The Value of Connectivity: High-Speed Broadband Internet and Real Estate Prices

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Motivation

- **Digital transformation** fundamentally changes economies and societies
- Digital infrastructure with the expansion of **high-speed broadband Internet to all households** is of central importance
- Governments invest large amounts of **public subsidies for provision** of fast Internet to **underserved rural areas**
- But the **economic value** of providing fast Internet access is still **not comprehensively understood and quantified**

Motivation

- Extensive literature on **capitalization effects of public infrastructure** into property prices (Ahlfeldt et al., 2017; Chay and Greenstone, 2005; Collins and Kaplan, 2017; Davis, 2011; Gibbons et al., 2013; Greenstone and Gallagher, 2008)
- Method leverages **regional variation in the availability of high-speed broadband** infrastructure in rural areas
- Surveys indicate that **Internet access is increasingly important for property valuations** by households (Eutelsat, 2021)
- **This paper: What is the causal effect of expanding high-speed broadband Internet on real estate prices in Germany?**

This Paper: Effect of High-Speed Internet on Property Prices

1. **Quasi-experiment of German states' preferences for broadband expansion in rural areas**
   - German states enacted expansion programs to rural areas with significant differences in scope, funding, and regulations
   - No federal program and unprofitable for private carriers
2. **Spatial RDD with hedonic price model for property valuation**
   - Exploit discontinuities of Internet access at interstate borders
   - Identify effect in similar rural municipalities located around the borders and only differ in broadband availability
3. **Novel and large data on broadband availability and real estate prices**
   - Novel, large zip-code level dataset on Internet and property offerings
   - Administrative micro-census data for exploration of mechanisms

Preview of Main Findings

1. **Significantly positive capitalization effects of fast Internet access**
   - 4 to 7 percent capitalization into sale prices and rents
   - Equivalent to 13,200 euros (sale price) and 23 euros (monthly rent)
2. **Analysis of heterogeneous effects**
   - Diminishing returns to higher broadband speeds
   - Increasing returns over time
   - Stronger effects for houses compared with apartments
3. **Evidence for Internet usage as a key mechanism**
   - Higher Internet availability in a municipality resulted in significantly more uptake by households
   - Capitalization effects driven by households' current demand

Contribution

1. **Capitalization effects of public goods and non-market externalities**
   (Ahlfeldt et al., 2017; Chay and Greenstone, 2005; Collins and Kaplan, 2017; Davis, 2011; Figlio and Lucas, 2004; Gibbons and Machin, 2005; Gibbons et al., 2013; Greenstone and Gallagher, 2008; Muehlenbachs et al., 2015)
   - Expand well-established capitalization method to a new setting and integrate it into spatial RDD
   - Find large capitalization effects of fast Internet access in rural areas

2. **Effects of broadband Internet on economic and political outcomes**
   (Akerman et al., 2015; Allcott and Gentzkow, 2017; Czernich et al., 2011; DeStefano et al., 2022; Falck et al., 2014; Gentzkow and Shapiro, 2011)
   - We focus on the effects of targeted public policies for rural areas
   - Examine high-speed Internet compared with previous studies on first-generation broadband

Institutional Background and Data

- **Differences in German states' preferences for broadband expansion in rural areas** resulted in spatial variation in availability of fast Internet across states
- Provides **quasi-experiment at borders** between "high" and "low" broadband states
- We focus on expansion in **rural municipalities between 2010-2019**
- Detailed **administrative data on Internet availability** on municipality- and state-level for broadband speeds 16, 30, and 50 Mbit/s
- Large **micro dataset on the German real estate market** comprising 2 million properties offered for sale and for rent
- Complemented by **regional socioeconomic characteristics**

Illustration of Border Sample: ∼ 5,000 Municipalities with ∼ 2 Million Real Estate Properties

“High” and “Low” Broadband States: Different Levels and Trends

- We investigate the **relevant time period and unit** of high-speed broadband expansion in Germany

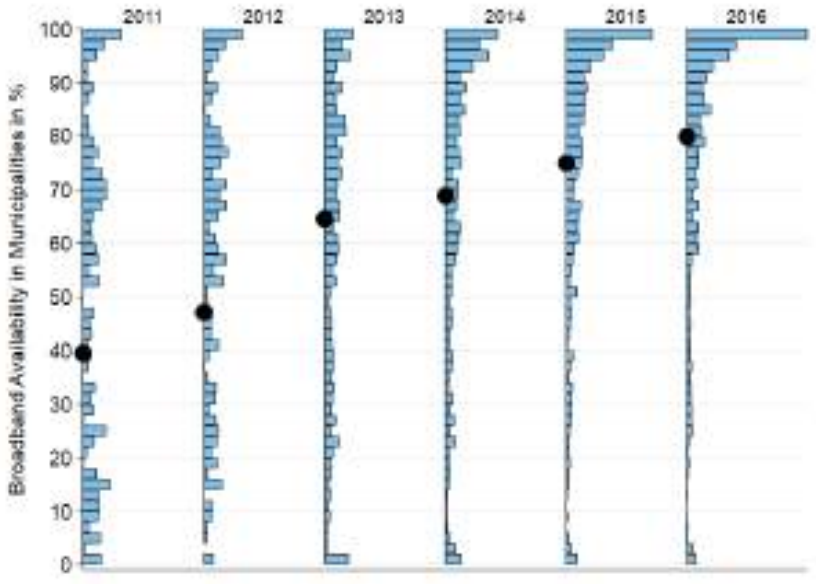


Figure: "High” Broadband States

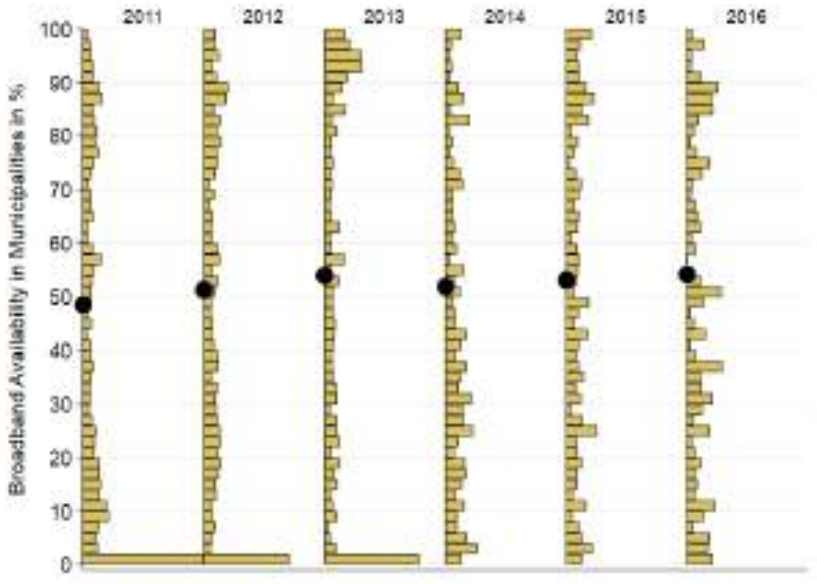


Figure: “Low” Broadband States

Empirical Approach: Spatial Regression Discontinuity Design

- **Spatial RDD** compares similar municipalities adjacent to each other but across the state border, i.e. some are located in “high” broadband states (treatment) and others in “low” broadband states (control)
- Spatial RDD estimates **local causal treatment effect** (intent-to-treat)
  - **“First stage”:** effect on broadband availability in municipalities
  - **“Reduced form”:** effect on real estate sale prices and rents
- **Identifying assumption** is that small municipalities located at state borders are valid comparison groups if controlling for regional socioeconomic and individual property characteristics and conditioning on year by border region fixed effects
- Remaining variation in property prices due to differing broadband access is **as good as external** to house buyers and/or tenants

Details

Spatial Regression Discontinuity Design: Estimation

$$y_{imt} = \alpha + \beta highbroadbandstate_{mt} + f(geographic\ location)_{b(m)} + X'_{imt}\gamma + \delta_{b(m)} \times \delta_t + \epsilon_{imt}$$

- First stage y_{mt}: broadband availability in municipality m in year t
- Reduced form y_{imt}: (log of) sale price or rent of property i in municipality m in year t
- $highbroadbandstate_{mt}$: dummy variable denoting whether municipality m in year t belongs to a "high" broadband state
- $f(geographic\ location)_{b(m)}$: spatial RDD function
  - First specification: RDD polynomials in distance to border
  - Second specification: RDD polynomials in longitude and latitude
- X'_{imt}: regional and property control variables
- $\delta_{b(m)} \times \delta_t$: border region by year fixed effects

Plots Outcomes: Effects of “High” Broadband States 16 Mbit/s

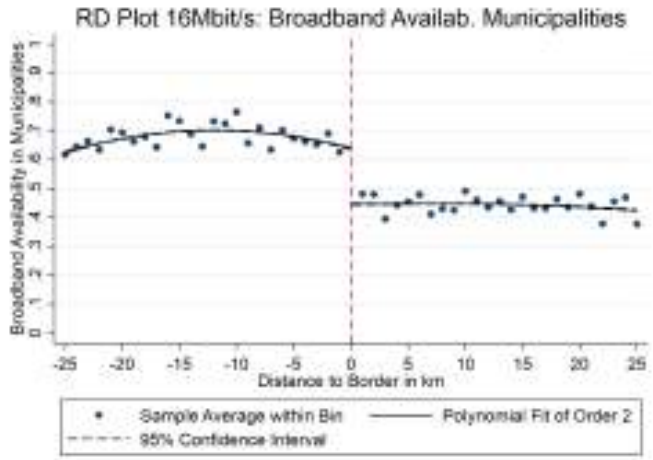


Figure: Broadband Availability

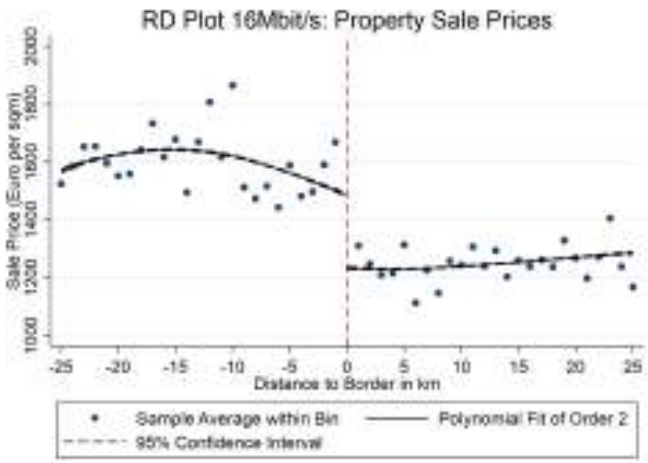


Figure: Property Sale Prices

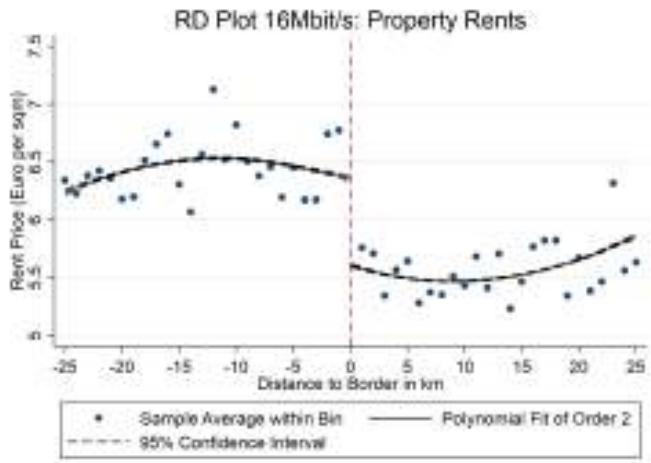
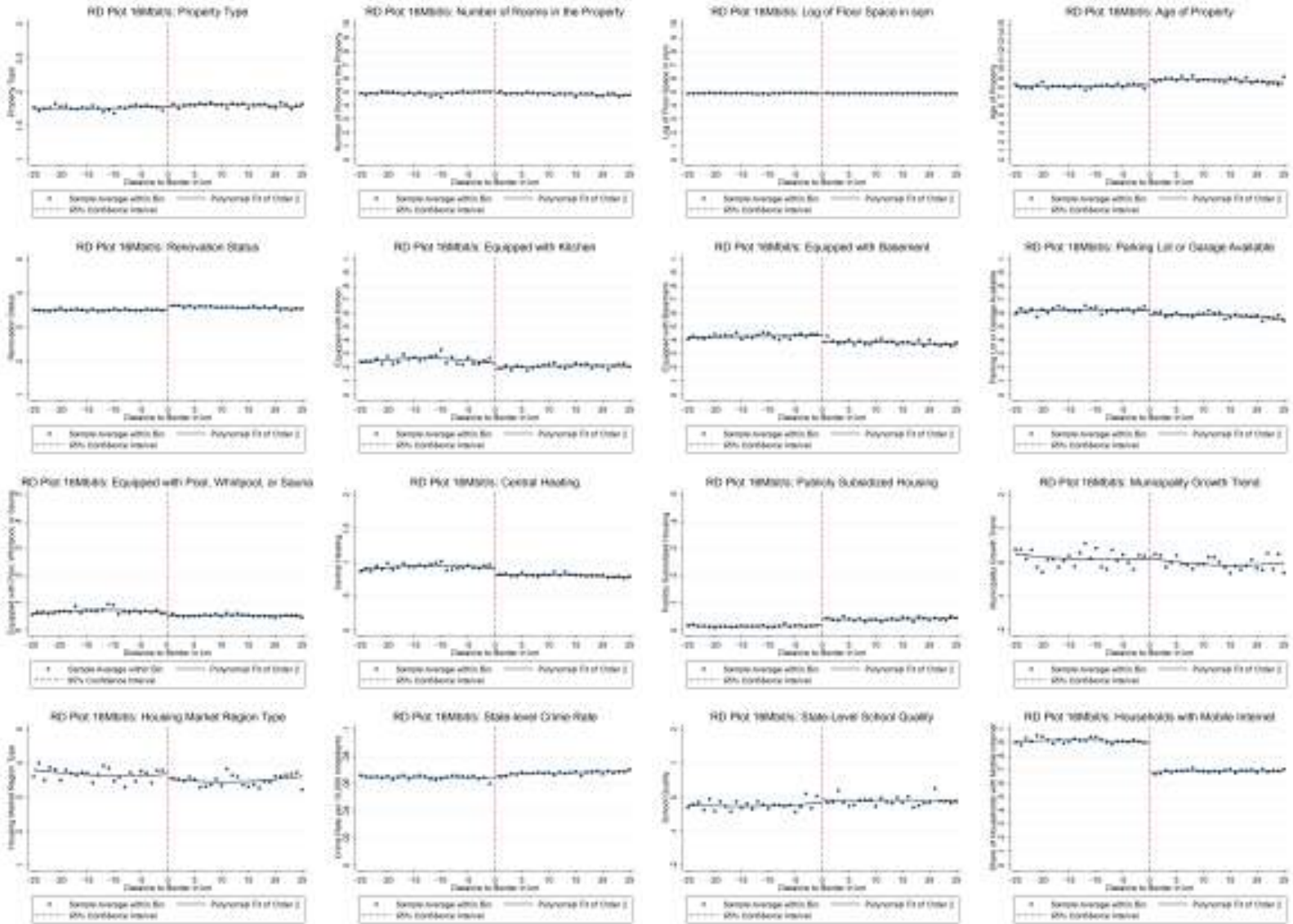


Figure: Property Rents

Plots Covariates: Effects of “High” Broadband States 16 Mbit/s



Main Results: Effects of "High" Broadband States 16 Mbit/s

Main Spatial RDD Estimates	Broadband Availability in Municipalities	Real Estate Sale Prices per sqm	Real Estate Rents per sqm
	(1)	(2)	(3)
Panel A: RDD Polynomials in Distance to Border			
Linear	0.0999***	0.0602***	0.0525***
	(0.0234)	(0.0020)	(0.0013)
Quadratic	0.0990***	0.0635***	0.0439***
	(0.0174)	(0.0015)	(0.0010)
Linear Interacted	0.1086***	0.0483***	0.0429***
	(0.0202)	(0.0018)	(0.0012)
Border Region by Year FE	✓	✓	✓
Regional Socioeconomic Controls	✓	✓	✓
Individual Property Controls		✓	✓
Observations		1,333,193	648,519
Municipalities	4,897	4,897	4,570
Data Availability Period	2011-2016	2010-2019	2010-2019

Note: *p<0.1; **p<0.05; ***p<0.01. Sale prices and rents are log values. Shown are the coefficients and standard errors for "high broadband state" under different RDD specifications.

Main Results: Effects of "High" Broadband States 16 Mbit/s

Main Spatial RDD Estimates	Broadband Availability in Municipalities	Real Estate Sale Prices per sqm	Real Estate Rents per sqm
	(1)	(2)	(3)
Panel B: RDD Polynomials in Longitude and Latitude			
Linear	0.0970***	0.0644***	0.0425***
	(0.0174)	(0.0015)	(0.0010)
Quadratic	0.0979***	0.0743***	0.0483***
	(0.0172)	(0.0015)	(0.0010)
Cubic	0.0931***	0.0701***	0.0435***
	(0.0174)	(0.0015)	(0.0010)
Quartic	0.1023***	0.0743***	0.0449***
	(0.0172)	(0.0016)	(0.0011)
Border Region by Year FE	✓	✓	✓
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Main Results: Effects of “High” Broadband States 16 Mbit/s

- The **average estimated effect on sale prices** relates to an increase of the **property price by 13,260 euros**
- For **property rents the average estimate** corresponds to an increase of the **monthly rent by 23 euros**
- **Sizable capitalization effects** reflect the implicit market prices and consumer surplus from fast broadband Internet at home
- Our **estimates for rural regions in Germany are higher** than those by Ahlfeldt et al. (2017) for the UK who do not restrict their analysis to rural areas
- Consumer **surplus might exceed costs** of broadband provision in many regions

Heterogeneity Analysis: Effects of “High” Broadband States

- **Heterogeneity by Internet speeds:** diminishing returns to higher Internet speeds of 30 and 50 Mbit/s (still significantly positive) which indicate a lower valuation of households for even faster broadband

  Heterogeneity by speeds

- **Heterogeneity by time:** increasing returns to the same Internet speeds over time suggest that valuation of speed increased over time
- **Heterogeneity by property types:** broadband availability capitalizes more strongly in prices and rents for houses rather than apartments
- **Heterogeneity by municipality types:** capitalization effects are more pronounced in slightly more populated municipalities compared to their very rural counterparts

Further Results: Specification, Robustness, Placebo Checks

- **Specification Checks:**
  - Different bandwidths, both larger and smaller Alternative bandwidths
  - “Donut hole” approach
  - Sensitivity to control variables and fixed effects
- **Robustness Checks:**
  - Alternative Samples: leaving out border regions; West vs. East Germany; without Bavaria in 2018-2019; without Rhineland-Palatinate; including bigger cities Leaving out border regions
  - Including additional controls Additional controls
  - Alternative cutoffs: 65% and 85%
  - Validity: sample vs. non-sample municipalities Validity
  - Alternative identification strategy: event study estimates Event Study
- **Placebo Tests:**
  - Property control variables as dependent variables
  - Regional control variables as dependent variables

Mechanism: Households' Internet Usage

- We use **data from the micro-census of German households on uptake** to better understand the drivers of the capitalization effects
- We **compare the availability** of different speed levels and the speeds of **households' purchased Internet contracts**
- In states, which reached a high availability of fast Internet earlier, not only the broadband availability was higher but importantly also **more households bought fast Internet contracts**
- **Strongly positive correlation** between broadband availability and households' uptake
- Broadband expansion **addressed existing demand and capitalization is driven by current demand** rather than future expectations

Mechanism: Households' Internet Usage

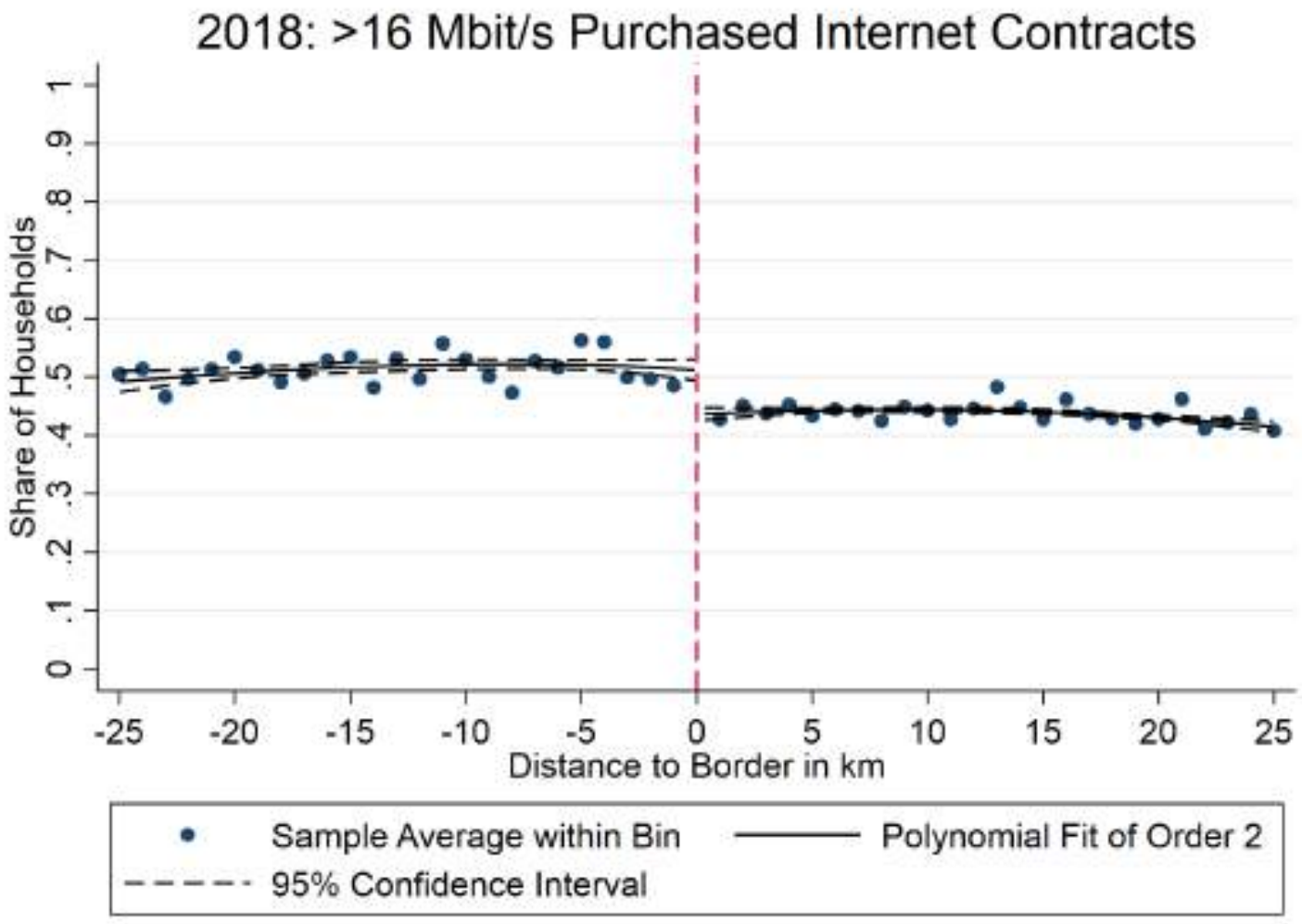

Figure: Spatial RD Plot for Households' Purchased Internet Speed

Conclusion

- We investigate the **causal effect of high-speed broadband Internet on real estate sale prices and rents in Germany**, exploiting the quasi-experiment of recent broadband expansion in German states
- Our two-stage **spatial RDD finds positive and significant effects** on broadband availability in municipalities of about 10 percentage points and on property sale prices and rents of 4 to 7 percent
- Capitalization effects are **driven by households' current demand** for high-speed Internet
- **Policy implications** include that there is a high economic value of broadband availability particularly in rural regions and that broadband expansion should have been conducted faster and more uniformly

Thank you!

I‘m looking forward to your comments and questions.

Back-up

Balanced Sample Distribution Around Interstate Borders

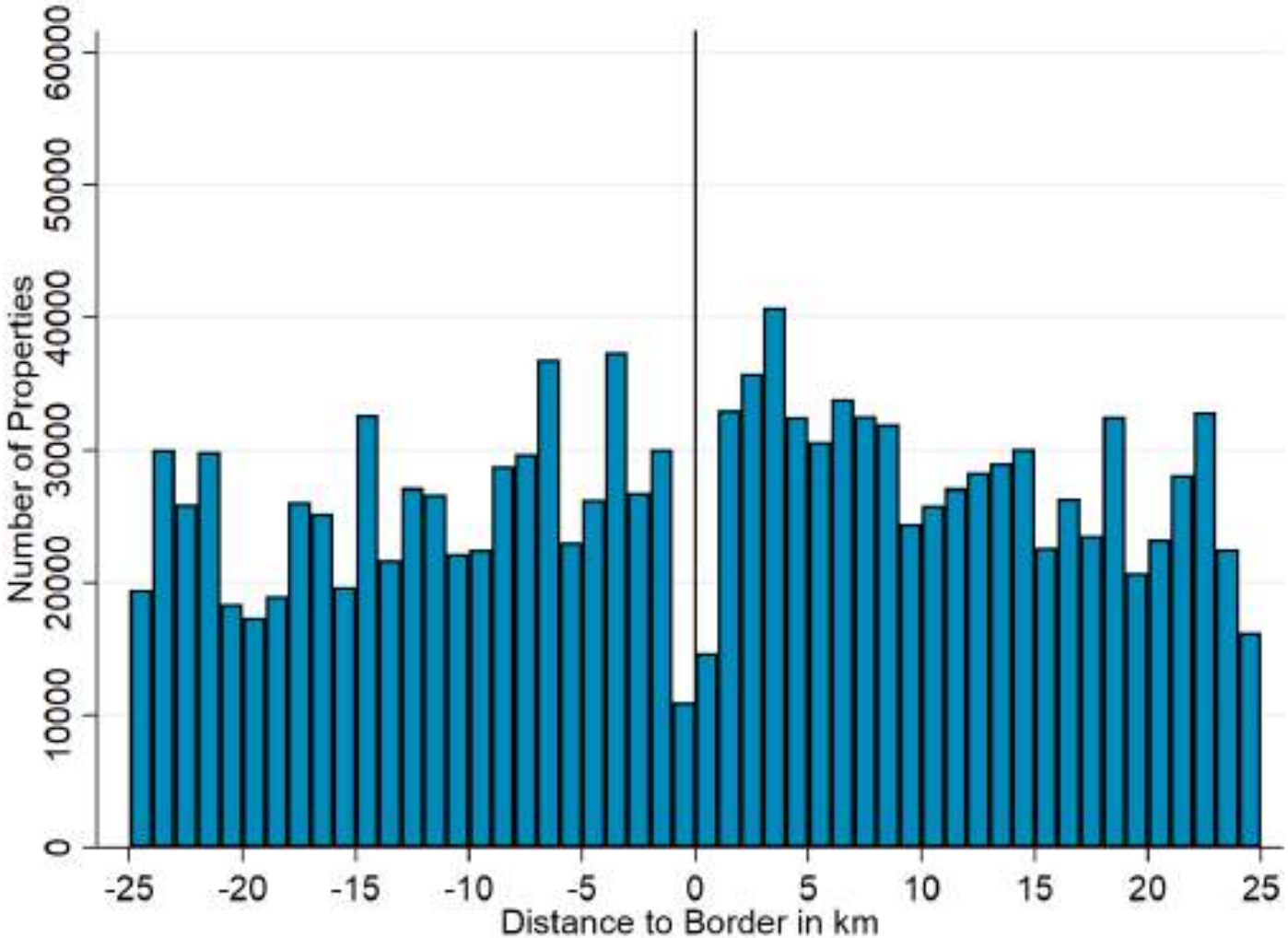

Figure: Sample Distribution Across Space 16 Mbit/s Broadband

Balanced Sample Distribution Over Time

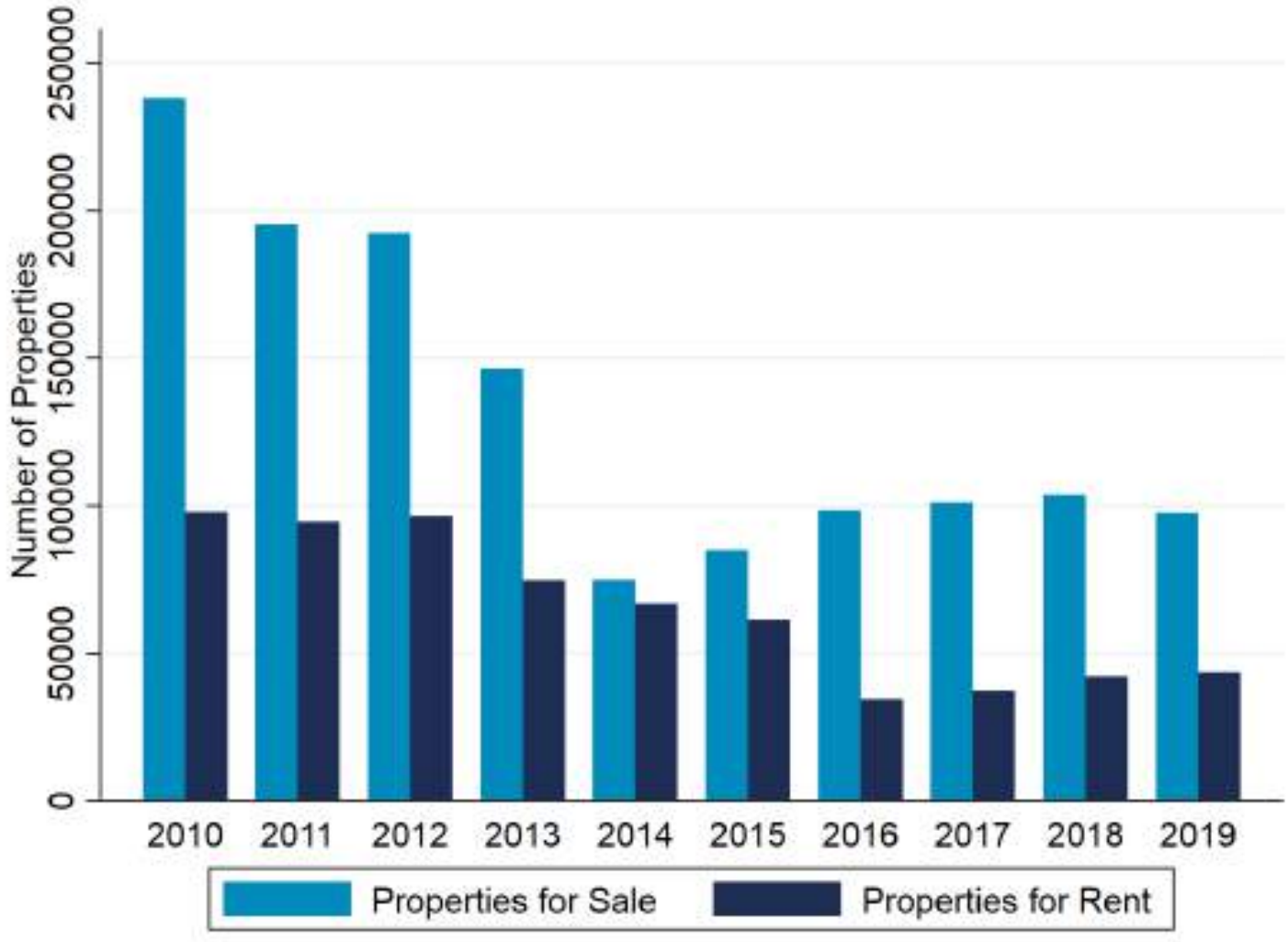

Figure: Sample Distribution Over Time 16 Mbit/s Broadband

Speed Distribution of Broadband Connections

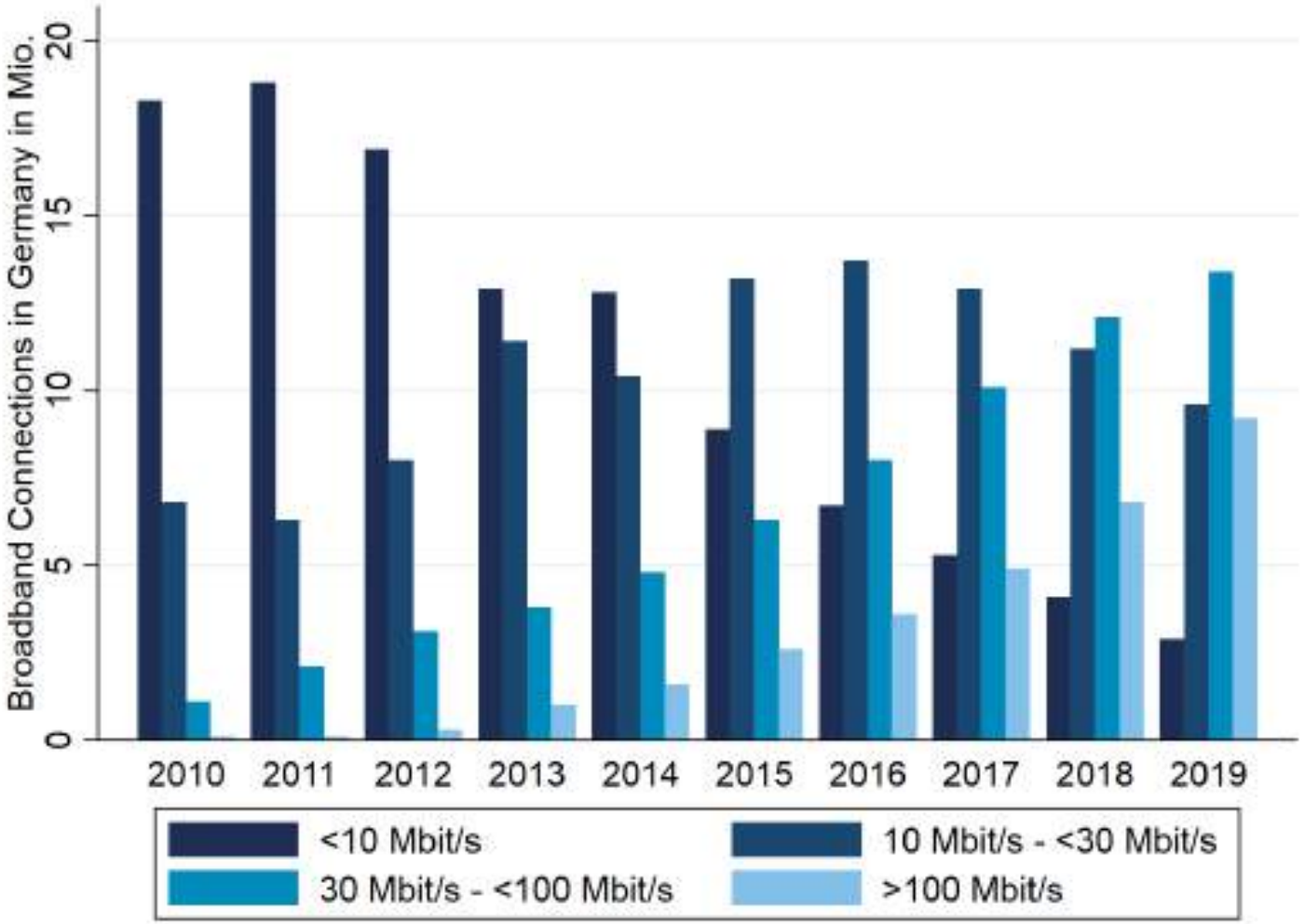

Figure: Speed Distribution of Broadband Connections Over Time in Germany

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Spatial Regression Discontinuity Design: Details

- **Two-stage spatial RDD** estimates the treatment effects of "high" broadband states on three main outcomes:
  - **"First stage":** effect on broadband availability in municipalities
  - **"Reduced form":** effect on real estate sale prices and rents
- **Definition** of "high" broadband states: "high" broadband if the state-wide availability exceeds 75% of households for a given broadband speed (threshold stems from NGA regulation objective)
- We **focus on small municipalities** with fewer than 20,000 inhabitants because state-funded broadband expansion programs materialized particularly in rural areas

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RD Plots: Effects of “High” Broadband States 30 Mbit/s

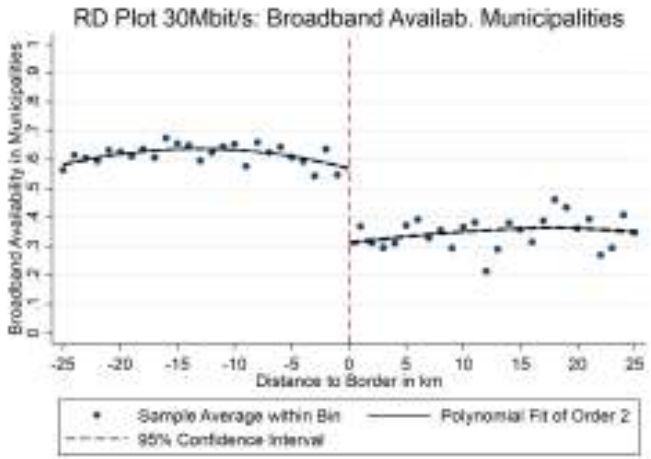

Figure: Broadband Availability

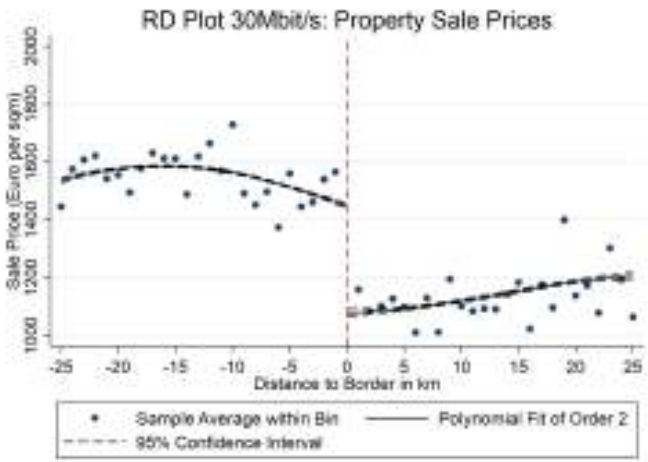

Figure: Property Sale Prices

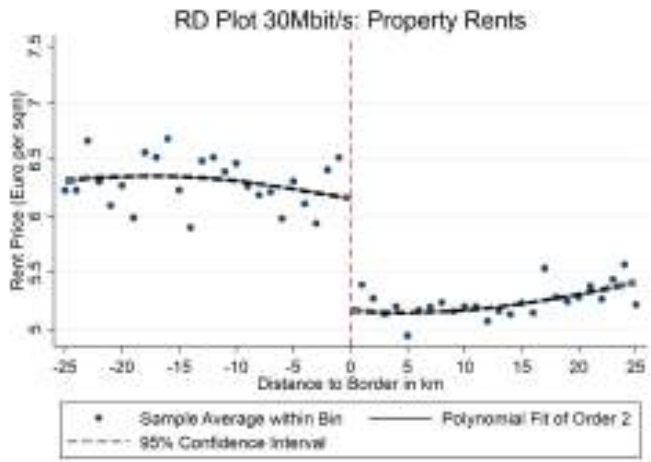

Figure: Property Rents

RD Plots: Effects of “High” Broadband States 50 Mbit/s

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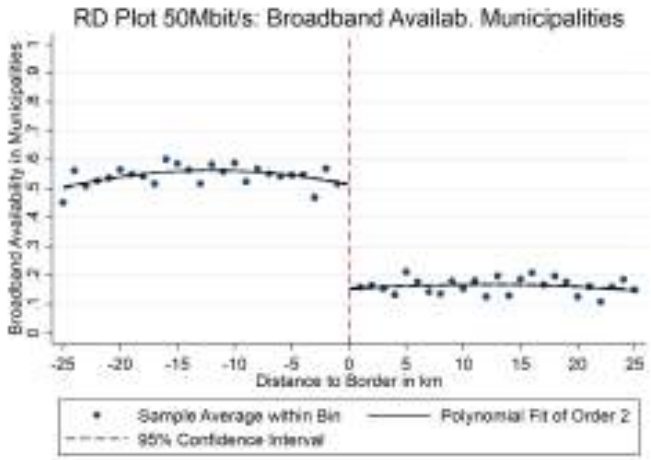

Figure: Broadband Availability

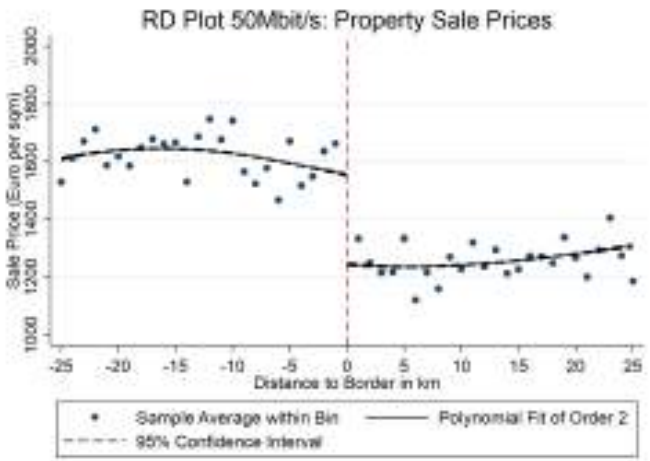

Figure: Property Sale Prices

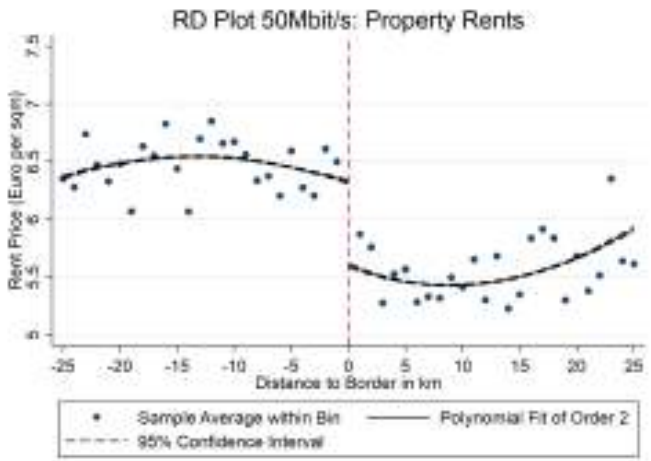

Figure: Property Rents

RD Plots Outcomes 16 Mbit/s: Larger Bandwidth of 50 km

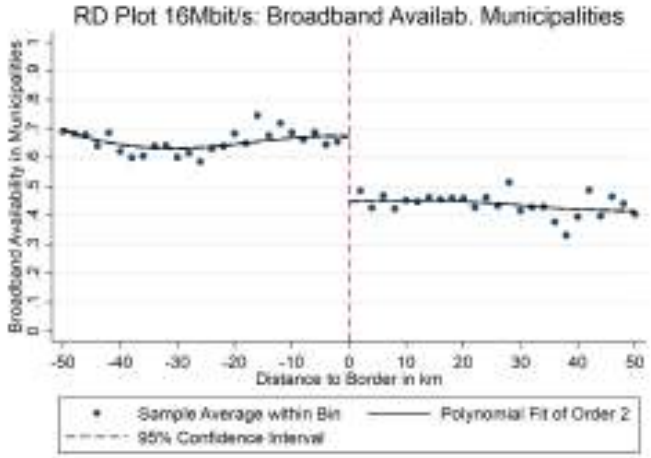

Figure: Broadband Availability

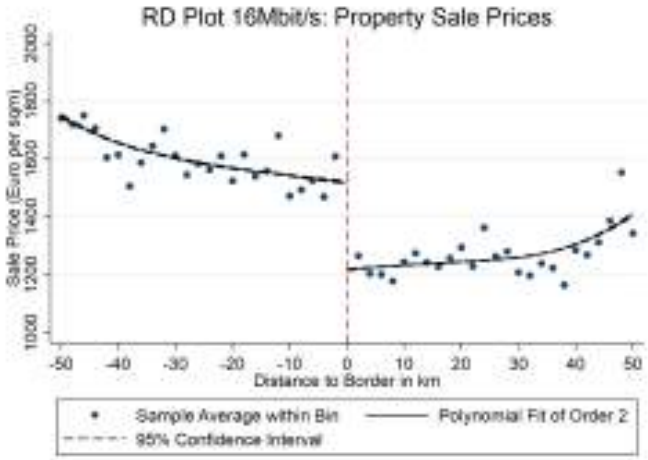

Figure: Property Sale Prices

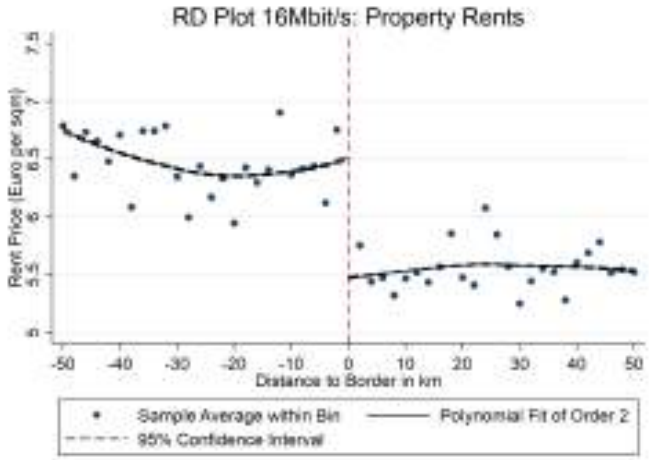

Figure: Property Rents

RD Plots Outcomes 16 Mbit/s: Smaller Bandwidth of 5 km

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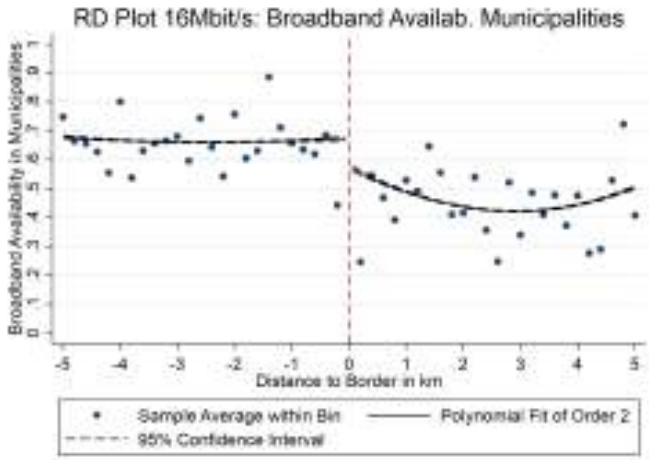
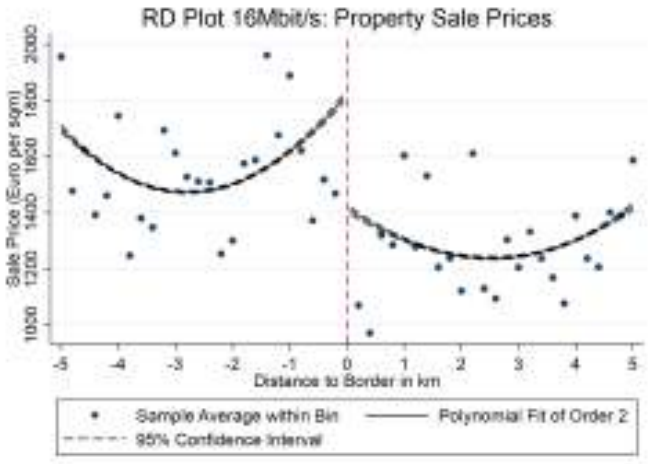


Figure: Broadband Availability



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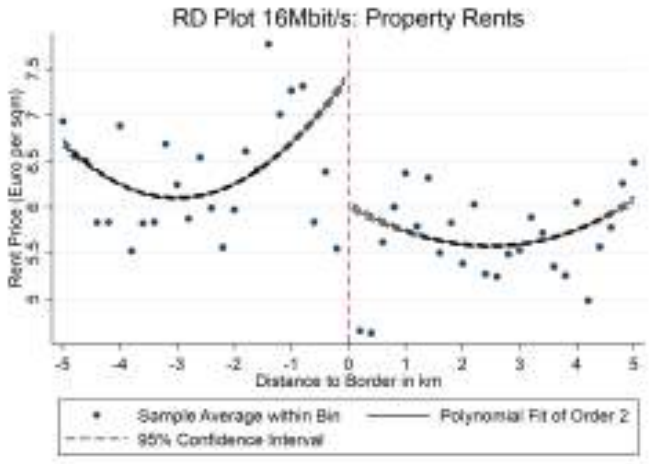

Figure: Property Rents

Robustness to Border Regions: Leave-one-out Approach

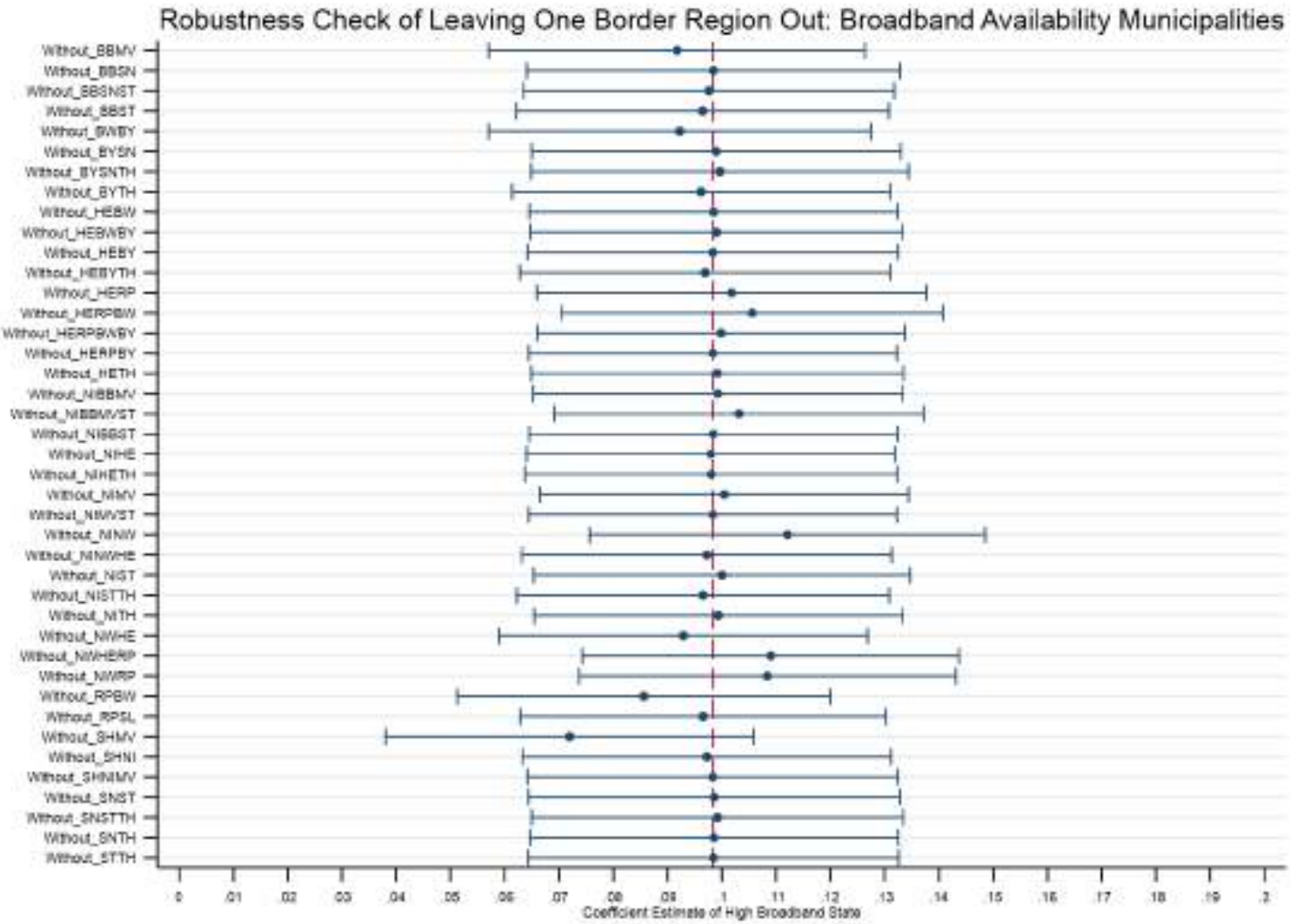

Figure: Leaving One Border Region Out: Broadband Availability in Municipalities

Robustness to Border Regions: Leave-one-out Approach

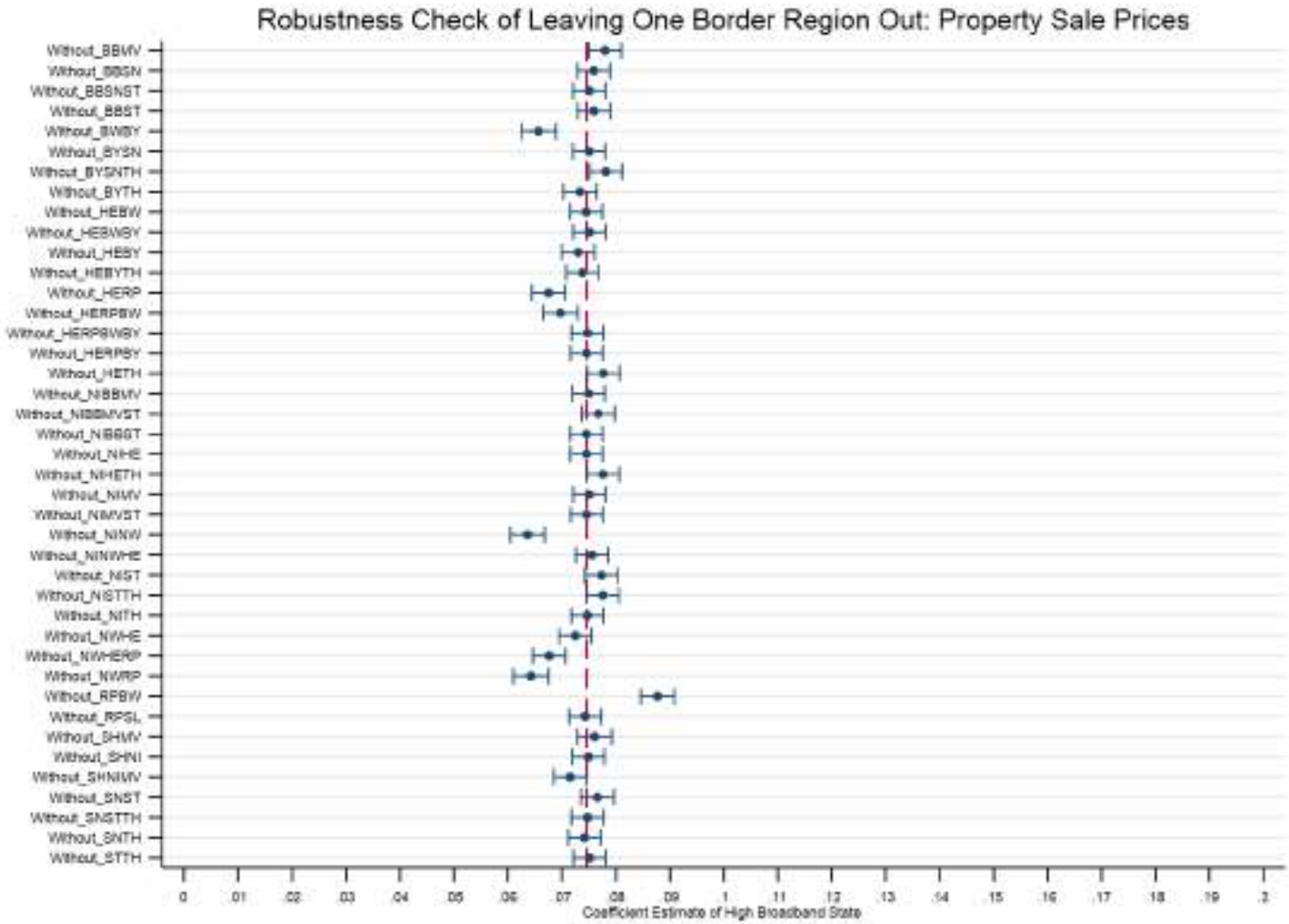

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Figure: Leaving One Border Region Out: Property Sale Prices

Robustness to Additional Controls: RD Plots of Covariates

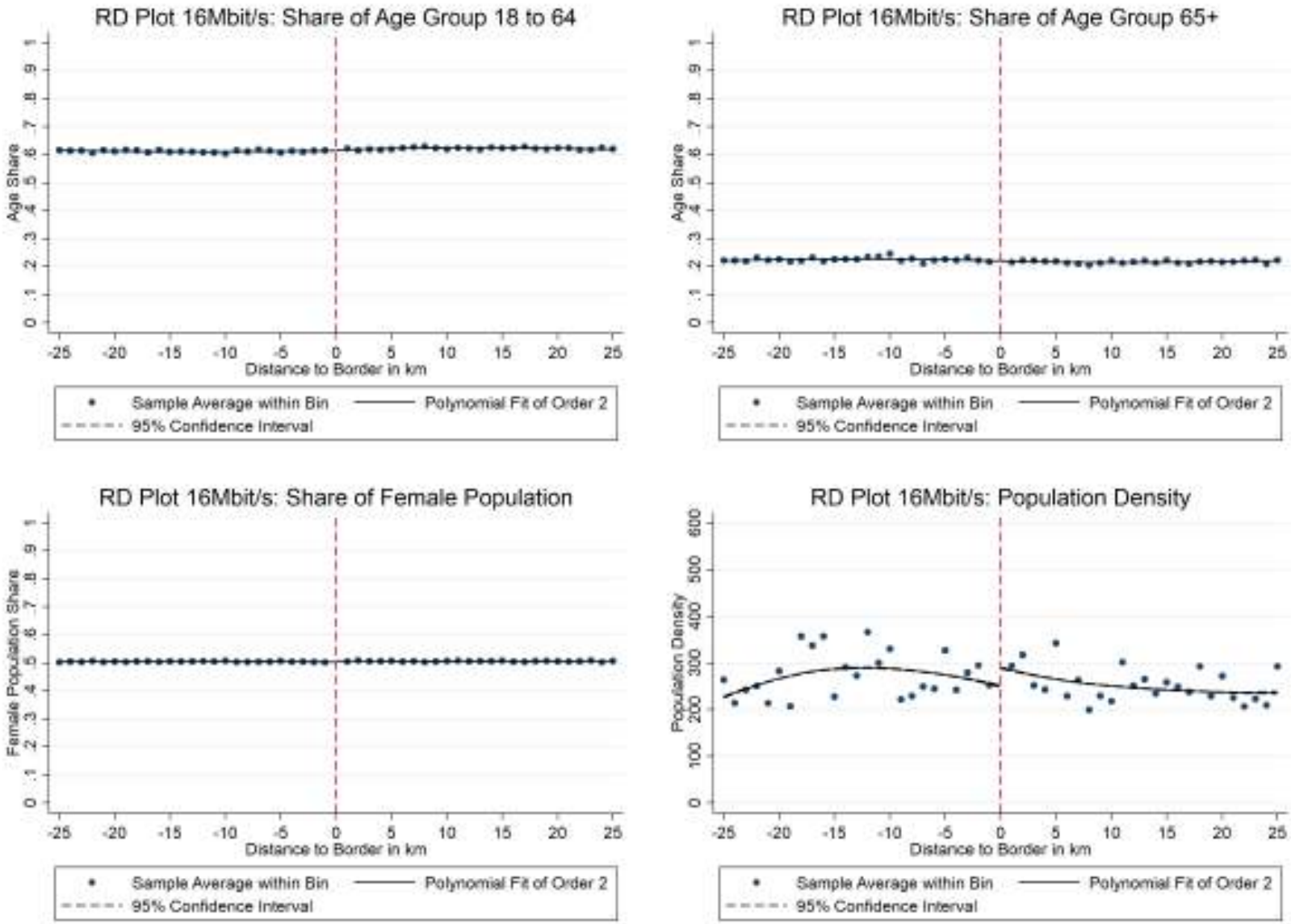

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Figure: Balanced Additional Controls Around Interstate Borders

Validity: Sample vs. Non-Sample Municipalities

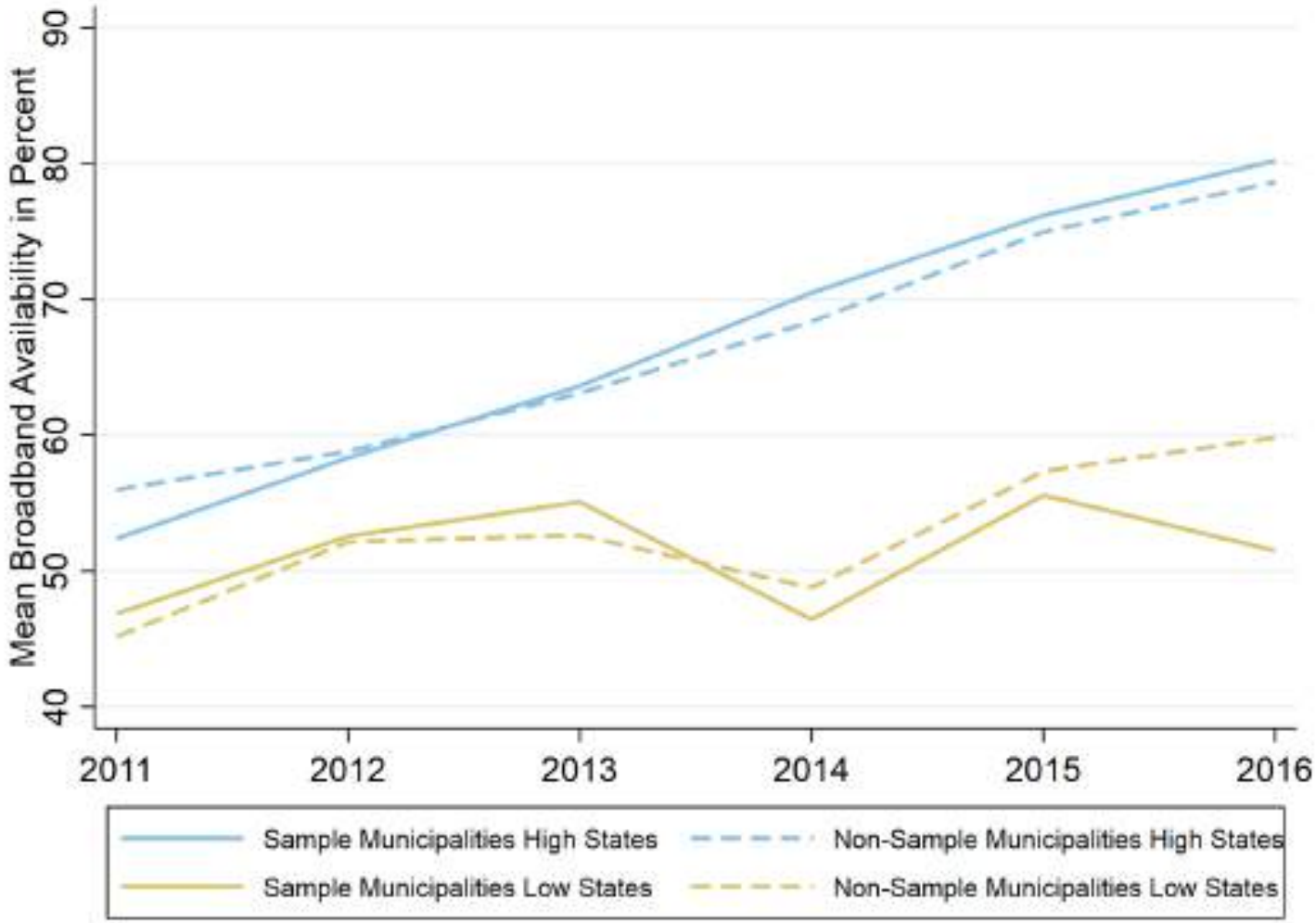

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Figure: Mean Broadband Availability in Municipalities in Percent

Alternative Identification Strategy: Event Study

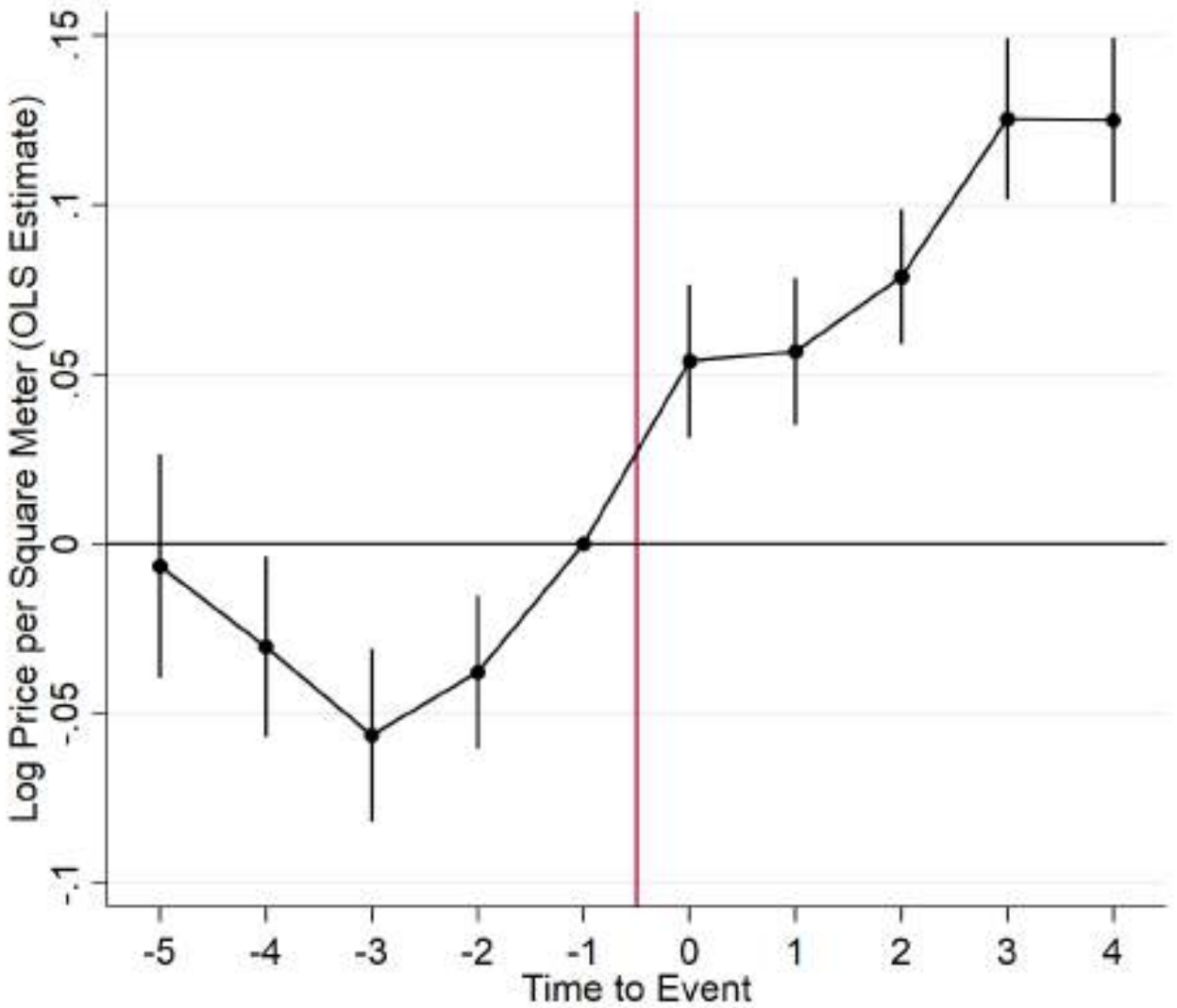

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Figure: Event Study Estimates for Property Sale Prices