Riding on the New Silk Road: Quantifying the Welfare Gains from High-Speed Railways

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Motivation

- Adequate infrastructure is essential for economic growth
  - e.g. highway, traditional rails ($120 - 160 km/h$), subway/bart, and increasingly popular **high-speed rails** (HSR, $250 - 350 km/h$)
- Whether to build HSR has led to the stark difference in policy choices across countries
  - e.g. China vs U.S.
  - lack of cost-benefit analysis
- Existing literature on infrastructure (HSR) paid relatively little attention to the indirect benefit as captured by a GE model
  - The goal of this paper is to try to fill this gap

This Paper

- Contribution to our understanding of the following questions:

  1. What is the effect of HSR connection on the average welfare (aggregate effect)?

  2. To what extend does the effect differ from skill and geographic dimensions (distributional effect)?

Methodology

1. Carry out reduced-form test to study the casual impacts of HSR on regional exporting performance
   - Adopt the least-cost-path (LCP) of HSR as IV to address the endogenous placement
   - Use an event study to ensure the casual relationship
   - Use export in "Processing" as the placebo test.

2. Motivated by the empirical evidence, we develop and calibrate a quantitative spatial equilibrium model, taking into account trade, migration, and outsourcing
   - Explicitly model HSR's impact as an improvement in firm-to-firm matching efficiency.

3. Perform counterfactual and cost-benefit analysis to explore various policy implications.

Summary of Findings

1. Connection to HSR significantly raises regional exporting performance
   - We estimate a 20% larger in export growth rates for cities connected to HSR than the ones not.
   - We detect the positive spillovers, which decay in distance to HSR hubs.
2. Welfare gains (CV) is 0.46% of China's 2007 GDP, and rise in national inequality.
   - Welfare effect is driven by productivity gains (firm access to more and better suppliers), which also explains 52% of export growth.
   - HSR induces regional specialization.
   - Improved outsourcing ability leads to adverse effects on the demand of unskilled labors and their returns
3. Gains from HSR are larger when labor migration costs are higher
   - HSR project would be an ideal policy for countries like China which feature high internal migration barriers
4. Cost-benefit analysis suggests that China's HSR investment requires 15 to 23 years to break even.

Related Literature

- **Gains from infrastructure construction:**
  - e.g. Faber (2014), Ahlfeldt (2015), Donaldson (2016), Baum-Snow et al (2017, 2018, 2019) and others
  - We focus on HSR that improve matching efficiency, instead of targeting reducing trade cost (traditional rails/highway) or reducing labor commuting cost (subway/bart)

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- **Effect of high-speed railways:**
  - Productivity gains: Bernard et al (2015) on Japan, Charnoz et al (2018) on France (easier information transmission)
  - Market expansion: Lin (2017) on China
  - Other HSR studies: AhlfedIt (2011), Schmieder and Heuermann (2018), AhlfedIt and Feddersen (2018)
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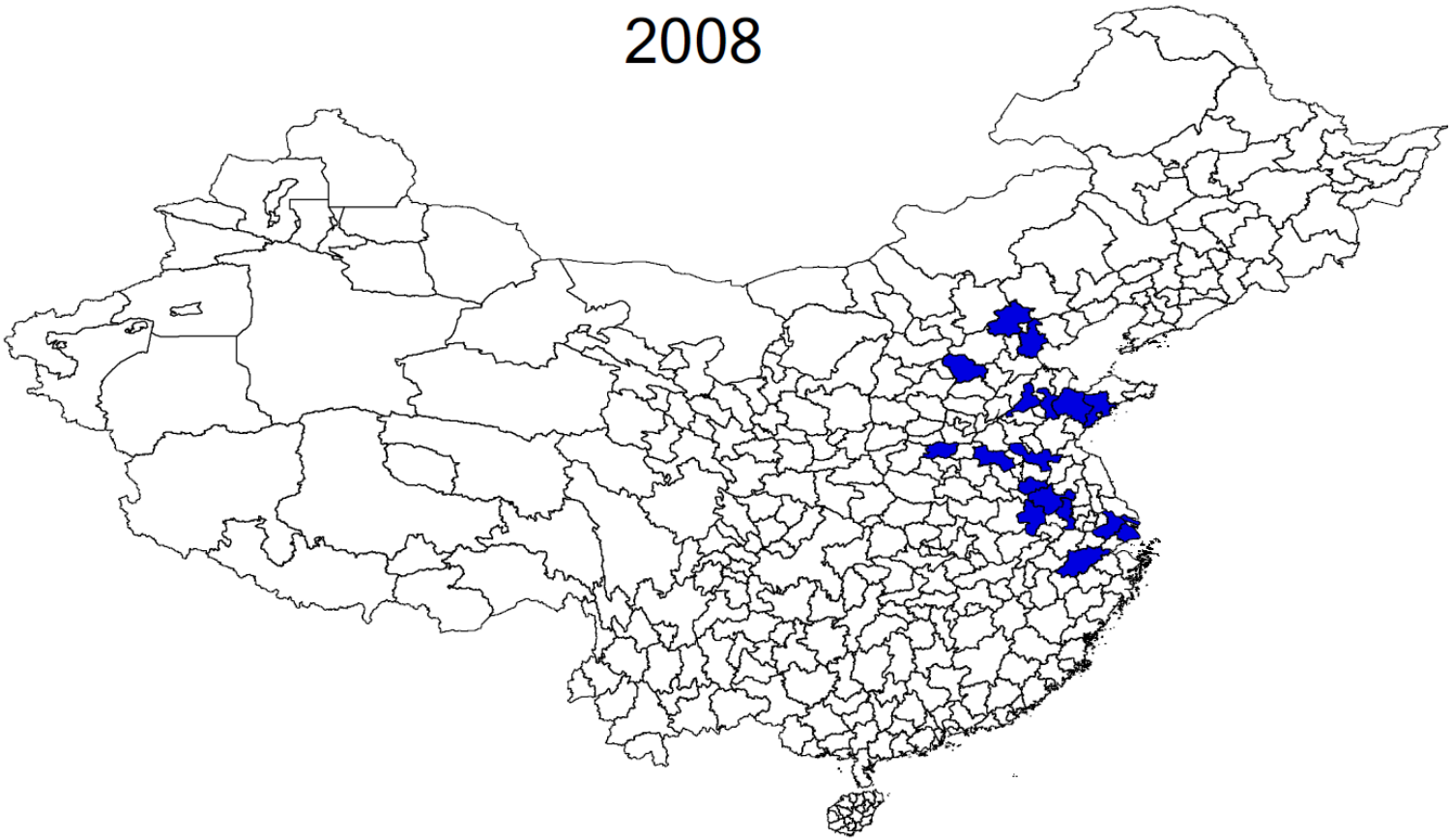
  - We study aggregate and distributional effects in a unified framework, and we differ from them in modeling HSR's impact
- **Theoretical elements:**
  - Eaton, Kortum and Kramarz (2016)
  - We build upon the original framework to allow a separate firm-consumer matching process and introduce frictional labor mobility.

HSR in China: Number of Cities Linked over Time



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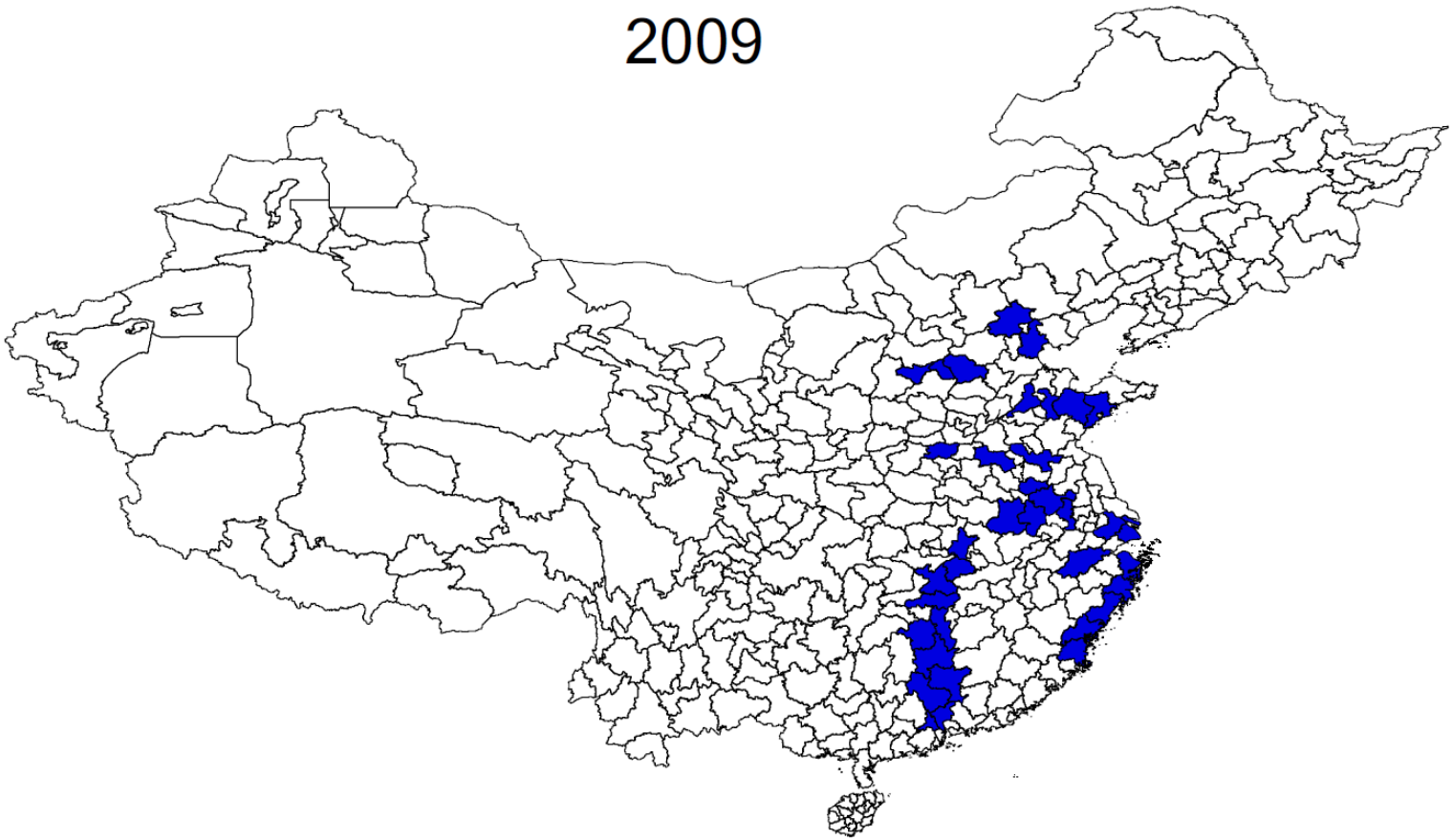

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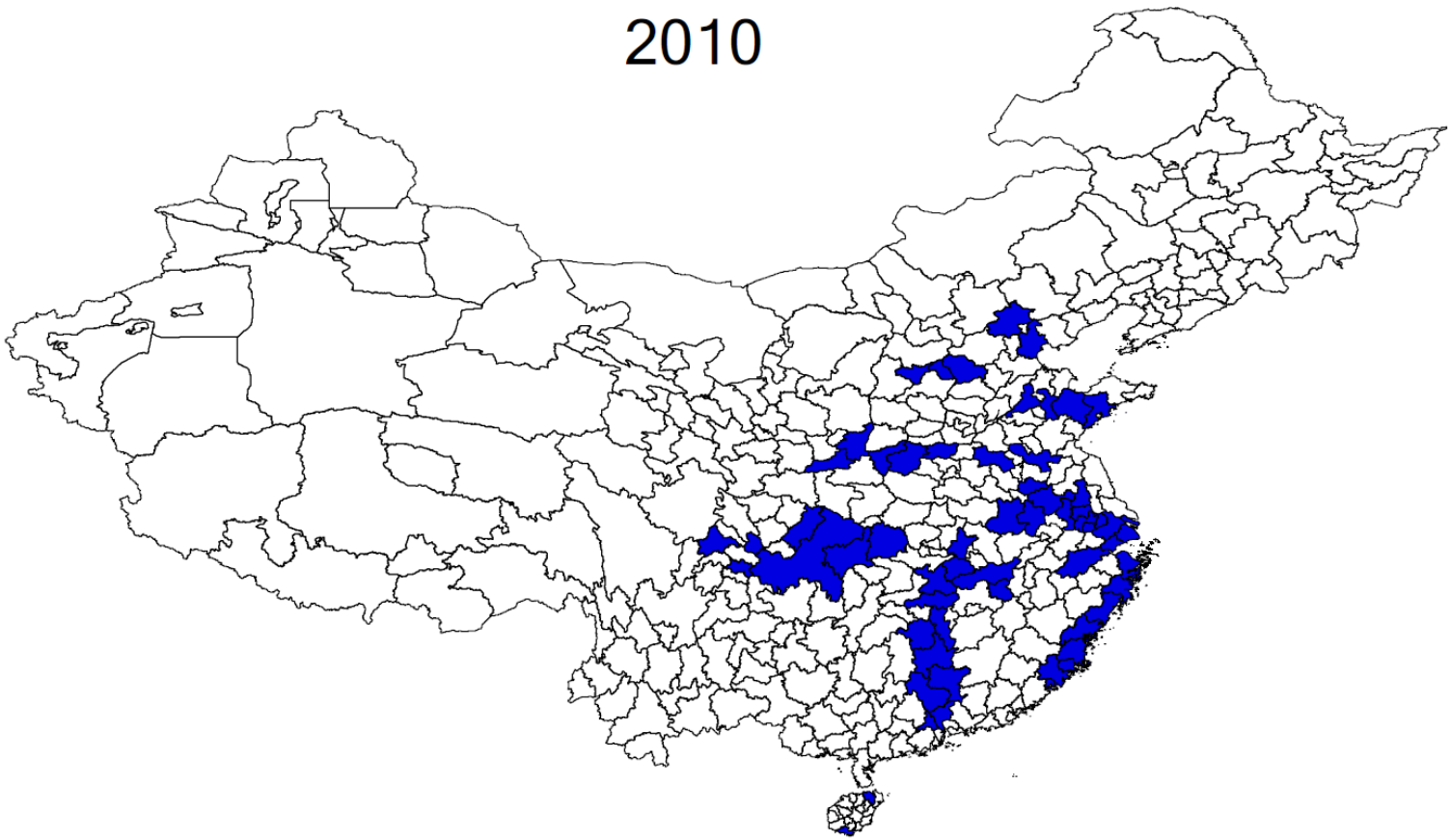

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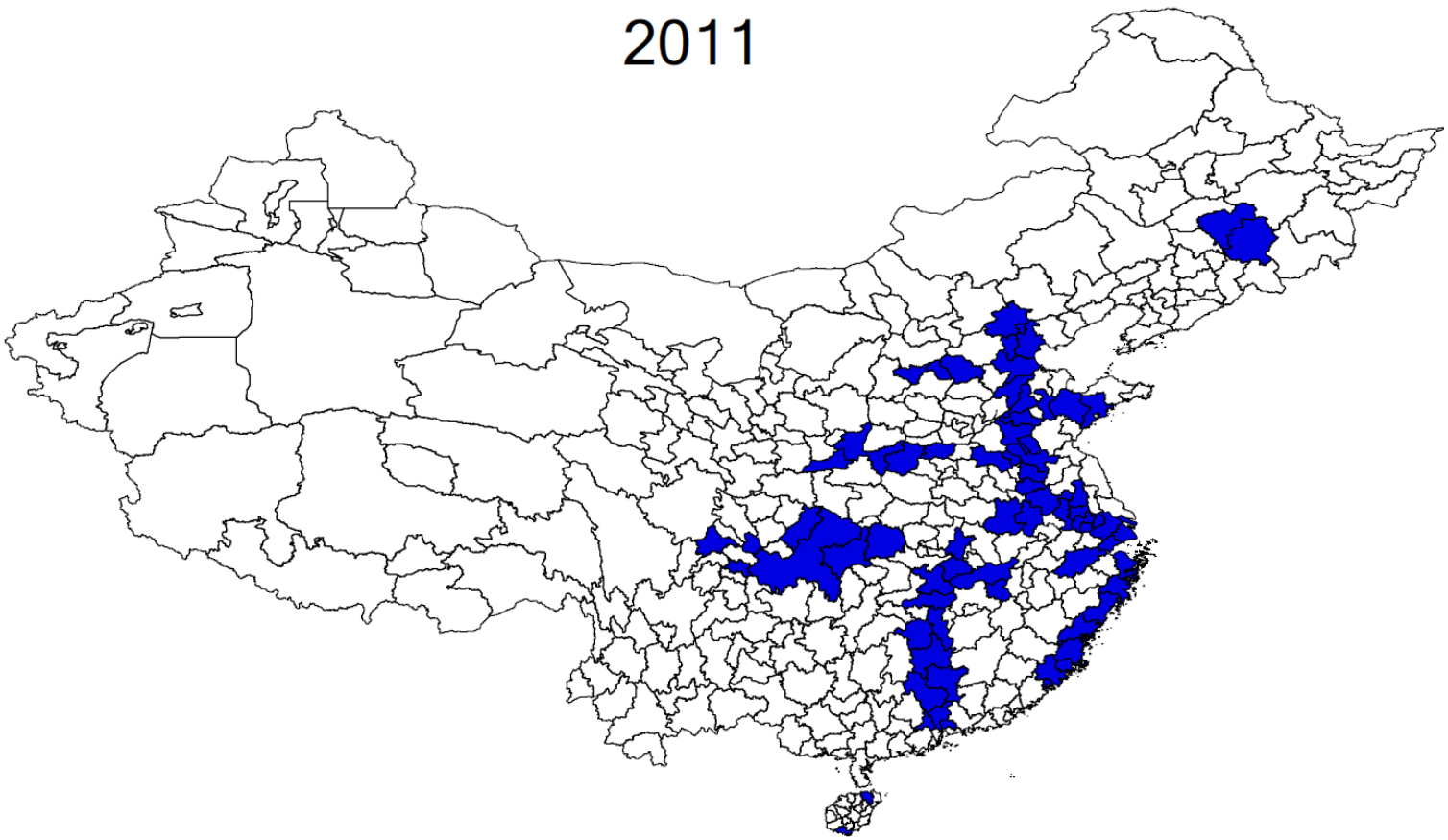

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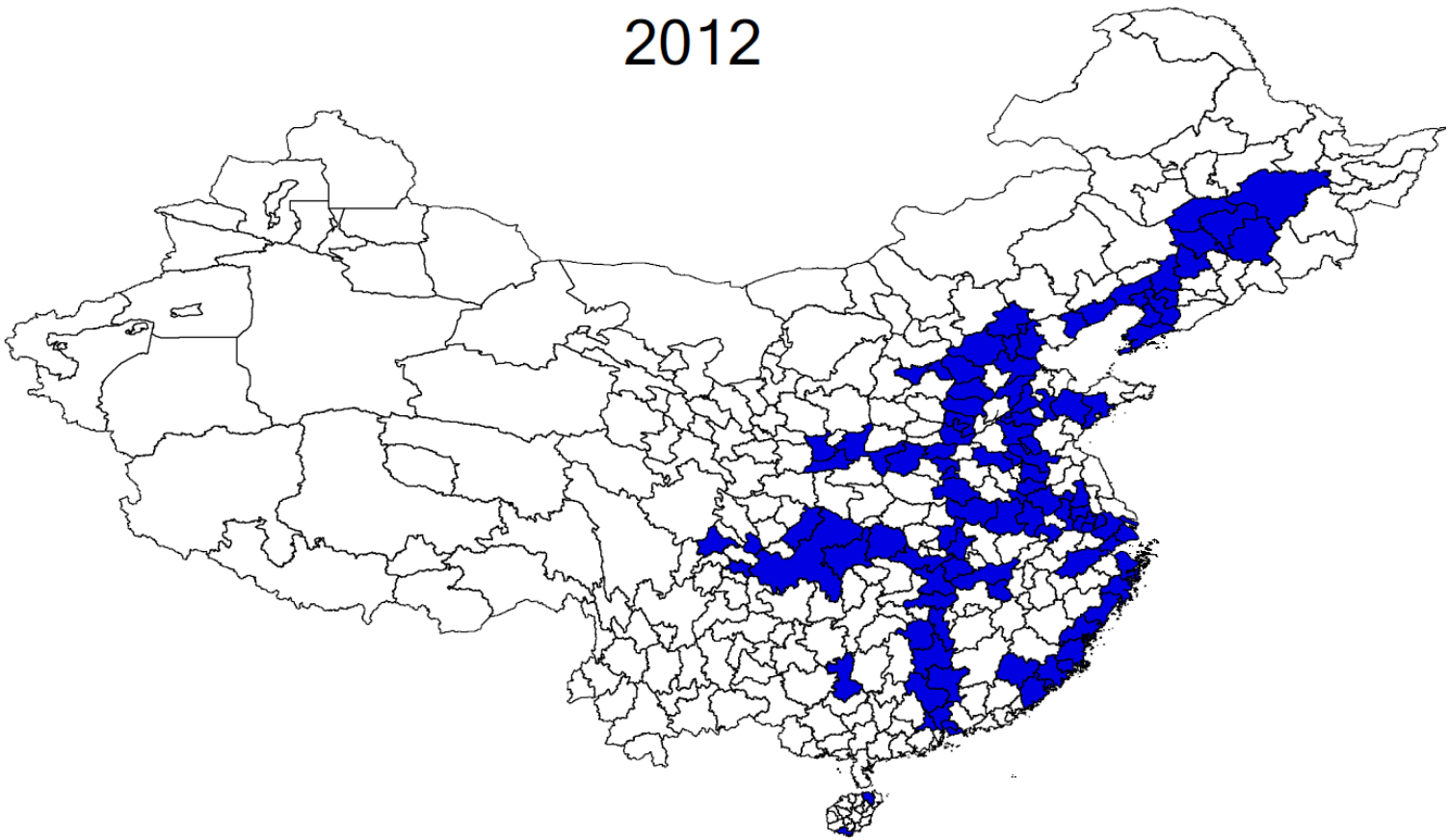

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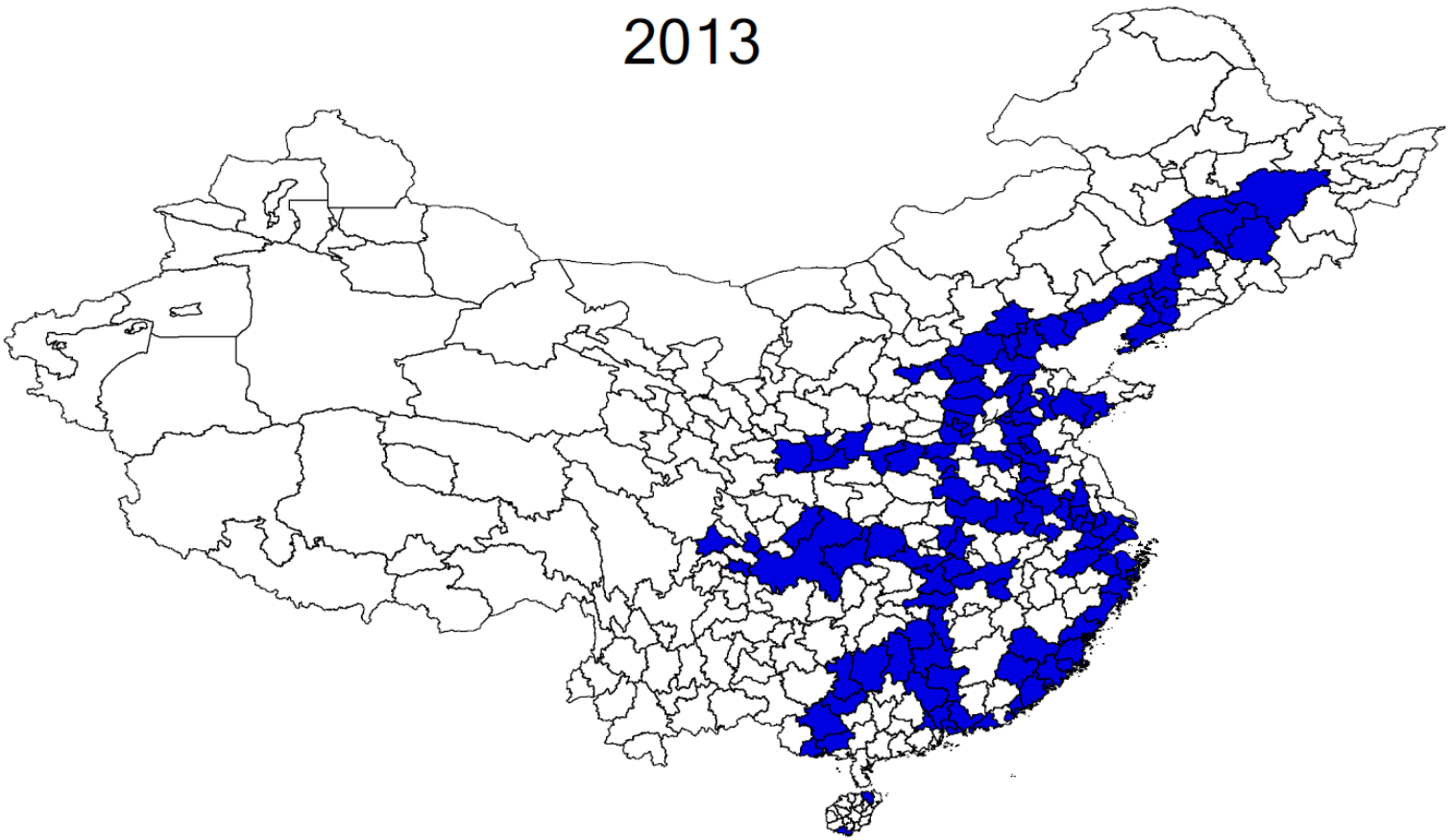

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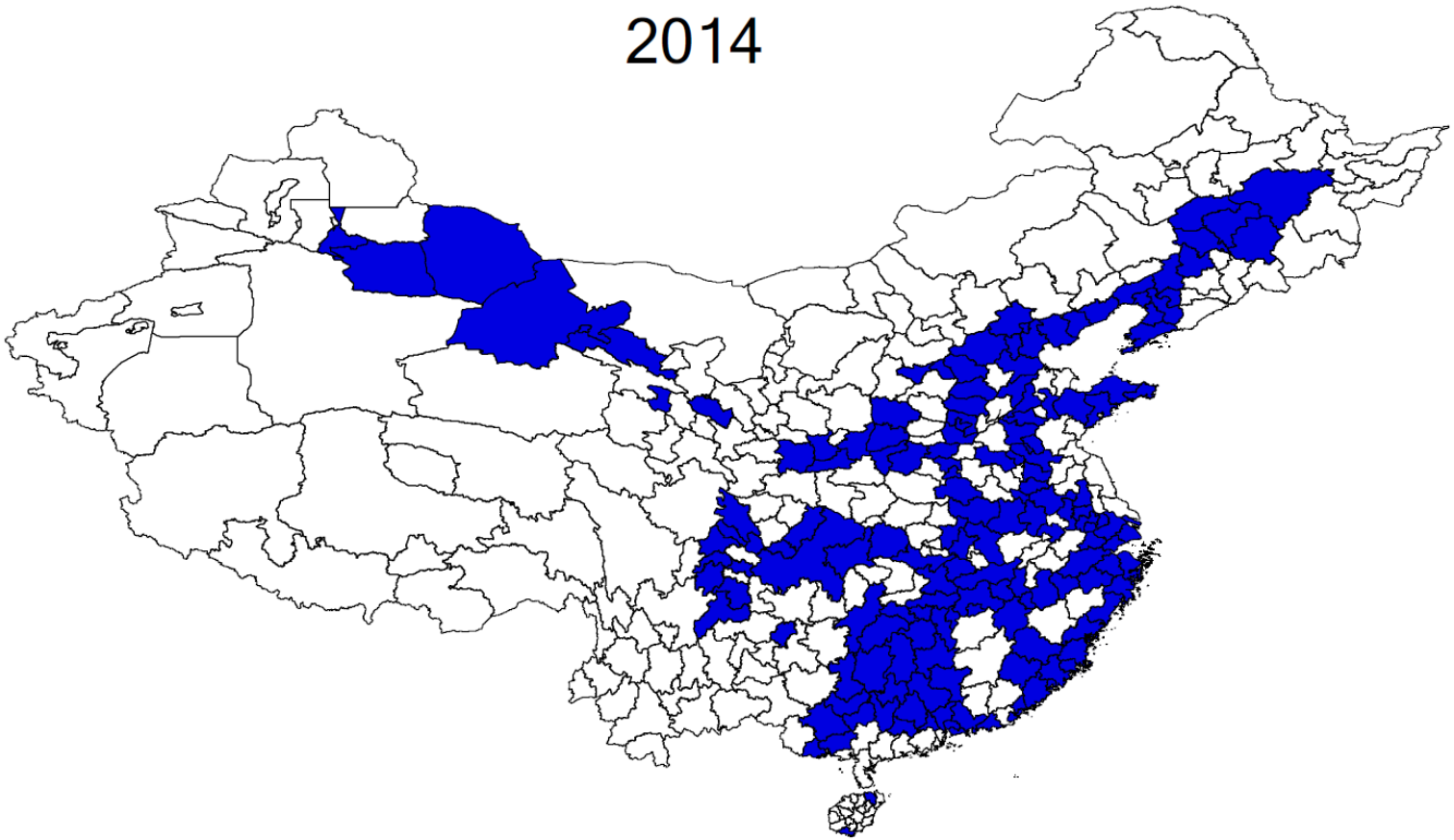

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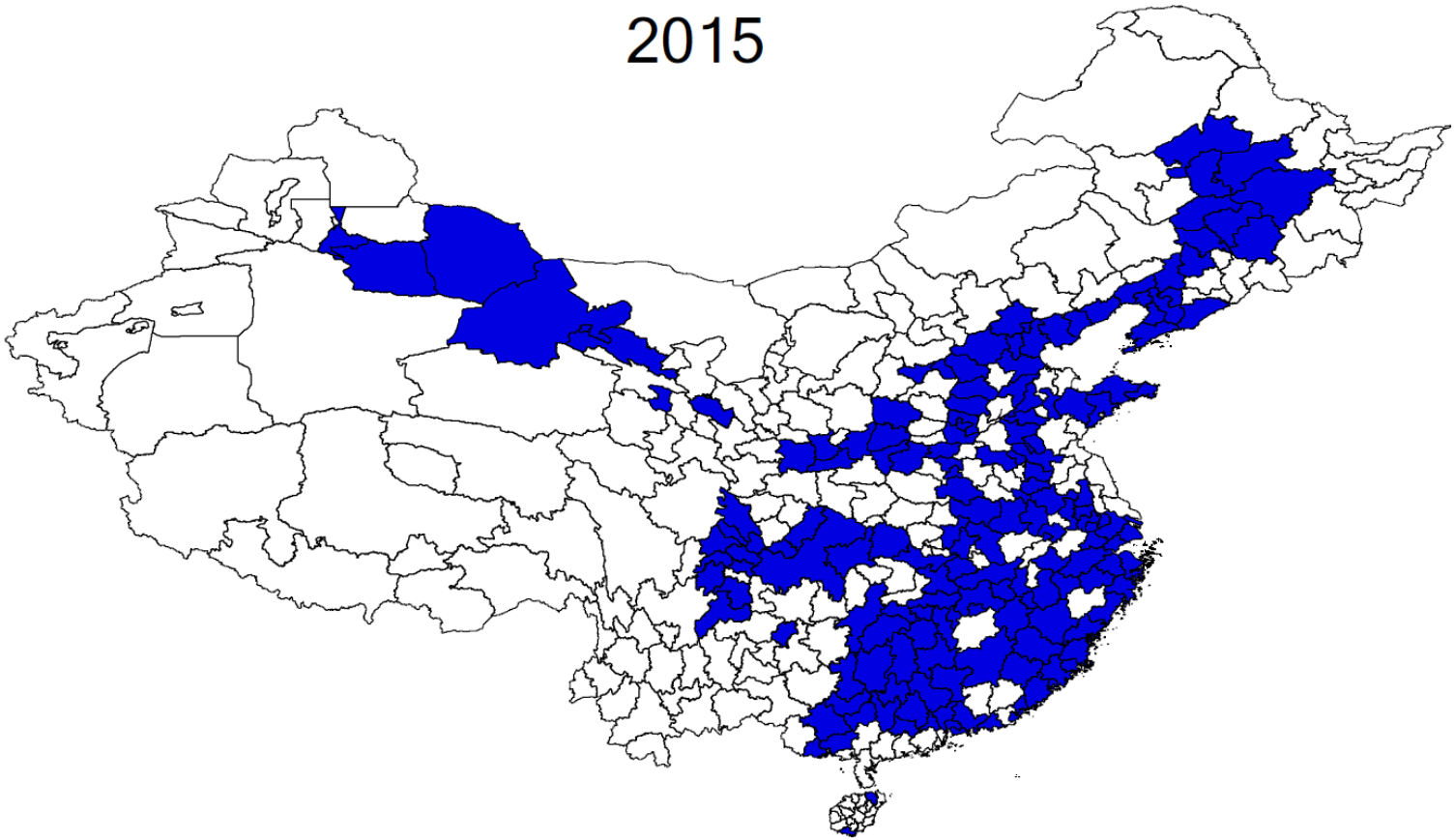

- By 2016, HSR network has connected 198 cities with total length of 22,000 km.

Empirical Evidence: How Do Export Differ Ex Post?

- Reduced form specification

$$\ln(y_{ct}) - \ln(y_{c2009}) = \beta Connect_{ct} + \eta \mathbf{X}_{ct} + \gamma_c + \epsilon_{ct}$$

where $Connect_{ct}$ indicates whether prefecture c was connected to the HSR network in year t. Other controls $\mathbf{X}_{ct}$ include per-capita GDP, population, average ridership (all types) and Internet coverage at prefectural level. OLS

- Potential endogeneity issues
  i. Selection of cities into HSR network (**LCP IV** LCP) IV
  ii. Violation of parallel trends of outcome between HSR-connected and the other cities (**Event Study**) Event

- Placebo test Placebo and other robustness checks Robustness

Model Summary: Model Implied Export Expansion

- Bilateral trade shares (n's purchases devoted to imports from i):

$$\pi_{ni} = \frac{T_i \Xi_i d_{ni}^{-\theta}}{\sum_j T_j \Xi_j d_{nj}^{-\theta}}$$

  where Ξ_i capture productivity gains from outsourcing, increasing in λ_i

- If shutting down outsourcing channel $\lambda_j = 0, \forall j$:

$$\pi_{ni} = \frac{T_i \left(\bar{w}_i d_{ni}\right)^{-\theta}}{\sum_j T_j \left(\bar{w}_j d_{nj}\right)^{-\theta}}$$

Model Summary: Aggregate Representation

- Consider the representative firms taking wage $w_{k,i}$, and intermediate prices $\bar{p}_{M,i}$ as given:

$$\bar{p}_{M,i} \propto \lambda_i^{-1/\phi} \Upsilon_i^{-1/\theta}$$

with endogenous measure of active firms as Υ_i

- Its production function is CES nested within Cobb-Douglas (roundabout):

$$Y_i = L_{S,i}^{\beta_S} \left[\tilde{\varphi} \left(L_{U,i} \right)^{\frac{\phi}{\phi+1}} + \left(1 - \tilde{\varphi} \right) \left(M_i \right)^{\frac{\phi}{\phi+1}} \right]^{\frac{\phi+1}{\phi} \times \beta_M}$$

with elasticity of substitution $1 + \phi$ and share scalar $\tilde{\varphi}$

Counterfactual Analysis: Productivity

- Productivity growth (2007 to 2015):

$$\pi_{ni} = \frac{T_i \Xi_i d_{ni}^{-\theta}}{\sum_j T_j \Xi_j d_{nj}^{-\theta}} \implies \widehat{\Xi_i}$$

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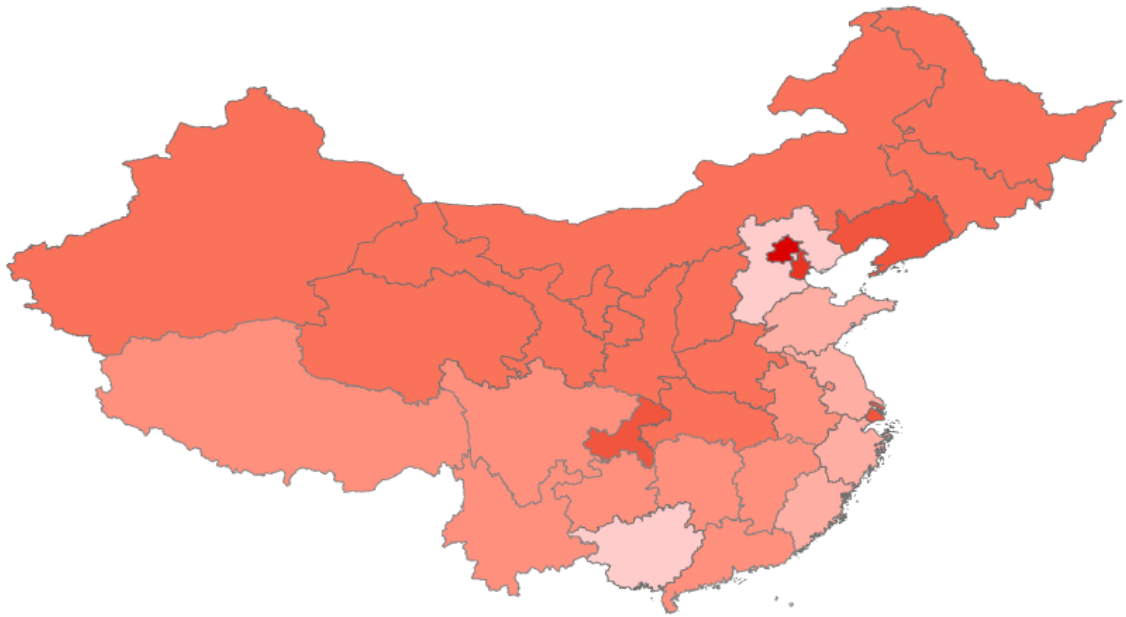


Figure 8: Technology Gains ($\widehat{T_i \Xi_i}$) From HSR

Counterfactual Analysis: Productivity

- Export Expansion due to HSR Construction

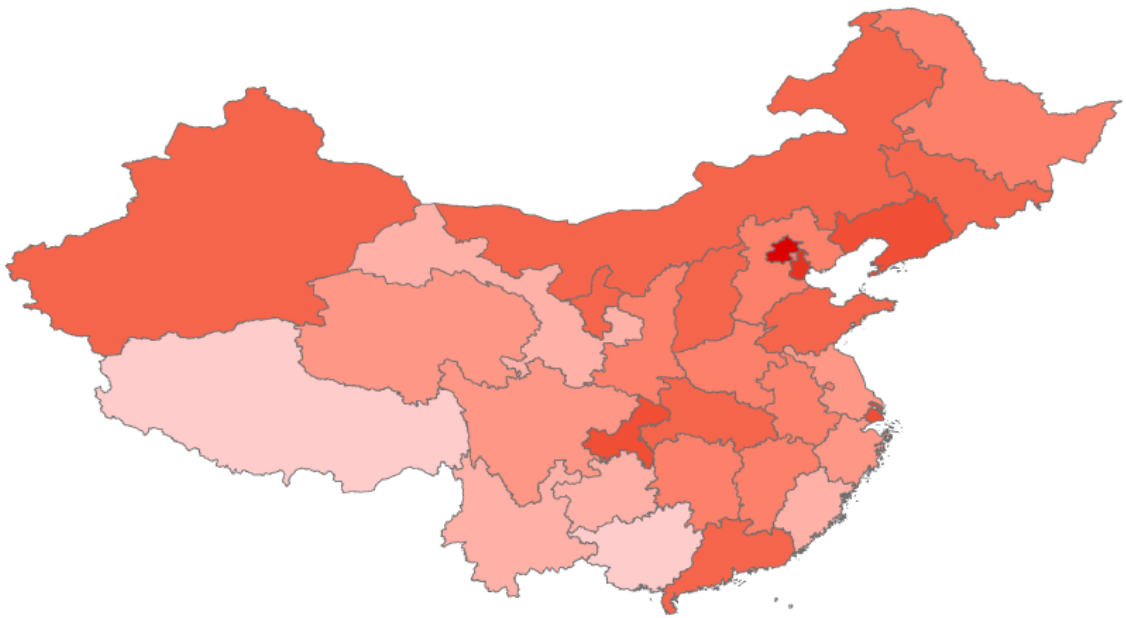
Table 5: Export Expansion due to HSR Construction

Dept. var $\Delta Export$ (2007 - 2015)	Ordinary Export	Processing Export
Model Fit	52%	14%

Notes: The table reports the R^2 as the indicator of model fit in explaining the expansion of export at the provincial level (including the municipalities) between 2007 and 2015.

Counterfactual Analysis: Welfare

- Welfare gain measured as compensating variation for HSR placement is 0.46% of China's 2007 GDP



Counterfactual Analysis: Cost-Benefit Analysis

- Welfare gain measured as compensating variation for HSR placement is 0.46% of China's 2007 GDP

	Unit	Data Source	Value	
Benefit				
(1) Annual Compensating Variation	% of Base Year GDP	Model	0.46%	
(2) Base Year GDP	trillion USD	World Bank	3.552	
(3) Annual Benefit	billion USD	(1) × (2)	16.339	
Cost				
(4) Total Length of HSR Lines by 2016	*km*	BBC News	22,000	
(5) Unit Cost - $350km/h$ / $250km/h$	million USD	World Bank	16.974	11.447
(6) Total Construction Cost	billion USD	(4) × (5)	373.421	251.842
Net				
(7) Benefit of HSR as	% of Total Cost	(3)/(6)	4.38%	6.49%
(8) Number of Years to Break-even	Year	1/(7)	22.9	15.4

Notes: The exchange rate of RMB to USD is 7.60 in 2007. The benefit of HSR network reported is solely generated by the improved matching efficiency among firms.

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Counterfactual Analysis: Distributional Effects

- Skill premium increases, especially for coastal regions.
- HSR raises the national inequality.
  - Theil index increases by 1.38%.
  - It is mostly driven by the widen gap between skilled and unskilled workers.
- The rising inequality could be alleviated by reforms with the goal of reducing internal migration costs.
  - Removing labor mobility barriers also generates additional welfare gains.

Concluding Remarks

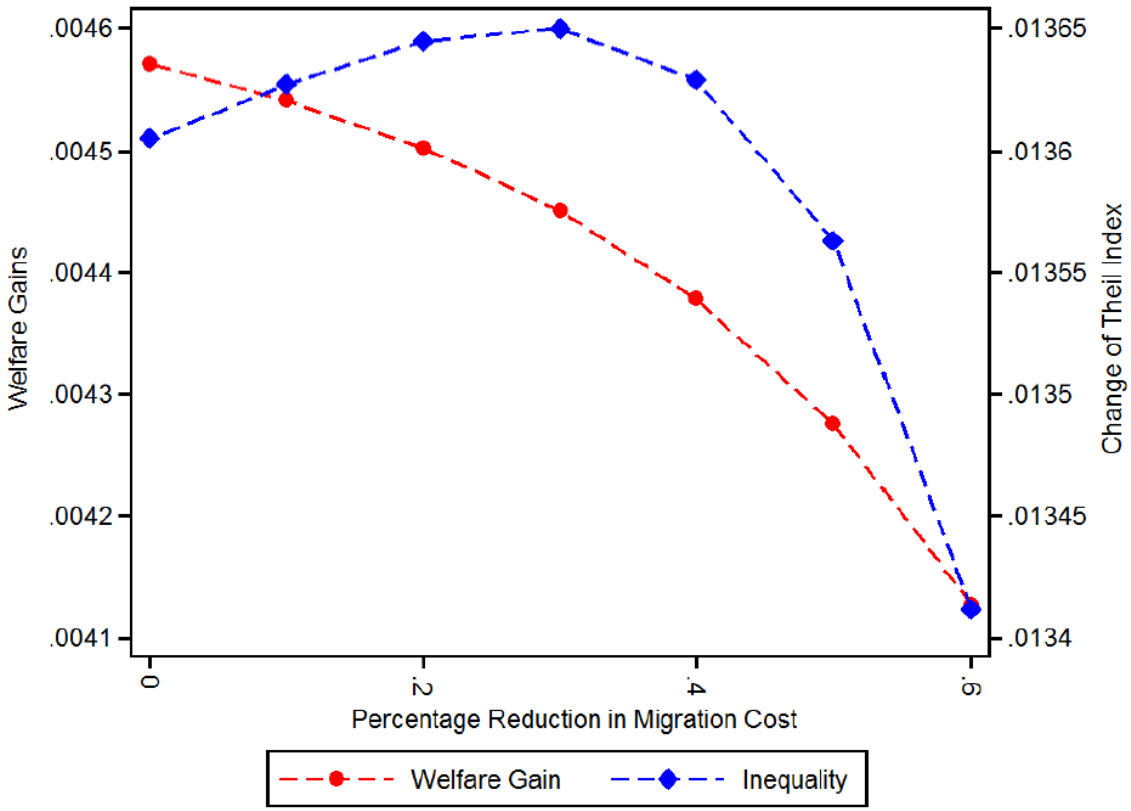
- We document the reduced-form (causal) evidence that access to HSR significantly promotes exports at the prefecture level.

- We propose a quantitative spatial equilibrium framework to study the general equilibrium effects of the HSR.
  - In spirit of Bernard et al 2017, HSR leads firms to search more suppliers which drives down the production cost (like productivity gain).
  - The improvement on producer-supplier linkage brings welfare gains, and affects inequality (through adverse impacts on unskilled labors due to outsourcing).

- We study the factors affecting HSR-induced changes in welfare and inequality
  - HSR gains are larger in country with higher internal migration costs
  - HSR generates sizable overall economic benefits after taking into consideration of constructing costs.

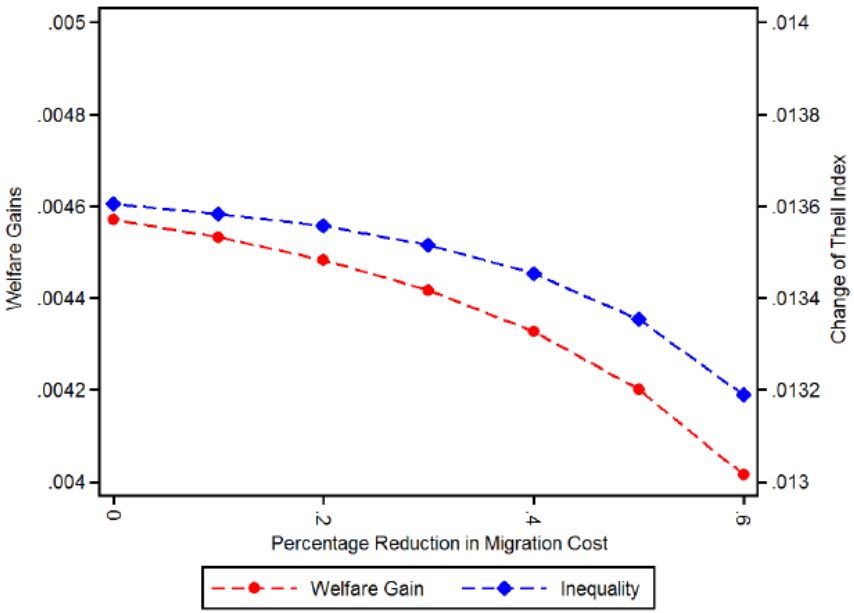
Counterfactual Analysis: Role of Labor Mobility

- HSR effects in economies with low migration costs v.s. high migration costs

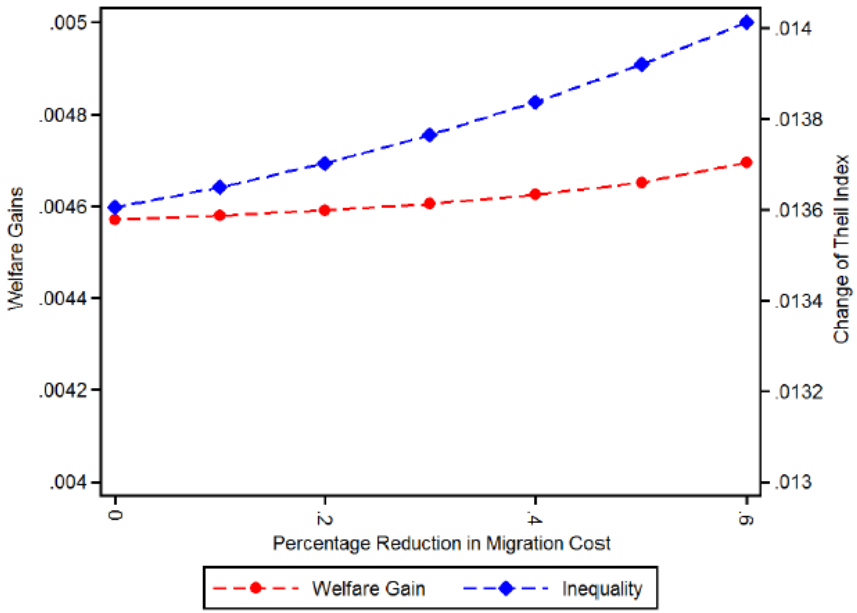


Counterfactual Analysis: Role of Labor Mobility

- HSR effects and migration costs by skills



(a) Reduction in *Unskilled* Migration Cost



(b) Reduction in *Skilled* Migration Cost

Regression Result: OLS

Table 1: The Impact of HSR Network Connection on Export

Dept. var	OLS		IV Approach		
$\ln y_{ct} - \ln y_{c0}$	(1)	(2)	(3) Euclid IV	(4) Slope IV	(5) LCP IV
Connection to HSR	0.529***	0.194***	0.994*	1.705***	0.896*
	(0.0414)	(0.0615)	(0.507)	(0.489)	(0.486)
First stage F-Stat	-	-	11.16	11.10	11.55
Observations	1,681	1,433	1,433	1,433	1,433
R-squared	0.422	0.574	0.506	0.332	0.522
City FE	YES	YES	YES	YES	YES
Other Control	NO	YES	YES	YES	YES

Notes: Each point estimate stems from a separate regression. All regressions include prefecture fixed effects. Euclid IV denotes the Euclidean distance spanning tree instrument. Slope IV stands for the cost path spanning tree instrument that uses average terrain slope gradient. LCP IV represents the least cost path spanning tree instrument. Other controls include per capita GDP, population, average rideship and internet coverage at prefectural level. Robust standard errors are clustered at the group level and reported in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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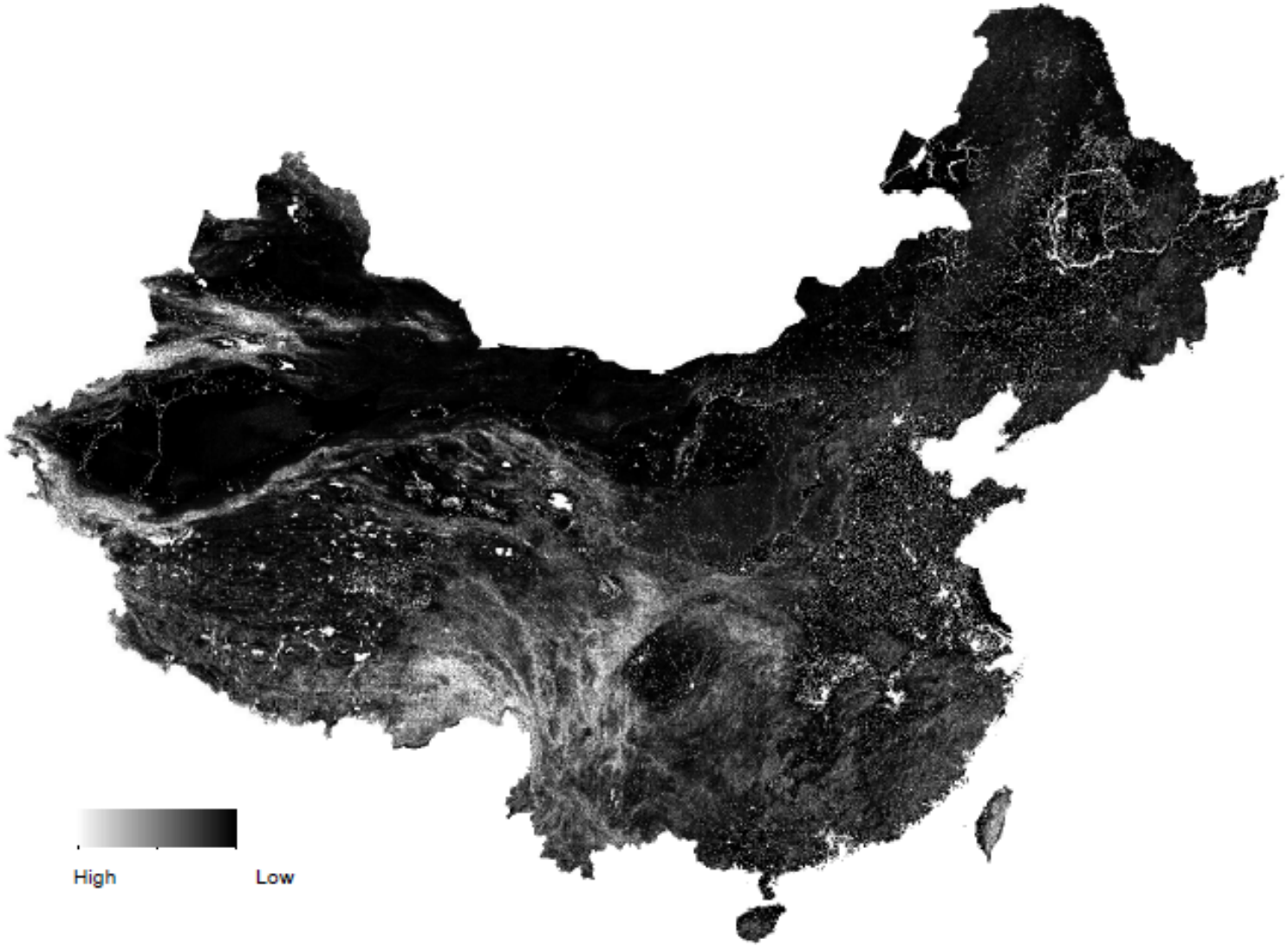
Construction of LCP

- **Political goal of HSR**: to connect all provincial capitals and other major cities with faster transportation (The Ministry of Railway of China).
- IV: Least Cost Path Spanning Tree Networks (Faber 2014)
  - Connect all capital city nodes on a single continuous network subject to global construction cost minimization.
  - Uses detailed satellite data such as land cover, land use and average slope
- Constructions method:
  1. Reclassify the resolutions of elevation and land cover to $1km \times 1km$, which gives about 18.8 million grid cells to cover China
  2. We assign construction cost as:

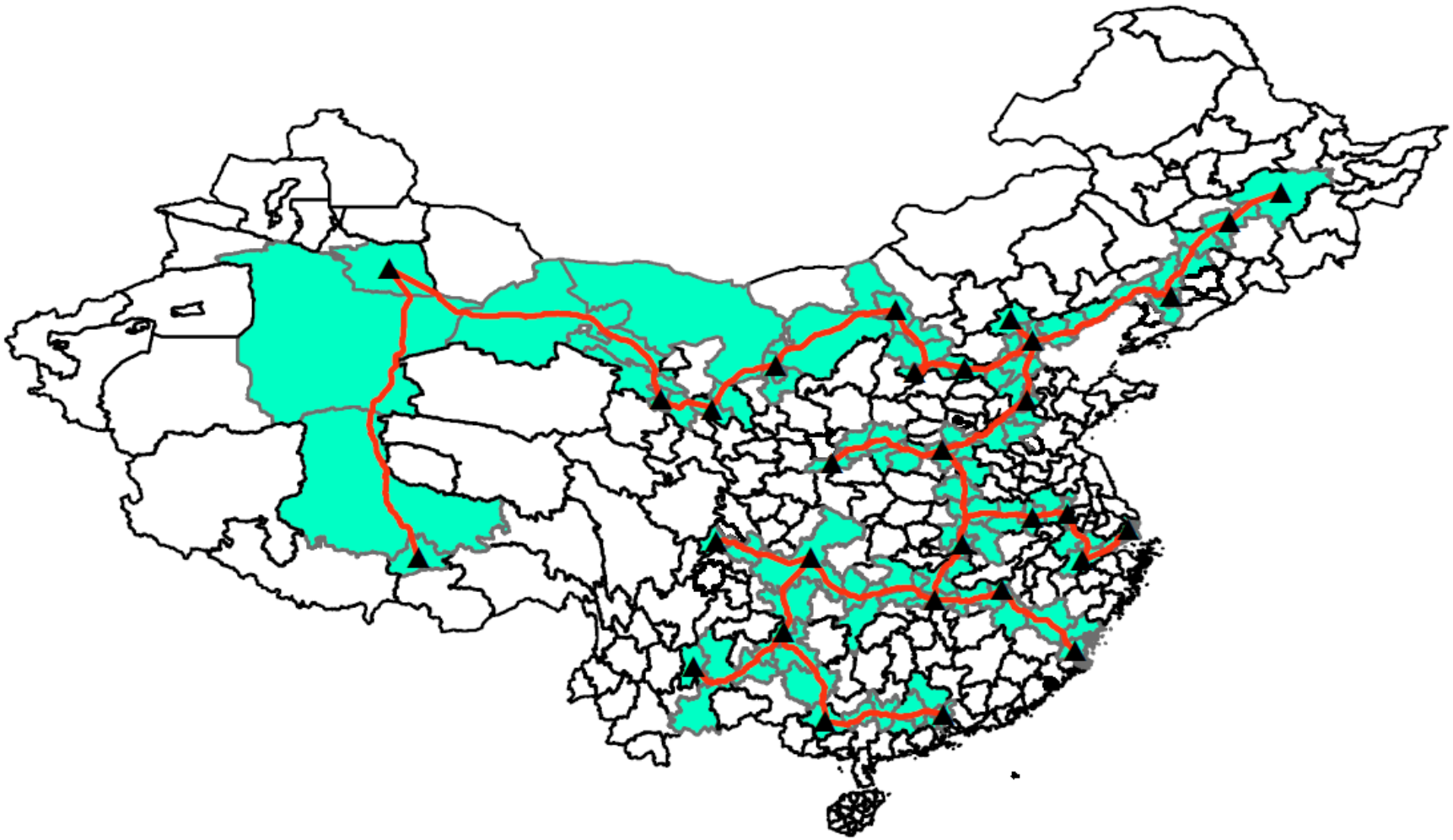
$$c_i = 1 + Slope_i + 25 \times Built_i + 25 \times Water_i + 25 \times Wetland_i$$

  3. Then we use Dijkstra's optimal route algorithm to construct the least cost HSR paths between all bilateral destinations

Construction of LCP: Cost Raster



Construction of LCP: Least-Cost Path



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Regression Result: IV

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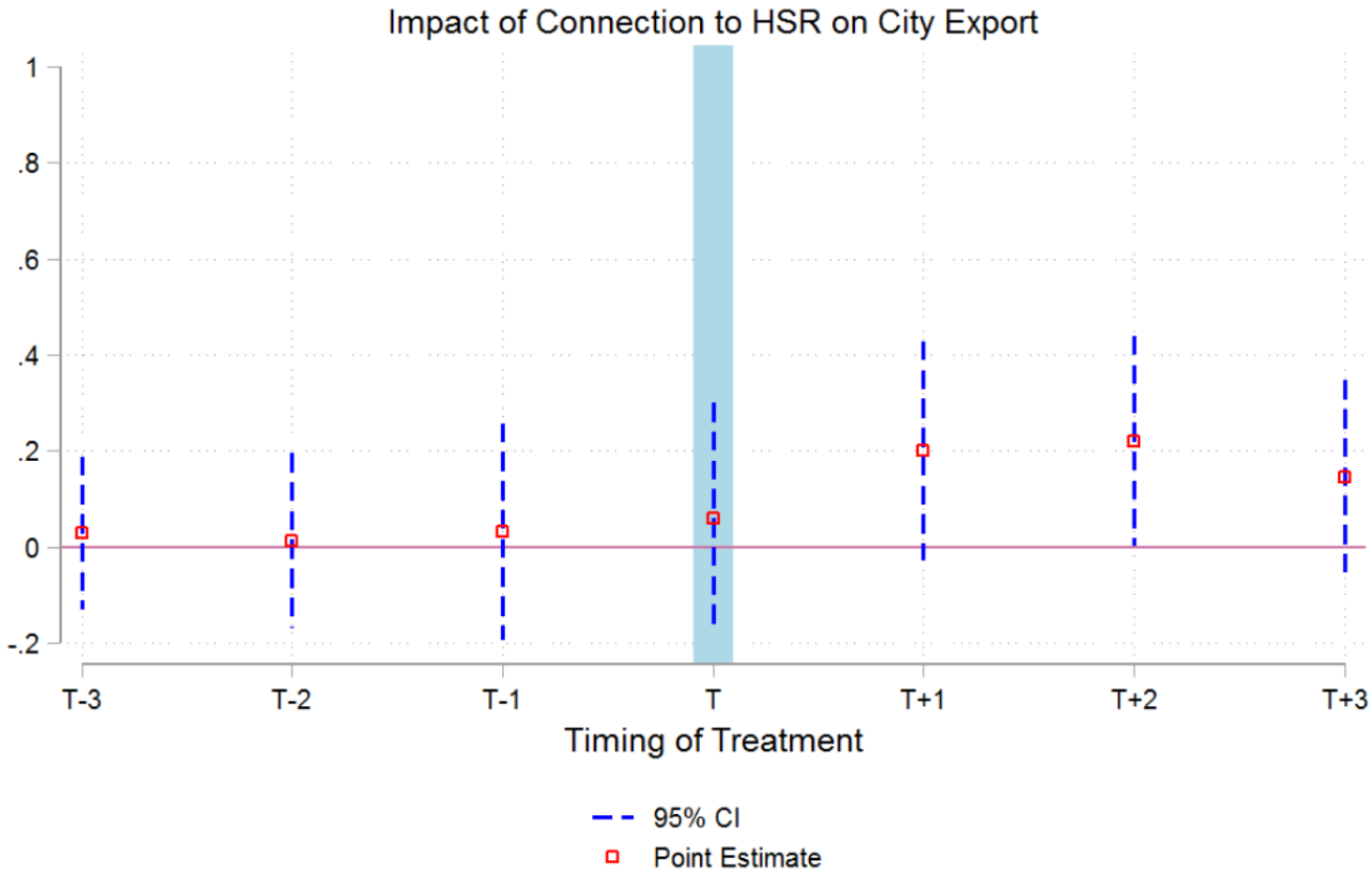
Event Study



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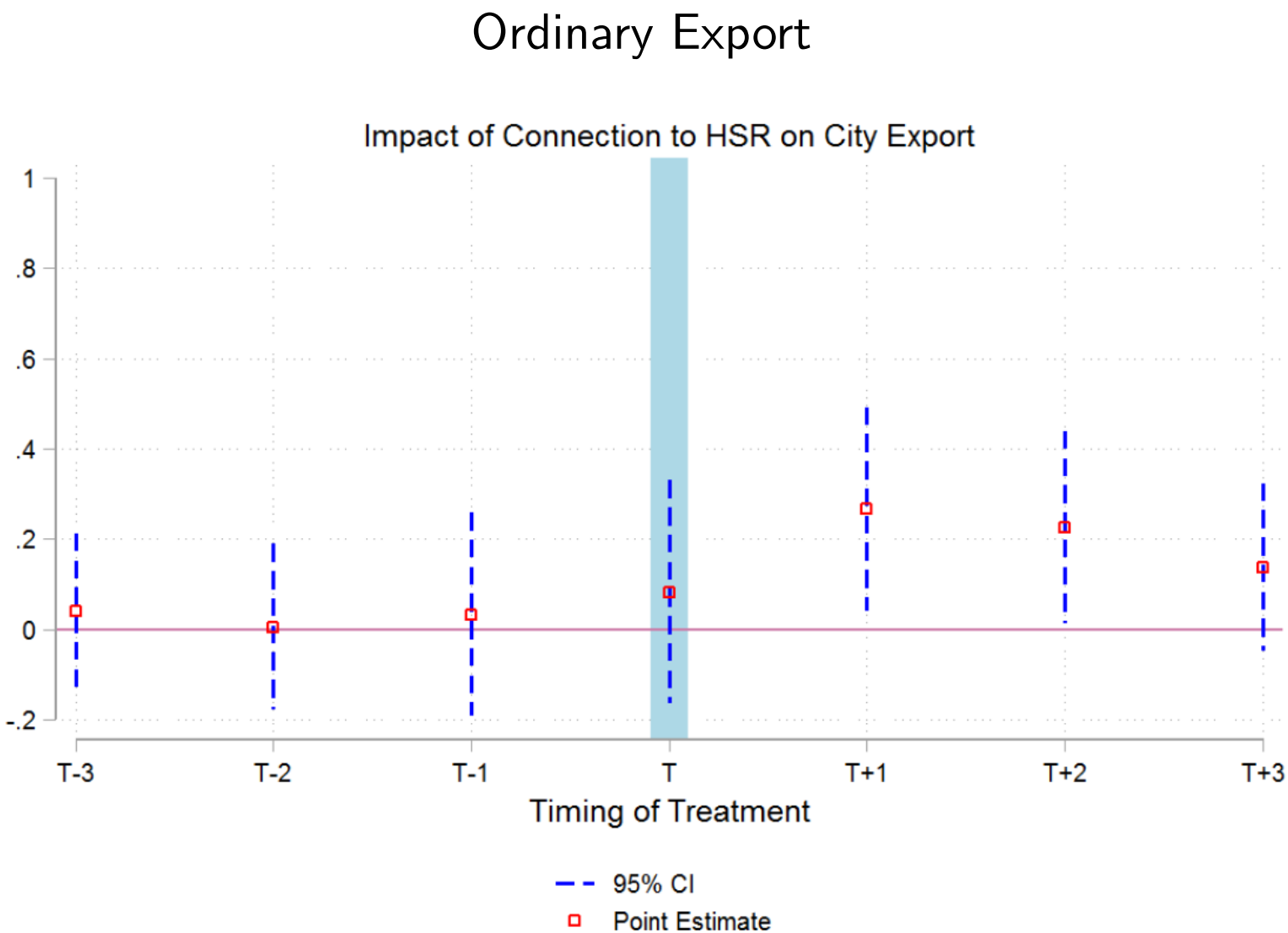
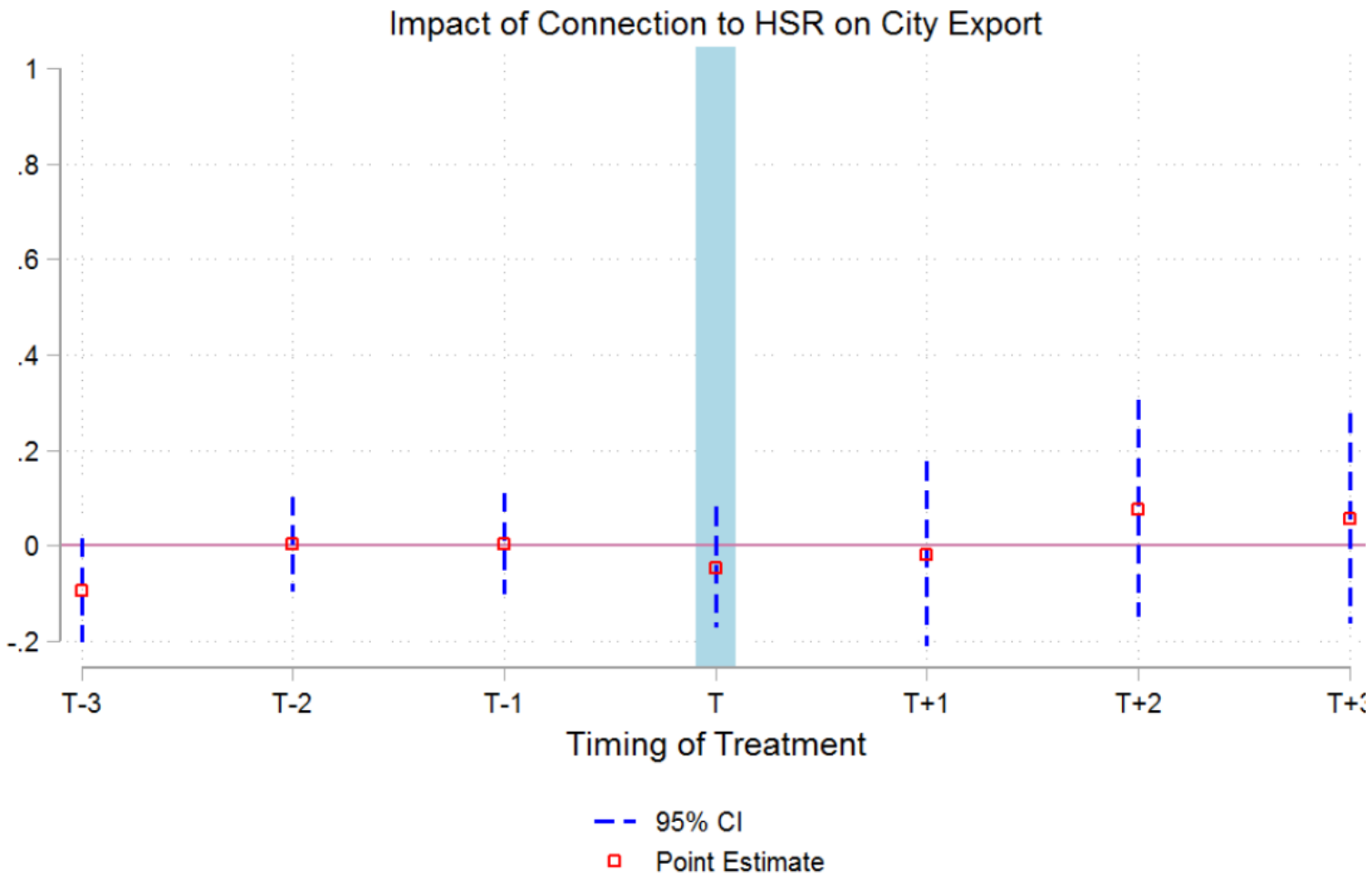
Placebo: Ordinary vs Processing



Placebo: Ordinary vs Processing

Processing Export



Other Robustness

Table A.4: Placebo Test: HSR Impact on Ordinary and Processing Export

Dept. var	Ordinary Export						Processing Export					
$\ln y_{ct} - \ln y_{c0}$	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
3 Years Prior to Initial Connection	0.040	0.067	0.063	0.111	0.119	0.050	-0.093*	-0.076	-0.081	-0.039	-0.080	-0.082
	(0.084)	(0.078)	(0.099)	(0.106)	(0.114)	(0.092)	(0.053)	(0.050)	(0.095)	(0.089)	(0.100)	(0.094)
2 Years Prior to Initial Connection	0.004	0.088	0.035	0.154	0.120	0.113	0.003	0.033	-0.003	0.080	0.015	0.026
	(0.090)	(0.091)	(0.108)	(0.128)	(0.141)	(0.135)	(0.049)	(0.046)	(0.105)	(0.100)	(0.117)	(0.111)
1 Year Prior to Initial Connection	0.033	0.160	0.051	0.225	0.169	0.192	0.004	0.044	-0.001	0.097	0.011	0.032
	(0.110)	(0.126)	(0.133)	(0.176)	(0.170)	(0.174)	(0.052)	(0.061)	(0.104)	(0.108)	(0.094)	(0.097)
Initial Connection	0.082	0.261	0.140	0.370	0.266	0.335	-0.045	0.009	-0.095	0.024	-0.060	-0.022
	(0.121)	(0.155)	(0.151)	(0.220)	(0.223)	(0.235)	(0.062)	(0.063)	(0.106)	(0.096)	(0.071)	(0.073)
1 Year After Initial Connection	0.266**	0.450***	0.322**	0.569**	0.443**	0.531**	-0.017	0.036	-0.082	0.044	-0.024	0.017
	(0.111)	(0.152)	(0.141)	(0.219)	(0.205)	(0.224)	(0.095)	(0.089)	(0.148)	(0.124)	(0.095)	(0.102)
2 Years After Initial Connection	0.225**	0.451**	0.280**	0.580**	0.421**	0.542**	0.078	0.140	-0.080	0.055	0.007	0.058
	(0.105)	(0.167)	(0.136)	(0.253)	(0.200)	(0.248)	(0.111)	(0.084)	(0.159)	(0.109)	(0.117)	(0.108)
3 Years After Initial Connection	0.137	0.390**	0.179	0.527**	0.296	0.479*	0.057	0.130	-0.173	-0.012	-0.101	-0.035
	(0.091)	(0.145)	(0.123)	(0.235)	(0.195)	(0.249)	(0.108)	(0.095)	(0.142)	(0.145)	(0.122)	(0.140)
Observations	2,177	922	1,912	720	1,269	474	1,761	864	1,497	662	990	434
R-squared	0.303	0.322	0.298	0.320	0.277	0.243	0.240	0.253	0.246	0.206	0.173	0.141
Group	267	113	236	90	233	88	213	106	183	83	181	81
Post 2008	NO	NO	NO	NO	YES	YES	NO	NO	NO	NO	YES	YES
None-Capital	NO	NO	YES	YES	YES	YES	NO	NO	YES	YES	YES	YES
Refined Sample	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES

Notes: Each regression controls for city fixed effects. *Post 2008* refers to the sample between 2009 and 2014. *None-Capital Cities* refers to the sample that are not provincial capital cities. *Refine sample* refers to the sample that are either constructed or planned to connect HSR by 2015. Other controls include per capita GDP, population, average rideship and internet coverage at prefecture level. For regressions using year 2006 to 2014, we also include financial crisis shock dummy variable. Robust standard errors are clustered at the province level and reported in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

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