Intraregional Spatial Inequalities and Regional Income Level in the European Union: Beyond the Inverted-U Hypothesis

by Panagiotis Artelaris and George Petrakos (2016)

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This paper follows the approach of Artelaris and Petrakos (2016) in examining the realtionship between intraregional spatial inequalities and regional income level in the European Union. A common assumption is that the relationship follows an Inverted-U pattern, meaning that as the income level rises, the inequality will first rise as well, until a certain level is reached from which on it will fall.

First of all, we have constructed a Regional Inequality Index, which consists of a weighted coefficient of variation of regional (NUTS 3) GDP per capita.

$$\mathrm{CV_w} = \left[\sum_t \left(X_i - \bar{x}\right)^2 \times \left(P_i / P\right) \right]^{1/2} \Big/ \bar{x}$$

In this equation, i denotes the region, X_i GDP/capita at the NUTS 3 level, $\bar{x}$ the average GDP/capita at the NUTS 2 level, P_i the population at the NUTS 3 level and P Population at the NUTS 2 level.

To test the Inverted-U hypothesis, we first estimate an OLS-model.

$$y = \alpha + \beta x_1 + \gamma (x_1)^2 + \delta x_2 + \epsilon, \quad \epsilon \sim \mathcal{N}(0, \sigma^2 I)$$

In this model y is vector of regional inequality ($\mathrm{CV_w}$ at NUTS 2 level), x_1 vector of GDP/capita at NUTS 3 level and x_2 number of NUTS 3 regions in each NUTS 2 region. The Inverted-U hypothesis is supported, if $\beta > 0$ and $\gamma < 0$. The results of the OLS-estimation can be found in Table 1. The results contradict the Inverted-U hypothesis, as for every year from 1996 to 2015, the β is negative and the γ is positive. This suggests an regular U-shaped relationship. Interestingly, the β stop being significant from 2011 onward, although the γ remain highly significant.

Table 1: OLS-Estimation

	Dependent variable:				
	Regional Inequality Index				
	1996	2000	2005	2010	2015
GDP per capita (β)	-1.877^{**}	-1.995^{**}	-1.769^{**}	-1.309^{*}	-0.829
	(0.863)	(0.813)	(0.812)	(0.785)	(0.752)
(GDP per capita $)^2(\gamma)$	60.784^{***}	49.588^{***}	42.072^{***}	33.088^{***}	23.759^{***}
	(9.950)	(8.776)	(7.547)	(6.162)	(5.079)
NUTS 3 Number (δ)	0.020^{***}	0.020^{***}	0.020^{***}	0.019^{***}	0.019^{***}
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Constant (α)	0.066^{***}	0.071^{***}	0.074^{***}	0.076^{***}	0.075^{***}
	(0.015)	(0.016)	(0.018)	(0.018)	(0.018)
Observations	266	266	266	266	266
R^2	0.470	0.447	0.425	0.415	0.390
Adjusted R^2	0.464	0.441	0.418	0.409	0.383
Residual Std. Error (df = 262)	0.091	0.095	0.101	0.101	0.104
F Statistic (df = 3; 262)	77.431^{***}	70.605^{***}	64.531^{***}	62.047^{***}	55.803^{***}
Note:					*p<0.1; **p<0.05; ***p<0.01

After extensive testing we came to the conclusion that OLS is not the appropriate approach to estimate the relationship between regional inequality and regional income level. We used a Breusch-Pagan Test to test the assumption of homoskedasticity, which is violated. The assumption of a normal distribution is also violated, as is suggested by the significant Jarque-Bera Test. Therefore, we should use another model which can handle these attributes. Moran's I suggests that spatial autocorrelation is present. To decide which spatial model we shall use, we used LM-tests for residual autocorrelation (LMERR) and LM-tests lagged for spatial endogenous variables (LM-LAG). The LMERR-Test suggested a spatial error model, but the robust version of the test was not significant anymore. Both the LM-LAG, as well as the robust version, are significant and therefore, we decided to use a SAR-Model.

$$y = \alpha + \rho W y + \beta x_1 + \gamma(x_1)^2 + \delta x_2 + \epsilon, \quad \epsilon \sim \mathcal{N}(0, \sigma^2 I)$$

The results are similar to the results of the OLS-estimation and can be found in Table 2. We can not support the Inverted-U hypothesis, as the β are negative and the γ are positive. From 2010 on, the β have lost significance, whilst the γ remain positive. This estimation uses a k-neraest weights matrix, with k set to 5. The results remain robust if other weights matrices are used (other values for k or inverse-distance based weights matrices).

Table 2: ML-Estimation of SAR-Model

	Dependent variable:				
	Intraregional Inequality Index				
	1996	2000	2005	2010	2015
Spatial-Lag (ρ)	0.300***	0.278***	0.263***	0.217***	0.224***
	(0.066)	(0.069)	(0.071)	(0.074)	(0.075)
GDP per capita (β)	−1.871**	−1.953**	−1.709**	−1.252	−0.769
	(0.835)	(0.787)	(0.790)	(0.776)	(0.747)
(GDP per capita)^2(γ)	59.631***	48.414***	40.929***	32.347***	23.014***
	(9.483)	(8.417)	(7.273)	(6.023)	(4.974)
NUTS 3 Number (δ)	0.017***	0.018***	0.018***	0.017***	0.017***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Constant (α)	0.032**	0.040**	0.043**	0.049***	0.047**
	(0.016)	(0.017)	(0.018)	(0.019)	(0.019)
Observations	266	266	266	266	266
Log Likelihood	270.565	259.502	242.178	237.662	231.179
σ^2	0.008	0.008	0.009	0.010	0.010
Jarque-Bera (normality)	92.706***	146.355***	132.881***	193.329***	336.419***
Breusch-Pagan	12.416***	15.936***	17.335***	17.774***	15.824***
LR Test (df = 1)	19.348***	15.713***	13.808***	8.967***	9.489***
Note:					*p<0.1; **p<0.05; ***p<0.01

Since the Breusch-Pagan Test and the Jarque-Bera Test suggest that the assumptions of normality and homoscedasticity are violated, we used a Two-Stage Least Squares estimation of the SAR-model to produce robust results. These results are not drastically different from the results of the regular SAR-model estimation.

One could argue that the results of our estimation look that way, because the included countries are already in a developed state. Therefore, they would already be on the declining side of the Inverted-U curve, what would explain the negative β. To test this, we estimate a linear model, excluding the squared-term of x_1. The results show that in this model the β are positive, so the hypothesis of the countries being developed enough to be on another part of the Inverted-U curve can be rejected.

Considering our results and their robustness over a wide range of tests and models, we can confidently reject the inverted-U hypotheses. It does not appear that inequality will first rise with income level and the fall after a certain threshold. Instead, the opposite seems to be the case.

References

P. Artelaris and G. Petrakos. Intraregional spatial inequalities and regional income level in the european union: Beyond the inverted-u hypothesis. *International Regional Science Review*, 39(3):291–317, 2016.