Good and bad convergence: a typology of regional total factor productivity performance in Europe

Abstract

The article investigates regional TFP dynamics in Europe and the contribution of individual regions to overall TFP convergence. Employing a TFP approach that estimates TFP levels and growth rates as individual model parameters, a classification scheme is derived that allows identifying groups of regions with different convergence characteristics such as technology leaders, catch-up regions and problematic regions. The classification scheme, derived endogenously with the TFP estimates and their standard errors, is applied to 270 European regions from 1990 to 2014. Results provide an in-depth analysis of TFP convergence and help comprehend this process far beyond conventional convergence measures.

Keywords: regional convergence, total factor productivity, European regions, cohesion policy, regional disparities

Subject classification codes: O18, O47, R11

Introduction

Many empirical studies focusing on the economic performance and competitiveness of countries and regions employ total factor productivity (TFP) as the main indicator of a country's and a region's economic success (Antonelli, Patrucco, & Quatraro, 2011; Capello & Lenzi, 2015; Dettori, Marrocu, & Paci, 2012; Madsen, 2008; Marrocu & Paci, 2013; Mitze, 2014). TFP is often preferred over alternative indicators such as labour productivity or per capita income as it takes into account cross-country or cross-regional differences in factor endowments of labour and physical capital and is therefore a good indicator of the efficiency of an economy. Furthermore, Hall & Jones (1999), Gundlach, Rudman, & Wößmann (2002), Caselli

(2005), and Byrne, Fazio, & Piacentino (2009) show that differences in TFP, rather than differences in factor inputs, are the major cause of cross-country and cross-regional disparities in development levels in terms of income per worker (or per capita). As such, TFP is a frequently used measure in studies analysing productivity differences between regions in the form of either TFP levels (Byrne et al., 2009; Derbyshire, Gardiner, & Waights, 2013; Scoppa, 2007) or TFP growth rates (Antonelli et al., 2011; Brixy, 2014; Melachroinos & Spence, 2013; Quatraro, 2010; Vogel, 2015).

As TFP plays a crucial role in regional income differences, the investigation of regional TFP convergence and the contribution of individual regions to the overall convergence process are essential for understanding dynamics of income disparities across European regions. However, prior literature on European regional TFP convergence primarily focuses on the investigation of overall convergence with mixed results: while Marrocu, Paci, & Usai (2013) and Vogel (2015) provide evidence for TFP convergence across European regions throughout the last decades, Di Liberto & Usai (2013) and Ladu (2010) do not find evidence for TFP convergence. Studies analysing the contribution of individual regions to overall convergence are generally lacking in the literature.

In order to fill this gap, the present work provides an in-depth analysis of European regional TFP convergence based on TFP estimates of 270 regions of the 28 EU member states plus Norway from 1990 to 2014. The recently proposed approach by Schatzer, Siller, Walde, & Tappeiner (2018) is adopted to estimate both regional TFP levels and TFP growth rates. In contrast to other currently employed TFP estimation approaches such as alternative regression techniques (Dettori et al., 2012; Marrocu & Paci, 2011) or the classic growth accounting (Antonelli et al., 2011; Brixy,

2014; Caragliu & Nijkamp, 2015; Scoppa, 2007), the approach by Schatzer et al. (2018) estimates regional TFP levels and growth rates as individual model parameters and thus, corresponding standard errors and confidence intervals of both TFP measures are obtained. Therewith a convergence classification scheme for regions is derived that allows the investigation of contributions of individual regions to overall convergence. Regions are classified with respect to TFP levels and growth rates according to statistically significant deviations from the European mean in below-mean, mean, and above-mean groups, resulting in nine regional groups with different convergence characteristics. This allows distinguishing between regions which contribute positively to overall convergence across Europe, i.e. low productive regions that catch up to the European mean by achieving higher TFP growth, and those that contribute negatively (higher productive regions with low growth rates). Similarly, regions counteracting the overall convergence process, e.g. technology leaders with both high TFP levels and growth rates, are specified.

In the classification scheme the bounds between the individual groups are – given a significance level – endogenously determined by TFP estimates and corresponding standard errors. By identifying regions whose TFP performance significantly deviates from the European mean, the classification scheme provides important information for individual regions, e.g. regions whose TFP growth rate is significantly lower than the European mean growth rate may define consequences for future regional policy.

Hence, the present work provides an important enhancement of conventional convergence analyses and permits a better understanding of TFP dynamics across Europe. In particular, the work contributes to the existing literature in three ways. Firstly, the analysis is based on the simultaneous estimation of TFP levels and TFP

growth as individual model parameters of the production function. Secondly, the so obtained standard errors of the TFP measures are employed to investigate TFP convergence across European regions and, thirdly, we propose a change from an overall measure of convergence to a more differentiated investigation that allows groups of regions with different convergence characteristics to be analysed. Applying the derived classification scheme to 270 European regions provides an in-depth view of European TFP convergence and helps comprehend the convergence process far beyond the classical β- or σ-convergence measures.

The remainder of the paper is organized as follows: the second section describes the chosen approach to estimating regional TFP levels and TFP growth rates. Furthermore, this section provides a description of the employed dataset and explains the approach to analysing TFP convergence across Europe. The third section presents and evaluates the results, while the fourth section discusses the main findings. Finally, the fifth section provides some concluding remarks.

Method and Data

TFP estimation

TFP levels and their growth rates are estimated using the approach by Schatzer et al. (2018). This approach allows regional TFP levels and TFP growth rates to be estimated as individual model parameters of the production function. The model is represented by the Cobb-Douglas production function of equation (1):

$$Y_{rt} = A_{rT} e^{\gamma_r (t-T)} K_{rt}^{\alpha} L_{rt}^{\beta} \theta_t u_{rt} \tag{1}$$

where $r = 1, \dots, N$ and $t = 0, \dots, T$ are regional and time subscripts, Y_{rt} represents the level of output, K_{rt} stands for the stock of physical capital, L_{rt} is the labour input, θ_t

are time fixed-effects that account for possible shocks affecting all regions simultaneously, A_{rT} is the regional TFP level of the last observation period, γ_r represents the mean annual regional TFP growth rate and u_{rt} is the error term. In order to control for the size of regions, input and output variables are normalized to population.

Regional TFP levels and TFP growth rates are obtained by estimating the log-linearised form of the Cobb-Douglas production function in equation (1). The estimated TFP level of a region at time t, denoted as $\hat{A}_{rt}$, is defined according to equation (2):

$$\hat{A}_{rt} = \hat{A}_{rT} e^{\hat{\gamma}_r (t-T)} \quad (2)$$

where $\hat{A}_{rT}$ is the estimated regional fixed-effect, and $\hat{\gamma}_r$ is the estimated mean annual regional TFP growth rate.

As shown by Schatzer et al. (2018), both TFP levels and TFP growth rates estimated by the approach described above differ from estimates of alternative approaches used in the literature to a considerable extent. While obtained estimates are similar to those of the fixed-effects approach without the regional time trend (applied on a European regional level by Ladu, 2010; Marrocu & Paci, 2013), they show substantial differences to TFP estimates obtained from approaches that exclude regional fixed-effects in their estimation procedure such as the pooled panel approach (Marrocu et al., 2013; Mitze, 2014) and the cross-section approach (Berlemann & Wesselhöft, 2012; Capello & Lenzi, 2015).

The size of differences between TFP estimates obtained from different approaches are exemplified in Figure 1, which compares regional TFP growth rates obtained from three different approaches, namely the above described fixed-effects approach including a regional time trend, the conventional fixed-effects approach

without the regional time trend and the pooled panel approach.[1] The figure clearly shows that TFP growth rates obtained from the two fixed-effects models produce similar estimates, while those of the pooled panel approach differ considerably. A more detailed discussion can be found in Schatzer et al. (2018).

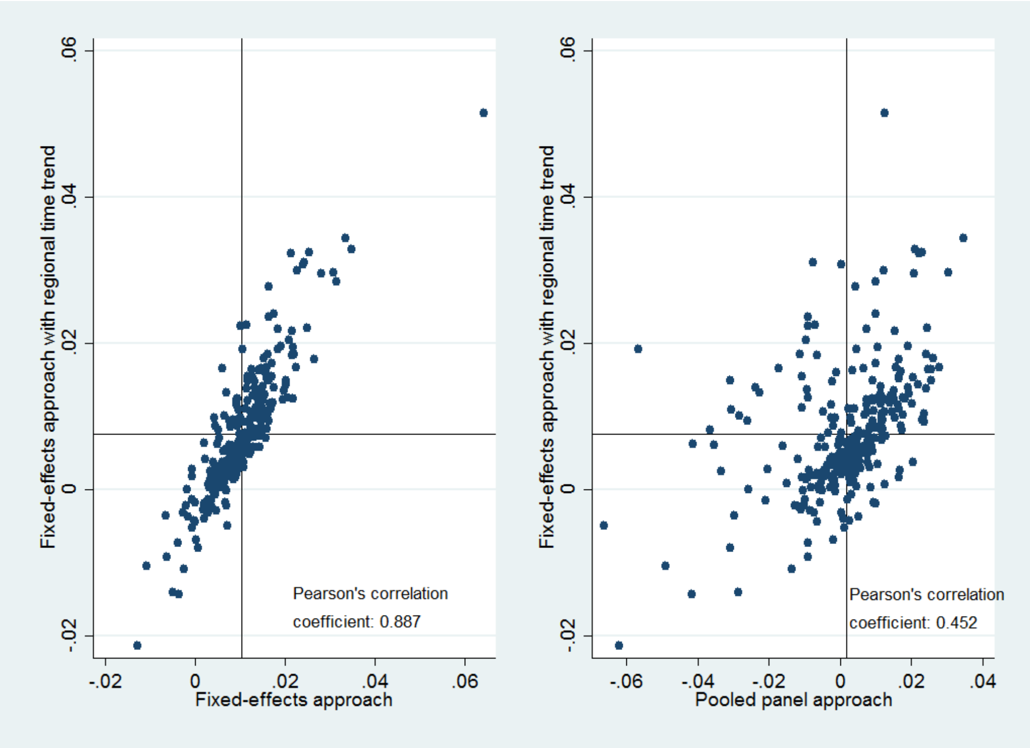


Figure 1. Comparison of mean annual TFP growth rates from 1991 to 2014 for 270 European regions obtained from three different TFP estimation approaches. Black lines indicate the European mean TFP growth rate for the different approaches.

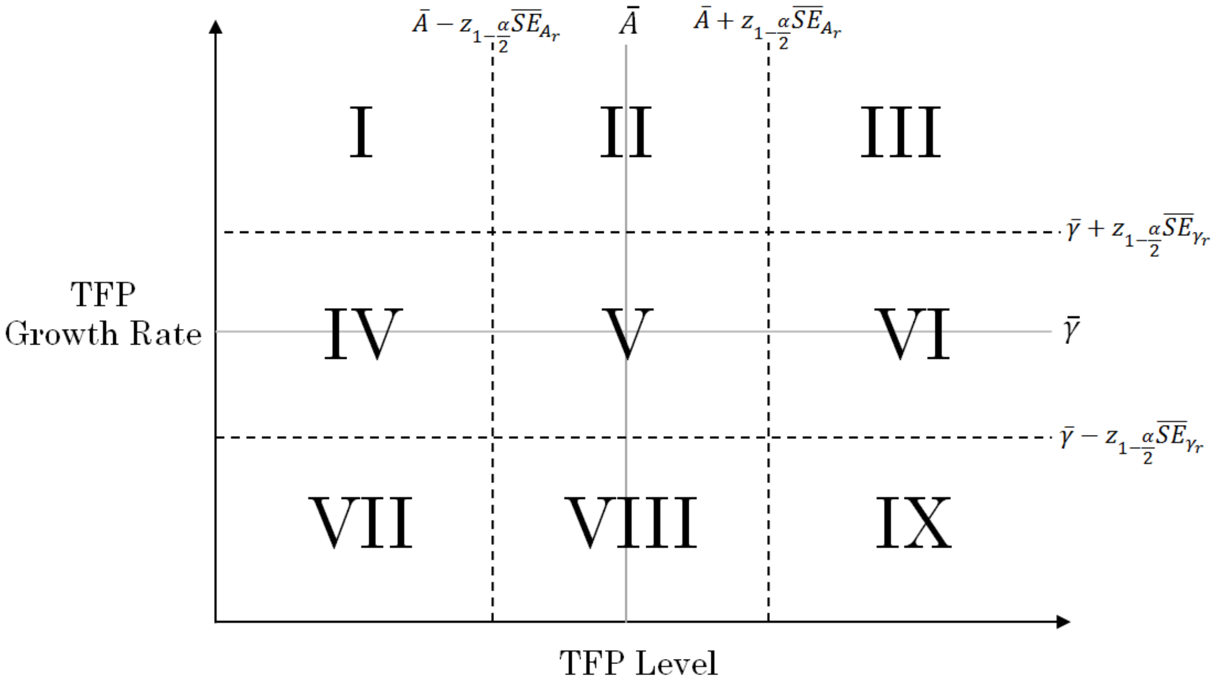
Regarding the econometric methodology of the TFP estimation process, the present work employs a spatial error model estimated with two-stage least squares (2SLS SEM). The 2SLS approach is used to tackle the issue of endogeneity of input factors. A SEM is applied to control for spatial dependence between observation units. An inverse square distance matrix normalized by its largest eigenvalue is employed. Furthermore, the weighting matrix is truncated at 300 km. This distance is chosen as Bottazzi & Peri (2003) show that innovation spillovers exist for regions within a radius of 300 km.[2]

Analysis of TFP convergence

In order to investigate the presence of β-convergence of TFP, the present work follows the same strategy as Bernard & Jones (1996). β-convergence is examined by regressing regional productivity growth rates on initial (log) TFP levels according to equation (3):

$$\hat{\gamma}_r = \alpha + \beta\hat{a}_{r,1991} + \varepsilon_r \tag{3}$$

where $\hat{\gamma}_r$ is the estimated mean annual TFP growth rate and $\hat{a}_{r,1991}$ is the natural logarithm of the estimated regional TFP level of the first observation year, i.e. the year 1991. While an estimated coefficient of β significantly smaller than zero provides evidence for β-convergence, a significantly positive coefficient indicates divergence of TFP levels across the sample. On the other hand, a coefficient insignificantly different from zero shows that, on average, there is neither a significant convergence nor divergence process across the sample regions. As the analysis of β-convergence provides information about the average convergence of regions (or about a priori defined subgroups of regions), it does not permit the contribution of individual regions to the overall convergence process to be investigated. This limitation can be overcome by employing the suggested TFP estimation approach. The regions are grouped according to statistical significant deviations from the mean by using the convergence classification scheme, which is illustrated in Figure 2.



Note: $\bar{A}$ denotes the mean TFP level over all regions, $\bar{\gamma}$ is the mean TFP growth rate, $\overline{SE}_{A_r}$ and $\overline{SE}_{\gamma_r}$ are the corresponding standard errors, $z_{1-\frac{\alpha}{2}}$ is the employed quantile of the standard normal distribution, and α is the significance level.

Figure 2. Typological framework of regional TFP levels and TFP growth rates.

Regions are grouped for both TFP levels and growth rates in below-mean, mean, and above-mean groups. By combining the two dimensions, nine groups of regions are obtained. The proposed classification scheme allows a simple interpretation of the different groups and permits an examination of how many and which regions contribute to overall convergence/divergence and which regions counteract this process.

Regions in Groups IV, V and VI, which do not significantly deviate from the mean growth rate, are static in a certain sense and thus neutral to overall convergence. Obviously, they differ in TFP levels, but do not change their position with regard to the mean. Groups I, II and III comprise regions with the highest TFP growth rates. Group I regions are low productive regions catching up to the European mean and therefore contribute positively to overall convergence. Regions in Groups II and III,

on the other hand, counteract the overall convergence process and contribute to overall divergence. However, as regions belonging to these two groups have both high TFP levels and high TFP growth rates, they can be considered to be technology leaders who promote the efficiency of the production process. At the other end of the classification scheme, Groups VII, VIII and IX include regions that encounter problems keeping up with mean regional TFP growth. Low productive regions in Groups VII and VIII are not able to catch up and diverge further from the European mean. High productive regions in Group IX, on the other hand, converge to the European mean, but in a negative manner.

In order to obtain the groups, a confidence level has to be chosen. Obviously, the chosen confidence level affects the number of regions appertaining to each group. The choice of a high confidence level leads to a larger number of regions in the mean groups and a lower number of regions in groups in the corners of the framework, while for lower confidence levels the opposite is the case. In order to reduce possible type II errors, choosing a low confidence level seems reasonable. Reducing possible type II errors is of particular importance, as falsely classifying a region into the mean group when it belongs in fact to the below-mean group could have serious consequences as it would give the region a false sense of being in a comfortable position. For this reason the results of the present analysis focus on the classification scheme obtained by applying a low confidence level of 80% ($\alpha = 0.2$). With the chosen $\alpha = 0.2$, regional TFP growth rates that are less than 50% of the European mean growth rate are not identified as significant deviations with a probability of about 70%.[3] Nevertheless, there is some arbitrariness in the choice of the confidence level which is investigated further in the results section by varying this level.

Data

In order to estimate regional TFP levels and TFP growth rates, the present work uses a panel dataset of 270 regions belonging to the 28 member states of the European Union plus Norway observed from 1990 to 2014.[4] Regional data are employed at the NUTS-2 level.[5] Data from the output variable value added and the input variable labour units are taken from Cambridge Econometrics. The stock of physical capital is calculated according to the perpetual inventory method:

$$K_t = (1 - \delta)K_{t-1} + I_t \quad (4)$$

where I_t is the flow of gross investments, which is also obtained from the Cambridge Econometrics database, and δ is the depreciation rate, which is assumed to be 6 percent.[6] The capital stock of each region in 1989 is estimated similar to Ezcurra, Iraizoz, & Pascual (2009) and Vogel (2015) as $K_{r,1989} = I_{r,1990}/(g_r + \delta)$, where g_r is the average annual growth rate of investments between the first and the last observation period.[7]

Results

TFP estimation

First, the log-linearised form of equation (1) was estimated by OLS. However, Moran's I test for spatial autocorrelation of OLS residuals as well as robust Lagrange multiplier (LM) tests for spatial error dependence support the choice of a spatial regression model. As indicated by robust LM tests, a SEM appears to be more appropriate than a spatial lag model.[8] The output elasticities of the SEM regression

estimated by 2SLS are 0.189 for capital and 0.614 for labour, indicating slightly decreasing returns to scale. Furthermore, the large spatial error coefficient of 0.703 indicates the need to use a spatial regression model. Summary statistics of estimated region-specific coefficients, i.e. (log) TFP levels and TFP growth rates, and respective standard errors are displayed in Table 1.

Table 1. Summary statistics of estimated coefficients and standard errors of (log) TFP levels and TFP growth rates.

	$\hat{a}_r$		$\hat{\gamma}_r$	
	Coefficient	Standard Error	Coefficient	Standard Error
Mean	2.62920	0.09530	0.00766	0.00486
Minimum	0.83312	0.04762	-0.02135	0.00480
25% Quartile	2.47654	0.09286	0.00236	0.00481
Median	2.80761	0.09939	0.00635	0.00481
75% Quartile	2.91614	0.10315	0.01222	0.00483
Max	3.97743	0.11547	0.05145	0.00585
n	270	270	270	270

Estimated (log) TFP levels range between 0.83 (the Bulgarian region Yuzhen Tsentralen) and 3.98 (Inner London) with a mean of 2.62. With a probability of 90%, 153 of 270 regions are significantly greater than the mean, while 72 are smaller and 45 insignificantly different from the mean. The geographical distribution of regional TFP levels in the last observation year, which is illustrated in Figure 3(a), shows a sharp frontier between low productive regions of former Eastern Bloc countries and higher productive regions of Western EU member states. While the top performing group includes agglomerated capital areas across Western Europe such as London, Luxembourg, Ile de France, and Stockholm as well as, surprisingly, all Norwegian regions, the other side of the distribution consists of most regions of Eastern Europe as well as some peripheral regions in Southern Europe such as areas in Greece, Portugal, and Southern Italy.

The estimated annual TFP growth rate of European regions between 1991 and 2014 is on average 0.77% and ranges from a negative growth rate of -2.14 % in the Bulgarian region Severen Tsentralen to 5.14% in Lithuania. Overall, 169 regional estimates are not significantly different from the mean, while 51 regions are significantly greater and 50 smaller (80% confidence level). The geographical distribution of TFP growth rates in Figure 3(b) reveals high growth rates in most Eastern European countries including regions in Romania, Poland, the Czech Republic, Slovakia and the Baltic states. At the other end of the spectrum, regions with negative growth rates comprise most regions in Italy, all Bulgarian regions and some scattered regions across Europe including regions in Hungary, Greece, Norway, the UK, and Germany. Overall, the two maps in Figure 3 reveal a contrasting picture with generally higher TFP levels and low growth rates in Western European regions, on the one hand, and low TFP levels and higher growth rates in Eastern Europe on the other hand, providing a first indication of an overall TFP convergence process across Europe.

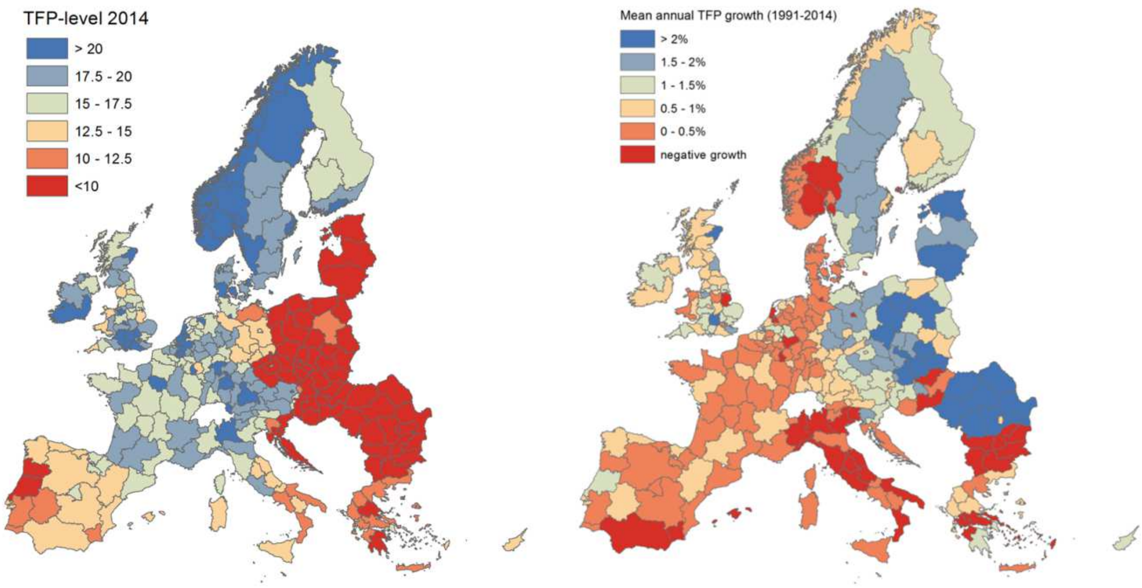


Figure 3. TFP levels 2014 (left-hand side) and mean annual TFP growth between 1991 and 2014 (right-hand side).

Results of European TFP convergence

The results of β-convergence of TFP are reported in Table 2. The highly significant estimate of β of the full sample indicates that TFP of European regions with relatively low initial levels grew faster than TFP of regions with higher initial levels across Europe. Initial TFP levels account for 25.4% of the variation in TFP growth rates across European regions.

Table 2. β-convergence.

	Regions	β	SE	t	P>|t|	R^2
EU28 + Norway (full sample)	270	-0.0079***	0.0008	-9.55	0	0.254
Western Europe	204	-0.0065***	0.0015	-4.25	0	0.082
Eastern Europe	66	-0.0089**	0.0034	-2.63	0.011	0.098

Notes: *** p<0.01, ** p<0.05

β-coefficients are estimated from equation (3).

When examining Western and Eastern European regions separately, results show that there is not only β-convergence in TFP between (less-productive) Eastern European and (higher-productive) Western European regions, but also across regions

within these two subgroups. The higher coefficient of the Eastern European sample suggests that the TFP convergence process across Eastern European regions is faster than that across Western Europe.

As results of β-convergence provide information on only overall convergence, regions are classified for TFP levels as well as TFP growth rates according to statistical significant deviations from the European mean. The obtained regional typology allows an investigation of how many and which regions contribute to the overall TFP convergence process taking place in Europe. Obviously the chosen confidence level affects the number of regions appertaining to each group (cf. Table 3).

Table 3. Number of regions of each group by applying different confidence levels. Groups in the corners of the classification scheme are highlighted in gray.

	Confidence Level			
Group	99%	95%	90%	80%
I	18	23	26	31
II	0	2	5	5
III	2	5	8	15
IV	41	36	32	30
V	105	62	43	25
VI	93	117	125	114
VII	7	8	9	11
VIII	3	8	10	15
IX	1	9	12	24

The lower the confidence level, the larger is the number of regions in the corners of the classification scheme. This applies in particular to groups III and IX. In order to reduce possible type II errors, the subsequently presented results focus on the classification scheme obtained by applying a confidence level of 80%.[9] The resulting distribution of the regional typology based on the 80% confidence interval-can be seen from Figure 4.[10]

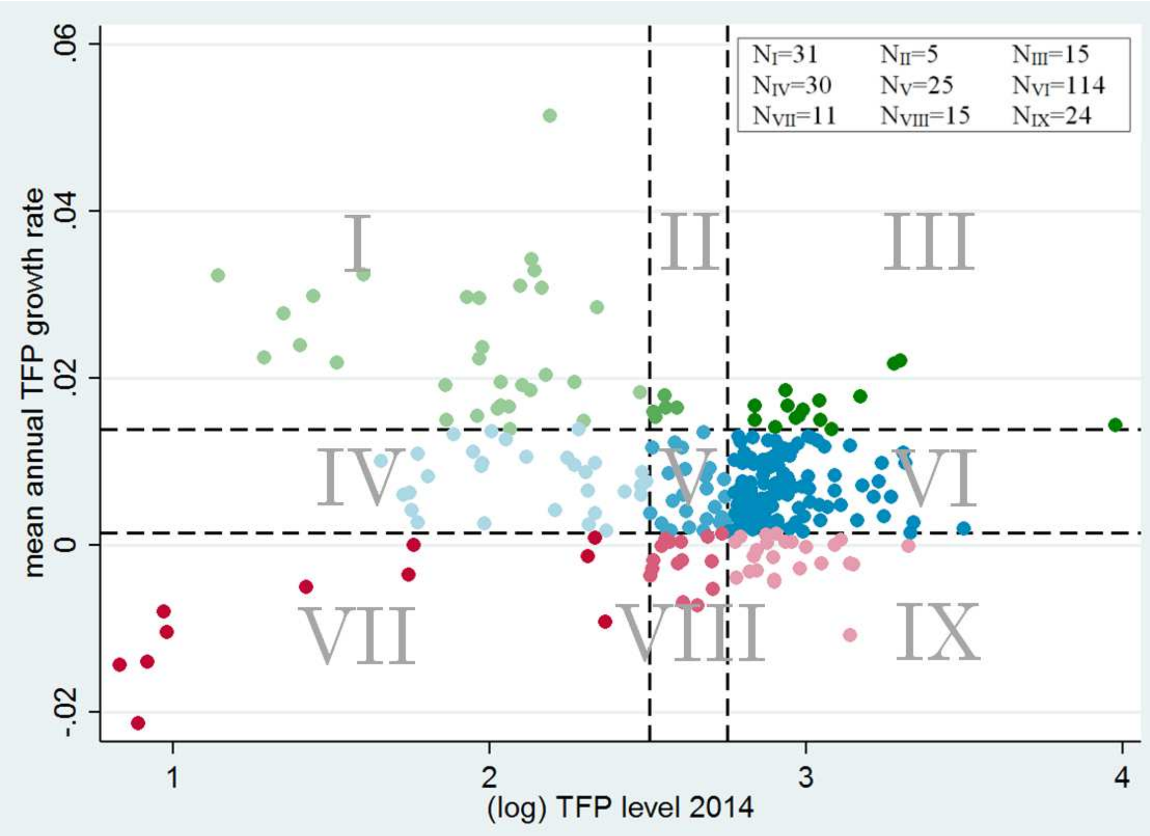


Figure 4. Distribution of TFP levels (2014) and TFP growth rates. The upper and lower bounds of the 80% confidence intervals of the mean TFP level and the mean TFP growth rate are indicated by the dashed lines. The number of regions in each group (N_i) is shown in the upper right corner of the figure.

A total of 31 regions contribute positively to the convergence process across Europe (Group I), while 24 regions converge to the European mean in a negative manner (Group IX). The groups of regions that diverge from the European mean, on the other hand, are substantially smaller: while the 15 regions in Group III (in a broader sense also the five regions in Group II) increase their positive gap to other regions even further, the 11 regions in Group VII (together with the 15 regions in Group VIII) diverge further from the European mean in a negative manner.

The geographical distribution of the regional typology is displayed in Figure 5. Some countries such as France, Finland, Ireland, Bulgaria and Romania show a

homogeneous pattern, as most regions of these countries belong to the same group. On the other hand, countries such as the UK or Germany show a great variability, with regions belonging to various groups, thus indicating considerable regional disparities within these countries.

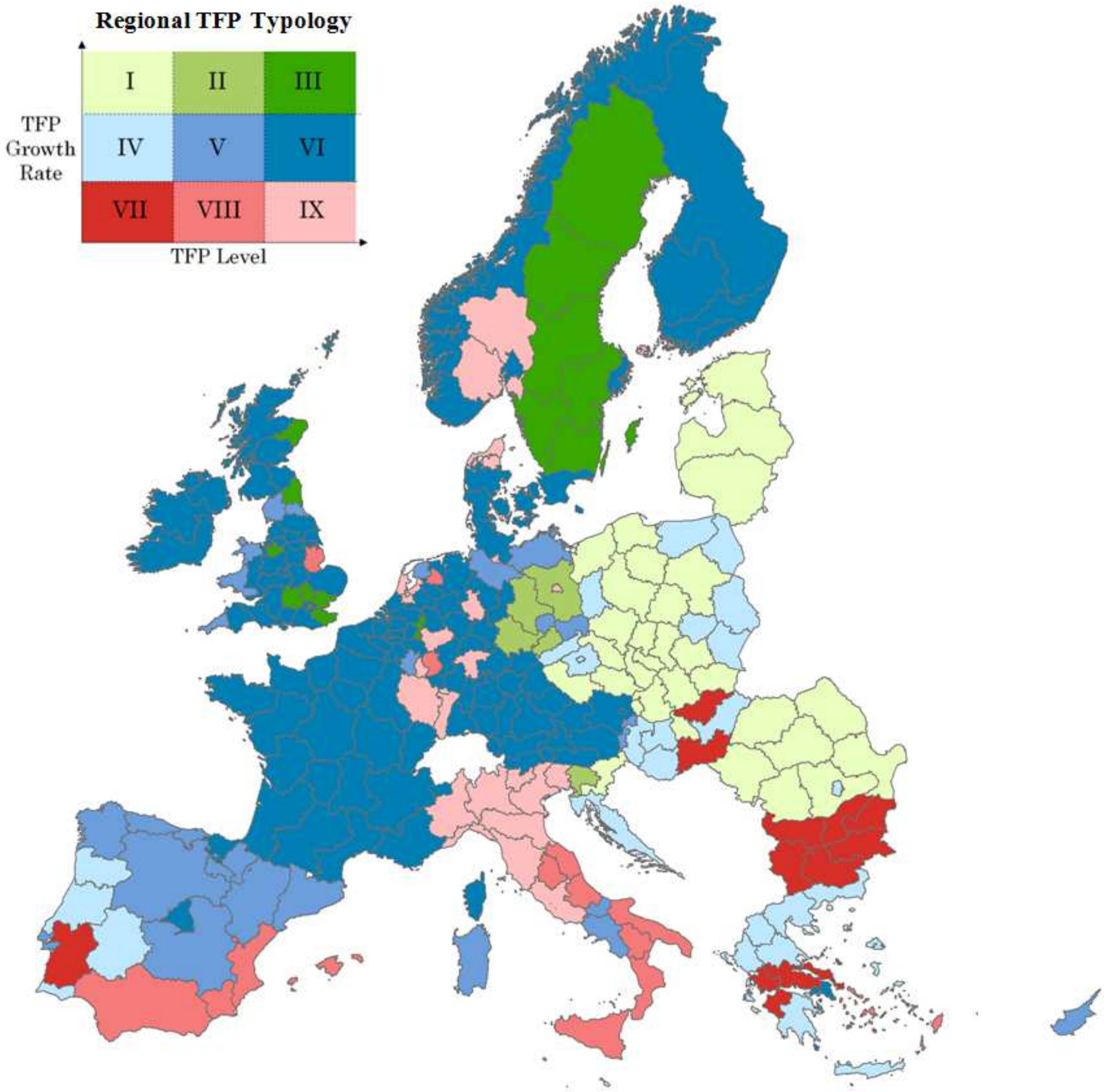


Figure 5. Geographical distribution of the regional TFP typology.

Discussion of the results

Since the early 1990s productivity levels of European regions have exhibited significant β-convergence, with TFP of initially low productive regions growing faster on average than that of initially higher productive regions. As shown by the results,

this overall convergence process across Europe is driven differently by specific groups of regions.

Catch-up regions (positive convergence): The group of regions with low TFP levels that are catching up to the European mean through higher growth rates (Group I) and hence contributing positively to the convergence process taking place across Europe consists exclusively of Eastern European regions: the Baltic states including the territory with the fastest TFP growth throughout the observation period, namely Lithuania, a great cluster of regions spanning from Poland over the Czech Republic to Slovakia as well as the entire country of Romania except its capital region are promoting TFP convergence across Europe in a positive manner. Regions in Group II, which over the past decades have already closed the negative gap to the European mean, are of a smaller size and comprise four ex-GDR regions and one Slovenian region.

Technology leaders (positive divergence): The top performing group in both dimensions (Group III), that is consequently in the process of diverging further from the European mean and counteracting the overall convergence process, is a rather small group that includes the greater part of Sweden, the Dutch region Limburg, London with most of its neighbouring regions as well as other scattered regions across the UK. Technology leaders are of particular importance for overall productivity in Europe as these regions promote the efficiency of the production process.

Former leaders in stagnation (negative convergence): At the other end of the spectrum are regions of Group IX, which converge to the European mean in a negative manner. These (still) high productive regions are losing ground against the European mean due to low TFP growth and include the greatest part of Northern Italy and some scattered areas across Central and Northern Europe. Most surprisingly,

some agglomerated areas in Germany such as the capital region of Berlin, Hamburg and Cologne as well as the Grand Duchy of Luxembourg are also part of this group.

Europe's problematic regions (negative divergence): This group of regions comprises almost exclusively Eastern and Southern European regions and includes regions with lowest TFP levels and TFP growth rates (Group VII), such as all of Bulgaria as well as regions in Hungary, Greece, and Portugal. Over the past decades these regions have widened their negative gap to the European mean even further. In addition, great parts of Italy's Mezzogiorno and Southern Spain (Group VIII), which are characterized by mean TFP levels but low growth rates, risk falling behind the rest of Europe.

The remaining regions (Groups IV, V and VI) exhibit TFP growth rates similar to the European mean and therefore contribute neither to TFP convergence nor to divergence. Great parts of Central and Northern Europe are characterized by above-mean TFP levels and mean TFP growth rates and hence are expected to remain in a comfortable position. On the other hand, less productive regions in Eastern and Southern Europe including areas in Poland, Hungary, Greece, and Portugal are developing according to the European mean, but this does not suffice to narrow the gap to the rest of Europe.

When looking at regional performance within individual countries some interesting insights can be gained: while a range of countries including France, Austria, Sweden, Finland, Poland and the Czech Republic show homogeneous regional patterns, others such as the UK and the Netherlands are characterized by substantial regional disparities. The biggest parts of both the UK and the Netherlands show a solid productivity performance with high TFP levels and growth rates similar to the European mean. Some regions in both countries, however, especially

agglomerated areas including the London area with some of its neighbouring regions as well as the Dutch region Limburg, show significantly higher productivity growth than does the European mean. On the other hand, productivity is stagnating in some less populated areas that are predominantly agricultural in land use such as Lincolnshire in the UK or Drenthe in the Netherlands.

Productivity performance of regions within Italy, Spain, and Germany are divided: the north/south divide is clearly present in both Italy and Spain, while Germany is characterized by the west/east divide. The south of Italy shows mediocre TFP levels and growth rates lower than the European mean and hence is among the worst performing areas across Western Europe. While the poor productivity performance of Italy's Mezzogiorno is of little surprise, the TFP dynamics of Northern Italy is rather unexpected and alarming at the same time: as all regions of Northern Italy, except the two autonomous alpine regions Bolzano and Valle d'Aosta, are characterized by high TFP levels, but growth rates below the European mean, these formerly leading regions are losing ground against other regions.

The poor performance of the south of Spain is similar to that of Southern Italy. However, Spain's north gives fewer reasons to be concerned as regional TFP growth is in line with the European mean. Finally, Germany is characterized by the west/east divide with the TFP of (formerly) low productive new *Länder* growing faster than that of higher productive old *Länder*. While most of the latter show solid performance with high TFP levels and TFP growth close to the European mean, some scattered agglomerated areas including Hamburg and Cologne indicate slower TFP growth.

Since the fall of the Iron Curtain TFP levels of most of the regions of the former Eastern Bloc countries have converged to the European mean. Some regions including all the regions of Bulgaria, however, have failed to catch up and are failing

to keep up with the rest of Europe. While in the years immediately after the fall of the Iron Curtain all Romanian regions were Europe’s worst performing regions in terms of TFP levels, these regions have caught up remarkably during the past decades and have overtaken the regions of the second-worst performing country of 1991 – Bulgaria. The latter regions are at the bottom of the TFP level ranking in Europe at the current time.

Conclusion

The present work investigated TFP dynamics of European regions and the contribution of individual regions to overall TFP convergence taking place across Europe. While conventional convergence analyses including β-convergence are restricted to the investigation of overall TFP convergence, the approach applied in this paper allows an analysis of whether and how individual regions contribute to the overall convergence process. As shown in the present work, employing a TFP approach that estimates TFP levels and TFP growth rates as individual model parameters and classifying regional TFP performance according to statistical significant deviations from the mean allows proper interpretation of regional TFP dynamics and provides the possibility for an in-depth analysis of the European convergence process.

In the classification scheme the upper and lower bounds of the mean groups are determined by TFP estimates, corresponding standard errors and the chosen confidence level. In this context, choosing a low confidence level seems reasonable in order to reduce possible type II errors. This can be exemplified by most regions in the north of Italy, which are classified in group IX (above-mean levels and below-mean growth rates) when a low confidence level is chosen, but in groups with mean TFP growth rates (groups V or VI) when a high confidence level is applied. As a

consequence, the application of a high confidence level might give these regions a deceptive sense of being in a comfortable position.

When investigating the individual contribution of regions to the overall convergence process, it is essential to differentiate between positive and negative contribution to convergence. Catch-up regions, on the one hand, contribute to overall convergence in a positive, desirable way. Former high productive regions with very low TFP growth rates, on the other hand, also promote overall convergence but, however, in a negative manner. As the slowdown of growth of the latter regions must be clearly addressed, not only policy actions promoting the European convergence process are necessary, but also policies counteracting this process: regions contributing to overall convergence in a negative manner such as Northern Italy need to introduce and implement reforms in order to not lose further ground to Europe's leading economies.

Notes

[1] For the model comparison the same data as in the main analysis of the present work is used. The detailed description of the data set can be found in the data section.

[2] For a more detailed explanation of the chosen econometric strategy, see Schatzer et al. (2018).

[3] Obviously, this probability increases with a decreasing significance level. For a graphical illustration see Figure A1 in the Appendix.

[4] Spanish exclaves and the Canary Islands, French overseas departments and territories, and the Portuguese regions Azores and Madeira are not included in the sample.

[5] Note that for smaller countries the NUTS-2 level corresponds to the NUTS-1 level and/or to the national level (e.g. Luxembourg).

[6] Depreciation rates in TFP studies on the European regional level generally range between 5 and 10 percent. In the present work various values within this range were considered. As the depreciation rate is assumed to be constant across regions, TFP estimates are affected only marginally by the choice of depreciation rate.

[7] As robustness check the initial capital stock is computed as the cumulative sum of investment flows over the preceding ten-year period from 1980 to 1989 (Dettori et al., 2012; Marrocu & Paci, 2011; Marrocu et al., 2013). However, as data on Eastern European regions are available only from 1990, only regions of the EU15 countries plus Norway are considered for the robustness check. TFP estimates based on this alternative initial capital stock remain basically unchanged.

[8] Both Moran's I test on OLS residuals and the robust LM test for spatial error dependence are highly significant, while the robust LM test for spatial lag dependence is not significant.

[9] Table A1 in the Appendix provides an overview of all 270 regions and their respective groups obtained by applying confidence levels of 80, 90, 95, and 99%.

[10] For the regional typology we use TFP levels from the last observation period, i.e. the year 2014.

Appendix

Table A1. 270 European regions and their respective groups obtained by applying confidence levels of 80, 90, 95, and 99%.

NUTS	Region Name	Confidence Interval 80	90	95	99
AT11	Burgenland	V	V	V	V
AT12	Niederösterreich	VI	VI	VI	VI
AT13	Wien	VI	VI	VI	VI
AT21	Kärnten	VI	VI	VI	VI
AT22	Steiermark	VI	VI	VI	V
AT31	Oberösterreich	VI	VI	VI	VI
AT32	Salzburg	VI	VI	VI	VI
AT33	Tirol	VI	VI	VI	VI
AT34	Vorarlberg	VI	VI	VI	VI
BE1	Région de Bruxelles-Cap	VI	VI	VI	VI
BE21	Prov. Antwerpen	VI	VI	VI	VI
BE22	Prov. Limburg (BE)	VI	VI	VI	V
BE23	Prov. Oost-Vlaanderen	VI	VI	VI	VI
BE24	Prov. Vlaams-Brabant	VI	VI	VI	VI
BE25	Prov. West-Vlaanderen	VI	VI	VI	VI
BE31	Prov. Brabant Wallon	VI	VI	VI	VI
BE32	Prov. Hainaut	VI	VI	V	V
BE33	Prov. Liège	VI	VI	VI	VI
BE34	Prov. Luxembourg (BE)	V	V	V	V
BE35	Prov. Namur	VI	VI	VI	V
BG31	Severozapaden	VII	VII	VII	VII
BG32	Severen tsentralen	VII	VII	VII	VII
BG33	Severoiztochen	VII	VII	VII	VII
BG34	Yugoiztochen	VII	VII	VII	VII
BG41	Yugozapaden	VII	VII	VII	VII
BG42	Yuzhen tsentralen	VII	VII	VII	VII
CY	Kypros	V	V	V	V
CZ01	Praha	IV	V	V	V
CZ02	Střední Čechy	IV	IV	IV	IV
CZ03	Jihozápad	I	I	I	IV
CZ04	Severozápad	IV	IV	IV	IV
CZ05	Severovýchod	I	I	IV	IV
CZ06	Jihovýchod	I	I	I	IV
CZ07	Střední Morava	I	I	IV	IV
CZ08	Moravskoslezsko	I	I	I	I
DE11	Stuttgart	VI	VI	VI	VI
DE12	Karlsruhe	VI	VI	VI	VI
DE13	Freiburg	VI	VI	VI	V
DE14	Tübingen	VI	VI	VI	VI
DE21	Oberbayern	VI	VI	VI	VI
DE22	Niederbayern	VI	VI	VI	VI
DE23	Oberpfalz	VI	VI	VI	VI
DE24	Oberfranken	VI	VI	VI	V
DE25	Mittelfranken	VI	VI	VI	VI
DE26	Unterfranken	VI	VI	VI	VI
DE27	Schwaben	VI	VI	VI	V
DE3	Berlin	IX	IX	IX	V
DE4	Brandenburg	II	II	V	V
DE5	Bremen	VI	VI	VI	VI
DE6	Hamburg	IX	IX	IX	VI
DE71	Darmstadt	IX	VI	VI	VI
DE72	Gießen	VI	VI	VI	V
DE73	Kassel	VI	VI	VI	V
DE8	Mecklenburg-Vorpomme	V	V	V	V

NUTS	Region Name	Confidence Interval 80	90	95	99
DE91	Braunschweig	VI	VI	VI	VI
DE92	Hannover	VI	VI	VI	VI
DE93	Lüneburg	V	V	V	V
DE94	Weser-Ems	VI	V	V	V
DEA1	Düsseldorf	VI	VI	VI	VI
DEA2	Köln	IX	IX	IX	VI
DEA3	Münster	VI	VI	VI	VI
DEA4	Detmold	IX	VI	VI	VI
DEA5	Arnsberg	VI	VI	VI	VI
DEB1	Koblenz	VI	V	V	V
DEB2	Trier	VIII	V	V	V
DEB3	Rheinhessen-Pfalz	VI	VI	VI	V
DEC	Saarland	VI	VI	VI	V
DED2	Dresden	V	V	V	V
DED4	Chemnitz	II	II	V	V
DED5	Leipzig	V	V	V	V
DEE	Sachsen-Anhalt	II	II	II	V
DEF	Schleswig-Holstein	VI	V	V	V
DEG	Thüringen	II	V	V	V
DK01	Hovedstaden	VI	VI	VI	VI
DK02	Sjælland	VI	VI	VI	VI
DK03	Syddanmark	VI	VI	VI	VI
DK04	Midtjylland	VI	VI	VI	VI
DK05	Nordjylland	IX	VI	VI	VI
EE	Eesti	I	I	I	I
EL11	Anatoliki Makedonia, Thr	IV	IV	IV	IV
EL12	Kentriki Makedonia	IV	IV	IV	IV
EL13	Dytiki Makedonia	IV	IV	IV	V
EL14	Ipeiros	IV	IV	IV	IV
EL21	Thessalia	IV	IV	IV	IV
EL22	Ionia Nisia	IV	V	V	V
EL23	Dytiki Ellada	VII	VII	IV	IV
EL24	Sterea Ellada	VII	VII	VII	VII
EL25	Peloponnisos	IV	IV	IV	IV
EL3	Attiki	VI	VI	V	V
EL41	Voreio Aigaio	IV	V	V	V
EL42	Notio Aigaio	VIII	VIII	VIII	V
EL43	Kriti	IV	IV	IV	IV
ES11	Galicia	V	V	V	V
ES12	Principado de Asturias	V	V	V	V
ES13	Cantabria	V	V	V	V
ES21	País Vasco	VI	VI	V	V
ES22	Comunidad Foral de Nava	V	V	V	V
ES23	La Rioja	V	V	V	V
ES24	Aragón	V	V	V	V
ES3	Comunidad de Madrid	VI	VI	V	V
ES41	Castilla y León	V	V	V	V
ES42	Castilla-La Mancha	V	V	V	V
ES43	Extremadura	IV	V	V	V
ES51	Cataluña	V	V	V	V
ES52	Comunidad Valenciana	VIII	V	V	V
ES53	Illes Balears	VIII	VIII	VIII	VIII
ES61	Andalucía	VIII	V	V	V
ES62	Región de Murcia	VIII	VIII	VIII	V

NUTS	Region Name	Confidence Interval 80	90	95	99
FI19	Länsi-Suomi	VI	VI	VI	V
FI1B	Helsinki-Uusimaa	VI	VI	VI	VI
FI1C	Etelä-Suomi	VI	VI	VI	VI
FI1D	Pohjois- ja Itä-Suomi	VI	VI	VI	V
FI2	Åland	IX	IX	VI	VI
FR1	Île de France	VI	VI	VI	VI
FR21	Champagne-Ardenne	VI	VI	VI	V
FR22	Picardie	VI	VI	VI	V
FR23	Haute-Normandie	VI	VI	VI	V
FR24	Centre	VI	VI	VI	V
FR25	Basse-Normandie	VI	VI	V	V
FR26	Bourgogne	VI	VI	VI	V
FR3	Nord - Pas-de-Calais	VI	VI	VI	V
FR41	Lorraine	IX	VI	V	V
FR42	Alsace	IX	VI	VI	VI
FR43	Franche-Comté	VI	VI	V	V
FR51	Pays de la Loire	VI	VI	VI	VI
FR52	Bretagne	VI	VI	VI	V
FR53	Poitou-Charentes	VI	VI	VI	V
FR61	Aquitaine	VI	VI	VI	VI
FR62	Midi-Pyrénées	VI	VI	VI	VI
FR63	Limousin	VI	V	V	V
FR71	Rhône-Alpes	VI	VI	VI	VI
FR72	Auvergne	VI	VI	V	V
FR81	Languedoc-Roussillon	VI	VI	VI	V
FR82	Provence-Alpes-Côte d'Azur	VI	VI	VI	VI
FR83	Corse	VI	VI	VI	V
HR03	Jadranska Hrvatska	IV	IV	IV	IV
HR04	Kontinentalna Hrvatska	IV	IV	IV	IV
HU1	Közép-Magyarország	I	I	I	IV
HU21	Közép-Dunántúl	IV	IV	IV	IV
HU22	Nyugat-Dunántúl	IV	IV	IV	IV
HU23	Dél-Dunántúl	IV	IV	IV	IV
HU31	Észak-Magyarország	VII	IV	IV	IV
HU32	Észak-Alföld	IV	IV	IV	IV
HU33	Dél-Alföld	VII	VII	VII	IV
IE01	Border, Midland and Western	VI	VI	VI	VI
IE02	Southern and Eastern	VI	VI	VI	VI
ITC1	Piemonte	IX	IX	VI	V
ITC2	Valle d'Aosta/Vallée d'Aoste	VI	VI	VI	VI
ITC3	Liguria	IX	IX	IX	VI
ITC4	Lombardia	IX	VI	VI	VI
ITF1	Abruzzo	VIII	VIII	VIII	VIII
ITF2	Molise	V	V	V	V
ITF3	Campania	V	V	V	V
ITF4	Puglia	VIII	VIII	VIII	V
ITF5	Basilicata	VIII	V	V	V
ITF6	Calabria	VIII	VIII	V	V
ITG1	Sicilia	VIII	V	V	V
ITG2	Sardegna	V	V	V	V
ITH1	Provincia Autonoma di Bolzano/Bo	VI	VI	VI	VI
ITH2	Provincia Autonoma di Trento	IX	VI	VI	VI
ITH3	Veneto	IX	IX	IX	V
ITH4	Friuli-Venezia Giulia	IX	VIII	VIII	V

NUTS	Region Name	Confidence Interval 80	90	95	99
ITH5	Emilia-Romagna	IX	VI	VI	VI
ITI1	Toscana	IX	IX	VI	V
ITI2	Umbria	VIII	VIII	VIII	VIII
ITI3	Marche	VIII	VIII	VIII	V
ITI4	Lazio	IX	IX	IX	VI
LT	Lietuva	I	I	I	I
LU	Luxembourg	IX	VI	VI	VI
LV	Latvija	I	I	I	IV
MT	Malta	IV	IV	IV	IV
NL11	Groningen	VI	VI	VI	VI
NL12	Friesland (NL)	V	V	V	V
NL13	Drenthe	VIII	V	V	V
NL21	Overijssel	VI	VI	V	V
NL22	Gelderland	VI	VI	VI	V
NL23	Flevoland	IX	V	V	V
NL31	Utrecht	IX	IX	IX	VI
NL32	Noord-Holland	IX	VI	VI	VI
NL33	Zuid-Holland	VI	VI	VI	VI
NL34	Zeeland	VI	VI	V	V
NL41	Noord-Brabant	VI	VI	VI	VI
NL42	Limburg (NL)	III	VI	VI	VI
NO01	Oslo og Akershus	VI	VI	VI	VI
NO02	Hedmark og Oppland	IX	IX	IX	VI
NO03	Sør-Østlandet	IX	IX	IX	IX
NO04	Agder og Rogaland	VI	VI	VI	VI
NO05	Vestlandet	VI	VI	VI	VI
NO06	Trøndelag	VI	VI	VI	VI
NO07	Nord-Norge	VI	VI	VI	VI
PL11	Łódzkie	I	IV	IV	IV
PL12	Mazowieckie	I	I	I	I
PL21	Małopolskie	I	I	I	I
PL22	Śląskie	I	I	I	IV
PL31	Lubelskie	IV	IV	IV	IV
PL32	Podkarpackie	IV	IV	IV	IV
PL33	Świętokrzyskie	IV	IV	IV	IV
PL34	Podlaskie	IV	IV	IV	IV
PL41	Wielkopolskie	I	I	I	I
PL42	Zachodniopomorskie	I	I	IV	IV
PL43	Lubuskie	IV	IV	IV	IV
PL51	Dolnośląskie	I	I	I	I
PL52	Opolskie	I	IV	IV	IV
PL61	Kujawsko-pomorskie	I	I	I	I
PL62	Warmińsko-mazurskie	IV	IV	IV	IV
PL63	Pomorskie	I	IV	IV	IV
PT11	Norte	IV	IV	IV	IV
PT15	Algarve	IV	IV	IV	IV
PT16	Centro (PT)	IV	IV	IV	IV
PT17	Área Metropolitana de Lis	V	V	V	V
PT18	Alentejo	VII	IV	IV	IV
RO11	Nord-Vest	I	I	I	I
RO12	Centru	I	I	I	I
RO21	Nord-Est	I	I	I	I
RO22	Sud-Est	I	I	I	I
RO31	Sud - Muntenia	I	I	I	I

NUTS	Region Name	Confidence Interval 80	90	95	99
RO32	Bucureşti - Ilfov	IV	IV	IV	IV
RO41	Sud-Vest Oltenia	I	I	I	I
RO42	Vest	I	I	I	I
SE11	Stockholm	VI	VI	VI	VI
SE12	Östra Mellansverige	III	III	VI	VI
SE21	Småland med öarna	III	III	III	VI
SE22	Sydsverige	VI	VI	VI	VI
SE23	Västsverige	III	VI	VI	VI
SE31	Norra Mellansverige	III	VI	VI	VI
SE32	Mellersta Norrland	III	VI	VI	VI
SE33	Övre Norrland	III	III	III	VI
SI01	Vzhodna Slovenija	I	IV	IV	IV
SI02	Zahodna Slovenija	II	II	V	V
SK01	Bratislavský kraj	I	II	II	V
SK02	Západné Slovensko	I	I	I	I
SK03	Stredné Slovensko	I	I	I	I
SK04	Východné Slovensko	I	I	I	I
UKC1	Tees Valley and Durham	V	V	V	V
UKC2	Northumberland and Tyne and Wear	III	III	VI	V
UKD1	Cumbria	V	V	V	V
UKD3	Greater Manchester	VI	VI	VI	VI
UKD4	Lancashire	VI	VI	V	V
UKD6	Cheshire	III	III	III	VI
UKD7	Merseyside	VI	VI	VI	VI
UKE1	East Yorkshire and Northern Lincolnshir	VI	VI	V	V
UKE2	North Yorkshire	VI	VI	VI	V
UKE3	South Yorkshire	VI	VI	V	V
UKE4	West Yorkshire	VI	VI	VI	VI
UKF1	Derbyshire and Nottinghamshire	VI	VI	VI	V
UKF2	Leicestershire, Rutland, Northamptonsh	VI	VI	VI	VI
UKF3	Lincolnshire	VIII	VIII	V	V
UKG1	Hereford-, Worcester- and Warwickshire	VI	VI	VI	VI
UKG2	Shropshire and Staffordshire	VI	V	V	V
UKG3	West Midlands	VI	VI	VI	VI
UKH1	East Anglia	VI	VI	VI	VI
UKH2	Bedfordshire and Hertfordshire	III	VI	VI	VI
UKH3	Essex	III	VI	VI	V
UKI1	Inner London	III	VI	VI	VI
UKI2	Outer London	VI	VI	VI	VI
UKJ1	Berk-, Buckingham- and Oxfordshire	III	III	III	III
UKJ2	Surrey, East and West Sussex	VI	VI	VI	VI
UKJ3	Hampshire and Isle of Wight	VI	VI	VI	VI
UKJ4	Kent	III	III	VI	VI
UKK1	Gloucestershire, Wiltshire and Bristol	VI	VI	VI	VI
UKK2	Dorset and Somerset	VI	VI	VI	VI
UKK3	Cornwall and Isles of Scilly	V	V	V	V
UKK4	Devon	VI	VI	VI	V
UKL1	West Wales and The Valleys	V	V	V	V
UKL2	East Wales	VI	VI	VI	VI
UKM2	Eastern Scotland	VI	VI	VI	VI
UKM3	South Western Scotland	VI	VI	VI	V
UKM5	North Eastern Scotland	III	III	III	III
UKM6	Highlands and Islands	VI	V	V	V
UKN	Northern Ireland	VI	VI	V	V

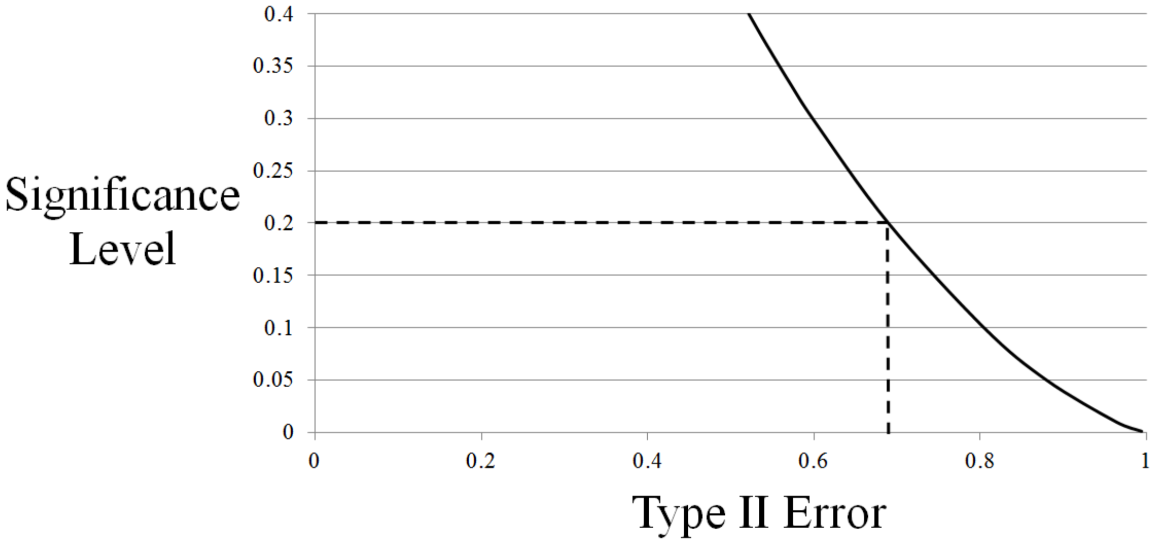


Figure A1. Relationship between the significance level and the probability that regional TFP growth rates that are less than 50% of the European mean growth rate are not identified as significant deviations (denoted by type II error). The dashed lines indicate the chosen significance level.

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