Regional per Capita-Income – The Importance of Region-Specific Production Factors

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JEL-Classification: C21,J24, H54, O18
Keywords: Quantile regression, regional cluster, production potential, efficiency

1. Introduction

A sufficient level of region-specific production factors can foster economic competitiveness and is widely regarded as a pre-condition for economic growth. A striking example is the contribution of Aschauer (1989) that suggests production elasticities about 0.4 for the provision of *transport infrastructure capital*.[1] Fritsch and Prud'homme (1997) find much lower, but still clearly positive, elasticities for French regions and more recently Holl (2002 and 2004) identifies positive results for the regions of Portugal.

Similar patterns can be found with regard to educational attainments and the ability to generate and absorb knowledge *(human capital)*. Lucas (1988), Romer (1990) or Barro and Lee (1993) incorporate human capital into their *national* growth models. The studies of Bröcker et al. (1983), Barro and Sala-i-Martin (1991), Bade (2000) or Kramar (2005) set a similar focus but analyse the economic development at the *regional* level.

Finally, the studies of Currid (2006) and Dziembowska-Kowalska and Funck (2000) analyse the importance of cultural *activities* for the regional development and confirm their general positive impacts.

The results of other studies, however, call for more caution in the interpretation of the empirical findings and add a complementary perspective. This new

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1 Production elasticity means that the output will increase by 0.4%, if the level of transport infrastructure is enhanced by 1%.

perspective focuses on the efficiency by which inputs defined by region-specific production factors are transformed into outputs measured for example as gross regional products. Vickerman et al. (1999), for example, indeed find that investments in the Trans-European Networks (TENs) are beneficial for peripheral regions, but as central regions might benefit even more, they clearly doubt that the net cohesion effect of such investments is positive. From this it can be derived that the effects of region-specific factors can vary according to different types of regions. Furthermore, Biehl (1995) points to the fact that an increasing level of infrastructure, human or cultural capital can only be expected to push the economic performance, if (one of) these factors define(s) a major bottleneck of regional growth. In order to identify such bottlenecks and to measure regional efficiency several methodologies can be applied. Following, for example, Biehl's (1975, 1991) potential factor analysis, efficiency can be defined as the difference between a region's observed and its potential gross regional product. Thus, a sequential bottleneck analysis, which covers different kinds of growth barriers, can be performed (Nijkamp, 2000).

Against this background, the paper intends not only to analyse the effect of the above-mentioned region-specific production factors transport infrastructure, human and cultural capital on economic performance in general, but also to analyse these effects for different types of regions (segregated by their industrial structure and regional wealth). Furthermore the regions' efficiency in utilising these factors will be identified.

The approach applied for this paper starts from the approach outlined by Biehl but incorporates significant changes related to the specific aims of the paper. The changes particularly refer to the clustering of regions and the way the regression analysis is performed. The clustering, as described in section 2, precedes the remaining analysis and partly captures the problems related to the regions' heterogeneity. In addition the regions' different wealth is taken into account by the application of this quantile regression analysis that is performed for each cluster and production factor in section 3.

Finally, based on the results of a quantile regression analysis, section 4 calculates the regions' production potential that is compared to the observed performance. Real outputs that exceed potential outputs point to an over-average efficient usage of the immobile factors and additional investments in these factors could indeed foster the economic performance. Vice versa, regions, whose potential outputs exceed their real performance, are generally less efficient in utilising their region-specific factors than the average region in their cluster. In this case policies to attract directly productive capital might be more efficient, at least from an economic point of view. Section 5 concludes.

2. Regional Cluster Analysis

As mentioned above, region-specific production factors might affect different types of regions in different ways. High educational attainments of qualified workforce, for example, are certainly important for any region, but it could be assumed that it is more important for service dominated metropolitan areas compared to rural regions.

Therefore, the first step of the analysis foresees the clustering of the considered 500 Austrian, German and Swiss NUTS 3 regions according to their land use pattern and sectoral structure.

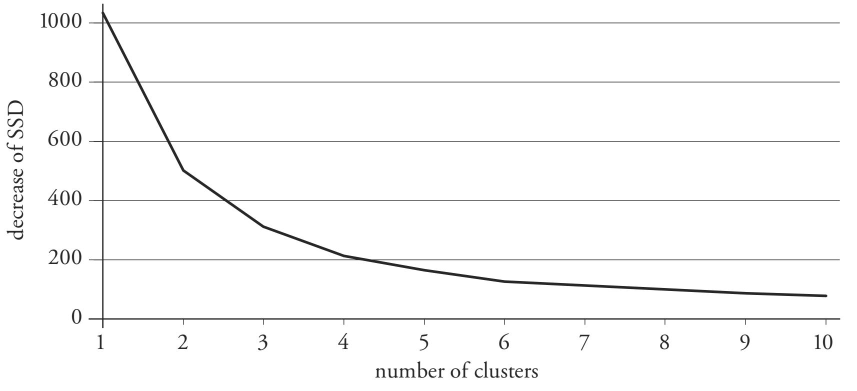
The cluster analysis is based on a hierarchical agglomerative classification method established by WARD (1963) and further developed by BERGS (1981) and BACKHAUS (2006). According to the Ward-approach the number of clusters, which equals the number of regions at the beginning, is decreased step by step. The method is formally concluded at the point, when all regions belong to one single cluster. However, the process can be stopped earlier, before a certain level of heterogeneity, defined as sum of squared deviations, is exceeded. At this point each region belongs to one out of k regional clusters. For each cluster C_k the sum of squared deviations is calculated for n_k regions in the following way:

$$SSD(C_k) = \sum_{i=1}^{n_k}\left(\sum_{j=1}^{m}(x_{ij} - \overline{x}_j)^2\right) \quad (1)$$

$SSD(C_k)$: sum of squared deviations of regional cluster C_k,
n_k: number of regions assigned to cluster C_k,
m: number of land use and sectoral categories,
x_{ij}: parameter value j (= 1 to 4) of region k,
$\overline{x}_j$: mean of parameter value j (=1 to 4) for cluster C_k.

$SSD(C_k)$ increases with a decreasing number of clusters. This is true since the deviations from the average become larger. The optimal number of clusters can be identified by comparing the increases of this sum in case that the number of clusters is reduced by one. The so-called *elbow criterion* illustrates this procedure. The largest kink of the corresponding graphic (see Figure 1), the so-called "elbow", points to the appropriate number of clusters (ALDENDERFER and BLASHFIELD, 1984).

Figure 1: Optimal Number of Clusters by the Elbow Criterion



Following Figure 1, the elbow criterion suggests to define four, three or two clusters. As the choice could be anyone that reflects the real situation in an appropriate way, four regional clusters are defined. These can be differentiated in the following way:

Cluster 1, industrial non-metropolitan regions, characterised by a relatively high share of Gross Value Added (GVA) related to manufacturing and construction services and medium or low population density,

Cluster 2, rural regions, characterised by a relatively high share of GVA and land use related to agriculture and mining,

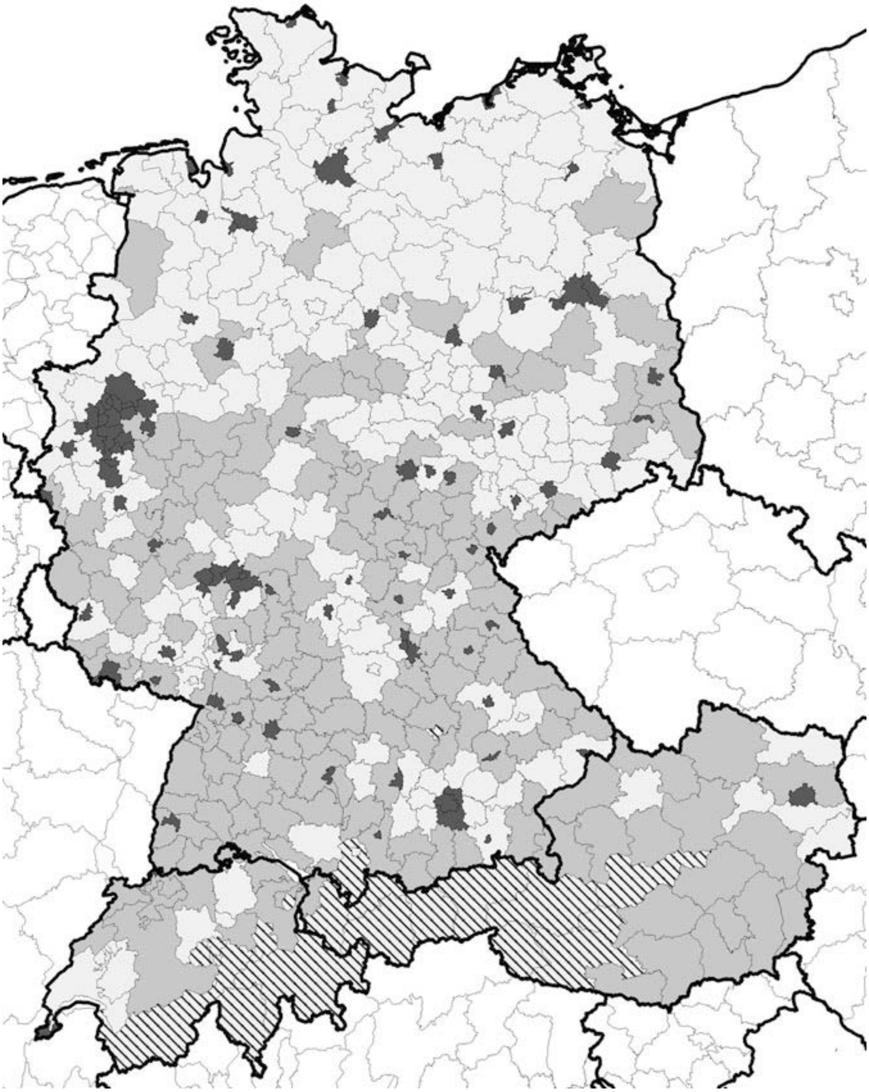
Cluster 3, metropolitan regions, characterised by a relatively high share of GVA related to the services sector and of settlement area,

Cluster 4, touristic regions, characterised by a relatively high share of GVA related to touristic activities and of natural area.

In order to optimise the assignment of the regions to one of the four clusters, the Ward-approach is followed by the *Methode Nuées Dynamiques* (Diday, 1971). With this procedure it can be guaranteed that each region is indeed assigned to a cluster in a way that the distance to the cluster's centre is minimised.[2]

2 The *Methode Nuées Dynamique* is also known as k-means approach. The approach reviews the first assignment to k clusters that results from the Ward-approach and might lead to a reassignment of the region to another of the k clusters, if the distance of this region to the centre of another cluster is smaller (Forgy, 1965).

Figure 2: Regional Cluster of Austrian, German, and Swiss regions (NUTS-3)



Type of region after application of Ward- and k-means clustering method

- Cluster 1: Industrial regions
- Cluster 2: Rural regions
- Cluster 3: Metropolitan regions
- Cluster 4: Touristic regions

Following this procedure 184 regions are assigned to the industrial cluster, 192 regions to the rural cluster, 104 regions to cluster 3 (metropolitan regions) and finally 20 regions to the touristic cluster (Figure 2). Each cluster includes regions from Austria, Germany and Switzerland. Exemplary the Obersteiermark (AT), Salzgitter (DE) and Berne/Solothurn (CH) could be mentioned as industrial, the Nordburgenland (AT), Gifhorn in Northern Germany or Vaud (CH) as rural regions. Metropolitan areas include for example Berlin, Vienna and Geneva. Finally, alpine regions such as Tyrol, Grisons and parts of the Allgaeu form the touristic cluster.

3. Quantile Regression Analysis

Following the regional growth theory, the regions' production potential can be estimated by setting up a production function (Richardson, 1973; Krugman, 1991; Barro and Sala-i-Martin, 1991; Eckey et al., 2004). This function, which could be of CES, Cobb-Douglas or Translog type, defines the potential outcome of a region under the condition of an allocation of production factors.[3] In this context, production factors can be subdivided into two categories. The first category includes indirectly productive, mostly immobile, factors. The second category comprises the directly productive, mostly mobile, factors.

Region-specific factors are of particular relevance, as a sufficient endowment with these factors can be considered a necessary condition to attract mobile factors. Following this argument Biehl (1991) and Blum (1982) suggest to explain the production potential exclusively by the endowment with these region-specific factors.

Therefore, production elasticities have to be estimated in a first step. If the observed output is above the calculated potential, the considered factor is used quite efficiently and the existing endowment might indeed limit further economic growth. Investments into this factor could then alleviate bottlenecks and further stimulate the economic performance. In contrast, the same investments might fail to have any major effects, if mobile but not immobile factors are identified the main limiting determinants.

3 CES functions are characterised by constant elasticity of substitution and can be applied in order to identify the relevance of technological change for regional growth (Grupp, 1997; Schade, 2007). Impacts on regional growth caused by (transport) infrastructure investments are generally estimated by using functions of Cobb-Douglas or Translog type (Pfähler et al., 1995; Weisbrod, 2008).

3.1 Explained Variable

Based on the System of National Accounting many studies aim to explain Gross Domestic Product (GDP) or the Gross Regional Product (GRP) respectively as the most popular indicator for economic performance. However, due to the different size of the considered regions (in terms of area and population), the explanatory power of this indicator is relatively low. Instead the growth of the regional product, employment generation (Bröcker et al., 1983), regional trade volumes (Krugman, 1981; Johansson, 2000) or knowledge-based indicators (Kramar, 2005) could be explained. Alternatively, the indicator could be a personalised one. Cutanda and Joaquina (1994), for example, suggest explaining the GRP per capita. The presented study follows this suggestion and denotes the GRP per capita with Y and the potential GRP per capita with Y^{pot}.

3.2 Explanatory Variables

For the study at hand Y^{pot} shall be explained by transport infrastructure, human and cultural capital respectively. All factors are considered highly immobile and region-specific.

Transport Infrastructure Capital (I)

Infrastructure capital is described by a composite indicator of the regions' endowment with road and rail infrastructure (internal) and the regions' accessibility (external).[4]

The internal part I^{in} is defined as the sum of the weighted road and railway density and the potential capacity utilisation. The density reflects the total length of roads (in km) (weighted according to the road category[5]) and railway lines (in km) divided by the regions' area (in sqkm). The potential capacity utilisation

4 Other networks, namely telecommunication and energy networks, have not been considered here. Although modern telecommunication networks can certainly be considered an important factor for the economic development in knowledge-based economies, first results suggest a very strong collinearity with the regions' human capital (Schaffer and Siegele, 2008). Furthermore, data availability is quite limited at regional level, particularly for qualitative aspects of the network. With regard to energy, we assume that this factor does not limit the development in the considered regions since safe energy supply should be available for any region in Austria, Germany and Switzerland.

5 Motorways are weighted by factor 3, national roads by factor 2 and other roads by factor 1. The weighting factors, which reflect the differences of construction and maintenance cost, are oriented at recommendations of the European Commission (e.g. Reynaud and Braun, 2001; EC, 2002).

results from the division of the regional population by the weighted length of roads and railway lines.

$$I_i^{in} = \frac{pop_i}{r_{\omega,i}} + n \cdot \frac{r_{\omega,i}}{a_i} \qquad (2)$$

I_i^{in}: internal transport infrastructure indicator for (NUTS 3) region i,
$r_{\omega,i}$: weighted length of road and rail network in region i (in km),
a_i: area of region i (in sqkm),
pop_i: population of region i,
n: levelling factor.

Factor n is chosen in a way that the average road density equals the product of average capacity utilisation and levelling factor.

While I^{in} measures the intra-regional equipment with transport infrastructure, the external part of infrastructure capital is defined as the regions' accessibility or centrality. The indicator is determined by the minimal travel time between the considered regions and other regions by road or rail and the accessible GRP.

$$I_i^{ex} = \sum_{j=1}^{k-1} GRP_j \cdot e^{\omega \cdot \min(t_{rail}(i,j), t_{road}(i,j))}, \; i \neq j \qquad (3)$$

I_i^{ex}: external transport infrastructure indicator of considered (NUTS 3) region i,
k: number of European NUTS 3 regions (EU 25),
GRP_j: GRP in the European NUTS 3 region j,
t_{rail}: travel time between region i and j by rail,
t_{road}: travel time between region i and j by road.

The chosen parameter ω is a weighting factor that fulfils the following condition:

$$e^{\omega \cdot T} = 0.5 \text{ for } T = 180 \text{ minutes} \qquad (4)$$

Thus, the GRP that can be reached within 180 minutes is weighted by 0.5. Smaller weights are attributed to the GRP further away and higher weights account for the GRP that can be reached faster.

Finally, the composite infrastructure indicator I for region i results from a combination of internal and external indicator:

$$I_i = I_i^{in} + n \cdot I_i^{ex} \tag{5}$$

n: levelling factor

Factor n is chosen in a way that the average standardised internal infrastructure equals the product of average standardised external infrastructure and levelling factor. Thus intra-regional infrastructure and accessibility are weighted the same.

Following equation (5) the highest Austrian, German and Swiss infrastructure capital can be identified for the regions of Vienna, Berlin and Basle respectively.

Human Capital (H)

The regions' endowment with human capital is represented by the innovation capacity and the educational achievements of the available workforce.

Considering that Europe aims to become the most dynamic and competitive knowledge-based economy in the world, the regions' ability to generate knowledge can doubtless be considered a key to economic growth. However, the question arises, whether knowledge generation is indeed immobile.

On the one hand, inventions (defined as number of patents based on the residence of inventors) are often specific and highly dependent on the degree of (rather mobile) public and private R&D investments. This clearly conflicts with immobility. On the other hand, the regions' ability to generate knowledge hardly changes over time, which, in turn, suggests that the patents reflect a certain region-specific structure that is rather constant in the medium term. Therefore the knowledge part of the human capital indicator H^K is defined in the following way:

$$H_i^K = \frac{p_i}{wf_i} \tag{6}$$

H_i^K: knowledge generation in (NUTS 3) region i,
p_i: number of granted patents between 2002 and 2005 in region i, based on residence of inventor,
wf_i: members of workforce (persons aged between 15 and 65 years) in region i.

Besides the ability to generate knowledge, educational achievements of the regions' workforce add to the regions' human capital. Following the International Standard Classification of Education (ISCED) seven general levels of education can be identified: ISCED level 2 comprises inhabitants (except students) aged between 15 and 65 who finished secondary (modern) school but do not dispose of occupational education. Persons with university entrance qualification but without occupational education belong to ISCED group 3A. Inhabitants, who finished their apprenticeship belong to ISCED groups 3B or 4 (in case they additionally dispose of university entrance qualification), which reflect the secondary level of education. ISCED group 5B accounts for persons, who finished their apprenticeship and visited a technical school afterwards. Finally, persons with university degree and doctorate belong to ISCED level 5A and 6 respectively.

In order to account for the regions' different qualification levels, educational achievements are weighted according to the average time use of teachers, professors and other employees of institutional education necessary to teach the students plus the average time efforts for qualification purpose of the students themselves. The weighting factor is set to 1 for educational achievements according ISCED 2 (finished secondary school) and reaches its maximum for doctorates with a factor of 3.2.[6]

Thus, the qualification part of the human capital indicator H^Q can be calculated according the following formula:

$$H_i^Q = \frac{\sum_{j=1}^{7} \omega_i \cdot wf_{ij}}{\sum_{j=1}^{7} wf_{ij}} \tag{7}$$

H_i^Q: qualification level of the workforce in (NUTS 3) region i,
ω_j: weighting factor according ISCED group j (2, 3A, 3B, 4, 5A, 5B and 6),
wf_{ij}: members of workforce (persons aged between 15 and 65 years)) in region i, who dispose of educational achievements according ISCED group j.

Taking into account the innovation ability and the qualification levels, the human capital indicator is defined in the following way:

6 A detailed derivation of the weighting factors is given by SCHAFFER and STAHMER (2006) and by EWERHART (2001). The factors are based on German data. However, due to missing data, the same weights are applied for the workforce of the Austrian and Swiss regions.

$$H_i = H_i^K + n \cdot H_i^Q \tag{8}$$

n: levelling factor

Factor n is chosen in a way that the average standardised knowledge generation equals the product of average standardised qualification levels and levelling factor.

According to this formula the highest human capital in Austria can be identified for the NUTS 3 region Rheintal Bodenseegebiet in Vorarlberg. For Germany Erlangen and its surrounding area show a remarkable level of human capital. The highest indicator in Switzerland can be found for Geneva.

Cultural Capital (C)

Finally, the cultural capital indicator C measures the regions' cultural environment. For this paper culture is limited to theatres and libraries. Besides the density of theatres and libraries of the corresponding regions, the number of visitors and users is considered as a quality indicator in the following way:

$$E_i = \frac{\sum_{j=1}^{n} t_{ij} \cdot v_{ij}}{pop_i} + n \cdot \frac{\sum_{j=1}^{k} l_{ij} \cdot u_{ij}}{pop_i} \tag{9}$$

E_i: cultural environment indicator for (NUTS 3) region i,
t_{ij}: theatre j in region i,
v_{ij}: annual visitors of theatre j in region i,
l_{ij}: library j in region i,
u_{ij}: users of library j in region i,
pop_i: population of region i,
n: levelling factor

Factor n is chosen in a way that the average accumulated number of annual theatre visitors per inhabitant of region i, equals the product of the average accumulated number of library users per inhabitant and levelling factor.

Following this definition, the highest cultural environment in Austria can be identified for Vienna and the Nordburgenland. The latter is highly ranked due to the broad variety of theatre festivals in this region. For Germany the formula identifies Weimar as the region with highest cultural capital per inhabitant.

Finally, the region of Berne and the metropolitan area of Basle show highest indicators for Switzerland.

The hypothesis is that each of the chosen indicators is positively correlated with the economic performance – this means regions with higher infrastructure, human and cultural capital should, in general, experience higher income per capita. In order to test this hypothesis, a quantile regression analysis is performed for each of the factors and the GRP per capita in the next section.

3.3 Regression Analysis

Following the definition of explained and explanatory variables above, per capita income in region *i* can be explained as follows:

$$Y_i = c_1 \cdot I_i^{\alpha} \tag{10}$$

$$Y_i = c_2 \cdot H_i^{\beta} \tag{11}$$

$$Y_i = c_3 \cdot C_i^{\gamma} \tag{12}$$

c_i: constant
α,β,γ: production elasticities

For the estimation of the production elasticities within the equations (10), (11) and (12) the variables are logarithmised and standardised.[7] The results for the estimation of the production elasticities are summarised in Table 1.

The regression coefficient with the GRP per capita exceeds 0.53 for infrastructure capital, 0.33 for human capital and 0.43 for cultural capital. In the different clusters the regression coefficients vary in the following way:

- In cluster 1 (industrial regions) infrastructure capital holds a value of more than 0.8, whereas human capital (with a value of 0.2) and cultural capital (with a value of 0.3) show clearly smaller correlations with the GRP per capita.
- In cluster 2 (rural regions) infrastructure capital exceeds a value of 0.63, whereas human capital (with a value of 0.21) and cultural capital (with a value of 0.32) correlate only slightly stronger with the GRP per capita than in cluster 1.

7 When the standardisation is applied, the logarithmised explained and explanatory variables take an average value of 0. The advantage thereof is that different dimensions of the variables do not matter. Hence simultaneously also the constants amount to 0.

– Cluster 3 (metropolitan regions) shows, compared to the correlations for all regions and for clusters 1 and 2, the highest value (0.5) for human capital and the lowest values for infrastructure capital (with a value of 0.23) and cultural capital (with a value of 0.17).
– In cluster 4 (touristic regions) the correlations for human and cultural capital are not significant. Although infrastructure capital shows a high correlation, cluster 4 is, due to the low number of 20 regions, not considered any further in the following.

Table 1: OLS Regression Results

Explained variable:		Explanatory variables	
GRP per capita	Infrastructure capital	Human capital	Cultural capital
		All regions	
Elasticites	0.539***	0.332***	0.436***
Goodness of fit (R^2)	0.44	0.45	0.36
		Cluster 1	
Elasticites	0.863***	0.204***	0.298***
Goodness of fit (R^2)	0.27	0.32	0.24
		Cluster 2	
Elasticites	0.632***	0.213***	0.319***
Goodness of fit (R^2)	0.28	0.25	0.34
		Cluster 3	
Elasticites	0.227**	0.500***	0.166**
Goodness of fit (R^2)	0.34	0.41	0.27
		Cluster 4	
Elasticites	0.300*	0.137	–0.576
Goodness of fit (R^2)	0.08	0.12	0.05

Note: significance level: *** for $p \leq 0.01$, ** for $p \leq 0.05$ and * for $p \leq 0.1$.

Methods applied in studies exploring regional performance in many cases rely on conventional OLS regression concentrating on the explanation of the mean of the dependent variable (e.g., the mean level of performance). In contrast, the presented paper aims to investigate the whole shape of the distribution of performance by applying a quantile regression method which allows to regress against every percentile of the distribution of the dependent variable separately

(Buchinsky, 1998).[8] Our intuition is that, especially in the tails of the performance distribution (for those regions with a very high and a very low performance level), the coefficients estimated by a quantile regression will deviate from those of a conventional OLS approach.

Considering all regions Figure 3 below plots the 9 quantile regression estimates for the quantiles ranging from 0.1 to 0.9 for each of the coefficients as a curve with dots.[9] The respective colour and shape of the dots represent the significance-level of the coefficient estimate at the respective quantile.[10]

The coefficients of the quantile regressions, reported in the figures, can be interpreted as the partial derivative of the conditional quantile of y with respect to particular regressors, $\partial Q_{\theta}(y_{it} \mid x_{it}) / \partial x$ (Coad and Rao, 2006). Yasar et al. (2006) stated that the derivative may be seen as the marginal change in y at the θ^{th} conditional quantile due to marginal change in a particular regressor. In other words, for each determinant the point estimates may be interpreted as the impact of a one-unit change of the determinant on GRP.

The horizontal axis of each of the plots shows the different quantiles and the vertical axis exhibits the strength of the effect of the coefficient estimates at each quantile. The two outer curves depict the confidence band for the quantile regression estimates in each figure.

The coefficients of the OLS regressions (conditional mean effect) are represented as horizontal lines; the levels of significance are as follows: solid lines = $p \leq 0.01$ and dashed lines = $p \leq 0.10$.[11]

The development of R^2 over the different quantiles strongly differs between the clusters and components.[12] In the overall model the infrastructure and cultural component show an increase of R^2 from the lowest to the highest quantile, while the human capital component nearly stays constant. For cluster 1 infrastructure

8 For more information on the advantages of quantile regressions as well as for details on the calculations see: Koenker and Basset (1978), Koenker and Hallock (2001), or Buchinsky (1998).

9 We connect the different dots of each regression coefficient for reasons of clearness, although these are just linear approximations of the potential development between the estimated coefficients.

10 In Figure 3 the significance level is 0.01 for all results, but the results for the different clusters which are illustrated in the same way in the annex vary.

11 Again in Figure 3 all OLS regressions are significant with $p \leq 0.01$, but the results in the appendix vary.

12 The values of R^2 of all quantile regressions in our empirical analysis range from about 0.0006 (cluster 2) to 0.24 (overall) in all estimation sets.

and culture have the same positive trend, but the R^2 of the human capital component decreases after a first initial increase. In cluster 2 all three components increase. In cluster 3 a positive trend can be observed for the human capital and cultural component, while the infrastructure component follows more or less an inverted U-shaped development. Hence, this indicates that for most estimation sets the three determinants allow to explain the GRP per capita the better the richer the regions are. But there are some specific developments for the human capital and the infrastructure component in the clusters.

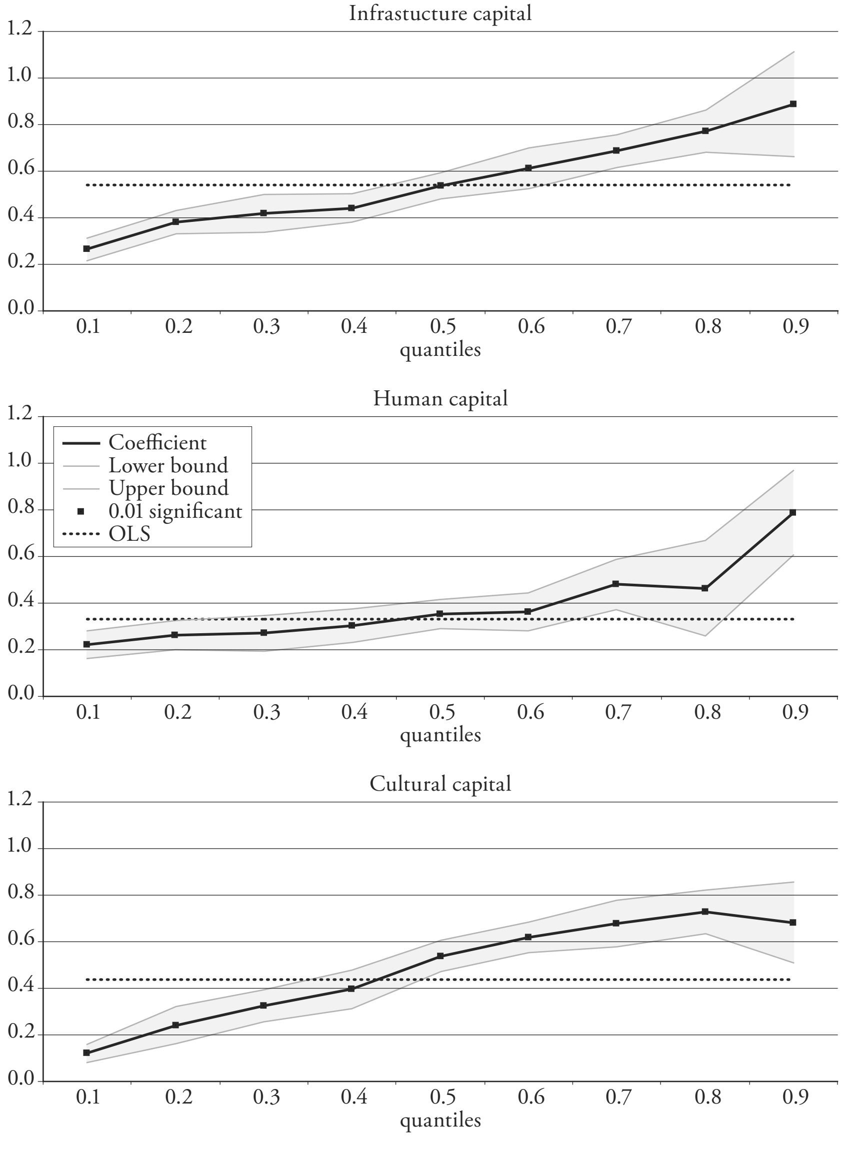
Compared to the OLS coefficients the curves of the quantile regression show that the values of each estimated coefficient vary over the conditional growth rate distribution and strongly deviate from the OLS coefficient for many quantiles. In the following, the discussion focuses on two aspects: i. which effect of the determinants can be observed for the different quantiles – with a peculiar focus on the lower and upper tails of the distribution – and ii. how does this differ between the different models (the results for the single clusters are reported in the appendix).

Infrastructure capital

The curve of the 9 quantile regression coefficients reveals a differentiated picture. All coefficients are highly significant and the effect of the infrastructure component is positive showing that an increase of infrastructure at all times positively affects the GRP per capita (in the following simply referred to as GRP). But the values of the coefficient more than triples between the two tails of the distribution. Hence, the positive effect is the weakest in those regions with a relatively low GRP and the strongest in the regions with a high GRP. For the single clusters the following results can be deduced:

– Cluster 1 (industrial regions): Compared to the overall case the increase between the two tails is even stronger and for each quantile the coefficients are larger than in the overall case. Additionally, the infrastructure component is the one affecting the GRP in this cluster the most. Hence, infrastructure plays an important role in this cluster and the effect is especially strong in those regions already possessing a higher level of GRP.
– Cluster 2 (rural regions): In the development of the quantile coefficients two growth phases can be observed. One explanation for this development is that for the regions with low GRP, some basic infrastructure is necessary which positively affects the level of GRP. Not before a certain level of GRP is overcome, better infrastructure is needed which boosts the level of GRP once more.

Figure 3: Results of the Robust OLS and Quantile Regressions – Basic Model



– Cluster 3 (metropolitan regions): The quantile regressions are not significant for most quantiles. The significant coefficients are around the OLS-coefficient and stay relatively constant. Thus, the effect of infrastructure in this cluster is low compared to the other components (especially human capital) and weak compared to the effect of this component in the other clusters. Infrastructure can be regarded as a baseline pre-requisite constantly affecting the GRP over all quantiles by a certain level, but having no peculiar additional effect which differs between the regions. This cluster mainly consists of larger cities with a certain level of inhabitants and linked to this a certain level of infrastructure capital. Hence, over all quantiles we can expect that basic infrastructure is already present in the region and that the effect of additional infrastructure is only minor.

Human Capital

As in the case of infrastructure capital the effect of human capital is always positive and it increases from those regions with a relatively low GRP to those with a high one (again the coefficient more than triples). But for human capital an especially strong increase from the 0.8 to the 0.9 quantile can be observed after an only modest increase before. Hence, particularly the highest quantile gains the most from the existence of human capital in the regions.

– Cluster 1 (industrial regions): Although the human capital component still has a positive impact on GRP for most quantiles, it is in general lower than in the overall model. Furthermore, the significant coefficients stay relatively constant around the OLS coefficient while they are increasing in all other estimations sets. This points to a general impact of human capital in this cluster independent of the peculiar local condition (measured in our case by GRP). All industrial regions benefit from a high level of human capital in a comparable way.
– Cluster 2 (rural regions): The development consists of three phases: an initial strong increase, a more or less stable phase in-between and then a steep increase. For all quantiles the coefficients are smaller than in the overall case. The reason for the development might be based on the fact that there is a certain threshold with regard to the level of human capital or the related level of GRP. If GRP is below this threshold, an increase in human capital positively and increasingly affects the level of GRP. Above this threshold an increase in human capital still leads to an increase in the level of GRP but this is constant; only after the next threshold is overcome, e.g. positive externalities might

emerge which lead to an increase in the effect of human capital again. These thresholds can be determined by the structure of economic activities in these regions and their necessity to employ qualified human capital.
– Cluster 3 (metropolitan regions): Although the coefficients are high for most of the quantiles – indicating that human capital has a peculiarly strong effect in this cluster – especially the strong increase towards the last quantile shows that there must be very special conditions in these regions. Even or especially in the regions with the highest GRP in this cluster, an increase in the human capital component has a considerable effect on GRP. This effect might result from the fact that in these regions a critical mass of human capital is present which lead to positive externalities of scope or scale.

Cultural Capital

As in the previous cases the effect of the cultural component is always positive and it mostly increases from those regions with a relatively low GRP to those with a higher one.
– Cluster 1 (industrial regions): The quantile regressions are not significant for the lower quantiles and the highest one. Thus, only starting with the 0.4 quantile the existence of cultural capital has a positive effect on GRP. This again points to the importance of thresholds and synergies in the provision of infrastructure: Only in regions which have a certain degree of GRP cultural capital affects the regional performance because probably the amount or composition of this cultural infrastructure also reaches a threshold resulting, for example, in the attraction of firms or executives. But if this threshold is overcome, the effect on GRP is relatively strong.
– Cluster 2 (rural regions): The development is similar to the one in cluster 1, but the increase in the coefficient even takes place later (for the 0.6 quantile). Hence, cultural capital only has an effect on GRP in those regions which already reached a certain level of GRP.
– Cluster 3 (metropolitan regions): Many quantiles are again not significant. The significant ones are relatively constant and on the level of the OLS coefficient. As pointed out above the cluster mainly consists of larger cities. In all these cities at least a certain level of cultural capital can be expected over all quantiles. Additional provision of cultural capital hardly affects the regional GRP.

4. Efficient Employment of Regional Factors

Section 3 points to the positive correlation of human, infrastructure and cultural capital with per capita income for Austrian, German and Swiss regions. Nevertheless, further investments in one of these factors will only serve as a major impulse for the regions' economic performance if investments indeed alleviate bottlenecks. This, is turn, relies on the causality and utilisation of the existing human, infrastructure and cultural capital stock.

Presuming causality from investments in the considered factors to GRP, effects would be the strongest, if the available factors are used efficiently. In order to measure the factor-specific efficiency the production potential of each region is calculated in the following way:

$$Y_{n_{ik}}^{pot} = c \cdot f_{n_{ik}}^{\alpha_{n,k,q}} \tag{13}$$

$Y_{n_{ik}}^{pot}$: potential GRP per capita based on component n (human, infrastructure or cultural capital) in region i of cluster k,
$f_{n_{ik}}$: parameter values of component *n* in region *i* of cluster *k*,
$\alpha^{n,k,q}$: production elasticity of component *n* in cluster *k* and quantile *q*.

In a second step the potential GRP per capita ($Y_{n_{ik}}^{pot}$) is compared with the real GRP per capita (Y_{ik}) for each of the 500 regions. After the comparison the regions can be subdivided into two groups:

1. Over-average efficient regions with regard to the utilisation of component *n* ($Y_{ik} > Y_{n_{ik}}^{pot}$); and
2. under-average efficient regions ($Y_{ik} < Y_{n_{ik}}^{pot}$).

Figure 4 gives an insight into the specific efficiencies of the regions' utilisation of infrastructure, human and cultural capital. Due to the wide spread of per-capita-income of the last quantile we further separated these high-income regions into two groups (and applied the elasticities of the last quantile). Therefore, the nine quantiles are transferred into ten percentiles. Each point represents one of the regions assigned to one of the percentiles. The x-value reflects the order of the regions in terms of per capita income (within each percentile and as a whole) and the y-value always represents the observed GRP per capita. The step functions identify the percentiles' average potential GRP per capita that can be estimated by taking into account the percentiles' average endowment with the considered human, infrastructure or cultural capital stock and the corresponding elasticities.

Regions above (below) the curve can be considered over-average (under-average) efficient in using the respective kind of capital.[13]

The trend is similar for all factors. Considering the relative endowment with human, infrastructure and cultural capital, efficiency of poor regions is mostly under-average. In contrast, rich regions tend to utilise their endowment with immobile factors quite efficiently.

In general over-average efficient (mostly the richer) regions are much better equipped with directly productive capital than under-average efficient regions (SCHAFFER and SIEGELE, 2008). This implies that the costs of attracting and using directly productive capital is lower in high performing regions than in low performing ones. In this case investments should focus on enhancing the endowment with immobile factors. This, in turn, could alleviate bottlenecks and subsequently result in higher growth rates of the regional product. However, these regions run the risk of growing beyond their optimal degree of agglomeration and of increasing their benefits, e.g. at the cost of pollution.

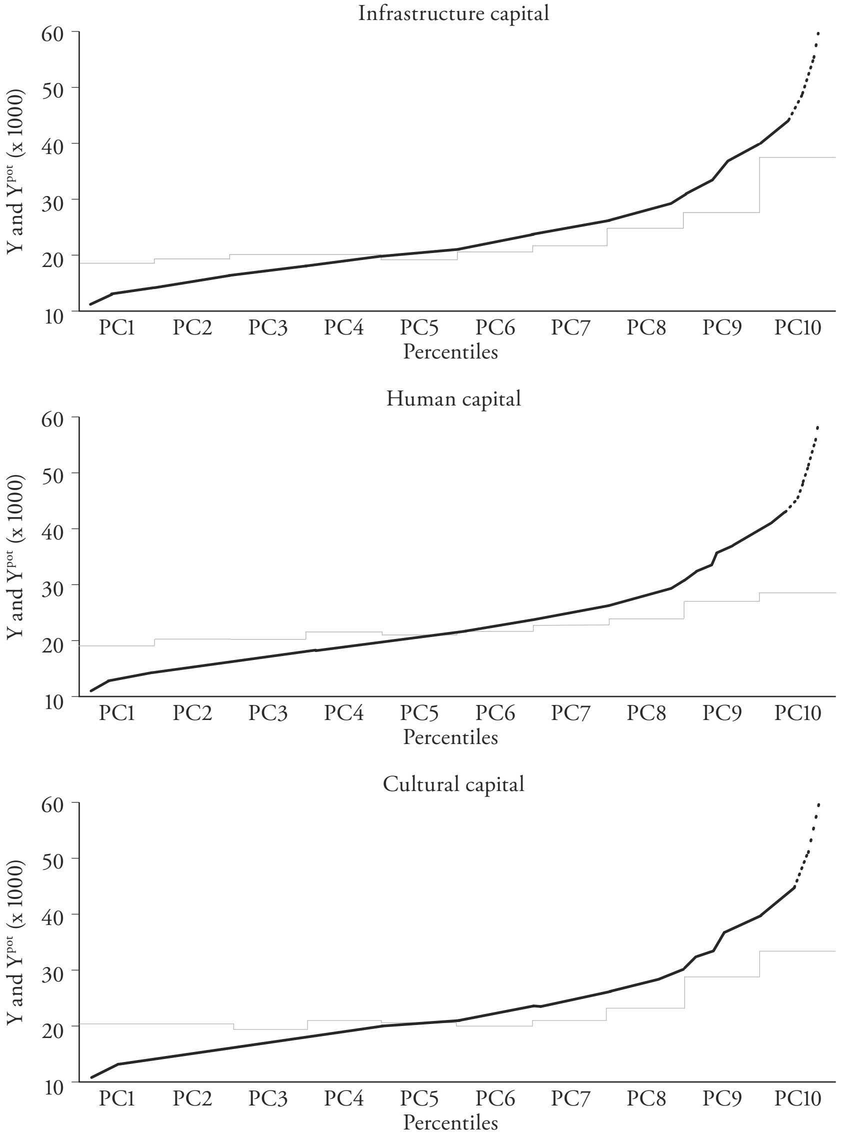
In contrast to the over-average efficient regions, under-average performing regions (mostly the poorer) generally lack adequate quantities and qualities of directly productive capital. Therefore, policy makers should concentrate their efforts in this case on attracting directly productive capital. In the short run it may be helpful to subsidise private investors. This strategy can be particularly recommended, if the endowment with public capital is high in absolute terms.

It should be emphasised that, from a methodological point of view, under- and over-average efficiency, as defined in this study, hardly gives an idea of the regions absolute competitiveness but rather points to an under- or over-average efficient utilisation of existing public endowment.

Thus, the step functions could run quite differently and they do for some factors and clusters. Looking for example at the step function derived for human capital in the industrial cluster (see Figure A2 in the appendix), some potential values exceed observed ones for upper quantiles. Vice versa some lower income regions seem to be quite efficient in using this factor. Thus, some regions that are over-average efficient in the basic model (considering all regions) might be under-average average efficient in their cluster and vice versa. With regard to the

13 The approach outlined in this section follows in major parts the idea of the potential factor analysis, which has been developed to analyse the relevance and efficiency of region-specific production factors (BIEHL, 1991 and 1995; BLUM, 1982). In case efficiency would be defined in another way, the results of the quantile regression analysis would also allow for alternative approaches to measure the regions' efficiencies. In particular the data envelopment analysis could be applied (CHARNES et al., 1978; COOPER et al., 1999; BATTESE et al., 2004).

Figure 4: Potential GRP per Capita Based on the Endowment with Human, Infrastructure and Cultural Capital and Observed GRP per Capita (All Regions)



industrial cluster, the region of Lörrach, for example, is under-average efficient in utilising its human, but over-average efficient in using infrastructure and cultural capital. Reutlingen, in contrast, is over-average efficient in exploiting human and cultural capital, but under-average efficient in utilising the existing infrastructure capital. Other industrial regions are over- or under-average efficient in using all factors. Exemplary for the purely over-average efficient regions Ludwigshafen, the Rheintal Bodenseegebiet and the region around Berne can be mentioned.

Considering the metropolitan areas, Essen or Vienna are over-average efficient in using human but under-average efficient in exploiting their infrastructure capital. Vice versa Kiel and Mannheim are over-average efficient in utilising their infrastructure but under-average efficient in employing the existing human capital. Munich, Hamburg and Basle can be identified as purely over-average efficient regions.

5. Conclusions

The paper at hand analyses the role of region-specific production factors, namely transport infrastructure, human and cultural capital, for the per-capita income of Austrian, German and Swiss regions. Following a quantile regression analysis, the regional conditions determined by the three production factors correlate positively with the poor and rich regions' economic performance. This holds in general for all considered types of regions and the income quantiles within these types.

From an economic perspective it can be concluded that the regions' environment with transport infrastructure, human and cultural capital is indeed a necessary but not automatically a sufficient requirement for regional growth competitiveness. The expected economic impacts rather depend on the regions' ability to utilise the existing immobile factors in an efficient way. Hence, a policy focusing on the provision of these production factors provides the basis for a prosperous development, but this is not an automatic processes. There exist well-equipped regions with only a relatively low per-capita income because the potential is not transformed into real economic activities and regional income in the end. One such mechanism which converts relevant knowledge and infrastructure in economic activities is entrepreneurship (Carlsson et al., 2007).

The strengthening of one or several of region-specific factors, examined in this paper, should not be considered a panacea for regional growth and competitiveness. A significant impact can only be expected, if the regional development is indeed limited by one of these factors. Vice versa the return on investments might be rather modest, if this factor does not hamper the development. In this case other complementary measures to attract private capital in a more direct way might be more promising. These include but are not limited to SME programs or tax-incentives (Evers et al., 1984; Marcati et al., 2008; Bondonio and Greenbaum, 2007).

Nevertheless, sometimes investments into region-specific immobile production factors might serve different purposes than those measured by economic variables directly. Besides their direct economic impact, investments into, for example, cultural capital might fulfil other purposes as well and can therefore not exclusively be evaluated by measures of economic efficiency. Such investments for sure have indirect economic effects because they make the region more attractive, strengthen the image of the region for the outside or might generate a positive economic climate inside the region. Additionally there are reasons outside the economic domain which might justify such investments. However, in the latter case, political decision makers should be very transparent in their (normative) reasoning.

From these considerations further research questions can be derived. It seems for example important to have a closer look on the interaction between the region-specific immobile production factors and those factors which translate these into economic activities. Based on such additional findings, new policy recommendations might be generated to convert the potentials given by the regions' infrastructure, human and cultural capital stocks into a flourishing economy.

Appendix

Figure A1: Results of the Robust OLS and Quantile Regressions for the Different Clusters

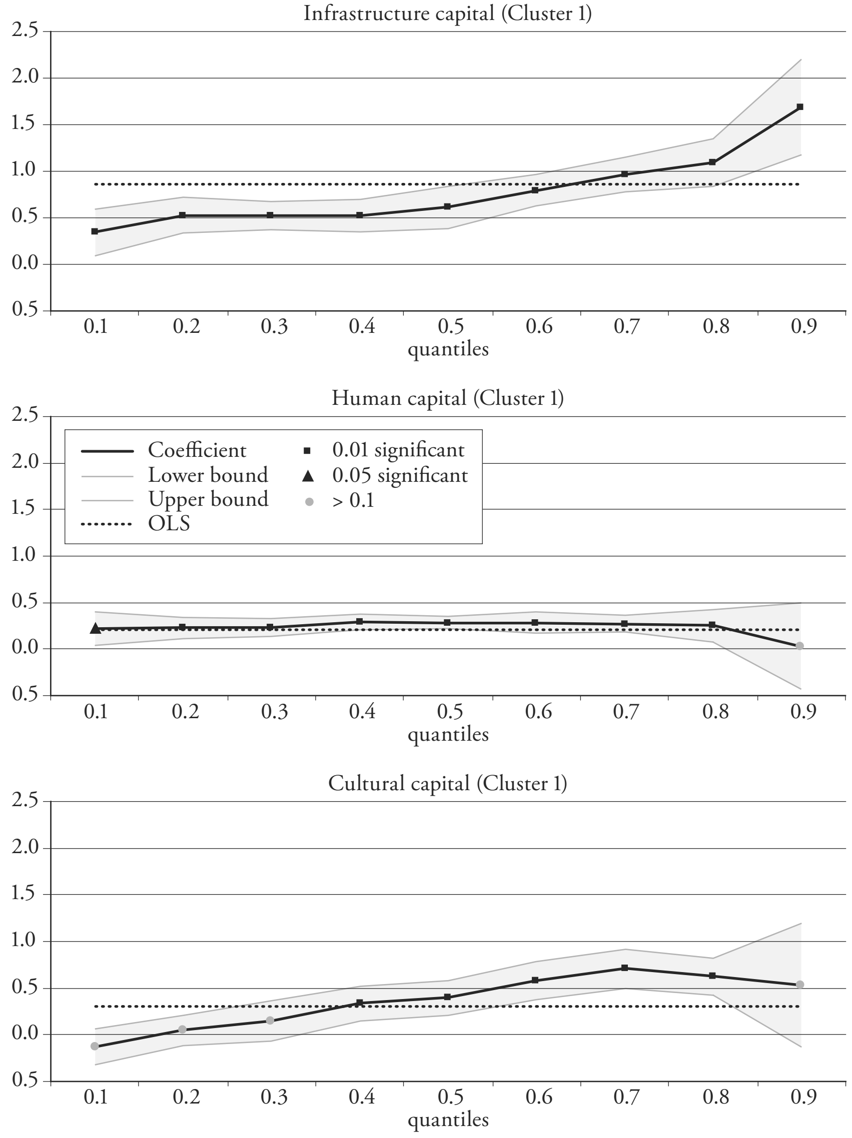


Figure A1 (continued)

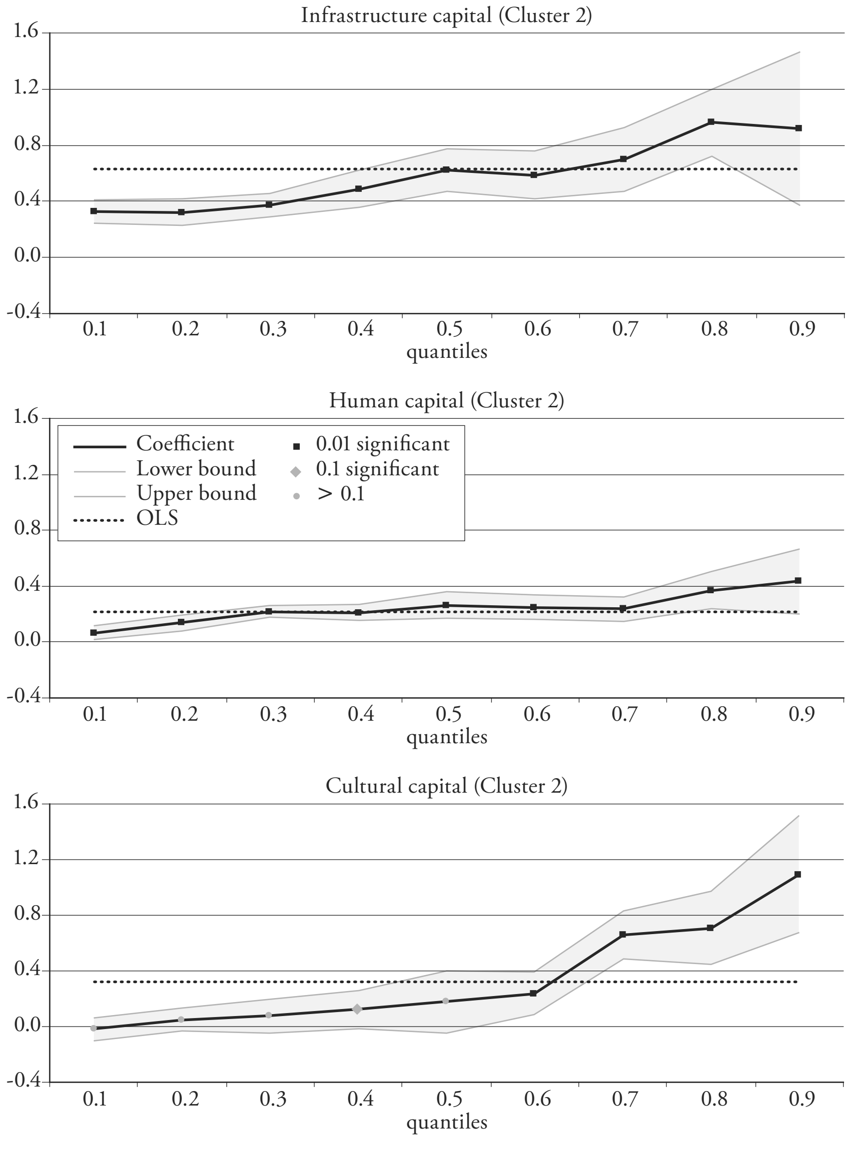


Figure A1 (continued)

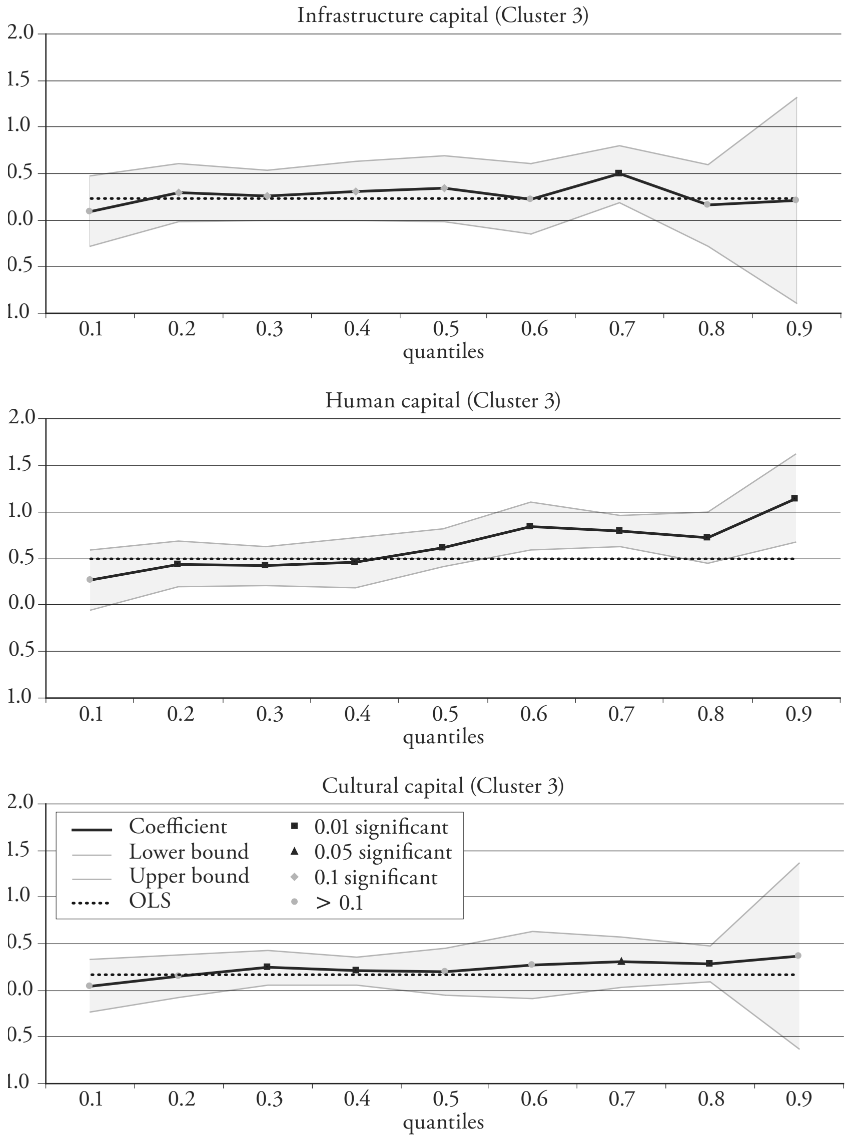
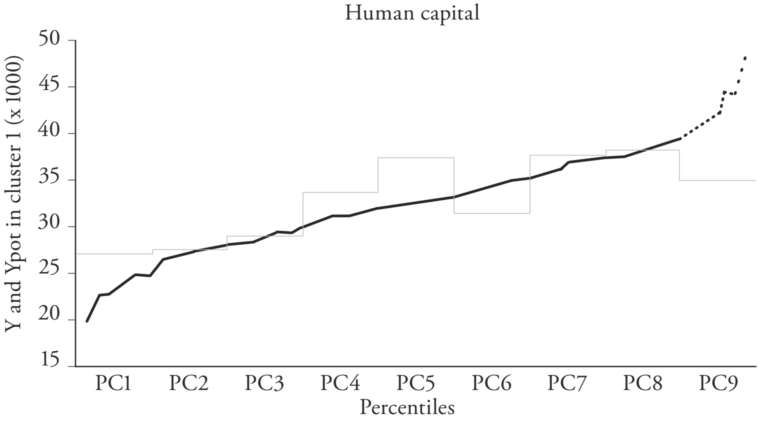


Figure A2: Potential GRP per Capita Based on the Endowment with Human Capital and Observed GRP per Capita for the Industrial Cluster



References

Aldenderfer, Mark, and Roger Blashfield (1984), *Cluster Analysis*, Newbury Park (CA), Sage.

Aschauer, David (1989), "Is Public Expenditure Productive?", *Journal of Monetary Economics,* 23, pp. 177–200.

Backhaus, Klaus, Bernd Erichson, Wulff Plinke, and Rolf Weiber (2006), *Multivariate Analysemethoden*, Berlin, Springer.

Banister, David, and Joseph Berechman (2001), "Transport Investment and the Promotion of Economic Growth", *Journal of Transport Geography*, 9, pp. 209–218.

Battese, George, Prasada Rao, and Christopher O'Donnell (2004), "A Metafrontier Production Function for Estimation of Technical Efficiencies and Technology Gaps for Firms Operating Under Different Technologies", *Journal of Productivity Analysis*, 21, pp. 91–103.

Bergs, Stefan (1981), *Optimalität bei Clusteranalysen, Experimente zur Bewertung Numerischer Klassifikationsverfahren*, Münster.

Biehl, Dieter (1975), *Bestimmungsgründe des regionalen Entwicklungspotentials*, Tübingen, J. C. B. Mohr.

Biehl, Dieter (1991), “The Role of Infrastructure in Regional Development”, in: R. Vickerman (ed.), *Infrastructure and Regional Development*, London, Pion Limited, pp. 9–35.

Biehl, Dieter (1995), „Infrastruktur als Bestimmungsfaktor regionaler Entwicklungspotentiale in der Europäischen Union“, in: H. Karl and W. Heinrichsmeyer (eds), *Regionalentwicklung im Prozess der Europäischen Union*. Bonner Schriften zur Integration Europas, Bonn, pp. 59–86.

Blum, Ulrich (1982), “Effects of Transportation Investments on Regional Growth”, paper of Regional Science Association, pp. 151–168.

Bondonio, Daniele, and Robert Greenbaum (2007), “Do Local Tax Incentives Next Term Affect Economic Previous Term Growth? What Mean Impacts Miss in the Analysis of Enterprise Zone Policies”, *Regional Science and Urban Economics*, 37 (1), pp. 121–136

Bröcker, Johannes, Karin Peschel, and Werner Reimers (1983), *Regionales Wachstum und ökonomische Integration*, München, V. Florentz.

Buchinsky, Moshe (1998), “Recent Advances in Quantile Regression Models: A Practical Guideline for Empirical Research”, *The Journal of Human Resources*, 33, pp. 88–126.

Carlsson, Bo, Zoltan J. Acs, David B. Audretsch and Pontus Braunerhjelm (2007), “The Knowledge Filter, Entrepreneurship, and Economic Growth”, CESIS Electronic Working Paper Series, Paper 104.

Centre Européen du Développement Régional (CEDRE) (1993), «Etude Prospective des Régions Atlantiques», Report to European Commission, CEDRE, Strasbourg.

Charnes, Abraham, William W. Cooper, and Ewaldo Rhodes (1978), “Measuring the Efficiency of Decision Making Units”, *European Journal of Operational Research*, 2, pp. 429–444.

Coad, Alex and Rekha Rao (2006), “Innovation and Firm Growth in High-Tech-Sectors: A Quantile Regression Approach”, (LEM Working Paper Series 2006/18), Pisa.

Conrad, Klaus, and Helmut Seitz (1994), “The Economic Benefits of Public Infrastructure”, *Applied Economics* 27/94, pp. 303–311.

Cooper, Wiliam W., Lawrence Seiford, and Kaoru Tone (1999), *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software*, Kluwer Academic Publishers, Boston.

Cutanda, Antonio and Paricio Joaquina (1994), “Infrastructure and Regional Economic Development: The Spanish Case”, *Regional Studies* 94 (1), pp. 69–77.

Diday, Edwin (1971), «La méthode des nuées dynamiques», *Revue de Statistique Appliquée*, 19 (2), pp. 19–34.

Eckey, Hans-Friedrich, Reinhold Kosfeld, and Matthias Türck (2004), *Regionale Produktionsfunktionen mit Spillover-Effekten für Deutschland.* Volkswirtschaftliche Diskussionspapiere des Fachbereichs Wirtschaftswissenschaften an der Universität Kassel, Nr. 64/04, Kassel.

European Commission (2002*), European Transport Scenarios*, final report of the SCENES project, Cambridge.

Ewerhart, Georg (2001), *Humankapital in Deutschland*, IAB, Nürnberg.

Ewers, Hans-Jürgen, Michael Fritsch, and Josef Kleine (1984), *Regionale Entwicklung durch Förderung kleiner und mittlerer Unternehmen,* Schriftenreihe 06 Raumordnung des Bundesministers für Raumordnung, Bauwesen und Städtebau, Bonn.

Fritsch, Bernard, and Rémy Prud'homme (1997), "Measuring the Contribution of Road Infrastructure to Economic Development in France", in: E. Quinet and R. Vickerman (eds), *The Econometrics of Major Transport Infrastructures*, Mac Millan Press, London, pp. 45–67.

Gather, Matthias (2003), "Regionale Effekte der Fernstraßeninfrastruktur auf die wirtschaftliche Entwicklung in Thüringen", Studie der Fachhochschule Erfurt mit Unterstützung des Thüringer Ministeriums für Wissenschaft, Forschung und Kunst.

Grupp, Hariolf (1997), *Messung und Erklärung des technischen Wandels: Grundzüge einer empirischen Innovationsökonomik*, Heidelberg: Springer.

Holl, Adelheid (2002), "Transport as a Location Factor: New Start-Ups and Relocations in Portugal", conference paper, ERSA 2002, Dortmund.

Holl, Adelheid (2004), "Start-Ups and Relocations: Manufacturing Plant Location in Portugal", *Papers in Regional Science*, 83 (4), pp. 649–668, Springer Berlin / Heidelberg

Johansson, Börje (2000), "Regional Competition: Endogenous and Policy-Supported Processes", in: P. W. J. Batey and P. Friedrich (eds), *Regional Competition*, Heidelberg, Springer, pp. 34–65.

Koenker, Roger, and Gilbert Basset (1978), "Regression Quantiles", *Econometrica*, 46, pp. 33–50.

Koenker, Roger, and Kevin Hallock (2001), "Quantile Regression", *Journal of Economic Perspectives*, 15, pp.143–156.

Kramar, Hans (2005), *Innovation durch Agglomeration: Zu den Standortfaktoren der Wissensproduktion*, Wiener Beiträge zur Regionalwissenschaft, Band 20, Technische Universität Wien.

Krugman, Paul (1981), "Trade, Accumulation and Uneven Development", *Journal of Development Economics*, 8, pp. 149–161.

Krugman, Paul (1991), "Increasing Returns and Economic Geography", *Journal of Political Economy*, 99, pp. 483–499

Marcati, Alberto, Gianluigi Guido, and Alessandro Peluso (2008), "The Role of SME Entrepreneurs' Innovativeness and Personality in the Adoption of Innovations", *Research Policy*, 37, pp. 1579–1590

Nijkamp, Peter (2000), "Infrastructure and Suprastructure in Regional Competition: A Deus ex Machina?", in: P. W. J. Batey and P. Friedrich (eds), *Regional Competition*, Heidelberg, Springer, pp. 87–107.

Pfähler, Wilhelm, Ulrich Hofmann, and Ulrich Lehmann-Grube (1995), „Infrastruktur und Wirtschaftsentwicklung. Kritische Bestandsaufnahme, Erweiterungen und Fallstudien", in: A. Oberhauser (ed.), *Finanzierungsprobleme der deutschen Einheit*, Berlin, Duncker & Humblot, pp. 71–188.

Prud'homme, Rémy (1996), "Assessing the Role of Infrastructure in France by means of Regionally Estimated Production Functions", in: D. F. Batten and C. Karlsson (eds), *Infrastructure and the Complexity of Economic Development*, Berlin, Springer, pp. 37–48.

Reynaud, Christian, and Catherine Braun (2001), *SCENARIOS Final Report*, INRETS, Paris.

Richardson, Harry (1973), *Regional Growth Theory*, New York: Wiley.

Rietveld, Piet and Frank Bruinsma (1998), *Is Transport Infrastructure Effective?,* Berlin, Springer.

Romer, Paul (1986), "Increasing Returns and Long-Run Growth", *Journal of Political Economy*, 94, pp. 1002–1037.

Romer, Paul (1990), "Endogenous Technical Change", *Journal of Political Economy*, 98, pp. 71–102.

Schade, Burkhard (2007), "CES-Production Functions of Transport Sectors of Germany", Proceedings of the 11th World Conference on Transport Research. University of California, Berkeley.

Schaffer, Axel, and Jochen Siegele (2008), „Regionale Potentiale – Bedeutung und Nutzung von Potentialfaktoren in den NUTS 3 Regionen Deutschlands und Österreichs", *Jahrbuch für Regionalwissenschaft*, 28 (2), Berlin/Heidelberg, Springer.

Schaffer, Axel, and Carsten Stahmer (2006), "Women's GDP – A Time-based Input-Output Analysis", *Swiss Journal of Economics and Statistics*, 142, pp. 367–394.

Vickerman, Roger (1987), "The Channel Tunnel and Regional Development: A Critique of an Infrastructure Growth Project", *Project Appraisal*, 2 (1), Kent.
Vickerman, Roger (1993), "The Channel Tunnel and Regional Development in Europe: An Overview", *Applied Geography*, 14, pp. 9–25.
Vickerman, Roger (1994), "Transport Infrastructure and Region Building in the European Community", *Journal of Common Market Studies*, 32 (1), pp. 1–24.
Vickerman, Roger, Klaus Spiekermann, and Michael Wegener (1999), "Accessibility and Economic Development in Europe", *Regional Studies*, 33 (1), pp. 1–15.
Ward, Joe (1963), "Hierarchical Grouping to Optimize an Objective Function", *Journal of the American Statistical Association*, 58, pp. 236–244.
Weisbrod, Glen (2008), "Models to Predict the Economic Development Impact of Transportation Projects: Historical Experience and New Applications", *The Annals of Regional Science*, 2008, 42 (3), pp. 519–543.
Worldbank (1994), *An Overview of Monitoring and Evaluation in the World Bank.* Report 13247, Operations Evaluation Department, Washington D.C.
Yasar, Mahmut, Carl Nelson, and Roderick Rejesus (2006), "Productivity and Exporting Status of Manufacturing Firms: Evidence from Quantile Regressions", *Weltwirtschaftliches Archiv*, 142, pp. 675–694.

SUMMARY

Endowment with infrastructure, human and cultural capital is highly significant for regional economic performance. After clustering the regions, this hypothesis is tested for Austrian, German and Swiss NUTS 3 regions by applying a quantile regression analysis.

First results confirm the hypothesis for all factors. However, coefficients differ significantly both between clusters as well as among the quantiles of each cluster. Furthermore, insights into the regions' efficiency in using these factors are generated: investments into region-specific factors will not push the regional economy automatically, but the under- or over-average efficiency has to be taken into account.