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Abstract

This paper develops a multi regional growth model of the second generation type with horizontal and vertical innovations. Technology goods are tradable between regions, creating a regional analogy of the weak scale effect introduced by Jones (2004). Per capita production in one region is a function of the weighted population sizes of trading partner regions. Thus the scale of partner regions diffuses between them. This result is empirically tested using data on the NUTS regions of the EU 15. A highly significant relationship is found between per capita GDP and an interregional scale variable, defined as a weighted sum of the populations of all EU 15 regions.

Keywords: Regional growth, scale effects, interregional trade
JEL Classification Number: R12, O33, O52

1 Introduction

Scale effects play an important role in the new trade theory, the new economic geography and endogenous growth theory. In the new trade theory (Krugman 1980, 1981) it is increasing returns to scale in a framework of monopolistic competition which gives the motivation for trade between different countries. The new economic geography (e.g. Krugman 1991, Fujita et al. 1999) is concerned with scale effects and agglomeration in space and finally scale effects are an important outcome of endogenous growth models (e.g. Jones 1995 or Young 1998), for a recent discussion about scale effects in growth models see Jones (2004).

Scale effects are thus an important topic and a target both for theoretical and empirical work in the economic literature. One perspective, the literature has taken by looking at scale effects, is the regional level of aggregation. This aggregation level is the starting point for this contribution to the literature which is both theoretical and empirical. The aim of this paper is to create a regional theory taking account of the ideas in the research areas mentioned in the above paragraph and by the same time to elaborate on the definition of scale. One common feature of the studies dealing with scale effects is an individualistic perspective, i.e. the measure of scale utilitized by several authors is tied to the economic unit under consideration. The argument of this paper is that not only the scale of one region is the important figure but also the scale of the regions with which economic interactions take place. As an application for the developed theory, the distribution of labor productivity or per capita production in European regions is chosen. This is done in order to compare the outcome of the spatial model to be presented below with the existing literature and to highlight the importance of the correct measure of scale. The model below uses elements from endogenous growth and the new trade theory to obtain a spatial model explaining per capita production or alternatively labor productivity on the regional level.

One strand of the literature directly relevant to this paper is concerned with convergence of income or per capita production between countries and regions. There can be found many empirical results in the literature. Maurseth (2001) reviews the theoretical and empirical literature on income disparities and convergence between countries and regions. He concludes that there are many theoretical reasons why income levels should and should not converge. While the neo-classical growth theory supports convergence this might not take place in models of the new growth theory, depending on the spatial patterns of knowledge spillovers. More than the new growth theory does the new economic geography take account of these spatial patterns and therefore finds reasons for disparities in numerous models. A stylized fact seems to be that conditional convergence, after controlling for country or region specific effects, in income per capita took place at an annual rate of roughly 2% per annum between countries, European regions and US states up to the 1980s and slowed down afterwards[1]. There are several studies concluding that convergence failed to take place after the 1980s in the European regions (e.g. Neven and Goyette 1995, Fagerberg and Verspagen 1996; Quah 1996a and 1996b finds somehow opposite results). More recent studies as LeGallo (2004), Gardiner et al. (2004) also find evidence for low convergence in recent decades between European regions. Gianetti (2002) offers a theoretical explanation why income per capita may converge at the country level but does not so at the regional level. The mechanism behind his model is that countries consist of technologically heterogenous regions which force per capita income to be different within countries at the regional level but to converge between countries at the aggregate level. He finds empirical support for this hypothesis by looking at regional European data. Taking together this literature can be seen as supportive for the thesis that absolute convergence of per capita production is not likely to take place and this is as such one outcome of the theoretical model in this paper. It is merely spatial heterogeneity which prevents regions from achieving the same per capita production.

One key argument of this paper is that economic size is an important variable in explaining per capita production on the regional level. This observation is in line with previous findings in the literature. One influential study is Ciccone and Hall (1996) who try to find empirical evidence for their theoretical model with increasing

[1]See Sala-i-Martin (1996).

returns to scale. The implied hypothesis is that economically larger regions, i.e. regions with a higher density of production factors, ceteris paribus, have a higher labor productivity. Ciccone and Hall (1996) estimate a relationship between productivity and economic density for the US states and find strong support for their theory.

Fingleton (2001) uses a similar theoretical model as Ciccone and Hall (1996) to motivate his empirical study. He uses data for European regions and tries to explain the development of productivity in the manufacturing sector by the development among other factors of the population density in the different regions. He uses a spatial econometric model to account for spatial productivity effects and spatially correlated technology shocks. Fingleton (2001) finds reasonable evidence that a region's population density is a determining factor for manufacturing productivity in that region.

Ciccone (2002) is also concerned with labor productivity in Europe. He analyses the relationship between labor productivity and population density for a finer set of European regions than previously examined in Fingleton (2001). The theoretical argument for this relationship is again the model of Ciccone and Hall (1996). Ciccone (2002) obtains similar results for this relationship as previously found by Ciccone and Hall (1996) for the US.

One thing that all the previously mentioned studies have in common is a theoretical relationship between per capita production or labor productivity in a specific region and the population density of that particular region. Some of the studies account for spatial effects through the specification of the empirical model. The present paper aims to add to the literature by introducing a new perspective for looking at productivity or per capita production by directly introducing spatial effects into the theoretical model. This is done by using an endogenous growth model and extending this by regional trade. This links regions with each other and yields a relationship between per capita production and the scale of one region. Rather than measuring the scale of one region simply by its population, in this context the scale of one region means something different. Productivity is determined by the available technology and technology created by one economic region is by itself determined by the extend of the work force, a general outcome of endogenous growth models. Therefore by scale of one region the access to technology provided by the region itself and all other economic regions is meant. Through the link between technology and the extend of the work force this gives rise to a scale variable specific to each economic region under investigation composed of the extend of the work forces of all regions, an interregional scale variable. This results in a spatial model linking per capita production and the effective scale of one region which serves as a starting point for the empirical analysis.

Concerning the link to the existing empirical literature it must be noted that this paper borrows to some extend from the literature concerned with technology diffusion. Studies trying to measure knowledge or technology diffusion generally construct variables that should measure world wide available technology. This is usually done by computing R&D stocks from historical investments in R&D or by historical patent behavior of sectors and countries. One influential study is Coe and Helpman (1995) who explain total factor productivity for the OECD countries and Israel with home and foreign R&D stocks. The foreign R&D stock is thereby a weighted sum of country specific R&D stocks. As weights Coe and Helpman (1995) use bilateral import shares between the home and foreign countries to compute the aggregated foreign R&D stock.

There is a number of studies building on the work of Coe and Helpman (1995) trying to refine their methodology (for a survey of the literature see Keller 2001a). Most of this literature is working on finding better weights as e.g. in Lichtenberg und Pottelsberghe de la Potterie (1996) where FDI is used to obtain weights or in Xu and Wang (1999) where bilateral import shares in capital intensive goods are used. Xu (2000) uses data on multinational enterprises to construct weights. Keller (1999) uses the original Coe and Helpman (1995) methodology but applies it to different sectors of the G7 countries instead on the whole economy. Keller (2002b) uses a technology flow matrix to account for technology diffusion between sectors and bilateral industry specific import shares for diffusion between countries in order to analyze total factor productivity on the sector level for the OECD countries.

The empirical analysis in this paper is therefore to some extend related to the above cited papers concerning technology diffusion because for the purpose of measuring an interregional scale variable. The main difference is that this paper reduces technology to its model oriented origin, the extend of the work force. Articles dealing with technology diffusion generally do not go that far, but try to measure technology by using expenditures for technological purposes.

In the empirical section of this paper data on production and the labor force of European regions are used. In particular the relationship between per capita GDP and an interregional scale variable for 221 European NUTS (Nomenclature of Territorial Units for Statistics) regions in the EU 15 [2] is estimated. The interregional scale variable is a weighted sum of the work forces of all regions. In construction of this scale variable for each of the 221 regions the inverse great circle distance from the region under consideration to all other regions is used. Finally, since the regional work force is probably an endogenous variable, it is instrumented for by regional geographical characteristics. The result of the estimation is that the interregional scale variable is a highly significant determinant of per capita GDP with an estimated elasticity of 0.45.

The paper is organized as follows: Section 2 sets up the theoretical regional growth model yielding the motivation for the empirical section. Section 3 deals with the data and estimation issues and presents the results for the relationship between interregional scale and per capita production. Concluding remarks can be found in the last section.

2 The Model

This section developes a multi regional endogenous growth model with trade friction to highlight the importance of scale effects in explaining labor productivity. Production takes place in several stages: One sector is engaged in producing final output using labor and intermediate input factors. The second sector is producing

[2]These are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Luxemburg, the Netherlands, Portugal, Spain, Sweden and the UK.

these intermediate input factors with an increasing returns to scale technology. Before producing the intermediate input factors, firms have to incur quasi fixed R&D costs. Production then takes place at constant marginal costs which are caused by rented capital goods required to produce intermediate inputs.

The model employs the production technology familiar from Romer (1986, 1987) and combines it with the growth mechanism of Young (1998) to obtain a multi regional growth model. At the first sight the model seems to be similar to the model in Spolaore and Wacziarg (2005) but there are important differences. First Spolaore and Wacziarg (2005) do not account for steady state growth in there model. This is due to their assumption that technology is only given by the horizontal differentiation of production as in the first generation growth models (Romer 1986, 1987 or Grossman and Helpman 1991). Second, and more important, they assume in a multi country and multi region setup capital immobility between countries besides trade in goods between regions and countries. This assumption merely serves as a capacity constraint to obtain a result for level of technology. In the model to be presented below capital is allowed to move freely between regions, the necessary restriction to yield a solution for the level of technology is instead taken from the endogenous growth mechanism of the Young (1998) model which adds another dimension of growth through vertical innovations to the model. This gives a set of more economic plausible assumptions for a multi regional growth model.

Regions in this economic environment are assumed to be heterogenous with respect to several factors. First it is assumed that every region is endowed with a given labor supply. Second in every region firms producing intermediate input factors can enter the market. Finally, what is a distinct feature of the model with respect to the set-up in Ciccone and Hall (1996), the intermediate input factors can be traded between regions. Therefore every region can potentially access all variants of intermediate input factors. Nevertheless there exist transport costs in intermediate input factors modelled as in Samuelson (1954) as "iceberg" costs. For one unit of a particular intermediate input factor originating from region i to reach final good producers in region j $\tau_{i,j} > 1$ units have to be produced and shipped.

Time in the model is discrete. To simplify the notation the time subscript is suppressed where no confusion can occur, variables without time subscript correspond to the current time period t.

Households: The economic environment is assumed to admit a representative agent who maximizes lifetime utility given by

$$U = \sum_{t=0}^{\infty} \frac{\ln c_t}{(1+\rho)^t}, \tag{1}$$

where c_t is consumption in period t and ρ is the rate of time preference. Maximizing (1) with respect to an intertemporal budget constraint gives the well known optimality condition

$$\frac{c_{t+1}}{c_t} = \frac{1+r_t}{1+\rho}, \tag{2}$$

where r_t is the net interest rate of the economy. Households own the total capital stock. Capital goods can be linearly produced from final output with unit productivity and are traded freely between regions. The rate of depreciation on capital goods is denoted by δ. Full financial integration is assumed with an identical interest rate for all regions.

Production: Production in this multi regional context takes explicitly account of spatial interaction between regions. The general M region case is considered and production of final output in region i in time period t is given by

$$Y_i = L_{p,i}^{\alpha} \int_0^N (\lambda_j x_j)^{1-\alpha} dj. \tag{3}$$

$L_{p,i}$ is labor employed in production in region i and x_j denotes the quantity of the jth variant of an intermediate input factor used in the production of the final good Y_i and λ_j is its quality level. The total labor supply L_i to region i is given exogenously and it will become obvious below how $L_{p,i}$ is related to L_i. With this production function it is clear that productivity is determined by the available set of intermediate input factors N and their quality levels, i.e. economic growth can take place through vertical and horizontal technical innovations.

Growth: In order to solve the model one has to compute the set of available intermediate input factors. The assumptions concerning these are very similar as in Young (1998) and are as follows. Before entering the market for intermediate input factors a potential producer of the jth variant has first to decide every time period on the quality level. The chosen quality level determines the quasi fixed R&D costs in terms of labor according to the following real cost function

$$F_j = \begin{cases} f e^{\mu \lambda_j / \bar{\lambda}_{t-1}} & \text{if } \lambda_{j,t} \geq \bar{\lambda}_{t-1}, \\ f e^{\mu} & \text{otherwise,} \end{cases} \tag{4}$$

with $\bar{\lambda}_{t-1} = \frac{1}{N_{t-1}} \int_0^{N_{t-1}} \lambda_{j,t-1} dj$ as the average quality level in period $t-1$.

The optimal choice of λ_j is the quality level that maximizes the profits for the producer of one particular variant of the intermediate input factors. Once the quasi fixed costs for R&D have been incurred the units of the particular intermediate input factors can be produced from capital goods with a linear production technology with unit productivity.

The particular intermediate input factor producer is faced with demand from all M regions including region i where his production is located. Given the production function (3), the demand function the producer j in region i is faced with is given by

$$x_j^d = \sum_{k=1}^{M} \left(\frac{\chi_{ik}}{p_j} \right)^{-\frac{1}{\alpha}} (1-\alpha)^{\frac{1}{\alpha}} \lambda_{j,t}^{\frac{1-\alpha}{\alpha}} L_{p,k}, \tag{5}$$

where χ_{ik} is the nominal price a producer from region i charges in region k, p_k is the price of the final good in region k. This demand function can be obtained by aggregating the single demand functions derived from marginal product conditions in the M different regions. Since capital goods have the same price in all regions and are produced from final output linearly, $p_k = p$ for all j, p is normalized to one in the following.

The individual intermediate input factor producer is assumed to possess some market power which allows him to set a price as a mark-up γ on marginal costs. Therefore for one unit of his product he charges the price $\chi_{ik} = \gamma\tau_{ik}(r+\delta)$.

The remaining problem of the producer in i of the jth variant of the intermediate input factors is to choose λ_j in order to maximize

$$\pi_{i,j} = (\gamma-1)\gamma^{-\frac{1}{\alpha}} \sum_{k=1}^{M} \left(\tau_{ik}(r+\delta)\right)^{-\frac{1-\alpha}{\alpha}} (1-\alpha)^{\frac{1}{\alpha}} \lambda_j^{\frac{1-\alpha}{\alpha}} L_{p,k} - w_i F_j. \tag{6}$$

Setting the derivative of (6) with respect to λ_j equal to zero and noting that entry into the market of intermediate input factors occurs until profits are driven down to zero, gives as the optimality condition

$$\frac{\lambda_j}{\bar{\lambda}_{t-1}} = \frac{1}{\mu}\frac{1-\alpha}{\alpha}, \tag{7}$$

which is very similar to the result in Young (1998). The optimality condition shows that all intermediate input factor producers chose the same quality level in period t given the average quality level in time period $t-1$, i.e. $\lambda_j = \bar{\lambda}$, and that the average quality level grows with a constant rate from period to period.

As mentioned before producers enter the market for intermediate input factors as long as there are profits to be earned. Thus equilibrium requires the profits to equal zero in all of the M regions of the economy[3]. This exactly gives M equations that can be solved for the M unknowns N_i, $i = 1, ..., M$, which give the number of intermediate input factors produced in region i. To find the solution one first has to elaborate a little bit more on the R&D costs. These are costs in terms of labor and in this model labor earns the same wage rate regardless whether it is employed in production of the final good or R&D. This means that the wage rate, the intermediate input producer has to pay for workers employed in R&D, is equal to the marginal product of workers employed in production of the final good, i.e.

[3] In Spolaore and Wacziarg (2005) this assumption is replaced by a capital shortage constraint due capital immobility. In an open economy context this however unrealistic.

$\frac{w_i}{p} = \alpha \frac{Y_i}{L_{p,i}}$.

Using the marginal product condition for the demand of intermediate input factors and integrating over all available variants in the production function (3) gives the reduced form

$$Y_i = (1-\alpha)^{\frac{1-\alpha}{\alpha}} \gamma^{-\frac{1-\alpha}{\alpha}} \bar{\lambda}^{\frac{1-\alpha}{\alpha}} (r+\delta)^{-\frac{1-\alpha}{\alpha}} L_{p,i} \left(\sum_{k=1}^{M} N_k \tau_{ik}^{-\frac{1-\alpha}{\alpha}} \right), \tag{8}$$

and therefore the real wage rate in region i as

$$\frac{w_i}{p} = \alpha (1-\alpha)^{\frac{1-\alpha}{\alpha}} \gamma^{-\frac{1-\alpha}{\alpha}} \bar{\lambda}^{\frac{1-\alpha}{\alpha}} (r_t+\delta)^{-\frac{1-\alpha}{\alpha}} \left(\sum_{j=1}^{M} N_j \tau_{ij}^{-\frac{1-\alpha}{\alpha}} \right), \tag{9}$$

Together with this last result the zero profit conditions for all M region imply

$$N_i = \frac{1-\alpha}{\alpha} \frac{\gamma-1}{\gamma} f^{-1} e^{-\frac{1-\alpha}{\alpha}} L_{p,i}, \tag{10}$$

Labor is divided into production and R&D. With (10) the number of workers engaged in R&D, $L_{r,i}$ in region i is simply

$$L_{r,i} = N_i f e^{\frac{1-\alpha}{\alpha}} = \frac{1-\alpha}{\alpha} \frac{\gamma-1}{\gamma} L_{p,i}, \tag{11}$$

and therefore with $L_{p,i} + L_{r,i} = L_i$

$$L_{p,i} = \frac{\alpha\gamma}{\gamma+\alpha-1} L_i, \tag{12}$$

$$L_{r,i} = \frac{(1-\alpha)(\gamma-1)}{\gamma+\alpha-1} L_i. \tag{13}$$

With the results in (3), (8), (10) and (12) it is now easy to compute per capita production in reduced form

$$\frac{Y_i}{L_i} = c_1 \bar{\lambda}^{\frac{1-\alpha}{\alpha}} (r_t+\delta)^{-\frac{1-\alpha}{\alpha}} \left(\sum_{j=1}^{M} \tau_{ij}^{-\frac{1-\alpha}{\alpha}} L_j \right). \tag{14}$$

$$c_1 = (1-\alpha)^{\frac{1-\alpha}{\alpha}} \gamma^{-\frac{1-\alpha}{\alpha}} f^{-1} e^{-\frac{1-\alpha}{\alpha}} \left(\frac{\alpha\gamma}{\alpha+\gamma-1} \right)^2 \frac{\gamma-1}{\gamma} \frac{1-\alpha}{\alpha}.$$

This equation shows the relationship between per capita production and scale. The relevant figure determining scale is an interregional scale variable given by a weighted sum of work forces of all participating regions. The weights are given by functions in the transport costs. The mechanism behind this is that every region contributes to the available level of technology by providing intermediate input factors with a specific level of quality. Although the level of quality is identical in all regions, the other determinant of technology, the available set of intermediate input factors, is more heterogeneous. Each region is able to produce a set of these factors which extend is directly proportional to its work force. Because of trade frictions the effective available set of intermediates is different for every region. Therefore per capita production or labor productivity is determined besides the quality level $\bar{\lambda}$ by the scale of a region given by its access to other regions. The relevant scale variable for one regional unit is thus not only its own size but a weighted sum of population sizes of regions with which trade takes place. This is also an open economy analogy to the terminology "weak scale effect" introduced in Jones (2004), the implication of second generation growth models that larger economies have a higher per capita production than smaller.

The strong result in (14) is that the elasticity of per capita production with respect to the interregional scale variable is equal to one. In the empirical section below a more general specification with an elasticity to be estimated will be employed.

Balanced Growth Path: Since the populations of the different regions are assumed to be stationary, the growth rate of production of final goods in every region is determined by growth of the quality level of intermediate input factors. The reduced form of the production function (3) is given by, using (3), (8), (10) and (12),

$$\begin{aligned} Y_i &= c_1 \bar{\lambda}^{\frac{1-\alpha}{\alpha}} (r_t + \delta)^{-\frac{1-\alpha}{\alpha}} L_i \left(\sum_{j=1}^{M} \tau_{ij}^{-\frac{1-\alpha}{\alpha}} L_j \right). \qquad (15) \\ c_1 &= (1-\alpha)^{\frac{1-\alpha}{\alpha}} \gamma^{-\frac{1-\alpha}{\alpha}} f^{-1} e^{-\frac{1-\alpha}{\alpha}} \times \\ &\quad \times \left(\frac{\alpha\gamma}{\alpha+\gamma-1} \right)^2 \frac{\gamma-1}{\gamma} \frac{1-\alpha}{\alpha}. \end{aligned}$$

On the balanced growth rate final output and consumption grow at the same rate determined by the optimality condition of the households

$$\frac{c_{t+1}}{c_t} = \frac{Y_{i,t+1}}{Y_t} = \frac{1+r_t}{1+\rho} = \left(\frac{\bar{\lambda}_{t+1}}{\bar{\lambda}_t}\right)^{\frac{1-\alpha}{\alpha}} \left(\frac{r_{t+1}+\delta}{r_t+\delta}\right)^{-\frac{1-\alpha}{\alpha}}. \tag{16}$$

With a constant interest rate and the optimality condition (7) this gives

$$\frac{c_{t+1}}{c_t} = \left(\frac{1}{\mu}\frac{1-\alpha}{\alpha}\right)^{\frac{1-\alpha}{\alpha}} \tag{17}$$

and (18)

$$r = \left(\frac{1}{\mu}\frac{1-\alpha}{\alpha}\right)^{\frac{1-\alpha}{\alpha}} (1+\rho) - 1. \tag{19}$$

The zero profit condition for producers of intermediate input factors also implies that trade in intermediate input factors between regions is always balanced. Equilibrium in the regional markets for the final good implies that trade in final and capital goods is balanced as well. It can be shown that the model has the usual saddle path properties.

3 Diffusion of Scale in the EU 15

This section empirically tests the theoretical results of the previous section, in particular equation (14) which gives a relationship between regional per capita production and an interregional scale variable. The regions under consideration in this section are European regions of the EU 15 (NUTS regions). Equilibrium in goods markets requires that the economy jumps immediately on the balanced growth path.

Data: The regional units under consideration are the NUTS2 regions of the EU 15 in the year 2002. For the EU 15 there are 214 NUTS2 regions. One exception is Denmark where NUTS2 regions are not defined. Therefore the 15 NUTS3 regions were used in the case of Denmark. The analysis below applies to the core regions of the EU 15, for France the 4 overseas Departments were excluded as well the regions Azores and Madeira in the case of Portugal and the exclaves of Spain on the

African continent Ceuta and Melilla. These peripheral regions are often subject to special economic conditions like tax exemptions which are not part of the theoretical analysis of section 2. It seems therefore reasonable to work with the remaining 221 regions.

Per capita production is obtained from GDP measured at purchasing power parity divided by the regional population with the age from 16 to 64 years. These data were obtained from the REGIO database of Eurostat. In the analysis below trade costs are proxied by geographical distance between regions. For this the great circle distances between the geographical centroids of the NUTS regions were computed.

Estimation Issues: The empirical model is motivated by equation (14) of the theoretical section and is specified as

$$\ln\left(\frac{Y_i}{L_i}\right) = \alpha_0 + \alpha_1 \ln\left(\sum_{j=1}^{221} \omega_{ij} L_j\right) + \sum_{h=1}^{14} \delta_h d_h + \varepsilon_i. \tag{20}$$

In (20) the interregional scale variable is a weighted sum of regional work forces. The weights ω_{ij} are proxied by the inverse great circle distance between the regional centroids as is often done in spatial econometrics (see e.g. Anselin 1988). For the weights ω_{ii} one half of the square root of the regions land area is used to proxy for the average distance within a region. Finally d_h are country dummies defined for all countries except Luxemburg which serves as the base country.

It is very likely that regional population in the age from 16 to 64 is an endogenous variable. Regions with a high GDP per capita and therefore high wages might attract workers from other regions. There might be also externalities that affect the population of neighboring regions. To circumvent this problem the regional population in working age is instrumented for by geographical characteristics. In a fist step regression the regional population in working age is regressed on the regional land area, the squared area, area to the power of three and country dummies (table 1 in the appendix), the predicted values from this regression were then used to compute the scale variable in (20).

As this is essentially a spatial economic analysis with geographical units, the residuals of the model (20) might be spatially autocorrelated. Standard OLS estimates of the parameters are in this case still consistent but the usual estimator for the covariance matrix of the coefficient is not. To make valid inferences about the parameters, standard errors are computed by the estimator proposed by Conley (1999) which accounts for spatial autocorrelation[4]. Additional standard errors using the White estimator are reported as well.

Finally it must be noted that there might be variables other than those in (20) that influence per capita GDP. To justify it can be argued that, first, equation (14) which serves the motivation for the empirical analysis is a reduced form and that the empirical model tries to estimate this reduced form after other endogenous factors have adjusted to the scale variable. Second, there are other factors not accounted for in the theoretical model, so that the last argument might not apply for these, but these variables might of course be endogenous and adding them to the empirical model without using suitable instruments is problematic. And third, it is very unlikely that the interregional scale variable is correlated with other economic variables, so that omitting them might not be that problematic.

Results: Table 2 gives the results of the estimation of model (20). Of great importance is the estimate of the scale elasticity which takes a value of 0.45 and is highly significant meaning that an interregional defined scale variable is an important determinant of per capita production. This result can also be seen as support for the theoretical result of endogenous growth models to create weak scale effects. Concerning the in the introduction cited literature on convergence in per capita production or income, this result gives an argument why total convergence might not take place. Since geographical location and thereby access to the scale of other regions is heterogeneous it is not to be expected that per capita production can converge. This can be seen from figures 1 and 2 showing the distribution of actual and by the model predicted GDP per capita in the EU 15 regions.

Fingleton (2001) uses total manufacturing output in one particular region as the scale

[4]For this the Stata files scale.ado and x_ols.ado provided by T.G. Conley were used.

variable. His estimates for the elasticity with respect to scale are somewhat higher ranging from 0.59 to 0.80. Ciccone (2002) uses population density in one particular region as the scale variable to explain production per capita. The elasticities he obtains for the European regions are about 0.05. However these results can not be directly compared with the ones in this paper since the definition of scale is here a different one, i.e. it takes trade into account whereas this is not included in the studies of Fingleton (2001) and Ciccone (2002).

4 Conclusion

The theoretical part of this paper has presented a multi region endogenous growth model with interregional trade in intermediate or technology goods. This model shares the feature of second generation growth models to create weak scale effects. In the regional context this means that a region has a higher per capita production as it is more closely related to other regions giving it a higher technology scale. In reduced form this scale is given by a weighted sum of population sizes of trading partner regions, the interregional scale variable. The weights are given by functions of the trade frictions.

This theoretical result is tested empirically by employing a new approach in defining the scale variable for the geographical units under consideration, a weighted sum of working age populations. As weight, as is often done in spatial econometrics, the inverse distance between units is used. The geographical regions considered were the NUTS regions of the EU 15. The results show a highly significant positive relationship between per capita GDP in the EU 15 regions and the interregional scale variable with an estimated elasticity of about 0.45.

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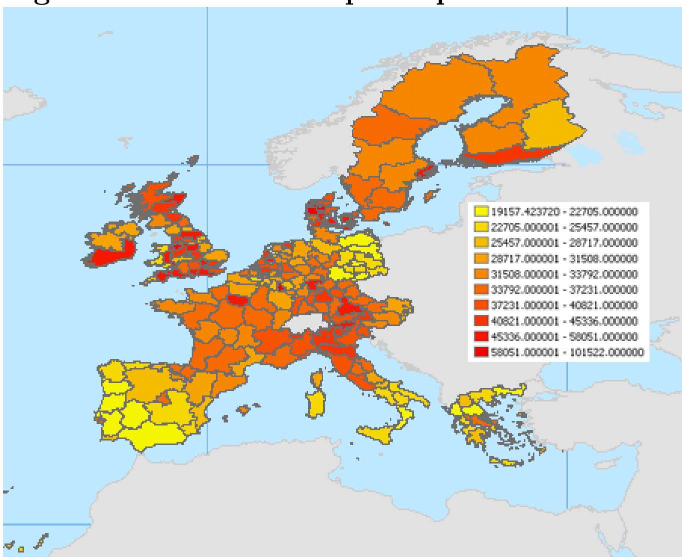
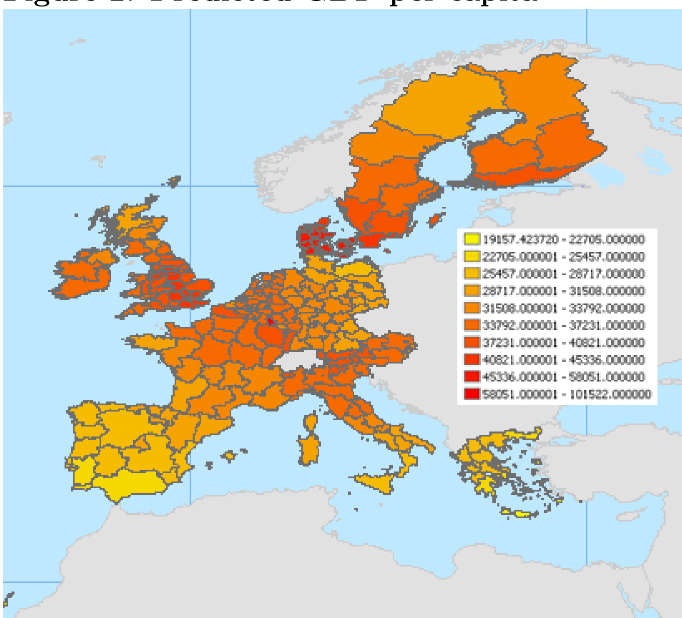
6 Appendix

Figure 1: Actual GDP per capita



Distribution of actual GDP per capita in the EU 15 NUTS2 regions (NUTS3 regions for Denmark). All figures correspond to 2002 Euros at purchasing power parity.

Figure 2: Predicted GDP per capita



Distribution of predicted GDP per capita in the EU 15 NUTS2 regions (NUTS3 regions for Denmark). All figures correspond to 2002 Euros at purchasing power parity.

Table 1: First step regression for regional population

Dependent variable: Population		
Variable	OLS est.	White std. errors
Area	43.466	23.030
Area^2	-0.0005	0.0005
Area^3	$1.63\ 10^{-9}$	$2.60\ 10^{-9}$
AT	260533	205967
BE	492597	105391
DE	1002129	201347
DK	109695	71143
ES	1069470	384901
FI	-82996	442888
FR	964914	521495
GR	175590	291440
IE	376508	594595
IT	1309733	357662
LU	188773	56426
NL	779521	200390
PT	574801	357629
SE	-68877	405352
UK	714096	156748
Observations	221	
R^2	0.251	

First step regression results of population aged 16 to 64 in the European NUTS regions.

Table 2: Estimation Results

Dependent variable: Log of GDP per capita Variable	OLS est.	White std. errors	Conley (1999) std. errors
Log Scale	0.455	0.114	0.088
AT	-0.445	0.071	0.063
BE	-0.668	0.085	0.82
DE	-0.698	0.039	0.036
DK	-0.096	0.083	0.071
ES	-0.542	0.088	0.070
FI	0.005	0.180	0.148
FR	-0.532	0.049	0.042
GR	-0.464	0.142	0.113
IE	-0.263	0.183	0.169
IT	-0.488	0.064	0.054
NL	-0.609	0.050	0.048
PT	-0.546	0.157	0.133
SE	-0.143	0.135	0.110
UK	-0.427	0.057	0.046
const.	-6.728	1.511	1.169
Observations	221		
R^2	0.450		

OLS estimation results of model (20). Column 3 contains heteroskedasticity consistent standard errors, column 4 Conley (1999) standard errors corrected for spatial dependence in the residuals. Luxemburg is the base country