Can polycentric urban development simultaneously achieve both economic growth and regional equity? A multi-scale analysis of German regions

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Introduction

Scholarly debates on polycentric urban regions:

- have moved beyond methodological discussions of operationalization and measurement
- to explaining urban spatial structure and discussing the outcomes of spatial patterns.

Empirical studies

- European Spatial Development Perspective (1999): more competitive and balanced territorial development.
  - Economic productivity, regional disparities, accessibility to urban amenities (functions), air quality (Ouwehand, 2022; Meijers and Sandberg, 2008; Sun et al., 2017; Han et al., 2018)
  - Multiple countries—the United States, China, OECD (Brezzi and Veneri, 2015), Spain (Garcia-Lopez and Muñiz, 2010), Italy (Veneri, 2010)

Research Objective

Polycentricity as an integral policy tool to realize ***economic competitiveness*** and ***social cohesion*** (ESDP, 1999; BMVBS, 2006; EU Ministers, 2020)

- **Gap 1: a lack of empirical evidence linking multiple goals of PUR.**
  - these goals are often interpreted as incompatible (Davoudi, 2003; Burgalassi, 2012)
- **Gap 2: the mechanism to achieve this "win-win" scenario is ambiguous.**
- **Gap 3: no empirical justification regarding polycentricity in Germany**—one of the most polycentric country in the EU.

In response to the integral benefits of polycentricity:

- Whether polycentric development results in greater economic growth ***and*** fewer regional inequalities?
- The reasons and mechanisms for the finding—borrowing size and agglomeration shadow effects.

Theoretical and policy debates

PURs and economic productivity:

- City-scale evidence:
  - monocentric (AMM) model vs. polycentric model;
  - agglomeration economies vs. agglomeration diseconomies
- megacity regions, polycentric metropolis (Hall and Pain, 2006; Parr, 2008)
  - Randstad of Netherland, Ruhr of Germany, Yangtze River Delta of China
  - economic benefits can scale up to regions (Phelps, 2004, Parr, 2008)
- alternative explanation for agglomeration benefits
  - “regional externalities” and “urban network externalities” (Parr, 2004; Capello, 2000)
  - **PURs are better suited to realize regional network and the associated benefits.**

PURs and regional disparities:

- Spillover effects—economic benefits -> large cities -> small cities -> peripheral and rural areas (CEC, 2004, ESDP, 1999, EU, 2011)
- Achieve via regional urban network and cooperation.
- Mixed results in empirical studies.

Borrowed size: linking inequalities and economic productivity

- **Borrowed size** (Alonso, 1964): smaller cities achieve better economic performance by leveraging network spillovers
- **Agglomeration shadows**: the negative side of network externalities.

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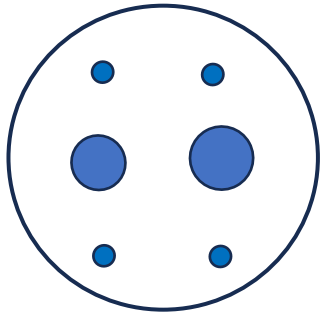
Polycentricity and Regional disparities?

PURs

Borrowed size?



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Polycentricity and Regional disparities?

PURs

↓

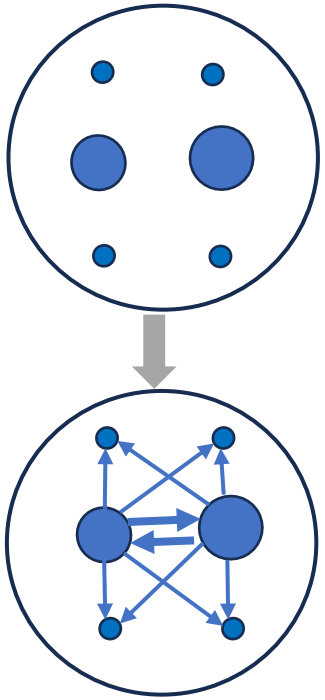
Borrowed size?

↓

Mutual spillovers between urban cores and peripheries

↓

Narrowed gap



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Polycentricity and Regional disparities?

PURs

Borrowed size?

Mutual spillovers between urban cores and peripheries

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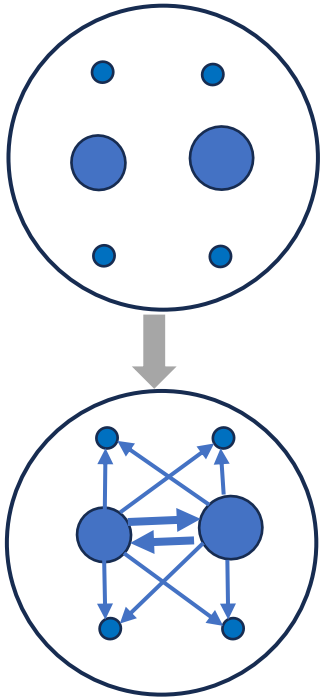
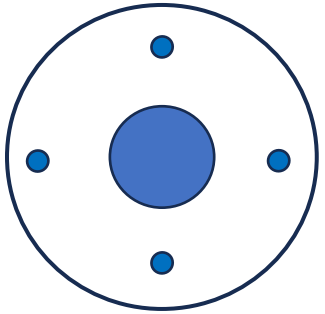


Versus



MURs

Agglomeration shadow

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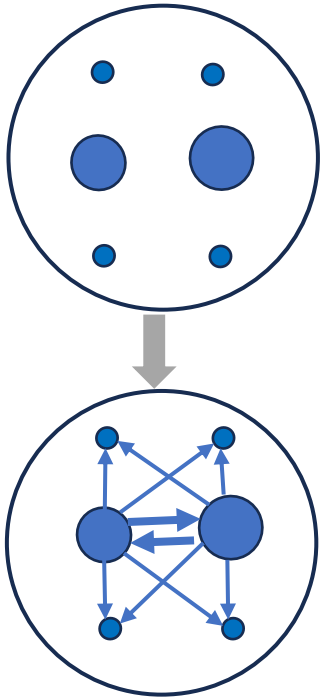
Polycentricity and Regional disparities?

PURs

Borrowed size?

Mutual spillovers between urban cores and peripheries

Narrowed gap



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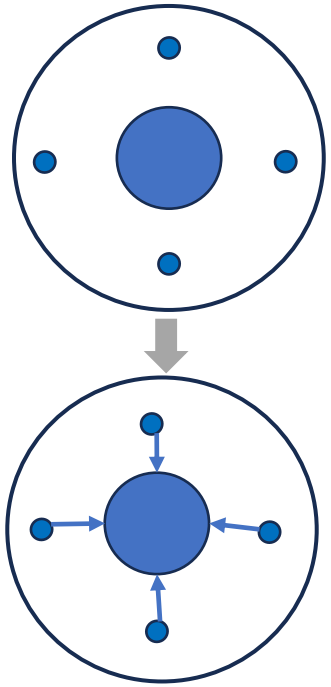


MURs

Agglomeration shadow

Competition between urban core and peripheries

Greater gap

Borrowed size: linking polycentricity and economic productivity

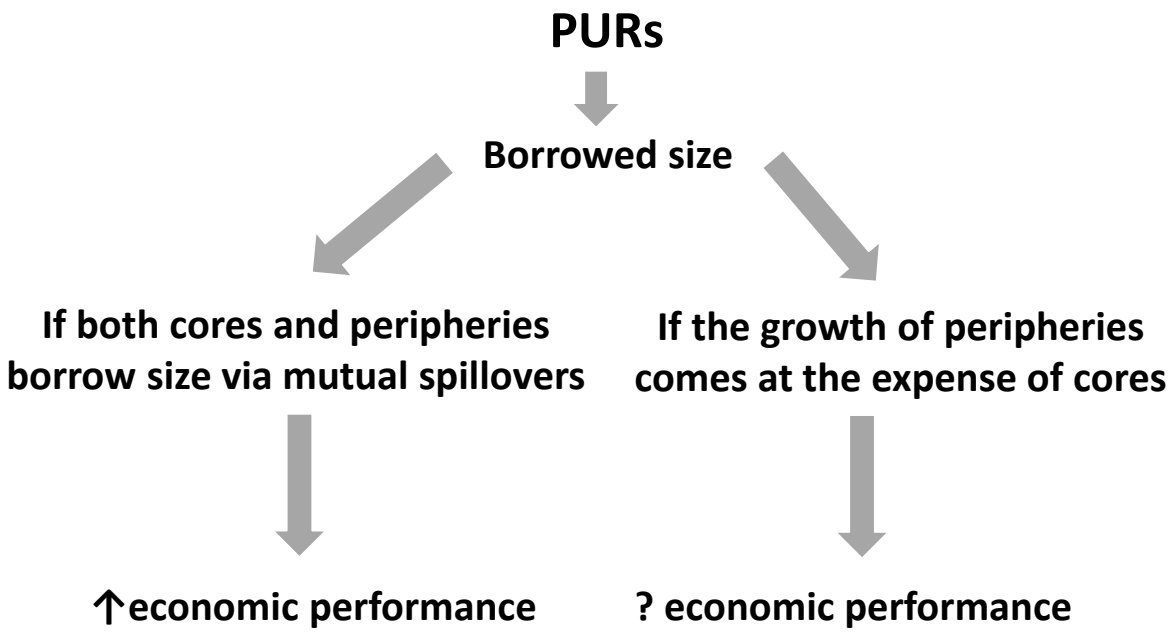
Polycentricity and Economic performance?

PURs

Borrowed size

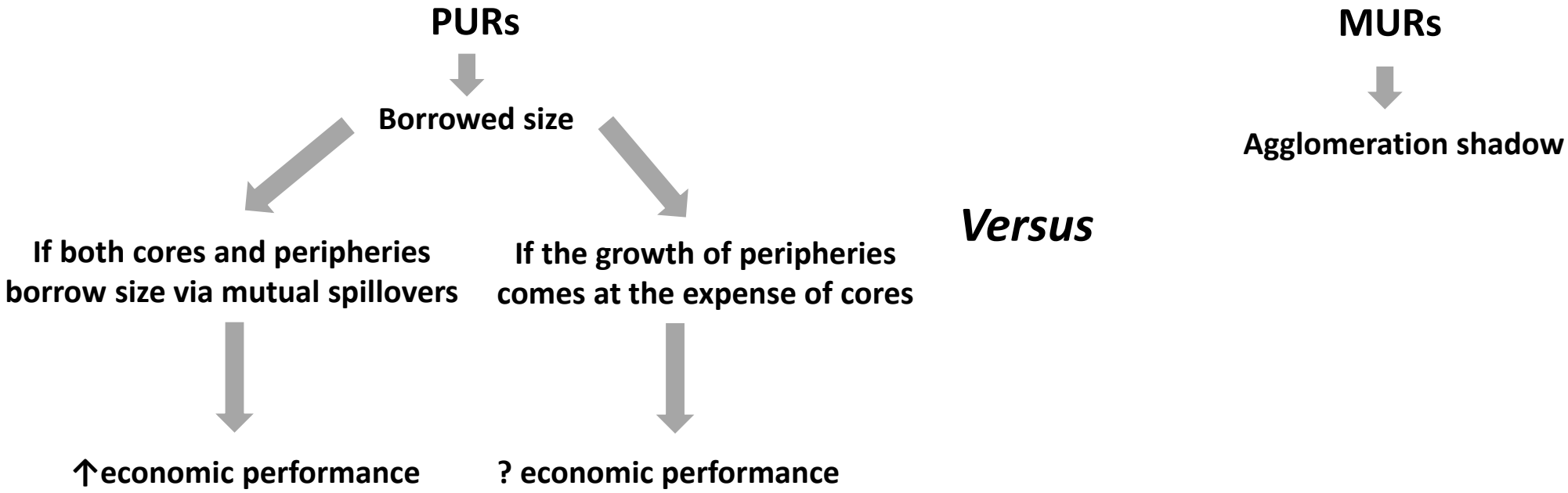
Borrowed size: linking polycentricity and economic productivity

Polycentricity and Economic performance?



Borrowed size: linking polycentricity and economic productivity

Polycentricity and Economic performance?



Borrowed size: linking polycentricity and economic productivity

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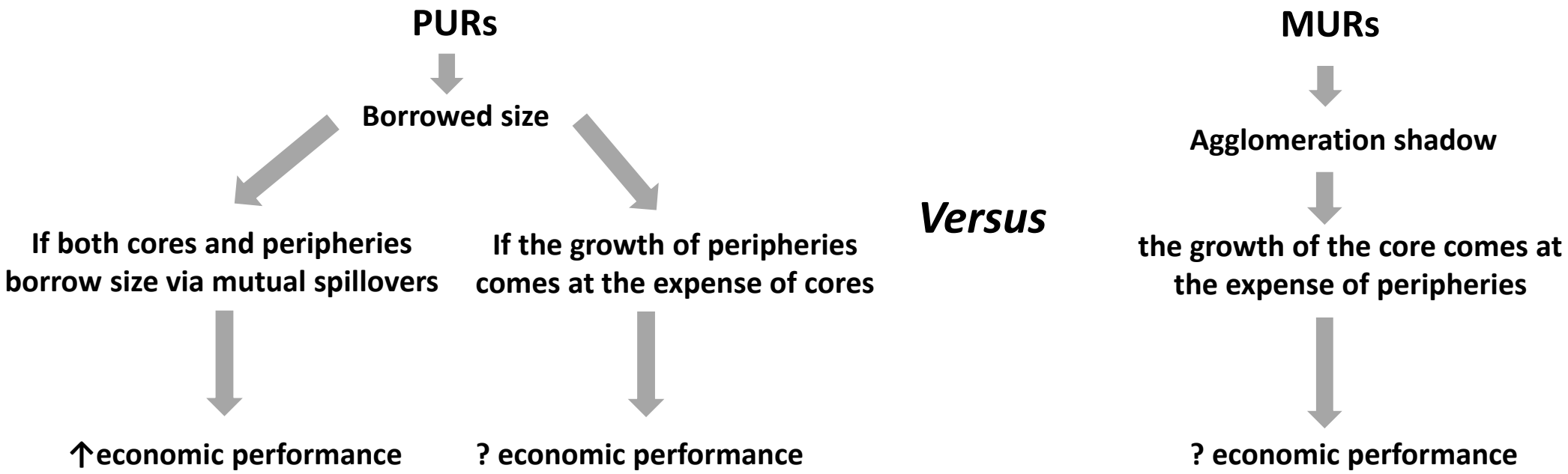


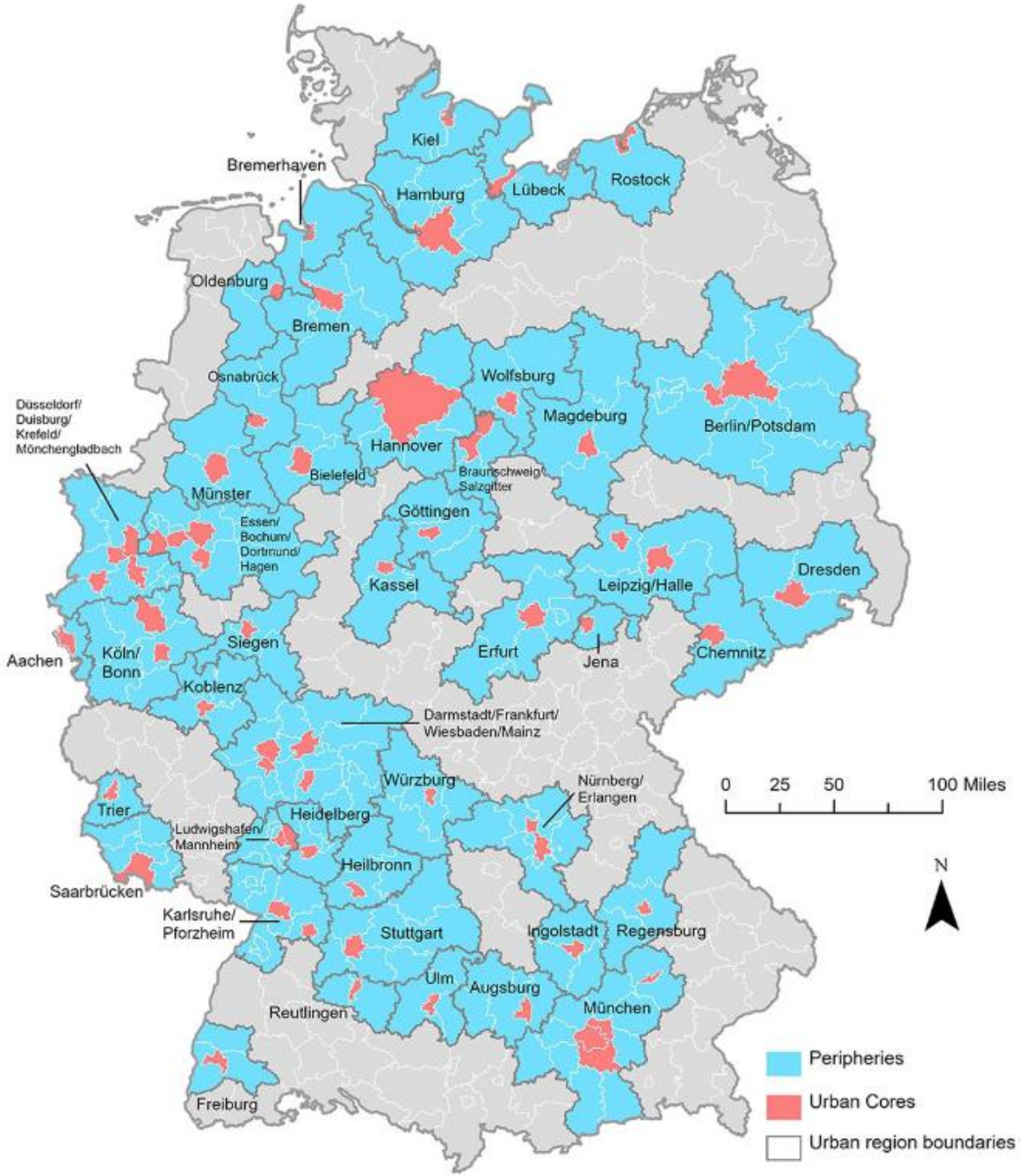
Study regions and datasets

German urban regions (Großstadtregionen)

- one or multiple **urban cores** with a population greater than 100,000
- **hinterlands** with strong commuting relationships with the cores.
- good representation of the regional labor market and the functional urbanized area.
- 45 regions

Datasets

- Economic data: INKAR data platform (BBSR)
- Commuting flow: the Federal Employment Agency
- Historical variables for IVs:
  - (1) topography: SRTM DEM product
  - (2) historical population: Roesel (2022)

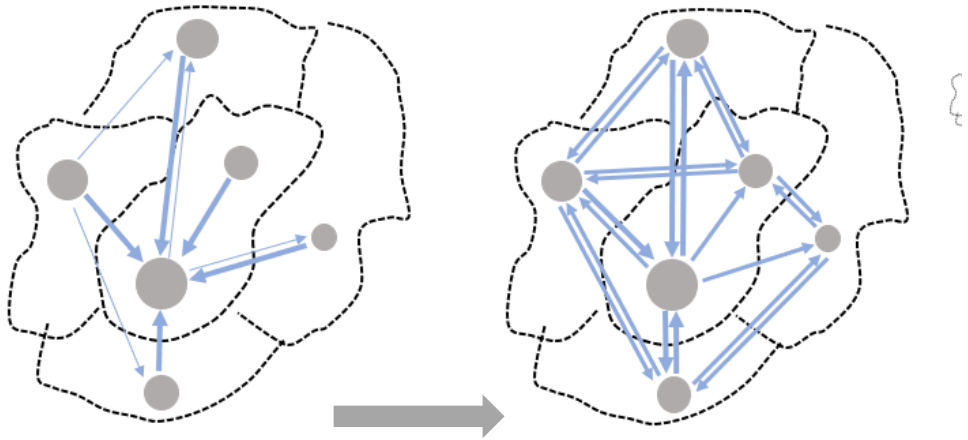


Method—measuring polycentricity

Functional polycentricity:

$$P_F(n) = \left(1 - \sigma_f / \sigma_{fmax}\right) * \Delta$$

σ_f: std.dev of **commuting flows** among municipalities
$\sigma_{f,\max}$: std.dev of benchmark monocentric region;
Δ: density of the network



Higher level of functional polycentricity

Morphological polycentricity:

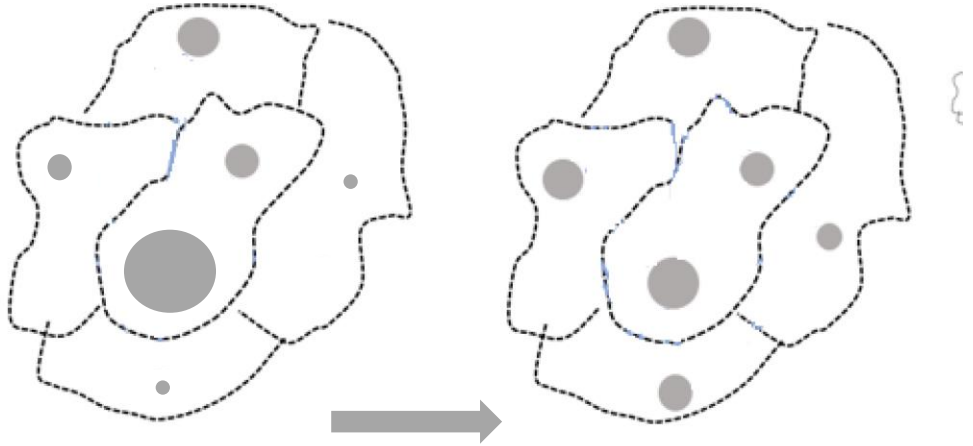
$$P_i(n) = 1 - \sigma_n / \sigma_{\max} \ (n = 2,3,4)$$

σ_n: std.dev of **employment** distribution among municipalities

Rank-size distribution:

$$\ln(Rank) = \alpha + \beta \ln(size)$$

Size: employment of a municipality,
Rank: the rank of employment within an urban region



Higher level of morphological polycentricity

Empirical strategy (Regional-scale models)

1. Economic inequalities and polycentricity:

$$Gini_i = c_i + \alpha_0 Poly_i + \alpha_1 GDPpc_i + \alpha_2 Pop_i + \alpha_3 Unemploy_i + \alpha_4 Redistr_i + \alpha_r + \epsilon_i \quad (2)$$

- $Gini_i$ is the Gini coefficient for urban region i.
- $Poly_i$: the degree of polycentricity
- Control variables: GDP per capita, total population, unemployment rate, fiscal equalization funds, regional dummies.

2. Economic performance and polycentricity:

$$GDPpc_i = c_i + \beta_0 Poly_i + \beta_1 PhyInv\_pc_i + \beta_2 Pop_i + \beta_3 Education_i + \alpha_r + \epsilon_i \quad (3)$$

- $GDPpc_i$: GDP per capita for urban region i.
- $Poly_i$: the degree of polycentricity
- Control variables: per capita physical investment expenditure , the share of employees with a college degree, and population, regional dummies.

Empirical strategy (District-level model)

Whether districts embedded in polycentric urban regions are able to borrow size from each other?

- A “win-win” scenario? Spillovers are shared by both urban core(s) and peripheries
- A “win-lose” scenario? Favor one at the expense of the other?

$$GDPpc_d = c_d + \gamma_0 Poly_d \times UrbanCore_d + \gamma_1 Poly_d + \gamma_2 UrbanCore_d + \gamma \boldsymbol{x}_d + s_d + \epsilon_d \quad (4)$$

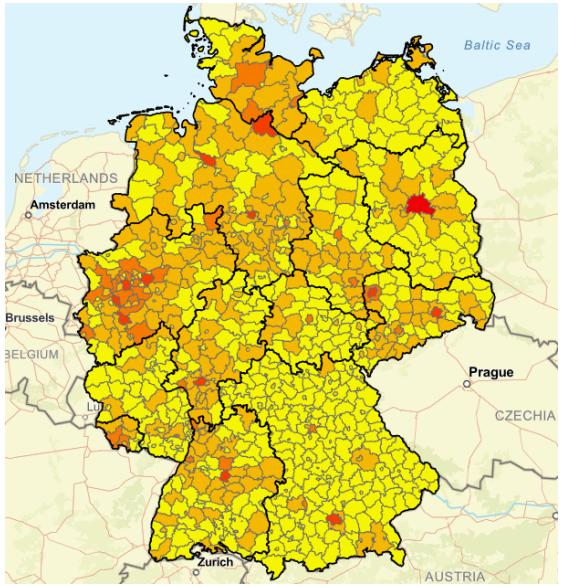
- $UrbanCore_d$: whether a district d is an urban core or a periphery within an urban region.
- $Poly_d$: the degree of *regional* polycentricity.
- $Poly_d * UrbanCore_d$: determine who benefits from polycentricity (core? Peripheries? or both?)

Empirical strategy - 2SLS

- Reverse causation: polycentricity—both a cause and consequence of regional socio-economic realities (Meijers and Burger, 2010; Wang et al., 2019)
- Instrumental variables (IV):
  - historical degree of polycentricity for urban regions in 1871
  - natural topography

First-stage: $\widehat{Poly_i} = \delta Poly_{1871} + \lambda Topo_i + \gamma \boldsymbol{x_{it}} + \alpha_i + \eta_i$

Second-stage: $y_i = \beta + \widehat{Poly_i} + \gamma \boldsymbol{x_{it}} + \alpha_i + \epsilon_i$

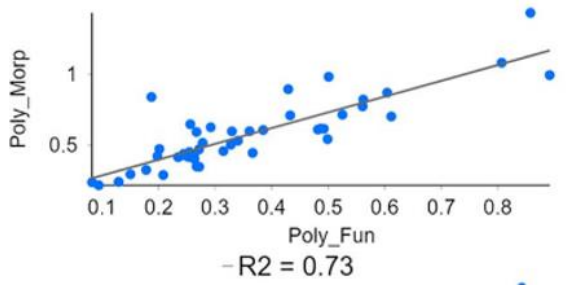


Historical IV:
Germany Population in 1871 at the district level

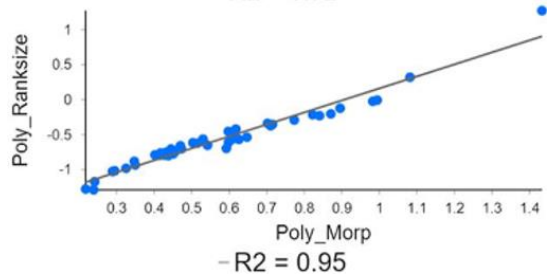
IV of natural condition: topography of Germany

Result: relationship between different measures of polycentricity

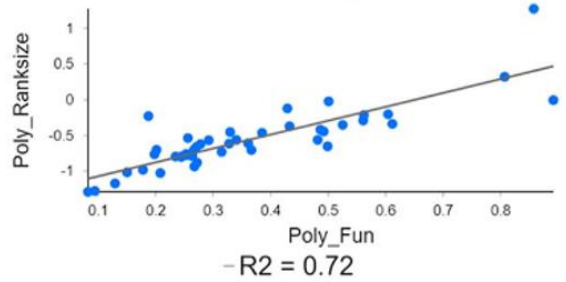
a-b



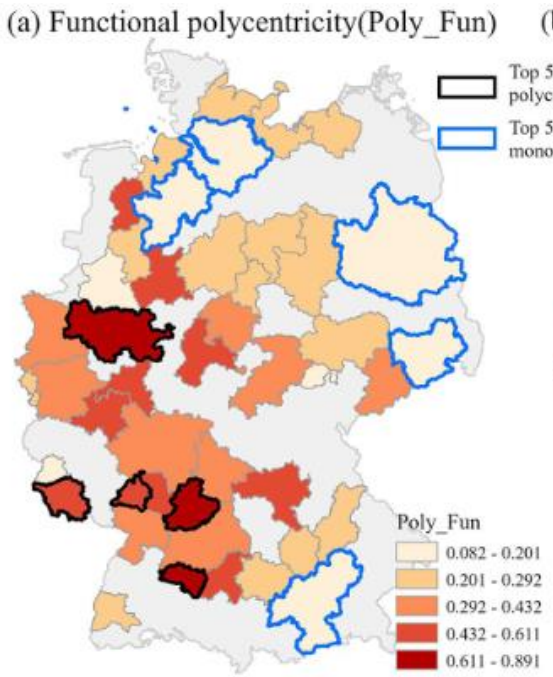
a-c



b-c



a



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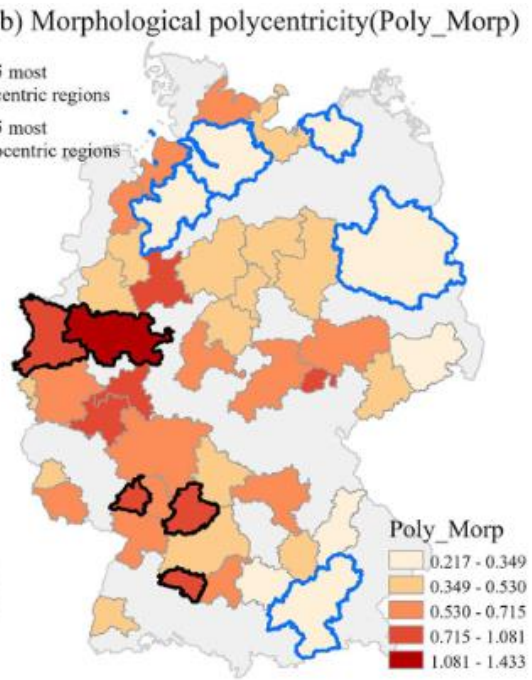

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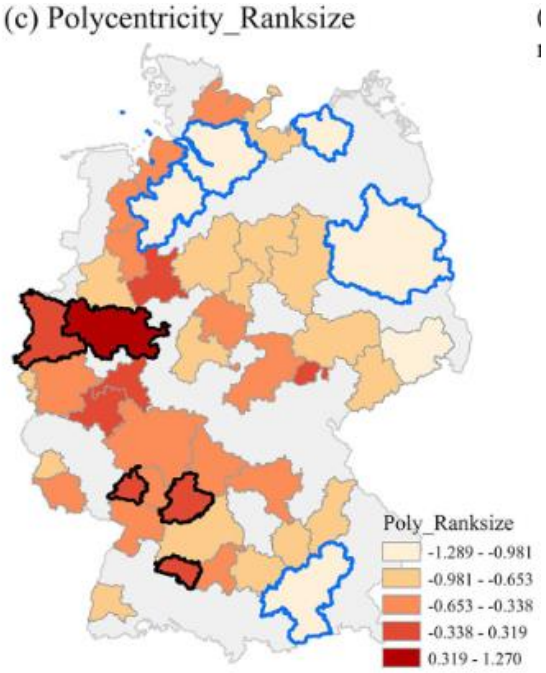


Result: relationship between polycentricity and regional disparities

Table 2. Cross-sectional regressions to test the effect of functional polycentricity (Poly_Fun) on regional disparities, as measured by the Gini coefficient in 2007 and 2017 using OLS and 2SLS estimators.

	OLS		2SLS	
	2007	2017	2007	2017
Variables[c] (in logarithmic form)	Model (1)	Model (2)	Model (3)	Model (4)
Poly_Fun	−0.359* (0.1426)	−0.4787** (0.1471)	−0.3145 (0.1633)	−0.5552** (0.163)
Population	−0.2594** (0.0727)	−0.1627** (0.0583)	−0.2519** (0.0631)	−0.1733** (0.0544)
GDP per capita	1.9814** (0.4302)	2.0449** (0.2464)	1.9379** (0.3669)	2.0841** (0.2345)
Unemployment	0.6553* (0.322)	0.2798 (0.3382)	0.5987* (0.2934)	0.3336 (0.3258)
Redistribution per capita	−0.0418 (0.1823)	0.2467 (0.149)	−0.0848 (0.1531)	0.2989* (0.1425)
Kleibergen-Paap *F*-statistics (Weak IV test)			16.366	14.032
Sargan-Hansen statistics (overidentification test)			0.919	0.480
Endogeneity test			0.584	0.470
Regional dummies[a]	Yes	Yes	Yes	Yes
Constant	−6.5294** (2.2097)	−9.802** (1.8894)	−6.0319** (1.883)	−10.323** (1.8695)
Observations[b]	44	44	44	44
R^2	0.5964	0.6773	0.5935	0.6741

Robust standard errors are in parentheses.
[a]All regressions include regional dummy variables (East, North, West, South).
[b]The urban region Aachen is removed from all models due to missing values of the Gini coefficient.
[c]All variables, except the dummy variables, are in logarithmic form.
**$p < 0.01$. *$p < 0.05$.

Result: robustness check—regional disparities

Table 3. Robustness check of the effects of different measures of polycentricity on regional disparities and economic productivity using 2SLS estimators.

Panel A: Robustness check for regional disparity regressions

Variables	2007-2SLS			2017-2SLS		
	Gini coefficient (Gini)	Coefficient of variations (Cov)	Population-weighted Gini (pwgini)	Gini coefficient (Gini)	Coefficient of variations (Cov)	Population-weighted Gini (pwgini)
Poly_Fun	−0.3145 (0.1633)	−0.3732* (0.1718)	−0.4768** (0.1794)	−0.5552** (0.163)	−0.5558** (0.1628)	−0.6690** (0.1685)
Poly_Morp	−0.2855 (0.1703)	−0.3475* (0.1701)	−0.4675* (0.1938)	−0.5857** (0.1919)	−0.5903** (0.1988)	−0.7043** (0.2060)
Poly_Ranksize	−0.5158 (0.3213)	−0.6084 (0.3254)	−0.8489* (0.3726)	−1.0157** (0.3493)	−1.032** (0.3611)	−1.2186** (0.3765)

Robust standard errors are in parentheses. Regressions include all control variables.
**$p < 0.01$. *$p < 0.05$.

Result: relationship between polycentricity and economic productivity

Table 4. Cross-sectional regressions to test the effect of functional polycentricity (Poly_Fun) on economic productivity measured by GDP per capita in 2007 and 2017 using OLS and 2SLS estimators.

Variables (in logarithmic form)	OLS		2SLS	
	2007	2017	2007	2017
	Model (1)	Model (2)	Model (3)	Model (4)
Poly_Fun	−0.0435 (0.0537)	−0.0201 (0.058)	0.0347 (0.0805)	0.0847 (0.0868)
Population	0.0723* (0.0351)	0.0427 (0.0311)	0.0656* (0.0288)	0.0407 (0.0301)
Investment per capita[b]	0.1459* (0.0539)	0.2148* (0.0966)	0.1263** (0.0477)	0.205* (0.0899)
Education	0.2722* (0.1222)	0.3432* (0.1272)	0.3363* (0.1399)	0.4407** (0.1565)
Kleibergen-Paap *F*-statistics (Weak IV test)			30.293	36.150
Sargan-Hansen statistics (overidentification test)			0.741	2.043
Endogeneity test			2.305	3.187
Regional dummies[a]	Yes	Yes	Yes	Yes
Constant	0.5563 (0.4443)	0.7583 (0.5914)	0.6981 (0.4767)	0.7263 (0.5733)
Observations[c]	42	45	42	45
R^2	0.6703	0.5534	0.646	0.5095

Robust standard errors are in parentheses.
[a]All regressions include regional dummy variables (East, North, West, South).
[b]The missing values in the 2007 physical investment per capita variable are replaced by the corresponding values in 2009 and 2013.
[c]Three urban regions, Saarbrücken, Erfurt, and Jena, are dropped from the 2007 regressions due to missing data.
**$p < 0.01$. *$p < 0.05$.

Result: robustness check—economic productivity

Table 3. Robustness check of the effects of different measures of polycentricity on regional disparities and economic productivity using 2SLS estimators.

Panel A: Robustness check for regional disparity regressions

Variables	2007-2SLS			2017-2SLS		
	Gini coefficient (Gini)	Coefficient of variations (Cov)	Population-weighted Gini (pwgini)	Gini coefficient (Gini)	Coefficient of variations (Cov)	Population-weighted Gini (pwgini)
Poly_Fun	−0.3145 (0.1633)	−0.3732* (0.1718)	−0.4768** (0.1794)	−0.5552** (0.163)	−0.5558** (0.1628)	−0.6690** (0.1685)
Poly_Morp	−0.2855 (0.1703)	−0.3475* (0.1701)	−0.4675* (0.1938)	−0.5857** (0.1919)	−0.5903** (0.1988)	−0.7043** (0.2060)
Poly_Ranksize	−0.5158 (0.3213)	−0.6084 (0.3254)	−0.8489* (0.3726)	−1.0157** (0.3493)	−1.032** (0.3611)	−1.2186** (0.3765)

Panel B: Robustness check for economic productivity regressions

Variables	2007-2SLS	2017-2SLS
	GDP per capita	GDP per capita
Poly_Fun	0.0347 (0.0805)	0.0847 (0.0868)
Poly_Morp	0.0359 (0.0685)	0.967 (0.0988)
Poly_Ranksize	0.0625 (0.1708)	0.1580 (0.1836)

Robust standard errors are in parentheses. Regressions include all control variables.
**$p < 0.01$. *$p < 0.05$.

Result: mechanism analysis at the district level

Model (4): a 100% increase in polycentricity in 2017 can contribute to a 10.55% increase in economic productivity for **peripheries**, also a decrease of 5.4% (10.55% minus 15.92%) for **urban cores**.

Table 5. Cross-sectional regressions at the district level to test the effect of functional polycentricity (Poly_Fun) on economic productivity measured by GDP per capita in 2007 and 2017 using OLS and 2SLS estimators.

Variables (in logarithmic form)	OLS				2SLS			
	2007	2007	2017	2017	2007	2007	2017	2017
	(1) Poly	(2) Poly × Core	(3) Poly	(4) Poly × Core	(5) Poly	(6) Poly × Core	(7) Poly	(8) Poly × Core
Poly_Fun	0.0384 (0.0363)	0.0805* (0.0365)	0.0733* (0.0339)	0.1055** (0.0347)	0.0522 (0.050)	0.0825 (0.0481)	0.1006* (0.0473)	0.1227* (0.0504)
UrbanCore × Poly_Fun		−0.199** (0.0753)		−0.1592* (0.066)		−0.1608* (0.078)		−0.1272* (0.0646)
UrbanCore	0.3951** (0.051)	0.1956* (0.0814)	0.3336** (0.0501)	0.1759* (0.0729)	0.3935** (0.0489)	0.2326** (0.0876)	0.3295** (0.0437)	0.2097** (0.0772)
Population	−0.0732* (0.0348)	−0.0755* (0.0336)	−0.0702* (0.0324)	−0.0715* (0.0315)	−0.0728* (0.0336)	−0.0748* (0.0325)	−0.0688* (0.0278)	−0.0697* (0.0299)
Investment per capita[b]	0.1693** (0.0461)	0.1791** (0.0451)	0.1581** (0.0542)	0.1638** (0.0537)	0.1707** (0.0454)	0.1783** (0.0434)	0.1613** (0.0348)	0.1655** (0.0521)
Education	0.4663** (0.049)	0.4513** (0.0469)	0.4729** (0.0596)	0.4565** (0.0571)	0.4688** (0.0487)	0.4561** (0.0477)	0.4802** (0.0532)	0.4621** (0.0591)
Kleibergen-Paap *F*-statistics (Weak IV test)					157.495	83.688	137.144	85.628
Sargan-Hansen statistics (overidentification test)					0.616	1.866	0.024	0.618
Endogeneity test					0.053	0.100	0.543	0.030
State dummies[a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.9138** (0.4589)	2.2876** (0.4529)	2.4056** (0.4348)	2.4635** (0.4224)	2.2318** (0.4594)	2.2733** (0.4426)	2.3732** (0.3632)	2.4288** (0.4121)
Observations[c]	230	230	250	250	230	230	250	250
R^2	0.7206	0.7326	0.6682	0.6778	0.7204	0.7309	0.6674	0.6754

Robust standard errors are in parentheses.

[a]All regressions include 13 state dummies. Notably, the city-state Berlin is merged into Brandenburg, the city-state Hamburg is merged into Schleswig-Holstein, and Bremen is merged into Niedersachsen.

[b]The missing values in the 2007 physical investment per capita variable are replaced by the corresponding values in 2009 and 2013.

[c]Observations dropped due to missing values include districts in urban regions of Erfurt and Jena, Aachen, and Reutlingen in 2007; and districts in Aachen and Reutlingen in 2017.

**$p < 0.01$. *$p < 0.05$.

Result: mechanism analysis at the district level

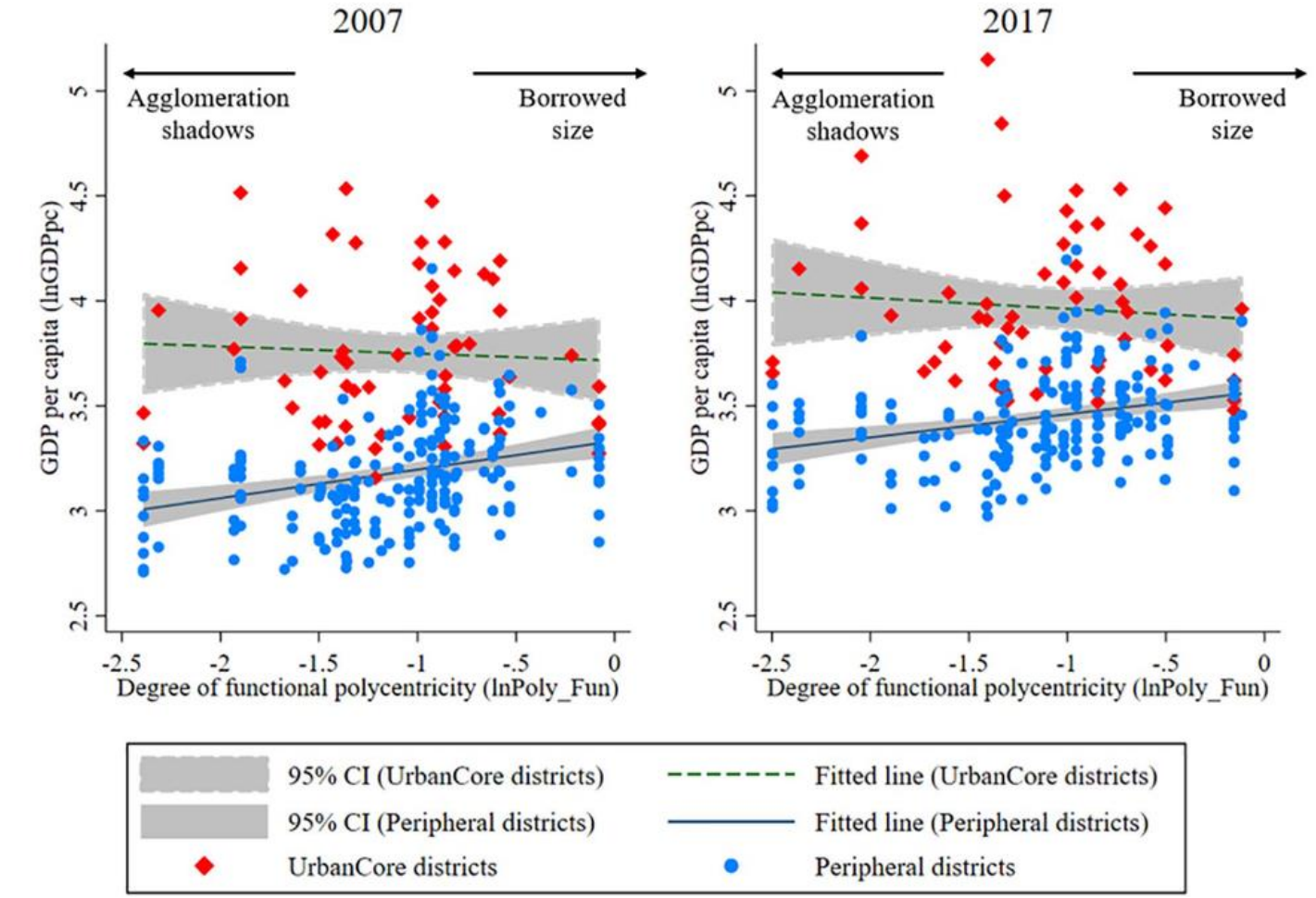


Figure 3. The scatterplots and corresponding fitted lines display the relationship between the degree of polycentricity and the economic productivity of peripheral districts and urban cores.

Borrowed size: linking inequalities and economic productivity

- **Borrowed size** (Alonso, 1964): smaller cities achieve better economic performance by leveraging network spillovers
- **Agglomeration shadows**: the negative side of network externalities.

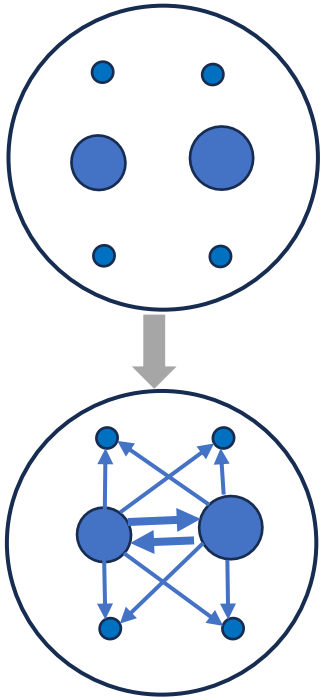
Polycentricity and Regional disparities?

PURs

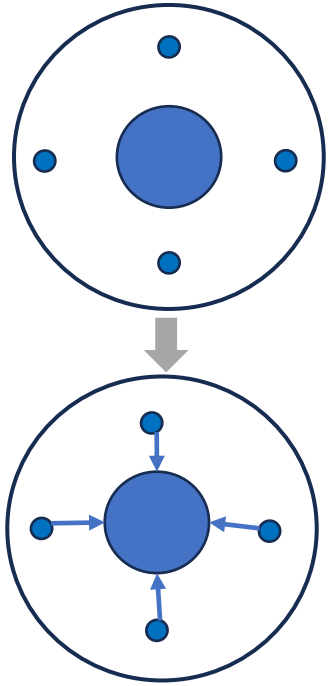
Borrowed size?

Mutual spillovers between urban cores and peripheries

Narrowed gap



Versus



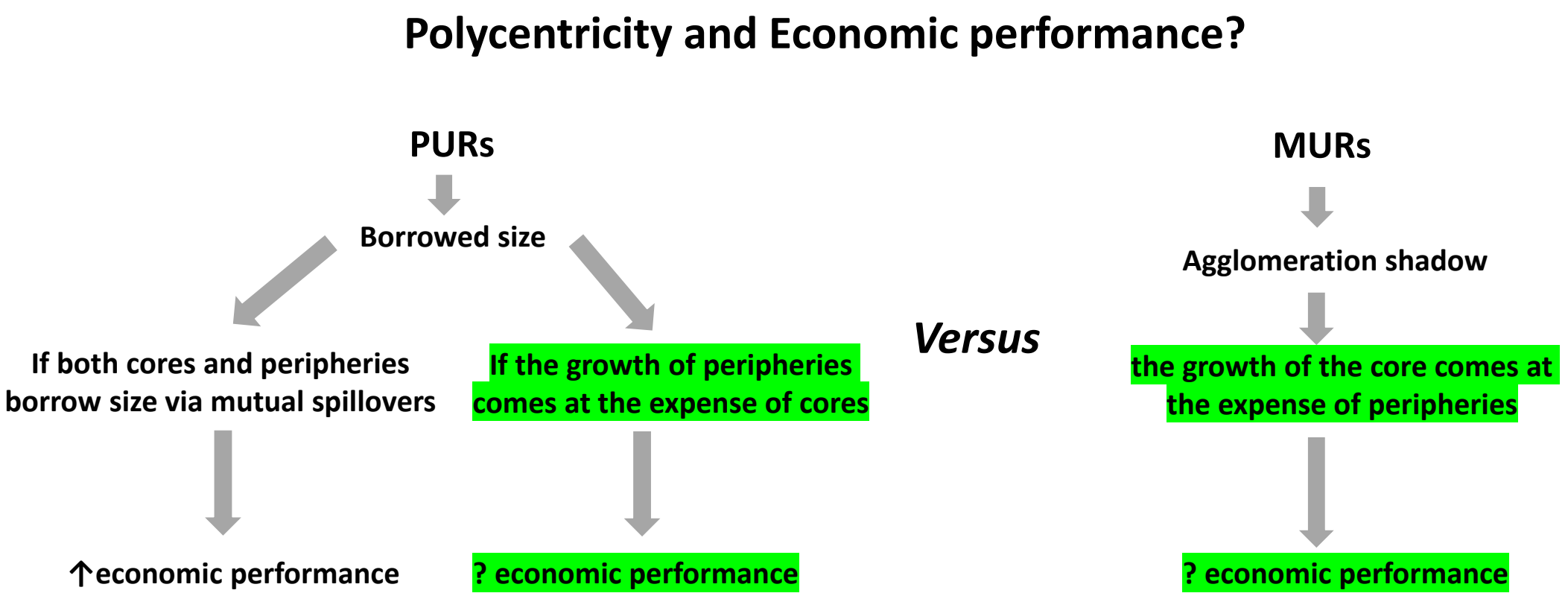
MURs

Agglomeration shadow

Competition between urban core and peripheries

Greater gap

Borrowed size: linking polycentricity and economic productivity



Result: robustness check—mechanism analysis at the district level

Table A1. Robustness check of the effect of polycentricity on economic productivity at the district level using 2SLS estimators.

Panel A: Robustness check using Poly_Morp				
	2007	2007	2017	2017
	(1) Poly	(2) UrbanCore × Poly	(3) Poly	(4) UrbanCore × Poly
Poly_Morp	0.0686 (0.0625)	0.1004 (0.0611)	0.1136* (0.0567)	0.1504* (0.0585)
UrbanCore × Poly_Morp		−0.1669* (0.073)		−0.2068** (0.0691)
UrbanCore	0.3937** (0.0489)	0.3098** (0.0582)	0.3310** (0.0439)	0.2345** (0.0539)
Panel B: Robustness check using Poly_Ranksize				
	2007	2007	2017	2017
	(1) Poly	(2) UrbanCore × Poly	(3) Poly	(4) UrbanCore × Poly
Poly_Ranksize	0.1257 (0.1142)	0.1823 (0.1105)	0.2037* (0.1029)	0.2614* (0.1056)
UrbanCore × Poly_Ranksize		−0.2916* (0.1316)		−0.3193** (0.1148)
UrbanCore	0.3929** (0.0490)	0.5675** (0.0909)	0.3307** (0.0442)	0.5316** (0.0836)

Robust standard errors are in parentheses. Regressions include all control variables.
**$p < 0.01$. *$p < 0.05$.

Conclusion and policy implication

- Functional polycentricity displays a good fit with the morphological ones, and the different measures produce consistent results.

Achieving the integral goal of polycentricity?

- polycentric development ***can*** effectively reduce regional disparities
- polycentric development ***cannot*** simultaneously improve regional economic productivity.

Reasons and Mechanism?

- a “win-loss” game between peripheries and urban core(s) within the same urban region.
  - Peripheries develop at the expense of urban core(s) -> more equitable regions.
  - the losses of urban cores cancel out the gains of the peripheries
  - the borrowed size effect yields similar overall economic outcomes to the agglomeration shadow effect

Not a panacea to address various regional issues simultaneously.

  - monocentric regions may consider polycentricism as an effective way of reducing regional economic disparities and to facilitate peripheries.

Questions and Comments

Thank you!

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Li, Wenzheng, Stephan Schmidt, and Stefan Siedentop. "Can polycentric urban development simultaneously achieve both economic growth and regional equity? A multi-scale analysis of German regions." *Environment and Planning A: Economy and Space* (2023): 0308518X231191943.

Introduction

Scholarly debates on polycentric urban regions:

- have moved beyond methodological discussions of operationalization and measurement
- to explaining urban spatial structure and discussing the outcomes of spatial patterns.

Existing studies:

- **Measures of polycentricity**
  - Center identification: Giuliano and Small (1991), McMillen (2001)
  - Morphological and functional terms (Green, 2007; Meijers and Burger, 2010; Zhang and Derudder, 2019)
- **Empirical studies**
  - Evidence of polycentricity: Arribas-Bei and Sanz-Gracia (2014), Li and Derudder (2022); Lee (2007)
  - Benefits Justification:
    - Economic productivity, regional disparities, air quality (Ouwehand, 2022; Meijers and Sandberg, 2008; Sun et al., 2017; Han et al., 2018)
    - Multiple countries—the United States, China, OECD (Brezzi and Veneri, 2015), Spain (Garcia-Lopez and Muñiz, 2010), Italy (Veneri, 2010)