum of thousands of reforms and regulations, and a birds-eye view is necessary in order to trace the combined impact of all these reforms. The bird should however not fly in too thin air, and through our modelling approach we have attempted to develop a “geographical economics” approach with sufficient specificity for the empirical analysis.

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Appendix

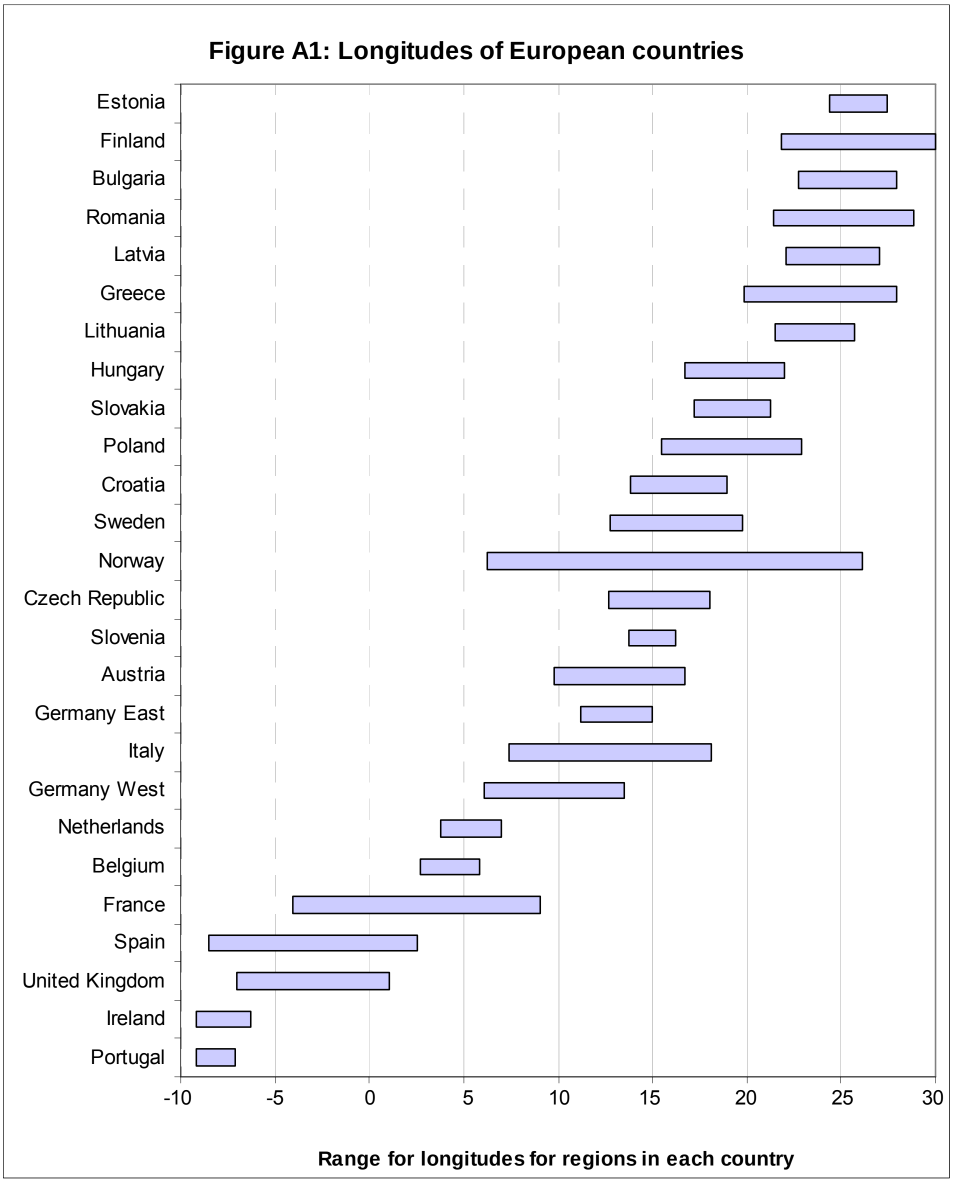
Figure A1: Longitudes of European countries
Estonia
Finland
Bulgaria
Romania
Latvia
Greece
Lithuania
Hungary
Slovakia
Poland
Croatia
Sweden
Norway
Czech Republic
Slovenia
Austria
Germany East
Italy
Germany West
Netherlands
Belgium
France
Spain
United Kingdom
Ireland
Portugal
-10
-5
0
5
10
15
20
25
30
Range for longitudes for regions in each country

Table A1: Data coverage

Countries	Years covered	Classifi-cation	Data source	Notes
Austria, Belgium, Czech Rep., Germany, Spain, Finland, France, Greece, Hungary, Ireland, Italy, Lithuania, Netherlands, Portugal, Sweden, Slovenia, Slovakia, UK (18 countries)	1995-2005	NUTS 3	Eurostat/Regio	- France: Overseas territories dropped. - Spain: Canary and Balearic Islands dropped. - Portugal: Ceuta, Melilla dropped. - Germany: Sachsen-Anhalt missing. - Germany: Split in West and East in some of the analysis. - UK: No data for "Highlands and Islands". - A few other regions dropped due to missing data: Belgium 2, Germany 1, Italy 8, Netherlands 2, UK 2.
Bulgaria, Latvia	1996-2005	NUTS 3	Eurostat/Regio	
Estonia	1997-2005	NUTS 3	Eurostat/Regio	
Poland	1995-2005	NUTS 2	Eurostat/Regio	NUTS3 data limited, NUTS2 data are used
Romania	1998-2005	NUTS 3	Eurostat/Regio	
Croatia	1995-2000	NUTS 3	Eurostat/Regio	
Norway	1995 and 1997-2005	NUTS 3	Eurostat/Regio Statistics Norway	Nation-level GDP data from Regio but regional allocation is calculated using regional GDP data from Statistics Norway
Turkey	1995-2001	NUTS 3	Eurostat/Regio	
Russia	1995-2005	National	Rosstat	Annual publications: Russian regions
Ukraine	1996-2005	National	SSCU	State Statistics Committee of Ukraine
Denmark, Iceland, Switzerland				Regional data not available from Eurostat
Cyprus, Malta, Luxembourg, Liechtenstein				Not included in analysis
Note: For more information about the number and size of regions etc., see Melchior (2008a). On NUTS classification, see Eurostat (2007).				

Table A2: Correlations between spatial variables

Variables:

- LON: Longitude of regions at levels (at NUTS3 level, except for Poland, Russia, Ukraine where NUTS2 or national classification has been used).
- LAT: Latitude
- CAP: Distance from region centre point to country capital. For West Germany, Bonn has been used.
- CORE: Distance to the country's economic centre point, measured as GDP-weighted average of regional coordinates.

In the table, standard Pearson correlations are reported, with P values below estimate. The number of observations is as in Tables A4 and A5.

	LON-LAT	LON-CAP	LON-DEC	LAT-CAP	LAT-CORE	CAP-CORE
Austria	0.39	-0.98	-0.74	-0.54	-0.32	0.77
	0.0202	<.0001	<.0001	0.0007	0.0601	<.0001
Belgium	-0.51	0.13	0.14	-0.48	-0.53	1.00
	0.0006	0.4021	0.3695	0.0015	0.0003	<.0001
Bulgaria	0.21	0.95	0.33	0.29	0.31	0.53
	0.2928	<.0001	0.0819	0.1294	0.1110	0.0035
Czech Republic	-0.32	0.74	-0.01	-0.47	-0.10	0.56
	0.2571	0.0023	0.9650	0.0936	0.7248	0.0358
Germany	-0.27	0.82	0.37	-0.17	0.06	0.79
	<.0001	<.0001	<.0001	0.0013	0.2725	<.0001
Germany East	-0.27	-0.32	-0.38	-0.19	0.30	0.86
	0.0293	0.0078	0.0015	0.1201	0.0132	<.0001
Estonia	0.04	0.71	0.60	-0.59	-0.43	0.86
	0.9515	0.1797	0.2879	0.2924	0.4678	0.0643
Spain	0.03	0.12	-0.39	-0.05	-0.13	0.83
	0.8554	0.4093	0.0061	0.7520	0.3975	<.0001
Finland	0.17	0.34	0.27	0.97	0.86	0.90
	0.4900	0.1593	0.2568	<.0001	<.0001	<.0001
France	-0.15	0.20	0.13	-0.90	-0.59	0.84
	0.1487	0.0486	0.2214	<.0001	<.0001	<.0001
Greece	-0.25	0.13	0.44	0.32	-0.16	0.85
	0.0812	0.3586	0.0014	0.0234	0.2738	<.0001
Croatia	-0.08	0.38	0.35	-0.84	-0.69	0.93
	0.7243	0.0924	0.1156	<.0001	0.0006	<.0001
Hungary	0.39	0.04	-0.01	-0.25	-0.11	0.98
	0.0890	0.8542	0.9622	0.2960	0.6584	<.0001
Ireland	0.19	-0.95	-0.62	-0.26	0.02	0.73
	0.6522	0.0003	0.0998	0.5295	0.9617	0.0392
Italy	-0.73	-0.23	0.51	0.09	-0.71	0.56
	<.0001	0.0199	<.0001	0.3513	<.0001	<.0001
Lithuania	-0.30	-0.93	-0.39	0.55	0.34	0.48
	0.3941	<.0001	0.2611	0.0973	0.3377	0.1564
Latvia	-0.11	0.42	0.25	-0.24	-0.22	0.98
	0.8403	0.4116	0.6272	0.6421	0.6730	0.0007
Netherlands	0.49	0.58	0.55	-0.09	0.30	0.85
	0.0019	0.0002	0.0003	0.6050	0.0719	<.0001
Norway	0.86	0.84	0.87	0.94	0.87	0.97
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Poland	-0.19	-0.74	0.01	-0.06	0.31	0.46

	LON-LAT	LON-CAP	LON-DEC	LAT-CAP	LAT-CORE	CAP-CORE
	0.4836	0.0011	0.9834	0.8350	0.2378	0.0740
Portugal	0.21	0.53	0.28	0.75	0.04	0.57
	0.2874	0.0038	0.1566	<.0001	0.8580	0.0014
Romania	-0.16	-0.52	-0.18	0.80	0.27	0.63
	0.3162	0.0004	0.2635	<.0001	0.0801	<.0001
Russia	-0.03	0.97	0.83	-0.14	-0.14	0.88
	0.7930	<.0001	<.0001	0.2203	0.2247	<.0001
Sweden	0.52	0.04	0.36	0.46	0.65	0.92
	0.0153	0.8707	0.1059	0.0351	0.0014	<.0001
Slovenia	0.60	0.59	0.13	0.54	0.21	0.83
	0.0401	0.0437	0.6941	0.0683	0.5137	0.0008
Slovakia	0.53	1.00	0.65	0.61	0.28	0.62
	0.1721	<.0001	0.0839	0.1081	0.5002	0.1020
Turkey	-0.13	0.76	0.85	-0.16	-0.15	0.99
	0.2633	<.0001	<.0001	0.1469	0.1991	<.0001
United Kingdom	-0.43	-0.78	-0.57	0.86	0.55	0.78
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Ukraine	-0.30	0.26	-0.55	-0.64	0.02	0.50
	0.1224	0.1849	0.0029	0.0004	0.9367	0.0073

Table A3: Correlation between initial income (y_0) and other variables Note: P values below estimate. Number of observations as in Table A4.				
Country	LON	LAT	CAP	CORE
Austria	-0.30	0.04	0.22	0.26
	0.0782	0.8112	0.2072	0.1353
Belgium	-0.09	0.36	-0.35	-0.36
	0.5497	0.0190	0.0240	0.0195
Bulgaria	-0.15	-0.07	-0.28	-0.12
	0.4429	0.7246	0.1496	0.5508
Czech Republic	-0.23	0.11	-0.53	-0.25
	0.4320	0.7204	0.0534	0.3810
Germany	-0.21	-0.23	0.11	0.09
	<.0001	<.0001	0.0254	0.0713
Germany West	0.00	-0.14	0.01	0.00
	0.9711	0.0084	0.8366	0.9694
Germany East	0.01	0.07	-0.22	-0.18
	0.9251	0.5770	0.0704	0.1557
Spain	0.62	0.58	-0.05	-0.38
	<.0001	<.0001	0.7344	0.0080
Finland	-0.22	-0.39	-0.40	-0.07
	0.3553	0.0996	0.0886	0.7772
France	0.03	0.25	-0.35	-0.22
	0.7707	0.0142	0.0005	0.0306
Greece	0.11	-0.16	-0.37	-0.32
	0.4227	0.2719	0.0067	0.0217
Hungary	-0.33	-0.06	-0.36	-0.31
	0.1493	0.7987	0.1144	0.1896
Italy	-0.75	0.86	0.11	-0.66
	<.0001	<.0001	0.2957	<.0001
Netherlands	-0.31	-0.15	-0.15	-0.15
	0.0610	0.3729	0.3781	0.3790
Norway	-0.16	-0.24	-0.28	-0.20
	0.5125	0.3213	0.2396	0.4150
Poland	-0.50	0.08	0.03	-0.26
	0.0503	0.7806	0.9061	0.3247
Portugal	-0.57	-0.46	-0.53	-0.06
	0.0016	0.0146	0.0039	0.7432
Romania	-0.12	-0.19	-0.18	-0.17
	0.4591	0.2321	0.2487	0.2846
Russia	0.29	0.53	0.22	0.12
	0.0092	<.0001	0.0551	0.2833
Sweden	0.23	0.21	-0.07	0.14
	0.3259	0.3515	0.7634	0.5593
Turkey	-0.68	0.13	-0.51	-0.57
	<.0001	0.2551	<.0001	<.0001
United Kingdom	0.23	-0.13	-0.26	-0.13
	0.0087	0.1524	0.0039	0.1451
Ukraine	0.53	0.21	-0.36	-0.61
	0.0043	0.2944	0.0649	0.0008

Table A4: Country-level regressions on spatial determinants of regional growth in GDP per capita, Europe 1995-2005

- Equation A: Distance to capitals and economic centre points in logs (equation (2) in the main text).
- Equation B: Linear distances to capitals and economic centre points (equation (3) in the main text).
- Equation C: Linear distances to capitals and economic centre points and quadratic terms added (equation (4) in the main text).
- Regressions are for change between first and last years during 1995-2005 except for A2 and C2, which are for the last half of this period (2000-2005).
- Robust regressions are reported where they affect conclusions about the significance level of estimates. For robust regressions R^2 is reported.

Country	Equation		Const.	LON	LAT	ln(CAP)	ln(CORE)	CAP	CAP^2	CORE	$CORE^2$	Adj. R^2	N
Austria	C	Est.	36.9	0.09	-0.70					-0.0109	0.0000	0.19	35
		P values	0.0013	0.3985	0.0039					0.0552	0.0645		
Belgium	A	Est.	-11.0	-0.22	0.34	0.77	-1.22					0.28	42
		P values	0.5414	0.1046	0.3152	0.1043	0.0505						
Bulgaria	A	Est.	1.5	0.29	0.00	-0.63						-0.02	28
		P values	0.9467	0.3552	0.9953	0.1317							
	A2	Est.	44.5	0.26	-0.93	-0.89						0.16	28
		P values	0.0822	0.4647	0.1186	0.0611							
Czech Rep.	C	Est.	380.1	25.34	-15.03			-0.0410	-0.0026		0.0027	0.86	14
		P values	0.0104	0.0174	0.0142			<.0001	0.0212		0.0183		
Germany	A	Est.	5.1	0.21	-0.05	0.16	-0.40					0.12	414
		P values	0.0709	<.0001	0.1780	0.2930	0.0004						
West Germany	B	Est.	6.8	0.18	-0.10					-0.0023		0.13	348
		P values	0.0001	<.0001	0.0035					0.0002			
East Germany	A	Est.	4.0	-0.16	0.04	0.86	-0.88					0.08	66
		P values	0.6498	0.4076	0.7979	0.0063	0.0324						
	A robust	Est.	8.10	-0.09	-0.13	0.34	0.34					0.10	66
		P values	0.3184	0.6212	0.3493	0.2372	0.3614						
Spain	A	Est.	5.1	-0.03	-0.06		0.49					0.41	47
		P values	0.0009	0.2108	0.0609		<.0001						
	C2	Est.	3.6	-0.24	-0.01					0.0062	0.0000	0.50	47
		P values	0.0866	<.0001	0.7725					0.0627	0.1296		
Finland	C	Est.	2.1	-0.07	0.07					-0.0028		0.07	19

Country	Equation		Const.	LON	LAT	ln(CAP)	ln(CORE)	CAP	CAP^2	CORE	CORE^2	Adj. R^2	N
		P values	0.8556	0.4060	0.6932					0.2817			
France	A	Est.	8.5	-0.04	-0.10	-0.10	0.17					0.21	96
		P values	<.0001	0.0082	0.0002	0.0787	0.0995						
	A robust	Est.	7.9000	-0.0400	-0.0900	-0.0800	0.1600					0.20	96
		P values	<.0001	0.0090	0.0007	0.1706	0.1242						
Greece	B	Est.	-18.4	-0.50	0.89			-0.0429		0.0446		0.10	51
		P values	0.1734	0.0378	0.0360			0.0066		0.0058			
Croatia	A	Est.	93.7	-0.57	-1.75	-0.78	0.96					0.35	21
		P values	0.0054	0.1627	0.0096	0.1422	0.3702						
Hungary	B	Est.	40.4	0.17	-0.78			-0.1084		0.1020		0.43	20
		P values	0.4412	0.6255	0.5228			0.0673		0.0947			
Italy	B	Est.	5.6	0.13	-0.10			0.0018		-0.0021		0.16	99
		P values	0.0401	0.0022	0.0908			0.1010		0.0696			
Netherlands	C	Est.	-2714.9	-21.88	54.15			0.0175	0.0071	-0.0227	-0.0070	0.00	38
		P values	0.0711	0.0717	0.0706			0.1626	0.0712	0.1087	0.0727		
Norway	A	Est.	1.4	-0.05	0.14	-0.12	-0.28					-0.10	19
		P values	0.8430	0.5033	0.3079	0.4687	0.4044						
	A robust	Est.	11.70	0.07	-0.11	0.32	-0.39					0.17	19
		P values	0.1095	0.4253	0.4285	0.0673	0.2725						
Poland	A robust	Est.	8.0	-0.04	0.04	-0.55	-0.16					0.26	16
		P values	0.4184	0.6922	0.8038	0.0035	0.6052						
Portugal	C	Est.	-6522.3	65.81	180.84			0.0115	-0.0081		0.0080	0.03	28
		P values	0.0515	0.0502	0.0513			0.2427	0.0510		0.0511		
Romania	A	Est.	5.2	-0.59	0.50	-1.11	-0.13					0.26	42
		P values	0.7153	0.0007	0.1198	0.0039	0.8343						
Russia	A	Est.	20.4	0.01	0.05	-0.56	1.00					0.07	79
		P values	0.0008	0.3893	0.4401	0.0514	0.0708						
Sweden	A	Est.	5.0	0.01	-0.02	-0.25	0.18					0.15	21
		P values	0.0531	0.8740	0.7203	0.0328	0.3526						
Turkey	C	Est.	-258.8	5.58	2.10			-0.0139	0.0005	0.0134	-0.0005	0.27	79
		P values	0.0097	0.0147	0.0023			0.3301	0.0161	0.3375	0.0163		

Country	Equation		Const.	LON	LAT	ln(CAP)	ln(CORE)	CAP	CAP^2	CORE	$CORE^2$	Adj. R^2	N
UK	A	Est.	8.1	-0.10		-0.44	-0.27					0.08	126
		P values	<.0001	0.2761		0.0069	0.1151						
Ukraine	A	Est.	52.3	0.14	-0.75	-1.15	1.52					0.18	27
		P values	0.0371	0.3538	0.0749	0.0110	0.1775						
	A robust	Est.	39.9	0.1	-0.57	0.19	0.96					0.24	
		P values	0.0159	0.3344	0.044	0.5037	0.2125						

Table A5: Country-level regressions on spatial determinants of regional growth in GDP per capita, Europe 1995-2005.
OLS regressions including initial income.

- Equation A: Distance to capitals and economic centre points in logs (eguation (2) in the main text).
- Equation C: Linear distances to capitals and economic centre points and quadratic terms added (equation (4) in the main text).

Country	Eq.		Constant	ln(y0)	LON	LAT	ln(CAP)	ln(CORE)	CAP	CORE	CAP^2	$CORE^2$	Adj. R^2	N
Austria	C	Est.	40.3	-0.56	0.05	-0.64				-1.06		0.28	0.20	35
		P values	0.0007	0.2246	0.6031	0.0077				0.0594		0.0674		
Belgium	A	Est.	-8.6	0.37	-2.39	2.27	0.93	-1.36					0.27	42
		P values	0.6411	0.4636	0.0904	0.5493	0.0781	0.0392						
Bulgaria	A	Est.	40.7	-5.24	6.30	-0.12	-1.46						0.17	28
		P values	0.1156	0.0182	0.0514	0.9798	0.0066							
Czech Rep.	C	Est.	388.3	-0.18	258.05	-153.07			-4.23	0.58	-26.5	27.20	0.82	14
		P values	0.0260	0.8878	0.0376	0.0321			0.0044	0.7254	0.0440	0.0397		
	A	Est.	83.6	-4.39	1.97	-7.27	-1.26						0.71	
		P values	0.0347	0.1096	0.0933	0.0554	0.0044							
Germany	A	Est.	15.8	-0.73	0.88	-1.09	0.28	-0.45					0.16	414
		P values	<.0001	<.0001	0.0011	0.0004	0.0033	0.0002						
West Germany	A	Est.	16.0	-0.64	1.14	-1.28	0.16	-0.40					0.16	348
		P values	<.0001	<.0001	0.0137	<.0001	0.2159	0.0008						
East Germany	A	Est.	15.6	-1.19	-1.72	0.41	0.75	-0.87					0.11	66
		P values	0.1697	0.1118	0.3766	0.7742	0.0189	0.0333						
Spain	A	Est.	-0.2	0.72	-0.61	-1.02	-0.03	0.54					0.41	47
		P values	0.9700	0.2758	0.1459	0.0463	0.7266	<.0001						
	A	Est.	-0.9	0.82	-0.68	-1.08		0.52					0.42	
		P values	0.8371	0.1669	0.0637	0.0235		<.0001						
Finland	A	Est.	41.0	-3.16	-0.85	-0.35	-0.35						0.26	19
		P values	0.0127	0.0317	0.2333	0.7471	0.0669							
France	C	Est.	3.5	0.40	-0.55	-0.69				-0.12		0.03	0.24	96
		P values	0.1289	0.0791	0.0011	0.0075				0.2535		0.0583		
Greece	A	Est.	35.7	-2.74	-0.15	-1.35	-1.10	0.98					0.14	51

Country	Eq.		Constant	ln(y0)	LON	LAT	ln(CAP)	ln(CORE)	CAP	CORE	CAP^2	$CORE^2$	Adj. R^2	N
		P values	0.0549	0.0726	0.9305	0.4454	0.0158	0.2554						
Hungary	C	Est.	-24.4	0.07	-3.27	8.19			-5.01		1.74		0.47	20
		P values	0.4357	0.9620	0.1288	0.1417			0.0219		0.0478			
Italy	C	Est.	11.2	-1.51	0.67	1.38				-0.40		0.05	0.20	99
		P values	0.0128	0.0075	0.0702	0.0499				0.0108		0.0229		
Netherlands	C	Est.	-2836.1	0.56	-227.57	564.48			1.83	-2.07	73.90	-73.20	-0.02	38
		P values	0.0631	0.4387	0.0645	0.0631			0.1494	0.1511	0.0637	0.0647		
Norway	A	Est.	-6.5	0.94	-0.30	1.09		-0.40					-0.06	19
		P values	0.5813	0.3137	0.6660	0.3376		0.1961						
Poland	A	Est.	17.4	-0.82	-1.22	0.37	-0.62	-0.16					0.43	16
		P values	0.5481	0.7452	0.4681	0.8077	0.0338	0.5215						
	A	Est.	19.6	-0.99	-1.39	0.15	-0.65						0.46	
		P values	0.4846	0.6875	0.3947	0.9168	0.0196							
Portugal	A	Est.	30.3	-1.72	1.45	-2.05	-0.17						0.03	28
		P values	0.0204	0.0859	0.7276	0.2496	0.4426							
Romania	A	Est.	-7.4	1.34	-5.40	4.82	-0.97	-0.02					0.26	42
		P values	0.7126	0.3647	0.0030	0.1394	0.0165	0.9727						
	A	Est.	-7.5	1.34	-5.39	4.81	-0.98						0.28	
		P values	0.6941	0.3462	0.0026	0.1338	0.0144							
Russia	C	Est.	14.8	1.41	-0.55	0.06			0.20	-0.04	-0.01	0.01	0.10	79
		P values	0.0307	0.1361	0.2641	0.9465			0.0938	0.7193	0.1225	0.0480		
Sweden	A	Est.	26.1	-2.23	-0.23	0.02	-0.40	0.33					0.13	21
		P values	0.3279	0.4251	0.8012	0.9702	0.0765	0.2306						
Turkey	C	Est.	-196.5	-1.17	44.15	17.10			-1.23	1.31	4.33	-4.32	0.29	79
		P values	0.0371	0.0680	0.0399	0.0081			0.3611	0.3188	0.0400	0.0397		
UK	C	Est.	-4.5	0.26	-2.31	1.49			-1.00		0.08		0.09	126
		P values	0.6594	0.6152	0.1278	0.4477			0.0113		0.0593			
	C	Est.	12.0	0.59	0.53	-2.30				-0.85		0.19	0.07	
		P values	0.1027	0.2375	0.5512	0.0166				0.0429		0.0483		
Ukraine	C	Est.	-1.8	7.88	-3.48	-4.01			-2.39		0.44		0.27	27
		P values	0.9520	0.0435	0.0969	0.3873			0.0341		0.0068			

Table A6: Country-level regressions on spatial determinants of regional change in population, Europe 1995-2005

Dependent variable: Population change 1995-2005, or closest available years.

	Constant term		Longitude		Latitude		Dist. to capital		Dist. to ec. centre		Initial per capita income				Adj. R^2	N
	Const.		LON		LAT		ln(CAP)		ln(CORE)		y_0		$\ln(y_0)$			
	Est.	P value	Est.	P value	Est.	P value	Est.	P value	Est.	P value	Est.	P value	Est.	P value		
Austria	1.792	0.8431	-0.184	0.0073	0.048	0.7918	-0.258	0.0351							0.14	35
	-6.077	0.5618	-0.111	0.1771	0.061	0.7344	-0.153	0.2679					0.589	0.1573	0.17	
Belgium	-4.279	0.5014	0.192	0.0003	0.072	0.5490	-0.211	0.2047	0.248	0.2496					0.30	42
	-0.101	0.9860	0.179	0.0005	-0.008	0.9457	-0.006	0.9151			0.006	0.5507			0.28	
Bulgaria	-2.017	0.7867	0.298	0.0084	-0.106	0.5446	-0.439	0.0037							0.24	28
	-7.771	0.4167	0.248	0.0428	-0.104	0.5533	-0.317	0.0980					0.768	0.3334	0.24	
Czech Rep.	-0.923	0.8422	-0.059	0.0687	0.031	0.7289	0.043	0.2406							0.14	14
	6.206	0.0574	-0.033	0.0771	-0.062	0.2601	-0.233	0.0033			-0.160	0.0008			0.74	
W. Germany	2.252	0.0145	-0.053	0.0332	-0.064	0.0002	0.032	0.6360	0.288	<.0001					0.09	348
	2.961	0.0022	-0.069	0.0066	-0.060	0.0007	0.180	0.0030			-0.003	0.4207			0.04	
E. Germany	3.751	0.5756	-0.331	0.0303	0.074	0.5036	-0.110	0.6411	-0.699	0.0270					0.16	66
	7.472	0.2748	-0.319	0.0409	-0.006	0.9550	-0.572	0.0019			-0.066	0.1406			0.13	
Spain	8.968	0.0002	0.178	<.0001	-0.159	0.0017	-0.040	0.7472	-0.187	0.3302					0.43	47
	-9.668	0.1847	0.075	0.1892	-0.296	0.0001	0.022	0.8432					2.381	0.0133	0.50	
Finland	2.005	0.7442	-0.037	0.4985	0.022	0.8493	-0.234	0.0494	-0.246	0.4396					0.37	19
	-6.513	0.5240	-0.050	0.3127	-0.050	0.5099	-0.119	0.3465					1.198	0.2143	0.40	
France	3.443	0.0143	-0.017	0.2161	-0.092	0.0001	-0.106	0.0320	0.347	0.0001					0.32	96
	-5.404	0.0912	-0.026	0.0657	-0.090	0.0002	0.113	0.0649					0.990	0.0002	0.32	
Greece	0.532	0.7428	-0.009	0.7713	-0.032	0.3373	-0.124	0.1488	0.347	0.0178					0.08	51
	0.068	0.9826	0.012	0.6967	-0.042	0.2413	0.032	0.6422					0.146	0.5807	-0.03	
Hungary	-8.339	0.2873	-0.045	0.4845	0.248	0.1589	0.661	0.0010	-1.202	0.0014					0.42	20
	-1.306	0.8974	-0.093	0.2821	0.107	0.6157	-0.150	0.3268			-0.207	0.0426			0.12	
Italy	-1.199	0.3294	-0.006	0.7720	0.058	0.0086	-0.011	0.8357	-0.156	0.0182					0.30	99
	-11.766	<.0001	0.028	0.1850	-0.012	0.6553	-0.018	0.6880					1.270	<.0001	0.39	
Netherlands	-1.299	0.9156	0.129	0.4874	0.040	0.8691	-0.066	0.6780	-0.166	0.3274					-0.05	38

	Constant term		Longitude		Latitude		Dist. to capital		Dist. to ec. centre		Initial per capita income					
	Const.		LON		LAT		ln(CAP)		ln(CORE)		y_0		$\ln(y_0)$		Adj. R^2	N
	Est.	P value	Est.	P value	Est.	P value	Est.	P value	Est.	P value	Est.	P value	Est.	P value		
	1.221	0.9219	0.118	0.5338	-0.012	0.9619	-0.140	0.3611			-0.009	0.8013			-0.08	
Norway	6.483	0.0601	0.006	0.8790	-0.109	0.0925	-0.141	0.0887	0.250	0.1297					0.50	19
	0.233	0.9733	0.040	0.3476	-0.140	0.0762	0.020	0.8765					0.847	0.2914	0.46	
Poland	-1.624	0.5188	-0.007	0.7867	0.027	0.5399	-0.062	0.2079	0.105	0.1887					0.02	16
	-0.986	0.7914	-0.018	0.7323	0.035	0.4679	-0.071	0.4035			-0.047	0.7270			-0.14	
Portugal	-8.140	0.0471	-1.121	<.0001	-0.064	0.4772	0.225	0.0624	0.144	0.3371					0.49	28
	-8.036	0.0500	-1.010	0.0001	-0.046	0.6156	0.287	0.0357			0.052	0.3752			0.48	
Romania	-7.175	0.0003	0.070	0.0014	0.112	0.0084	-0.033	0.4667							0.30	42
	-7.506	0.0002	0.078	0.0007	0.106	0.0120	-0.002	0.9677			0.052	0.2136			0.31	
Russia	8.761	<.0001	-0.011	0.0160	-0.127	<.0001	-0.053	0.5794	-0.218	0.2369					0.43	79
	8.376	<.0001	-0.018	<.0001	-0.158	<.0001	-0.021	0.8178			0.084	0.0045			0.48	
Sweden	4.494	0.0076	-0.005	0.9183	-0.060	0.0703	-0.171	0.0101							0.44	21
	4.272	0.0215	-0.001	0.9885	-0.065	0.0890	-0.151	0.1043			0.021	0.7533			0.41	
Turkey	19.458	<.0001	-0.069	0.1483	-0.466	<.0001	-0.249	0.4506	0.577	0.3226					0.20	79
	19.745	<.0001	0.034	0.3680	-0.544	<.0001	0.051	0.7715			0.263	0.0078			0.32	
UK	3.828	0.0180	-0.008	0.8146	-0.061	0.0808	-0.159	0.0243	0.086	0.1850					0.15	126
	4.027	0.0154	-0.013	0.7147	-0.065	0.0820	-0.106	0.2518			0.010	0.3123			0.15	
Ukraine	2.478	0.2183	-0.047	0.0013	-0.050	0.1456	-0.122	0.0018	0.213	0.0284					0.59	27
	4.447	0.0445	-0.070	0.0007	-0.062	0.1243	-0.079	0.0815			0.225	0.4193			0.51	