Fiscal Transfers in the Spatial Economy

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Online Appendix

A.1 Solving the system of non-linear equations

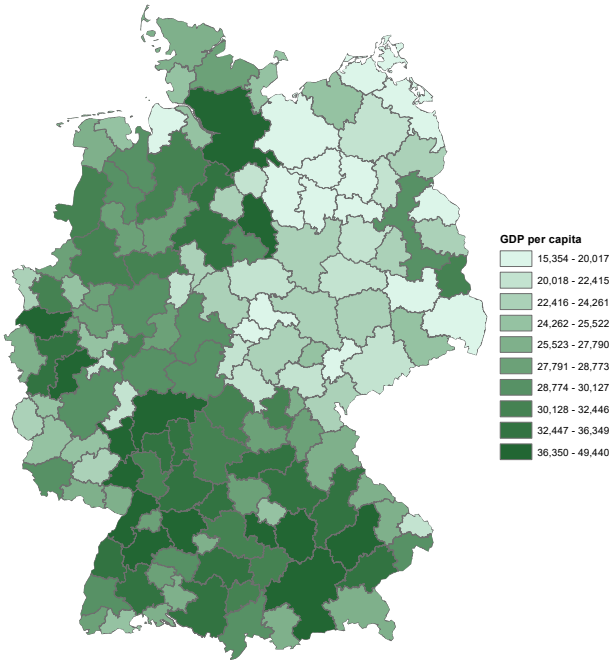
We employ a method of successive approximations to solve for the equilibrium of the system of non-linear equations (see Zabreiko et al., 1975). In the following, we briefly describe the steps of the iterative procedure. First, we choose an arbitrary vector of non-negative starting values for the endogenous variables in equations (13)-(14). Next, we simultaneously solve the system of equations (13)-(14) for a given parameterization of trade costs and parameter values to obtain new vectors of solutions for the endogenous variables. To ensure convergence, we normalize each new vector to sum up to one. We then update the starting values according to a weighted average of previous starting values and solutions of the previous iteration. Finally, we iteratively solve the system of equations until the metric distance between the starting values and solutions of the endogenous variables becomes sufficiently small.

Existence and uniqueness theorems for non-linear equations are described by Polyanin and Manzhirov (2008). Under the condition that the sequence of convergence is an element of a complete metric space, it will also converge to a limit point. Hence, the system of non-linear equations has at least one continuous solution.

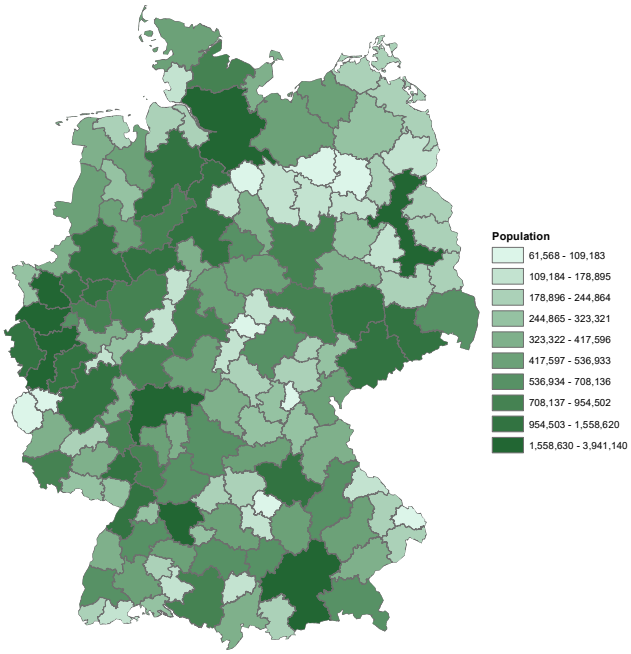
A.2 GDP per capita and population density

Figure A1: Distribution of GDP per capita and population density in 2010

(a) GDP per capita



(b) Population



Notes: This figure plots the quantiles of the GDP per capita distribution in Panel (a) and of the population distribution in Panel (b) for the year 2010. A darker shading indicates higher values.

A.3 Federal fiscal equalization scheme

Table A1 shows the volume of redistribution at each stage of the process. In sum, this amounts to 26.5 billion Euro or 5 percent of tax revenues. On a per-capita basis, Berlin leads the lists of recipients with 1,611 Euro per citizen and year. Hesse and Bavaria pay most in net terms with more than 400 Euro per year.

Table A1: Volume of redistribution, 2010

	VAT redistribution (million Euro)	Horizontal equalization (million Euro)	General grants (million Euro)	Special grants (million Euro)	Per capita transfers (Euro)
Bavaria	-1,545	-3,511	0	0	-403
Baden-Württemberg	-1,327	-1,709	0	0	-282
Berlin	58	2,900	912	1,706	1,611
Brandenburg	864	401	176	1,498	1,174
Bremen	-46	445	146	60	916
Hamburg	-220	-66	0	0	-160
Hesse	-749	-1,752	0	0	-412
Lower Saxony	378	259	127	0	96
Mecklenburg Western Pomerania	830	399	157	1,110	1,520
North Rhine-Westphalia	-2,204	354	119	0	-97
Rhineland Palatinate	-393	267	144	46	16
Saarland	125	89	46	63	317
Saxony	2,024	854	350	2,625	1,411
Saxony-Anhalt	1,201	497	202	1,616	1,506
Schleswig Holstein	-136	101	51	53	24
Thuringia	1,139	472	192	1,483	1,470
Sum	6,620	7,039	2,624	10,260	

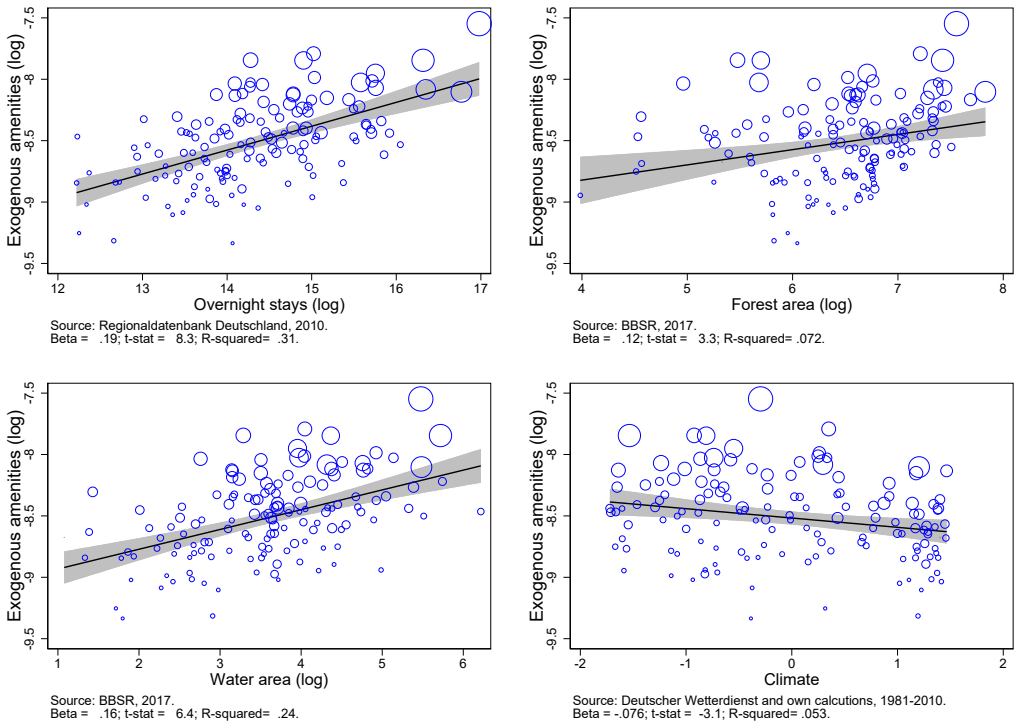
Source: Federal Ministry of Finance (2015).

A.4 Structural amenities and observable local characteristics

In this appendix, we relate the exogenous amenities $\bar{u}(j)$ to observable regional characteristics. To this end, we have compiled a data set including information about location attractiveness (number of overnight stays), areas covered with forest or water bodies, and climate. We provide details on definitions and data sources at the end of this section.

According to Figure A2, overnight stays, forests, and water bodies are positively correlated with exogenous amenities. To calculate a uni-dimensional measure for climate amenities, we combine average hours of sunshine with distance to the coast and to the alps. The further inland a region is located, the more it is characterized by warmer summers and colder winters. Panel (d) plots the standardized first principal component of all variables. We standardize to make sure the climate amenity measure has a zero mean and unit standard deviation. This proxy for climate amenities turns out to be negatively correlated with exogenous amenity, albeit at a small slope and a low R^2.

Figure A2: Exogenous amenities against measured amenities

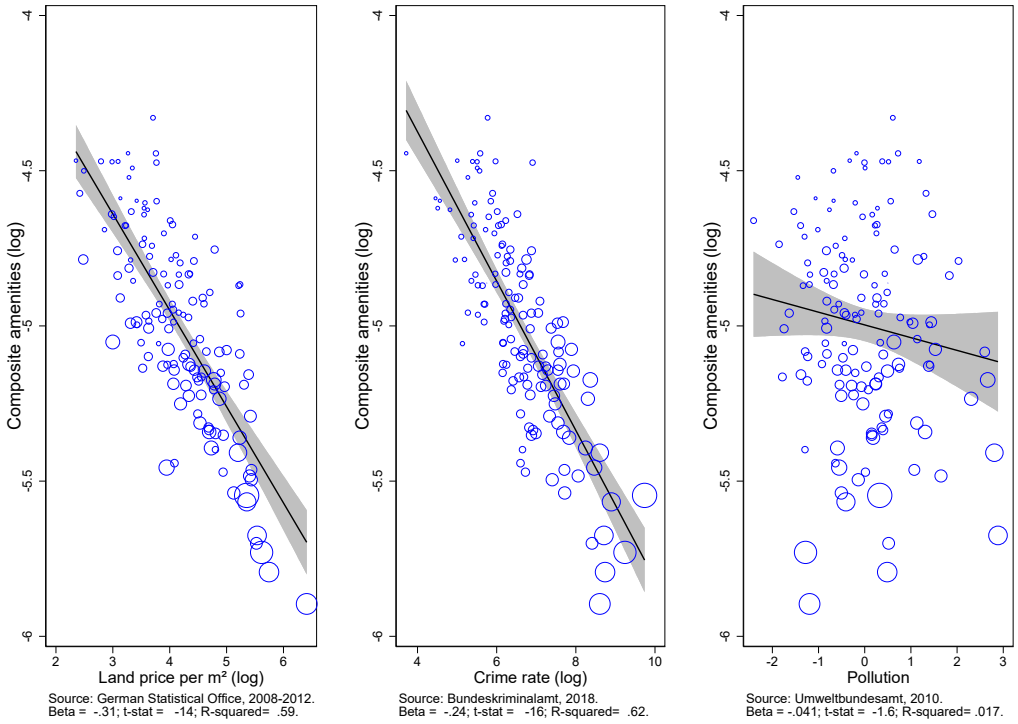


Notes: This figure plots the exogenous amenity levels from the model against various amenity measures. The size of the marker is proportional to the regional population size in 2010.

As our model allows for endogenous amenities, we can further check whether density-dependent outcomes like land prices, pollution, and crime rates are negatively correlated with composite amenities $u(j) = \bar{u}(j)L(j)$. Land prices are of interest as they work as an important congestion force captured, among other things, by the composite amenity terms in our model. Panel (a) of Figure A3 reveals a statistically significant elasticity of

−0.3 explaining about 60 percent of the variation. A similar pattern holds for crime rates. Pollution is also negatively correlated, albeit at lower significance levels and with a low R^2.

Figure A3: Composite amenities against measured amenities



Notes: This figure plots the composite amenity levels from the model against various amenity measures. The pollution variable is the (standardized) first principal component of nitrogen dioxide and fine dust pollution. The size of the marker is proportional to the regional population size in 2010. *Crime* measures the number of violent crimes per 100,000 inhabitants.

Data sources and definitions:

Overnight stays: The variable measures the number of overnight stays in tourist facilities in 2010 at the county level and is provided by Regionaldatenbank Deutschland, Statistik 45412-01-03-5. Own aggregation to labor market regions.

Forest area: Area in square meters covered by forest in 2017. Downloaded from Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR), county level. Own aggregation to labor market regions.

Water area: Area in square meters covered by bodies of water in 2017. Downloaded from Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR), county level. Own aggregation to labor market regions.

Climate: We use the yearly averages of sun hours (1981-2010), provided by Deutscher Wetterdienst, as well as own calculations of distance to the coast and to the alps using GIS-software and shapefiles provided by the Bundesamt für Geodäsie und Kartographie. We combine all variables by a principal component analysis. Own aggregation to labor

market regions.

Land prices: Reported purchase prices per square meter of developed sites. Average 2008-2012. Downloaded from www.regionalstatistik.de (German Statistical Office). Own aggregation to labor market regions.

Pollution: We use the yearly averages of nitro-dioxide (NO_2) concentration and fine dust (PM_10) in $\mu g/m^3$. Provided by the Umweltbundesamt at 2x2 km grids. We combine both variables by a principal component analysis. Own aggregation to labor market regions.

Crime rate: Provided by the crime statistics of the Bundeskriminalamt, this variable measures the number of violent crimes per 100,000 inhabitants at the county level in 2018. Violent crimes include murder, homicide, rape, sexual coercion, sexual assault, robbery, serious bodily harm, extortionate kidnapping, hostage-taking, and attacks on air and sea transport. Own aggregation to labor market regions.

A.5 Robustness: Population density as a measure of the mass of workers

We repeat our main exercise using population density instead of population size as an alternative measure for the mass of workers. In our baseline scenario, the qualitative and quantitative implications of abolishing fiscal transfers remain the same. Again, a total of 2.7 million individuals move from less productive towards more productive areas when fiscal transfers are abandoned. We observe an increase in average productivity by 2.6 percent and real GDP per capita by 2.6 percent at the national level. The corresponding drop in welfare is 0.07 percent after abandoning the transfer scheme. That is, $\hat{W} = -0.07$. The changes differ slightly from the counterfactual with population size as a measure of the mass of workers. The reason is that exogenous amenity and productivity levels differ slightly. The maps in Figure A4 show the patterns of exogenous and composite productivities and the respective amenities.

Appendix References

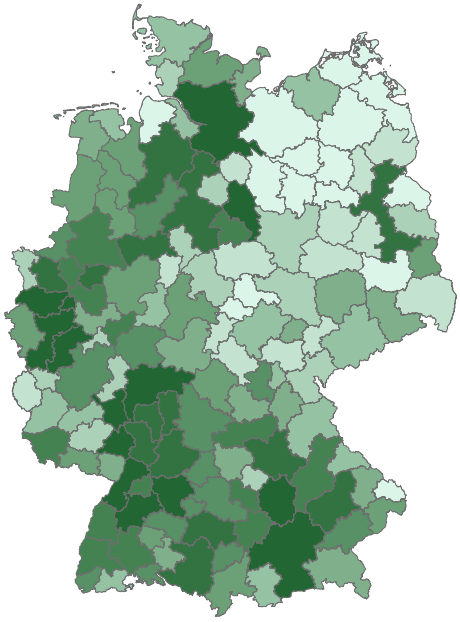
Polyanin, Andrei D., and Alexander V. Manzhirov. 2008. "Handbook of Integral Equations: Second Edition." London: Chapman and Hall/CRC.

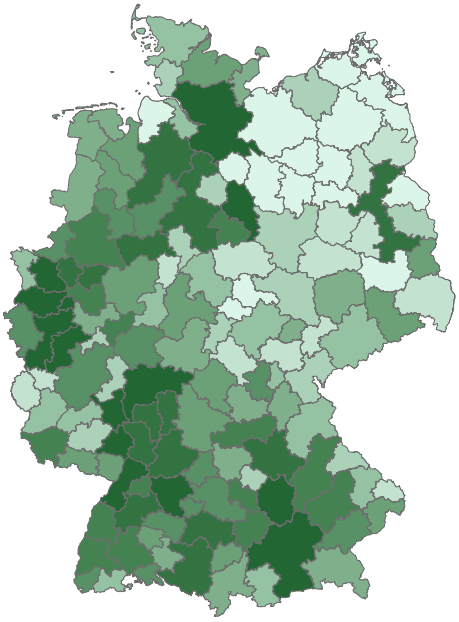
Zabreiko, Petr P., Aleksandr I. Koshelev, Mark A. Krasnoselski, Solomon G. Mikhlin, L. C. Rakovshchik, and Vladislav Y. Stetsenko. 1975. "Integral Equations: A Reference Text." Leyden: Noordhoff International Publishing.

Figure A4: Estimated exogenous productivities and amenities

(a) Exogenous productivities

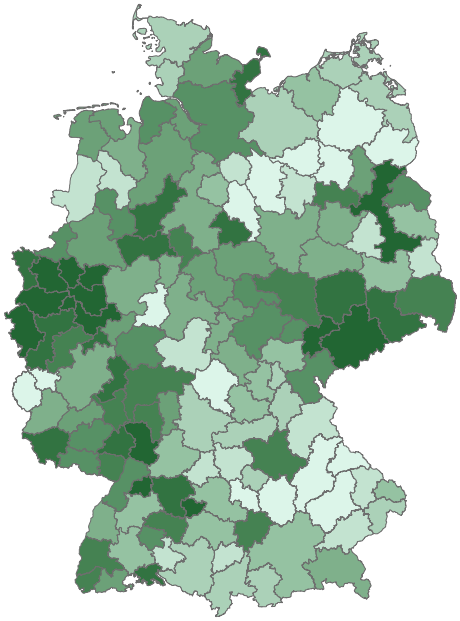
(b) Composite productivities

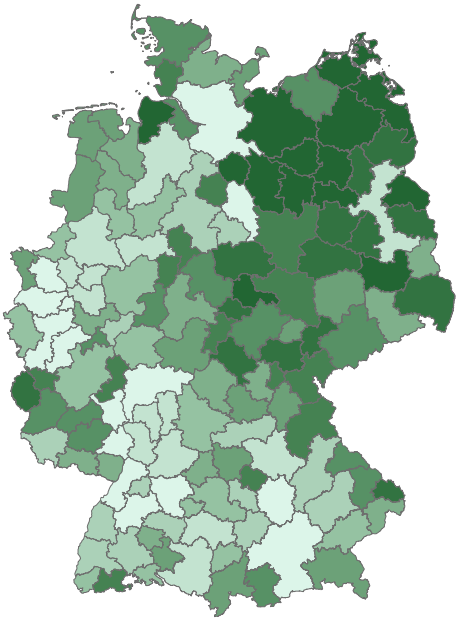




(c) Exogenous amenities

(d) Composite amenities





Notes: This figure plots the exogenous and composite productivities $\bar{A}(i)$ and $A(i)$, and the respective amenities $\bar{u}(i)$ and $u(i)$ for $\alpha = 0.05$, $\beta = 0.66$, $\gamma = 0.2$ and $\eta = 0$ when we use population density instead of population size as a measure of labor $L(i)$. A darker shading indicates higher values.