

Valuing Domestic Transport Infrastructure: A View from the Route Choice of Exporters

Jingting Fan (Pennsylvania State University)

Yi Lu (Tsinghua University)

Wenlan Luo (Tsinghua University)

2021 ASSA

Inland trans. infrastructure investment

- Investment on inland trans. infrastructure: 850 billion/year in 47 major countries, half of which in China (2% GDP in 2000 ↗ 5% in 2010)
- **Blue:** Expressway network 1999. **Red:** Expressway network 2010



- What are the impacts of transportation infrastructure improvement on regional and aggregate economy
 - Early work: first-order based measurement (Fogel, 1964) or reduced-form (Banerjee et al., 2012)
 - GE in nature → necessitates a structural model
- Recent progress:
 - **Market access approach**: Donaldson and Hornbeck (2016), Alder (2016), Baum-Snow et al. (2018), ...
 - **Quantification via structural counterfactual**: Donaldson (2018a), Allen and Arkolakis (2014, 2016), Fajgelbaum and Schaal (2017), ...

Background

Key to both approaches: identify the trade cost elasticity

- travel distance $\xrightarrow{\text{trade cost elast.}}$ trade cost $\xrightarrow{\text{trade elast.}}$ trade flow $\xrightarrow{\text{GE}}$ emp./wage
- How existing work recovers trade cost elast.
 - (1) external measure of freight rates: Baum-Snow et al. (2018)
 - (2) estimate using price gaps of homogeneous goods: Asturias et al. (2018), Atkin and Donaldson (2015), Donaldson (2018b)
 - (3) estimate using shipment flows: Allen and Arkolakis (2014, 2016)
- Approach (1) rules out the non-monetary component of trade cost
- (2) and (3) both demanding in data \rightarrow restricted to a small groups of products (thus one-sector models); trade cost elas. identified from cross-sectional variations in shipment flows

What we do

- A novel source of information to measure domestic shipment
 - export data from the Chinese customs 1999-2010
 - location of exporter, port of exit, volume and quantity \implies routing, price gap
- Combined with expressway expansion to estimate cost on expressway and regular roads
 - idea: A exports more through port 1 than port 2 $\implies \tau_{A,1} < \tau_{A,2}$
 - use **over-time variations** and an IV (Faber, 2014) to address various concerns
 - allow **trade cost heterogeneity** by weight-to-value ratio; discipline extent of heterogeneity using prices
- Parameterize a regional GE model
 - routing module from Allen and Arkolakis (2016)
 - idiosyncratic trucker preference over routes \implies tractable for characterization of the welfare effects
 - Caliendo and Parro (2015) with sector heterogeneity in trade costs

Main findings

- Transport costs parameters:
 - ad valorem for each 100 kilometer on regular road (4.2%) and expressway (3.4%)
 - doubling weight-to-value ratio increases cost by 23%

Main findings

- Transport costs parameters:
 - ad valorem for each 100 kilometer on regular road (4.2%) and expressway (3.4%)
 - doubling weight-to-value ratio increases cost by 23%
- Evaluate the return to expressway expansion: 1999-2010
 - 50,000 kilometer expressways built; total cost \$570 billion (10% of 2010 GDP)
 - welfare gains 5.1%, or 150% net return to investment
 - return smaller if shut down *international trade* (15% less), *regional specialization* (20%), *sector heterogeneity in cost* (5%), and *intermediate linkages* (75%)
 - ⇒ 0.89% welfare gains in one-sector model, or 56% negative return

Main findings

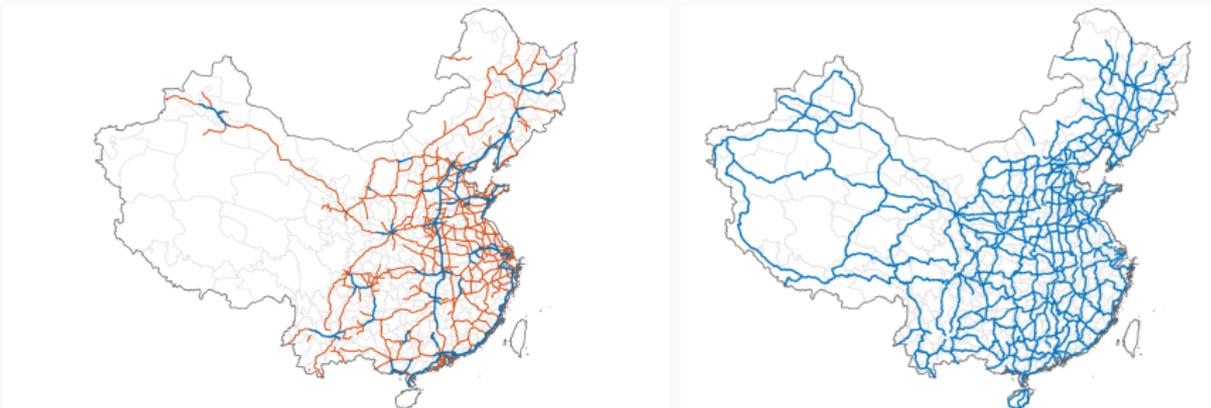
- Transport costs parameters:
 - ad valorem for each 100 kilometer on regular road (4.2%) and expressway (3.4%)
 - doubling weight-to-value ratio increases cost by 23%
- Evaluate the return to expressway expansion: 1999-2010
 - 50,000 kilometer expressways built; total cost \$570 billion (10% of 2010 GDP)
 - welfare gains 5.1%, or 150% net return to investment
 - return smaller if shut down *international trade* (15% less), *regional specialization* (20%), *sector heterogeneity in cost* (5%), and *intermediate linkages* (75%)
 - ⇒ 0.89% welfare gains in one-sector model, or 56% negative return
- The effects can be approximated accurately using a 2nd-order characterization
 - after the model is parameterized, no need for computing counterfactuals
 - apply to closed/open economy; accommodate mobile/immobile labor

- **Impacts of infrastructure projects on**
 - **regional development or growth** (Cosar et al., 2019, Fajgelbaum and Redding, 2014), **migration** (Morten and Oliveira, 2018), **within city activity** (Gu et al., 2018, Severen, 2018, Tsivanidis, 2018), **seller buyer match** (Xu, 2018), and **optimality for the aggregate economy** (Alder and Kondo, 2019, Allen and Arkolakis, 2016, Fajgelbaum and Schaal, 2019)
 - **difference: a new way of estimating trade cost elasticity**
- **Domestic trans. infra. promotes export**
 - using **country-level** (Limao and Venables, 2001) and **region-level** variations (Coşar and Demir, 2016 and Martincus et al., 2017)
 - **difference: focus are impact on trade cost and welfare, rather than export per se**
- **Chinese spatial economy.**
 - Fan (2019), Ma and Tang (2019), Tombe and Zhu (2019), Zi (2016),...
 - determine transport cost using **railway shipments** (account for only 10% of shipment; province level) or **regional input-output** table (imputed from railway)
 - **new: parameterize a domestic trade cost matrix**

- Data and Reduced-form Specification
- Model
 - Road network \rightarrow trade cost
 - Multi-sector EK
- Quantification and Counterfactuals
 - Welfare gains of the expressway expansion 1999-2010
 - Welfare gains of mega expressway projects
 - Nonlinearity and second-order characterization of welfare gains

Data and Reduced-form Specifications

Data: transportation network (Baum-Snow et al., 2018)



- Left: expressways for 1999 and 2010
- Right: regular roads ('national' and 'provincial' roads) in 2007
- Find distance along the shortest path between o and d ,
 $\{\text{dist}_{od}^t : t = 1999, 2010\}$
 - necessary to take a stand on relative costs of expressway and regular road
 - for now: 1 km on expressway equals to 0.5 km on regular road
 - later: pinned down in full quantification

Reduced-form specification: routing

$$\ln(v_{(o,RoW),d}^t) = \beta_{od} + \beta_o^t + \beta_d^t + \gamma \cdot \text{dist}_{od}^t + \epsilon_{od}^t$$

- $v_{(o,RoW),d}^t$: value exported from city o via port d in year t
- dist_{od}^t : *shortest* effective distance from o to d : $0.5 \times \text{dist}_{o \rightarrow d,H}^t + \text{dist}_{o \rightarrow d,L}^t$
- γ : composite of $\kappa_L \times \theta^F$
 - κ_L : effective cost for regular roads; θ^F : elasticity of substitution between ports

Reduced-form specification: routing

$$\ln(v_{(o,RoW),d}^t) = \beta_{od} + \beta_o^t + \beta_d^t + \gamma \cdot \text{dist}_{od}^t + \epsilon_{od}^t$$

- $v_{(o,RoW),d}^t$: value exported from city o via port d in year t
- dist_{od}^t : *shortest* effective distance from o to d : $0.5 \times \text{dist}_{o \rightarrow d,H}^t + \text{dist}_{o \rightarrow d,L}^t$
- γ : composite of $\kappa_L \times \theta^F$
 - κ_L : effective cost for regular roads; θ^F : elasticity of substitution between ports
- Remarks
 - limit case of the structural equation w/o. trader preference heterogeneity
 - omitting β_{od} leads to biased $\hat{\gamma}$
 - address endogeneity of road networks: (1) exclude major cities; (2) minimum-spanning tree IV; (3) sectoral-level specification

Expressway and Routing of Export Shipments

	(1)	(2)	(3)	(4)	(6)	(7)	(9)
	Effective Route Length and Export					By Type of Road	
	OLS				2SLS	OLS	2SLS
$dist_{od}^t$	-0.341*** (0.011)	-0.384*** (0.011)	-0.157*** (0.037)	-0.174*** (0.045)	-0.170*** (0.058)		
-on express						-0.088** (0.038)	-0.162** (0.068)
-on regular						-0.174*** (0.045)	-0.198*** (0.063)
Fixed Effects	<i>o, d, t</i>	<i>ot, dt</i>	<i>od, ot, dt</i>	<i>od, ot, dt</i>	<i>od, ot, dt</i>	<i>od, ot, dt</i>	<i>od, ot, dt</i>
Exclude Major Cities				yes	yes	yes	yes
Observations	3668	3660	2838	2068	2038	2068	2038
R ²	0.646	0.709	0.906	0.897	0.020	0.897	0.015
First Stage K-P F					1400.799		170.204

Notes: Standard errors are clustered at city-port level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Decompose variations in dist

Visualize variations

Export growth v.s rerouting

Sectoral data

Measuring in weights

Summary and Motivation for a routing model

- Reduced-form elasticity of routing w.r.t. effective distance around 15%
 - Elasticity lower w.r.t. expressway distance
 - Using cross-sectional variations more than doubles the estimate
 - Needs to take a stand on the relative cost of express/national, for shortest path
 - Confounding with port choice elasticity and router preference heterogeneity

Summary and Motivation for a routing model

- Reduced-form elasticity of routing w.r.t. effective distance around 15%
 - Elasticity lower w.r.t. expressway distance
 - Using cross-sectional variations more than doubles the estimate
 - Needs to take a stand on the relative cost of express/national, for shortest path
 - Confounding with port choice elasticity and router preference heterogeneity
- Extend the routing problem and embed into a GE model
 - allow traders to have heterogeneous preference for routes \implies both regular roads and expressways used; identify $\theta_F, \kappa_L, \kappa_H$
 - incorporates alternative modes
 - use the GE structure to infer the level of cost; counterfactuals

Routing Model

A Routing Model with Multiple Transport. Modes

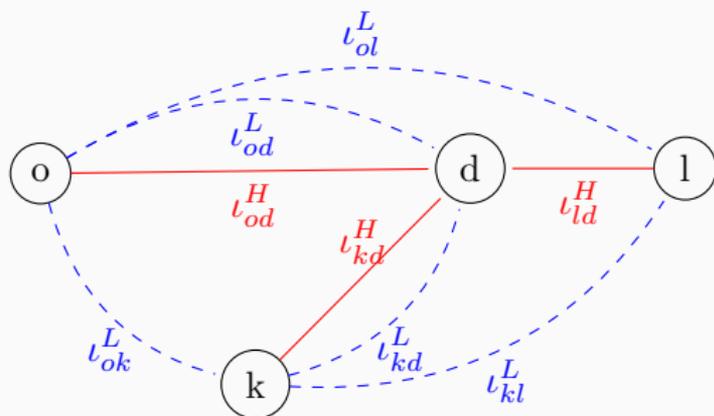


Figure: Routing on a Network: Four-Region Example

- iceberg cost $l_{kl}^x = \exp(\kappa^x \text{dist}_{kl}^x)$
- Two direct (one-step) paths; trucker draws pref. shocks from Frechet for each
- if made choices among the two, the expected cost is:

$$\tau_{od,1} \propto ([l_{od}^L]^{-\theta} + [l_{od}^H]^{-\theta})^{-\frac{1}{\theta}}$$

A Routing Model with Multiple Transport. Modes

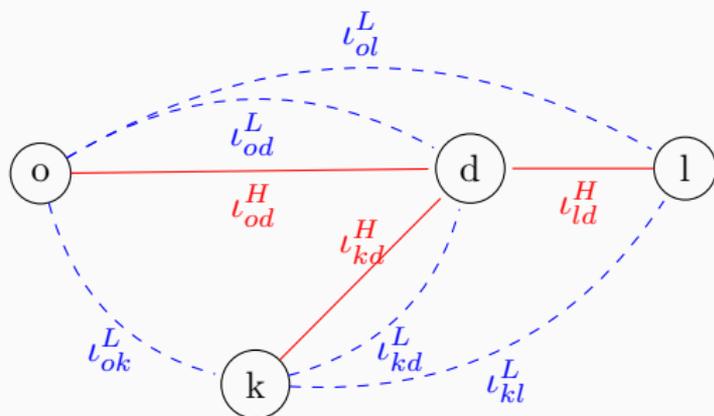
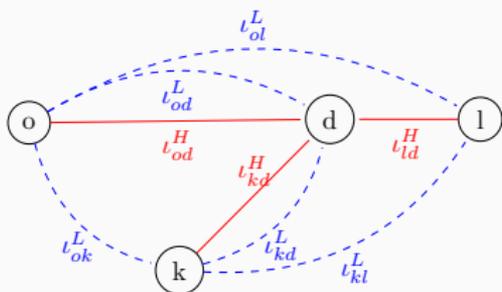


Figure: Routing on a Network: Four-Region Example

- Three *two-step paths*: $o \xrightarrow{L} k \xrightarrow{H} d$, $o \xrightarrow{L} k \xrightarrow{L} d$, and $o \xrightarrow{L} l \xrightarrow{H} d$
- if made choices among routes ≤ 2 steps, the expected cost is:

$$\tau_{od,2} \propto \left(\tau_{od,1}^{-\theta} + (t_{ok}^L t_{kd}^H)^{-\theta} + (t_{ok}^L t_{kl}^L)^{-\theta} + (t_{ol}^L t_{ld}^H)^{-\theta} \right)^{-\frac{1}{\theta}}$$

Routing Model: Matrix Representation

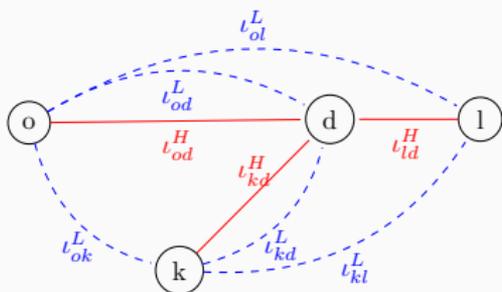


Define two adjacent matrices for regular and express

$$\mathbb{L} = \begin{matrix} & \begin{matrix} o & l & d & k \end{matrix} \\ \begin{matrix} o \\ l \\ d \\ k \end{matrix} & \begin{pmatrix} 0 & l_{ol}^{L-\theta} & l_{od}^{L-\theta} & l_{ok}^{L-\theta} \\ l_{lo}^{L-\theta} & 0 & l_{ld}^{L-\theta} & 0 \\ l_{do}^{L-\theta} & l_{dl}^{L-\theta} & 0 & l_{dk}^{L-\theta} \\ l_{ko}^{L-\theta} & 0 & l_{kd}^{L-\theta} & 0 \end{pmatrix} \end{matrix} \quad \mathbb{H} = \begin{matrix} & \begin{matrix} o & l & d & k \end{matrix} \\ \begin{matrix} o \\ l \\ d \\ k \end{matrix} & \begin{pmatrix} 0 & 0 & l_{od}^{H-\theta} & 0 \\ 0 & 0 & 0 & 0 \\ l_{do}^{H-\theta} & 0 & 0 & l_{dk}^{H-\theta} \\ 0 & 0 & l_{kd}^{H-\theta} & 0 \end{pmatrix} \end{matrix}$$

Then $\tau_{od,1} \propto [\mathbb{A}_{od}]^{-\frac{1}{\theta}}$ and $\tau_{od,2} \propto [\mathbb{A}_{od} + \mathbb{A}_{od}^2]^{-\frac{1}{\theta}}$, for $\mathbb{A} \equiv \mathbb{L} + \mathbb{H}$

Routing Model: Matrix Representation



Define two adjacent matrices for regular and express

$$\mathbb{L} = \begin{matrix} & o & l & d & k \\ \begin{matrix} o \\ l \\ d \\ k \end{matrix} & \begin{pmatrix} 0 & l_{ol}^{L-\theta} & l_{od}^{L-\theta} & l_{ok}^{L-\theta} \\ l_{lo}^{L-\theta} & 0 & l_{ld}^{L-\theta} & 0 \\ l_{do}^{L-\theta} & l_{dl}^{L-\theta} & 0 & l_{dk}^{L-\theta} \\ l_{ko}^{L-\theta} & 0 & l_{kd}^{L-\theta} & 0 \end{pmatrix} \end{matrix} \quad \mathbb{H} = \begin{matrix} & o & l & d & k \\ \begin{matrix} o \\ l \\ d \\ k \end{matrix} & \begin{pmatrix} 0 & 0 & l_{od}^{H-\theta} & 0 \\ 0 & 0 & 0 & 0 \\ l_{do}^{H-\theta} & 0 & 0 & l_{dk}^{H-\theta} \\ 0 & 0 & l_{kd}^{H-\theta} & 0 \end{pmatrix} \end{matrix}$$

Then $\tau_{od,1} \propto [\mathbb{A}_{od}]^{-\frac{1}{\theta}}$ and $\tau_{od,2} \propto [\mathbb{A}_{od} + \mathbb{A}_{od}^2]^{-\frac{1}{\theta}}$, for $\mathbb{A} \equiv \mathbb{L} + \mathbb{H}$

Allowing *all* routes, average trade cost: $\tau_{od} \equiv \tau_{od,\infty} \propto \mathbb{B}_{od}^{-\frac{1}{\theta}}$, for $\mathbb{B} \equiv (\mathbb{I} - \mathbb{A})^{-1}$

Routing Model: Summary and Discussions

- Bilateral trade cost along road networks summarized by $\tau_{od} \propto \mathbb{B}_{od}$ and $\mathbb{B} = \tilde{\mathbb{B}}(\kappa^L\theta, \kappa^H\theta)$.
- Routing reduces to shortest-path routing when $\theta \rightarrow \infty$
- Extended with sectoral-heterogeneity, alternative transport modes, and port choices, we have the following

$$\pi_{(o, RoW), d} = \frac{(\tau_{od} \cdot \tau_{d, RoW})^{-\theta_F}}{\sum_{\text{All ports } k} (\tau_{ok} \cdot \tau_{k, RoW})^{-\theta_F}},$$

$\pi_{(o, RoW), d}$: share of export from o via port d

θ_F : elasticity of substitution across ports

$\tau_{d, RoW}$ and denominator: port and city fixed effects after log linearization

- Use over-time variations in export routing to estimate $\kappa^L\theta, \kappa^H\theta, \theta_F$

Estimating the Routing Model

- Estimate the following with non-linear least square

$$\min_{\frac{\theta_F}{\theta}, \kappa^H \theta, \kappa^L \theta, \mathbf{f}} \sum_{o,d} \left[\frac{\theta_F}{\theta} \log \left([\tilde{\mathbb{B}}^t(\kappa^H \theta, \kappa^L \theta)_{(od)}] \right) + \mathbf{f} - \log(v_{(o, RoW), d}^t) \right]^2$$

	Point estimates	S.d.	Median	p10	p90
Panel A: export routing data					
$\kappa^L \theta$	4.68	1.90	4.67	4.26	6.18
$\kappa^H \theta$	3.78	1.08	3.77	3.36	4.83
θ_F / θ	0.06	0.03	0.05	0.03	0.09

Notes: Standard errors and percentiles are based on 200 bootstrapped samples.

- Takeaways:
 - $\kappa^H / \kappa^L \approx 0.8$: the ad valorem cost of expressway is 20% lower than regular road
 - $\theta_F < \theta$: routing is much more substitutable than port choice

Identification

The rest of the model

- 323 regions (prefectures)+RoW, 25 sectors (2-digit). Regions differ by sector productivity, amenity and fixed land supply
- Mobile workers with Cobb-Douglas preference over housing and sectoral final goods
- Rent from land redistributed via lump-sum transfer
- Intermediate good production: combine labor and sector final goods
- Final good production: aggregate intermediate inputs within the sector across source regions a la Armington

Quantification and Counterfactuals

Parameterize the rest of the model

Parameters	Descriptions	Value	Targets/Source
Parameters calibrated externally			
$\beta^i, \gamma^{ij}, \alpha^j$	IO structure and consumption share	-	2007 IO table for China
L_d	Total employment	-	2010 Population Census
σ	Trade elasticity	6	
θ_M	Elasticity of substitution across modes	2.5	
Parameters calibrated in equilibrium			
θ	Routing elasticity	111.52	} joint estimate of $\kappa^H\theta = 3.78, \kappa^L\theta = 4.68, \frac{\theta_F}{\theta} = 0.06, \frac{\partial \log p}{\partial \text{dist}} = 0.06$
θ_F	Port choice elasticity	6.35	
κ_H	Expressway route cost	0.034	
κ_L	Regular route cost	0.042	
h_0	Trade cost level	1.260	Average ground shipment distance: 177 km
$\bar{\kappa}$	Alternative mode cost	0.163	Share of non-road shipment: 0.24
μ	Cost-weight to value elasticity	0.3	estimated
$\tau_{RoW}^i, \tau_{RoW}^{i'}$	Export and import costs	-	Sectoral export and import
T_d^i	Region-sector productivity	-	City-sector sales in 2008 Economic Census

Price-distance Regression

Price-weight-to-value elasticity

Model validation

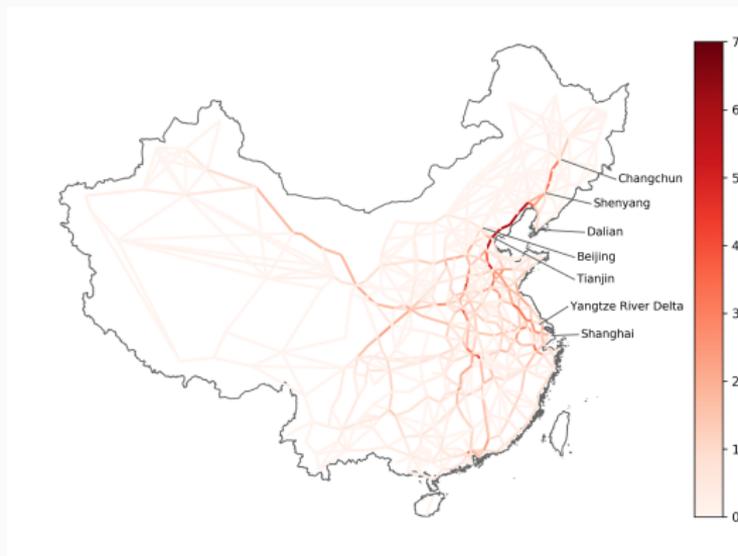


Figure: Model Predicted Shipment Flows

Export and export growth by cities

Transshipment via cities

The Effects of the Expressway Expansion, 1999-2010

Change in	Value	S.d.
Aggregate welfare	0.051	0.025
Log(Domestic trade)	0.136	0.052
Log(Exports)	0.097	0.080
Std Log(real wage) across regions	-0.017	0.010

Note: Changes in model statistics are calculated by comparing the calibrated equilibrium and a counterfactual equilibrium with the 1999 expressway network.

- Numbers in perspective: between 1999 and 2010, aggregate TFP increased by **36%** (Penn World Table)
- Expressway expansion explains about **14%** of the TFP increase

The Effects of the Expressway Expansion, 1999-2010

Change in	Value	S.d.
Aggregate welfare	0.051	0.025
Log(Domestic trade)	0.136	0.052
Log(Exports)	0.097	0.080
Std Log(real wage) across regions	-0.017	0.010

Note: Changes in model statistics are calculated by comparing the calibrated equilibrium and a counterfactual equilibrium with the 1999 expressway network.

- Numbers in perspective: between 1999 and 2010, aggregate TFP increased by **36%** (Penn World Table)
- Expressway expansion explains about **14%** of the TFP increase
- Total cost: 10% of 2010 GDP. Assuming 10% depreciation rate (Bai and Qian, 2010), 10% return to capital (Bai et al., 2006) \implies 155% net return to investment

The role of sectors

	Baseline	Model (2)	Model (3)	Model (4)	Model (5)
International trade	✓				
Trade cost heterogeneity	✓	✓			
Regional specialization	✓	✓	✓		
Intermediate Input	✓	✓	✓	✓	
Welfare gains	5.10%	4.47%	4.29%	3.36%	0.89%

Each model recalibrated to match the same sales by city ($\{T_d^i\}$) and average shipment distance (h_0).

- baseline \rightarrow (2): overlooks that expressways reduces import and export cost

The role of sectors

	Baseline	Model (2)	Model (3)	Model (4)	Model (5)
International trade	✓				
Trade cost heterogeneity	✓	✓			
Regional specialization	✓	✓	✓		
Intermediate Input	✓	✓	✓	✓	
Welfare gains	5.10%	4.47%	4.29%	3.36%	0.89%

Each model recalibrated to match the same sales by city ($\{T_d^i\}$) and average shipment distance (h_0).

- baseline \rightarrow (2): overlooks that expressways reduces import and export cost
- (2) \rightarrow (3): matched to the same average shipment distance, model (2) infers higher shipment values, which to the first order determine the gains

The role of sectors

	Baseline	Model (2)	Model (3)	Model (4)	Model (5)
International trade	✓				
Trade cost heterogeneity	✓	✓			
Regional specialization	✓	✓	✓		
Intermediate Input	✓	✓	✓	✓	
Welfare gains	5.10%	4.47%	4.29%	3.36%	0.89%

Each model recalibrated to match the same sales by city ($\{T_d^i\}$) and average shipment distance (h_0).

- baseline \rightarrow (2): overlooks that expressways reduces import and export cost
- (2) \rightarrow (3): matched to the same average shipment distance, model (2) infers higher shipment values, which to the first order determine the gains
- (3) \rightarrow (4): In the data and model (3) trade happens between large regions specializing in different sectors; model (4) predicts more trade between close partners. [Map](#)

The role of sectors

	Baseline	Model (2)	Model (3)	Model (4)	Model (5)
International trade	✓				
Trade cost heterogeneity	✓	✓			
Regional specialization	✓	✓	✓		
Intermediate Input	✓	✓	✓	✓	
Welfare gains	5.10%	4.47%	4.29%	3.36%	0.89%

Each model recalibrated to match the same sales by city ($\{T_d^i\}$) and average shipment distance (h_0).

- baseline \rightarrow (2): overlooks that expressways reduces import and export cost
- (2) \rightarrow (3): matched to the same average shipment distance, model (2) infers higher shipment values, which to the first order determine the gains
- (3) \rightarrow (4): In the data and model (3) trade happens between large regions specializing in different sectors; model (4) predicts more trade between close partners. [Map](#)
- (4) \rightarrow (5): inferred wrong sales/VA ratio

Evaluating mega projects



ID	Length (km)	Cost as % GDP	Cost per km (million)	Welfare Gains (%)	Net return to investment	% Change in dom. trade	% Change in Export
G1	1533.61	0.30	77.71	0.40	567.19%	1.16	0.56
G3	2513.38	0.54	85.53	0.49	354.10%	1.05	1.86
G10	891.73	0.15	67.25	0.02	-22.92%	0.09	0.02
G30	4356.49	0.85	78.04	0.39	129.32%	1.34	-0.10
...							
Total	30012.46	6.16		3.47		8.76	6.48

Note: Each row corresponds to a counterfactual experiment by removing from the 2010 expressway network a mega expressway project referred by 'ID'.

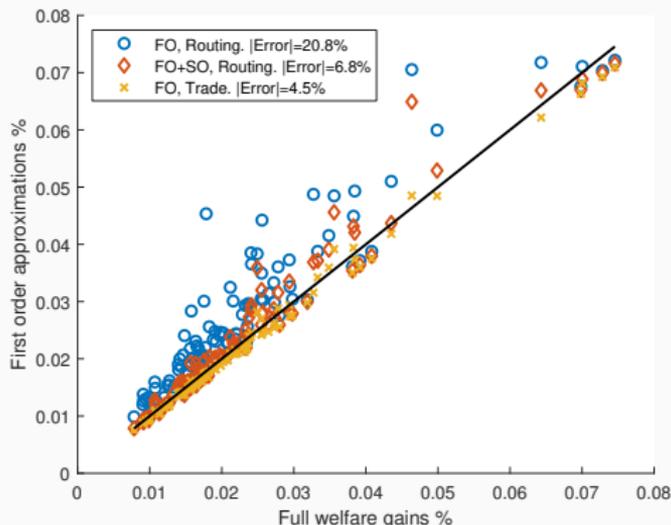
Welfare characterization

- Goal: calculate welfare gains from expressway expansion w/o solving equilibrium
- Solution: a formula that associates welfare gains from model statistics up to second order

$$\Delta W = - \underbrace{\sum_{o,d,i} \left(\frac{X_{od}^i}{Y} - \frac{\Lambda_o^i}{Y} 1_{d=RoW} \right) \sum_{kl \in C} \pi_{od}^{road} \pi_{od}^{kl} \Delta \log(\iota_{kl})}_{FO_R} + SO_R + Residual$$

- $\Delta \log(\iota_{kl})$: change in route cost; known after estimating (κ^L, κ^H)
- Y : Domestic GDP
- X_{od}^i : Domestic trade flows from o to d in sector i
- Λ_o^i : foreign consumption exposure to export cost
- $\pi_{od}^{Road}, \pi_{od}^{kl}$: routing patterns
- SO_R : second-order term that depends on routing patterns and routing elas. θ

Welfare gains: The miss of FO and corrections of SO



Note: Each point corresponds to an experiment with one expressway segment removed. The sample segments are the top 100 busiest city pairs in the baseline equilibrium.

- The FO approach (cost-saving approach) misses welfare gains by 21% on average and most likely overestimates the gains
 - Road upgrading should be considered a “large” shock
 - FO ignores the rerouting behavior after downgrading an expressway
- Incorporating SO reduces the error by 2/3

Apply the welfare formula to large projects

- Consider removing all expressway segments where there are existing regular roads

$$\underbrace{\Delta W}_{0.022} = \underbrace{\text{FO effect}}_{146\%} + \underbrace{\text{Own } SO_R}_{-58\%} + \underbrace{\text{Cross } SO_R}_{8\%} + \underbrace{\text{Residual}}_{4\%}$$

- Cross SO_R captures the cross-substitutes of road segments, and has an intuitive interpretation [Hessian Example](#)
- We publish the FO and the SO (Hessian) coefficients so policy makers can assess the welfare gains of expressway expansions without solving counterfactual

Conclusion

Conclusion

- Exploit over-time variations in city-to-port export to estimate the impact of transportation infrastructure on trade cost
 - construction of expressway reduces cost-distance elasticity by 20%
- Accommodating regional specialization / sectoral heterogeneity / intermediate input is important
 - neglecting these underestimate the gains and turns positive NPV into negative
- Our approach requires data on sectoral production and is computational intensive. For future work useful to think about ways to
 - circumvent parameterizing the full model and computing counterfactuals
 - 2nd-order characterization quite accurate, but requires full information on shipment and routing
 - reduce the data requirement while retaining accuracy

References

- Alder, Simon**, “Chinese Roads in India: The Effect of Transport Infrastructure on Economic Development,” *Working Paper*, 2016.
- **and Illenin Kondo**, “Political Distortions and Infrastructure Networks in China: A Quantitative Spatial Equilibrium Analysis,” *Working Paper*, 2019.
- Allen, Treb and Costas Arkolakis**, “Trade and the Topography of the Spatial Economy,” *The Quarterly Journal of Economics*, 2014, 129 (3), 1085–1140.
- **and** — , “The Welfare Effects of Transportation Infrastructure Improvements,” 2016.
- Asturias, Jose, Manuel García-Santana, and Roberto Ramos**, “Competition and the welfare gains from transportation infrastructure: Evidence from the Golden Quadrilateral of India,” *Journal of the European Economic Association*, 2018.
- Atkin, David and Dave Donaldson**, “Who’s getting globalized? The size and implications of intra-national trade costs,” *NBER Working Paper No. 21439*, 2015.
- Bai, Chong-En and Yingyi Qian**, “Infrastructure development in China: the cases of electricity, highways, and railways,” *Journal of Comparative Economics*, 2010, 38 (1), 34–51.

- , **Chang-Tai Hsieh, and Yingyi Qian**, “The Return to Capital in China,” *Brookings Papers on Economic Activity*, 2006, 2006 (2), 61–88.
- Banerjee, Abhijit, Esther Duflo, and Nancy Qian**, “On the Road: Access to Transportation Infrastructure and Economic Growth in China,” Technical Report 2012.
- Baum-Snow, Nathaniel, J. Vernon Henderson, Matthew A. Turner, Qinghua Zhang, and Loren Brandt**, “Does Investment in National Highways Help or Hurt Hinterland City Growth?,” Working Paper 24596, National Bureau of Economic Research May 2018.
- Caliendo, Lorenzo and Fernando Parro**, “Estimates of the Trade and Welfare Effects of NAFTA,” *The Review of Economic Studies*, 2015, 82 (1), 1–44.
- Coşar, A Kerem and Banu Demir**, “Domestic road infrastructure and international trade: Evidence from Turkey,” *Journal of Development Economics*, 2016, 118, 232–244.
- Cosar, A Kerem, Banu Demir, Devaki Ghose, and Nathaniel Young**, “Road Capacity, Domestic Trade and Regional Outcomes,” *Mimeo*, 2019.
- Donaldson, Dave**, “Railroads of the Raj: Estimating the impact of transportation infrastructure,” *American Economic Review*, 2018, 108 (4-5), 899–934.

- , “Railroads of the Raj: Estimating the impact of transportation infrastructure,” *American Economic Review*, 2018, 108 (4-5), 899–934.
- **and Richard Hornbeck**, “Railroads and American economic growth: A market access approach,” *The Quarterly Journal of Economics*, 2016, 131 (2), 799–858.
- Faber, Benjamin**, “Trade integration, market size, and industrialization: evidence from China’s National Trunk Highway System,” *Review of Economic Studies*, 2014, 81 (3), 1046–1070.
- Fajgelbaum, Pablo and Stephen J. Redding**, “External Integration, Structural Transformation and Economic Development: Evidence from Argentina 1870-1914,” *NBER Working Paper No. w20217*, 2014.
- Fajgelbaum, Pablo D. and Edouard Schaal**, “Optimal transport networks in spatial equilibrium,” Technical Report, National Bureau of Economic Research 2017.
- Fajgelbaum, Pablo D and Edouard Schaal**, “Optimal transport networks in spatial equilibrium,” *NBER Working Paper No. 23200*, 2019.
- Fan, Jingting**, “Internal geography, labor mobility, and the distributional impacts of trade,” *American Economic Journal: Macroeconomics*, 2019, 11 (3), 252–88.

- Fogel, Robert William**, *Railroads and American economic growth*, Johns Hopkins Press Baltimore, 1964.
- Gu, Yizhen, Junfu Jiang Chang Zhang, and Ben Zou**, “Subways and Road Congestion,” *Working Paper*, 2018.
- Limao, Nuno and Anthony J Venables**, “Infrastructure, geographical disadvantage, transport costs, and trade,” *The World Bank Economic Review*, 2001, 15 (3), 451–479.
- Ma, Lin and Yang Tang**, “Geography, trade, and internal migration in china,” *Journal of Urban Economics*, 2019.
- Martincus, Christian Volpe, Jerónimo Carballo, and Ana Cusolito**, “Roads, exports and employment: Evidence from a developing country,” *Journal of Development Economics*, 2017, 125, 21–39.
- Morten, Melanie and Jaqueline Oliveira**, “The effects of roads on trade and migration: Evidence from a planned capital city,” *NBER Working Paper*. Cambridge, MA, USA: National Bureau of Economic Research, 2018.
- Severen, Christopher**, “Commuting, Labor, and Housing Market Effects of Mass Transportation: Welfare and Identification,” *FRB of Philadelphia Working Paper 18-14*, 2018.

Tombe, Trevor and Xiaodong Zhu, “Trade, migration, and productivity: A quantitative analysis of china,” *American Economic Review*, 2019, 109 (5), 1843–72.

Tsivanidis, Nick, “The Aggregate and Distributional Effects of Urban Transit Infrastructure: Evidence from Bogot’s TransMilenio,” *Working Paper*, 2018.

Xu, Mingzhi, “Riding on the New Silk Road: Quantifying the Welfare Gains from High-Speed Railways,” *Working Paper*, 2018.

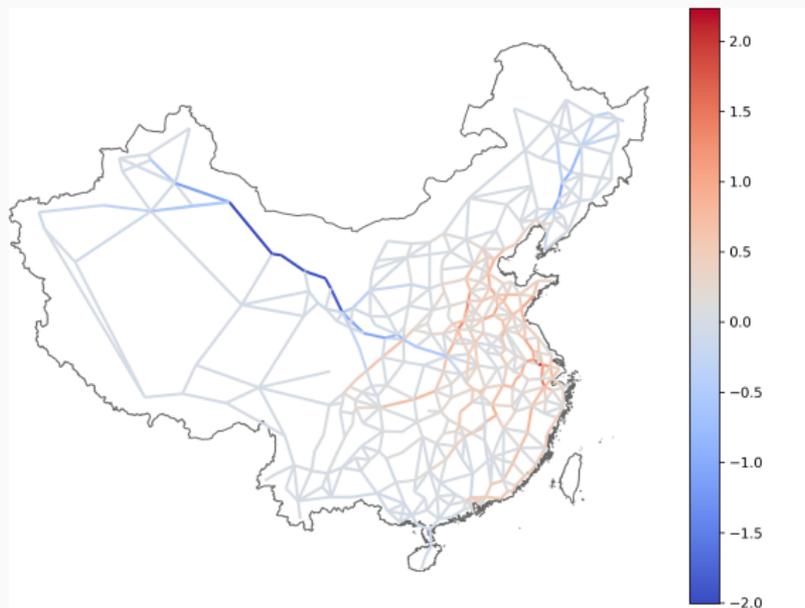
Zi, Yuan, “Trade liberalization and the great labor reallocation,” *Working Paper*, 2016.

The minimum-spanning tree IV (Faber, 2014)



- Red: min-distance network connecting 55 major cities; Blue: 2010 expressway
- IV for $dist_{ij}^{2010}$: Effective length of shortest-path along the (Blue) network
- IV for $dist_{ij}^{1999}$: $dist_{ij}^{1999}$
- Identification: National Trunk Highway System exogenous to small cities

Change in shipment flows without regional specialization



Note: The numbers are the differences in shipment value/GDP between Model (3) (with specialization) and Model (4) (no specialization). Cold colors indicate that there is less shipment in Model (4) than in Model (3).

Price-distance regression

Table: Price Distance Regression

	(1)	(2)	(3)	(4)
	OLS		IV	
$dist_{od}$	0.055*** (0.013)	0.061*** (0.022)	0.053*** (0.012)	0.058*** (0.021)
Fixed Effects	<i>dci, oci</i>	<i>dci, oci</i>	<i>dci, oci</i>	<i>dci, oci</i>
Exclude major cities	yes	yes	yes	yes
Exclude differentiated goods		yes		yes
Observations	1829372	232609	1829372	232609
R ²	0.323	0.340	-	-
First Stage KP-F statistic			1515.787	1156.297

Notes: o , d , c , i stand for origin city, port, destination country, and HS-8 product fixed effects, respectively. Standard errors are clustered at city-port level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Price regression: estimate trade cost-weight elasticity

Table: Transport cost and weight-to-value ratio

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	log price ratio				log price ratio		
Heaviness- HS2 Category	0.163*** (0.056)	0.161*** (0.056)	0.278*** (0.086)	0.199** (0.089)			
Heaviness- HS4 Category					0.303*** (0.044)	0.362*** (0.050)	0.253*** (0.043)
Fixed Effects	<i>o, d, c</i>	<i>odc</i>	<i>fdc</i>	<i>fdc</i>	<i>fdc, i</i>	<i>fdci</i>	<i>fdci</i>
Exclude major cities	yes	yes	yes	yes	yes	yes	yes
Exclude differentiated goods				yes			yes
Observations	1987140	1985946	1805563	190836	1805563	1126941	119077
R ²	0.063	0.074	0.375	0.481	0.417	0.596	0.639

Notes: *o, d, c, f, i* stand for origin city, port, destination country, firm, and HS2 category fixed effects, respectively.

Standard errors are clustered at HS2 category level (Columns 1-4) or HS4 category level (Columns 5-7). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

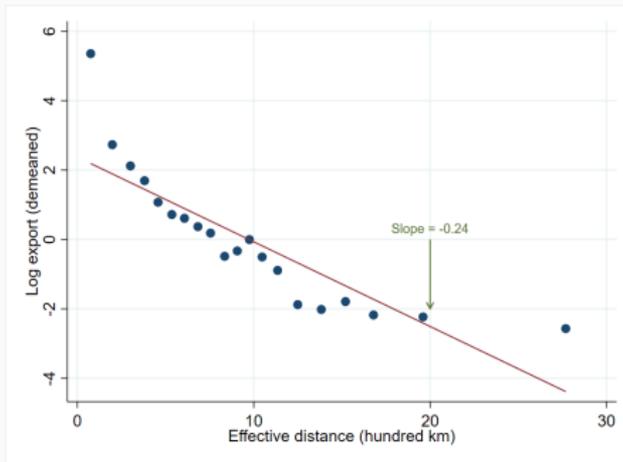
Descriptive Statistics of Changes in Route Length

Route-level variables	2000-2001		2010-2011	
	mean	std	mean	std
Export	164	2050	989	12100
<i>Total</i> length	20.40	11.60	17.24	10.45
Length of expressway segments	12.93	7.71	16.88	9.72
Expressway share in total length	0.65	0.24	0.99	0.05
<i>Effective</i> length	13.93	9.00	8.80	5.77

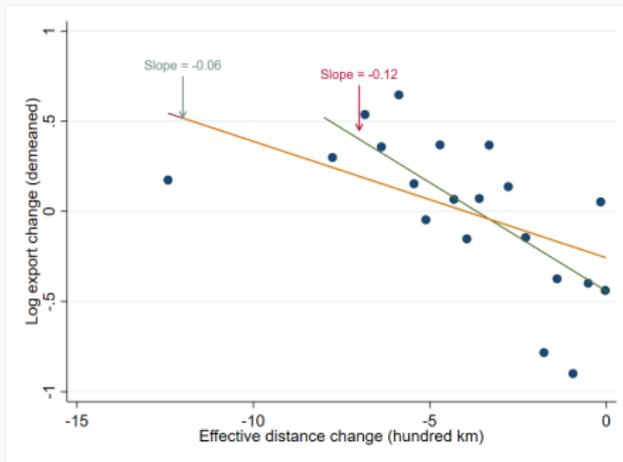
Notes: Export value in current year million dollars. Length of routes in 100km.

$$\underbrace{\Delta dist_{od}^t}_{-513 \text{ km}} = \Delta dist_{o \rightarrow d}^L + 0.5 \times \Delta dist_{o \rightarrow d}^H = \underbrace{(\Delta dist_{o \rightarrow d}^L + \Delta dist_{o \rightarrow d}^H)}_{-316 \text{ km (60\%)}} \underbrace{-0.5 \times \Delta dist_{o \rightarrow d}^H}_{-196 \text{ km (40\%)}}$$

Export v.s Route Length, Cross-section and Over-time variations



(a) Cross-section variations

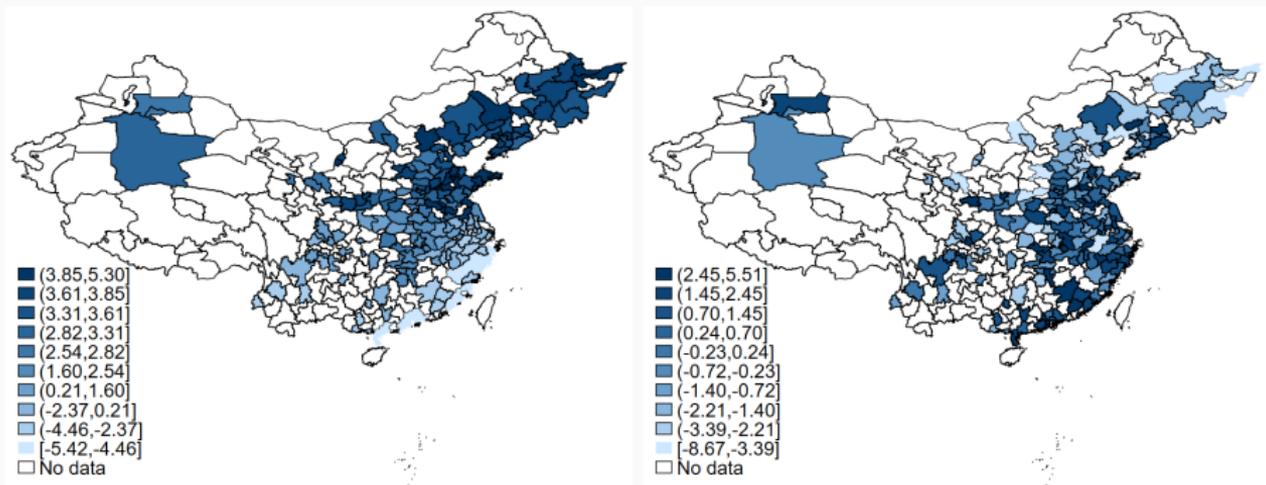


(b) Over-time variations

Figure: Bin-scattered Plots of $\text{Log}(\text{Export})$ and Route Length

Note: Panel (a) plots the $\text{log}(\text{export})$ of routes over the effective length of routes. Panel (b) plots the change in $\text{log}(\text{export})$ over the change in effective length from 1999 to 2010. [Back](#)

Export v.s Route Length, Visualize Regional Variations



(a) Relative Change in Port Access

(b) Relative Change in log(Export)

Figure: Relative Change in Port Access and Export: North Minus South

Note: Port access is measured by average effective distance to ports within a port group. The change is from 1999 to 2010. [Back](#)

- Compared to northern cities, southern cities export relatively more via northern ports after the distance to northern ports get shorter

Growth v.s Rerouting; Results from Sectoral Data

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Aggregate Data			Sectoral Data					
	Growth v.s. Rerouting			Baseline			Growth v.s. Rerouting		
$dist_{od}^t$	-0.185*** (0.049)	-0.166*** (0.041)	-0.157*** (0.041)	-0.373*** (0.017)	-0.138*** (0.044)		-0.157*** (0.041)	-0.137*** (0.039)	-0.137*** (0.039)
- on express						-0.075* (0.039)			
- on regular						-0.137*** (0.044)			
log(city export through other routes)		0.171** (0.073)						0.053** (0.026)	
Specification	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Fixed Effects	<i>og, ot, gt</i>	<i>od, p_ot, dt</i>	<i>od, p_ot, dt</i>	<i>oti, dti</i>	<i>odi, oti, dti</i>	<i>odi, oti, dti</i>	<i>ogi, oti, gti</i>	<i>odi, p_oti, dti</i>	<i>odi, p_oti, dti</i>
Exclude Major Cities yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	1036	2082	2082	20946	11758	11758	6816	12920	12920
R ²	0.933	0.870	0.869	0.593	0.896	0.896	0.927	0.850	0.850

Note: Column (1) replaces port fixed effects with port-group fixed effects. Column (2) replaces city fixed effects with province fixed effects [Back](#).

- Controlling for different levels of fixed effects does not change estimates much;
⇒ the variations in export mainly come from growth instead of rerouting
- Results are robust when using sectoral data

Robustness: Measuring in Weights

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Effective Route Length and Export						By Type of Road		
	OLS			IV Reduced Form		2SLS	OLS	IV Reduced Form	2SLS
distance_total_w05	-0.363*** (0.011)	-0.412*** (0.012)	-0.191*** (0.042)	-0.217*** (0.052)		-0.231*** (0.067)			
iv_distance_total_w05					-0.268*** (0.079)				
(first) distance_express_w05							-0.088** (0.044)		-0.163** (0.080)
(first) distance_road_w05							-0.215*** (0.052)		-0.248*** (0.074)
(first) iv_distance_express_w05								-0.161** (0.063)	
(first) iv_distance_road_w05								-0.285*** (0.086)	
Fixed Effects	<i>o, d, t</i>	<i>ot, dt</i>	<i>od, ot, dt</i>	<i>od, ot, dt</i>	<i>od, ot, dt</i>	<i>od, ot, dt</i>	<i>od, ot, dt</i>	<i>od, ot, dt</i>	<i>od, ot, dt</i>
Exclude Major Cities				yes	yes	yes	yes	yes	yes
Observations	3612	3603	2786	2024	1996	1996	2024	1996	1996
R ²	0.606	0.680	0.893	0.884	0.884	0.023	0.884	0.884	0.018
(Kleibergen-Paap F statistic):						1356.045			163.977

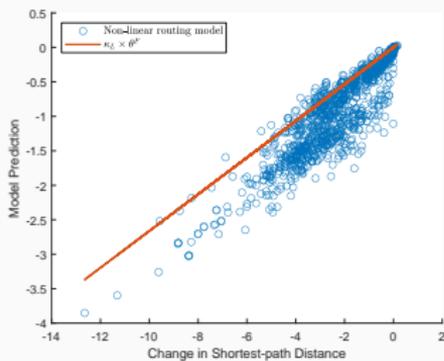
Notes: Export measured in kilograms.

[Back](#)

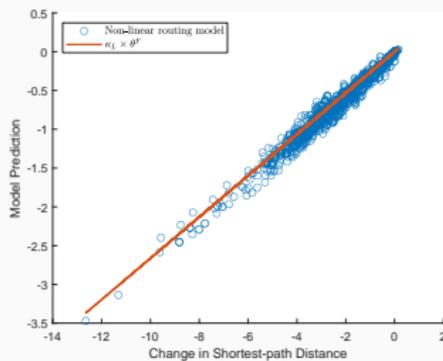
Standard errors are clustered at city-port level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

- Results are robust when measuring export in weights

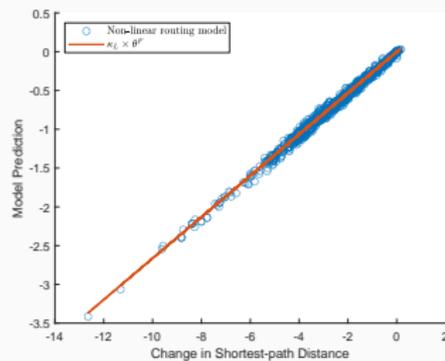
Identification of θ_F/θ



(a) $\theta = 0.75 \times \theta^*$



(b) $\theta = \theta^*$, the calibrated value



(c) $\theta = 1.5 \times \theta^*$

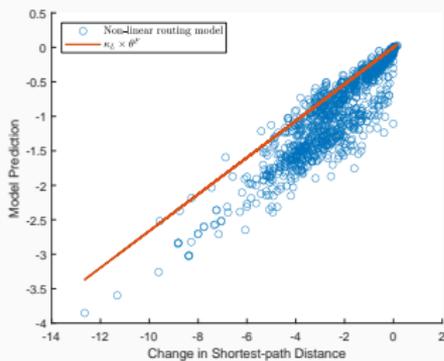
Figure: Model Prediction Varying θ

Horizontal: change in shortest-path distance in regular-road equivalent distance

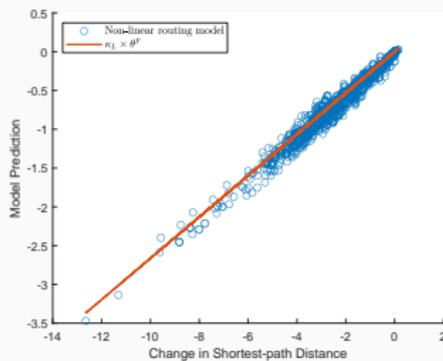
Vertical: Model prediction $\Delta \log \left([\tilde{\mathbb{B}}^t(\kappa^H\theta, \kappa^L\theta)_{(od)}] \right)$

Read line: $\kappa_L \times \theta^F$

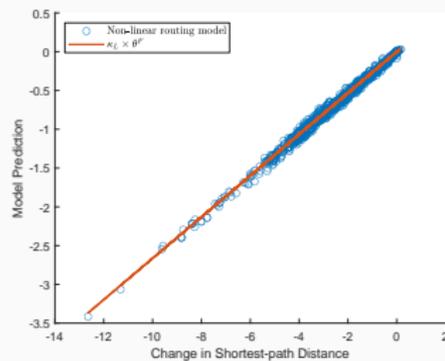
Identification of θ_F/θ



(a) $\theta = 0.75 \times \theta^*$



(b) $\theta = \theta^*$, the calibrated value



(c) $\theta = 1.5 \times \theta^*$

Figure: Model Prediction Varying θ

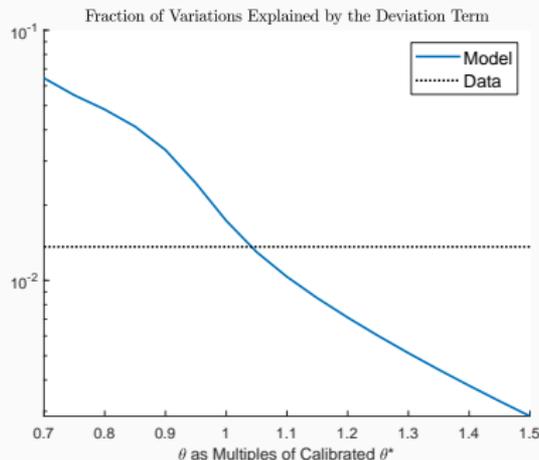
Horizontal: change in shortest-path distance in regular-road equivalent distance

Vertical: Model prediction $\Delta \log \left([\tilde{\mathbb{B}}^t(\kappa^H \theta, \kappa^L \theta)_{(od)}] \right)$

Read line: $\kappa_L \times \theta^F$

Key: Lowering θ preserves network structure *other than* shortest-path

Identification of θ_F/θ , cont'd



- Identification of θ (relatively to θ^F) is then given by the importance of network structure other than shortest-path in accounting for the data
- The figure reports the fraction of variations in data that is explained by the non-linear component when varying θ [Back](#)

$$\log(v_{(o, RoW), d}) = \underbrace{\kappa^L \theta^F \text{dist}_{od}}_{\text{linear}} + \beta \cdot \underbrace{\left(\frac{\theta^F}{\theta} \log([\mathbb{B}_{(o, d)}]) - \kappa^L \theta^F \text{dist}_{od} \right)}_{\text{non-linear}} + \mathbf{f}$$

Model validation: export level

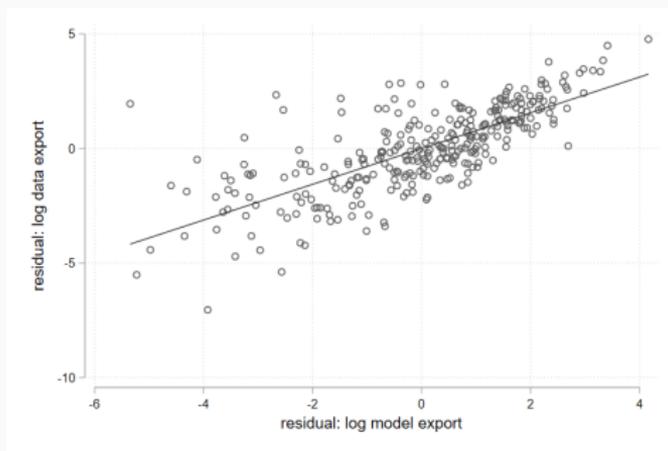


Figure: City-level export in 2010: Model versus Data

Note: The figure plots model-implied city export against the data, controlling for city employment

Model validation: export growth

Table: Predicting Export Growth

	(1)	(2)	(3)
Log(export), model	0.465*** (0.048)	0.953*** (0.189)	0.871*** (0.199)
Fixed Effects	<i>t</i>	<i>oi, it</i>	<i>oi, it</i>
Exclude major cities	no	no	yes
Observations	8472	8472	6576
R ²	0.333	0.878	0.860
F-statistic	92.706	25.332	19.223

Notes: The dependent variable is the log city-sector export in the data; the independent variable is the log city-sector export in the model. Letters *t*, *o*, *i*, in the 'Fixed Effects' stand for time, city, and sector (two-digit) fixed effects, respectively. Standard errors (clustered by city) in parenthesis.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

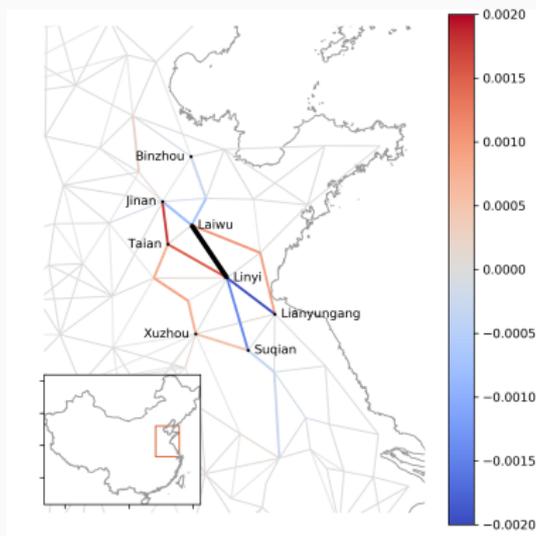
Model validation: transshipment

Table: Correlation with Shipment

	(1)	(2)	(3)
Log(shipment), model	0.314*** (0.040)	0.177*** (0.035)	0.176*** (0.041)
Log(employment)		0.594*** (0.059)	0.587*** (0.062)
Observations	240	240	234
Fixed Effects	no	no	prov
R ²	0.234	0.488	0.636

Notes: The dependent variable is the log city shipment in the data (2010); the independent variable is the log city shipment in the model. Robust standard errors in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Complementarities and substitutes of Road Segments: An Example



Note: The selected road segment is from Laiwu to Linyi, colored black. The map shows the cross derivative between each segment and the selected one (Laiwu to Linyi). Warm colors indicate that the cross derivative is positive, suggesting that an expressway between Laiwu and Linyi would draw traffic away from that segment. Cold colors indicate the opposite. Numbers are in percentage points of domestic Welfare. [Back](#)