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

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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 $\nearrow$ 5% in 2010)
- Blue: Expressway network 1999. Red: Expressway network 2010

Background

- 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 $\rightarrow$ 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 $\Longrightarrow$ 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 $\Longrightarrow$ $\tau_{A,1} < \tau_{A,2}$
  - 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 $\Longrightarrow$ 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%

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  - 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%) $\Longrightarrow$ 0.89% welfare gains in one-sector model, or 56% negative return

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    $\Longrightarrow$ 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

Literature

- 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 (Coșar 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

Outline

- 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, $\{\mathrm{dist}_{od}^{t} : t = 1999, 2010\}$
  - 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: pined down in full quantification

Reduced-form specification: routing

$$ln(v^t_{(o,RoW),d}) = \beta_{od} + \beta^t_o + \beta^t_d + \gamma \cdot \text{dist}^t_{od} + \epsilon^t_{od}$$

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

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- 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

Minimum-spanning Tree

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***	-0.384***	-0.157***	-0.174***	-0.170***		
	(0.011)	(0.011)	(0.037)	(0.045)	(0.058)		
-on express						-0.088**	-0.162**
						(0.038)	(0.068)
-on regular						-0.174***	-0.198***
						(0.045)	(0.063)
Fixed Effects	o, d, t	ot, dt	od, ot, dt	od, ot, dt	od, ot, dt	od, ot, dt	od, ot, dt
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
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  - 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 θ_F, κ_L, κ_H
  - incorporates alternative modes
  - use the GE structure to infer the level of cost; counterfactuals

Routing Model

A Routing Model with Multiple Tranport. Modes

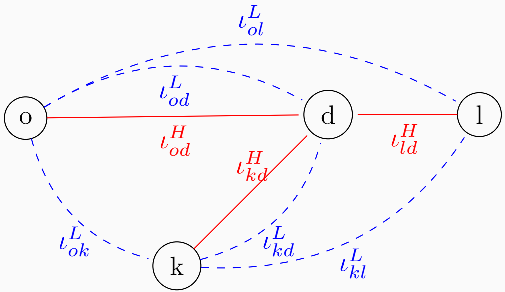

Figure: Routing on a Network: Four-Region Example

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

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

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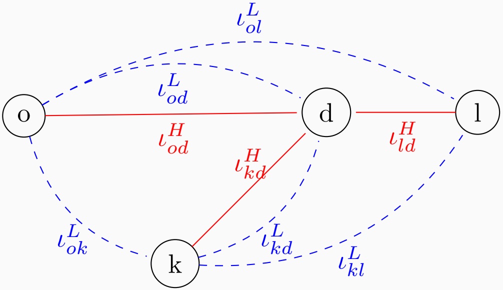
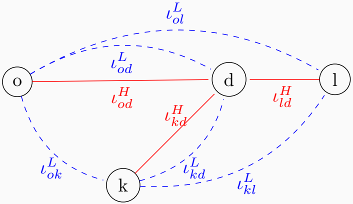


Figure: Routing on a Network: Four-Region Example

- 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:

$$\tau_{od,2} \propto \left(\tau_{od,1}^{-\theta} + (\iota^L_{ok}\iota^H_{kd})^{-\theta} + (\iota^L_{ok}\iota^L_{kd})^{-\theta} + (\iota^L_{ol}\iota^H_{ld})^{-\theta}\right)^{-\frac{1}{\theta}}$$

Routing Model: Matrix Representation



Define two adjacent matrices for regular and express

$$\mathbb{L} = \begin{array}{c c} & \begin{array}{cccc} o & l & d & k \end{array} \\ \begin{array}{c} o \\ l \\ d \\ k \end{array} & \begin{pmatrix} 0 & {\iota^L_{ol}}^{-\theta} & {\iota^L_{od}}^{-\theta} & {\iota^L_{ok}}^{-\theta} \\ {\iota^L_{lo}}^{-\theta} & 0 & {\iota^L_{ld}}^{-\theta} & 0 \\ {\iota^L_{do}}^{-\theta} & {\iota^L_{dl}}^{-\theta} & 0 & {\iota^L_{dk}}^{-\theta} \\ {\iota^L_{ko}}^{-\theta} & 0 & {\iota^L_{kd}}^{-\theta} & 0 \end{pmatrix} \end{array} \quad \mathbb{H} = \begin{array}{c c} & \begin{array}{cccc} o & l & d & k \end{array} \\ \begin{array}{c} o \\ l \\ d \\ k \end{array} & \begin{pmatrix} 0 & 0 & {\iota^H_{od}}^{-\theta} & 0 \\ 0 & 0 & 0 & 0 \\ {\iota^H_{do}}^{-\theta} & 0 & 0 & {\iota^H_{dk}}^{-\theta} \\ 0 & 0 & {\iota^H_{kd}}^{-\theta} & 0 \end{pmatrix} \end{array}$$

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

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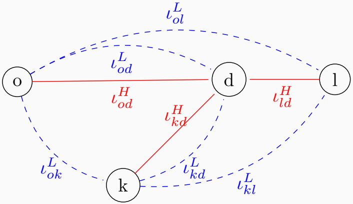

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Allowing *all* routes, average trade cost: $\tau_{od} \equiv \tau_{od,\infty} \propto \mathbb{B}_{od}^{-\frac{1}{\theta}}$, for $\mathbb{B} \equiv (\mathbb{I} - \mathbb{A})^{-1}$

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 $\theta \to \infty$
- Extended with sectoral-heterogeneity, alternative transport modes, and port choices, we have the following

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

  $\pi_{(o,RoW),d}$: 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

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

	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 $\kappa^H\theta = 3.78, \kappa^L\theta = 4.68, \frac{\theta_F}{\theta} = 0.06, \frac{\partial \log p}{\partial dist} = 0.06$
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
$\tau^i_{RoW}, \tau^{i'}_{RoW}$	Export and import costs	-	Sectoral export and import
T^i_d	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 Transhipment 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)
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- 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) $\Longrightarrow$ 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).

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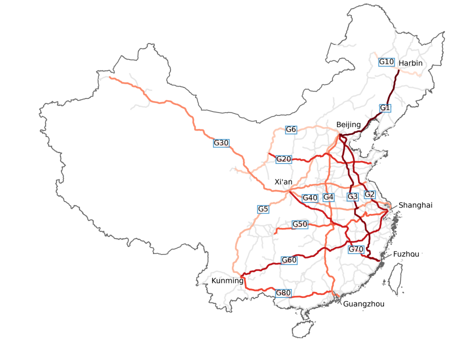
- (4) $\rightarrow$ (5): inferred wrong sales/VA ratio

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'.

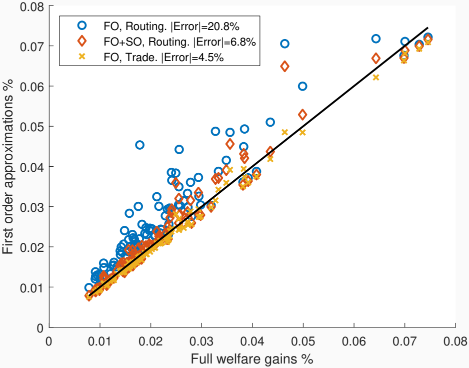
Welfare characterization

- 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

$$\Delta W = \underbrace{-\sum_{o,d,i}\left(\frac{X^i_{od}}{Y} - \frac{\Lambda^i_o}{Y}1_{d=RoW}\right)\sum_{kl\in\mathbb{C}}\pi^{road}_{od}\pi^{kl}_{od}\Delta\log(\iota_{kl})}_{FO_R} + SO_R + Residual$$

  - $\Delta\log(\iota_{kl})$: change in route cost; known after estimating (κ^L, κ^H)
  - Y: Domestic GDP
  - X^i_{od}: Domestic trade flows from o to d in sector i
  - Λ^i_o: foreign consumption exposure to export cost
  - $\pi^{Road}_{od}, \pi^{kl}_{od}$: 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

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- 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

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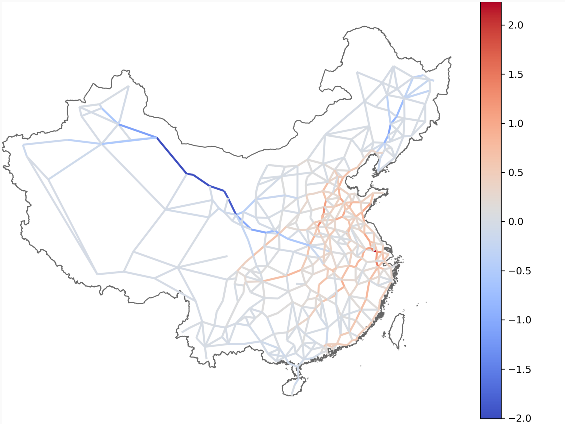
The minimum-spanning tree IV (Faber, 2014)

- 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

Back

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).

Back

Price-distance regression

Table: Price Distance Regression

	(1)	(2)	(3)	(4)
	OLS		IV	
dist_{od}	0.055***	0.061***	0.053***	0.058***
	(0.013)	(0.022)	(0.012)	(0.021)
Fixed Effects	dci, oci	dci, oci	dci, oci	dci, oci
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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Back

Price regression: estimate trade cost-weight elasticity

Table: Transport cost and weight-to-value ratio

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable	log price ratio				log price ratio		
Heaviness- HS2 Category	0.163***	0.161***	0.278***	0.199**			
	(0.056)	(0.056)	(0.086)	(0.089)			
Heaviness- HS4 Category					0.303***	0.362***	0.253***
					(0.044)	(0.050)	(0.043)
Fixed Effects	*o*, *d*, *c*	*odc*	*fdc*	*fdc*	*fdc*, *i*	*fdci*	*fdci*
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). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Back

Descriptive Statistics of Changes in Route Length

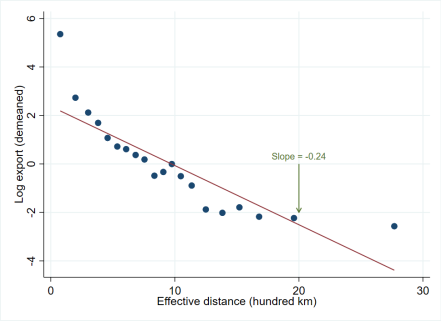
	2000-2001		2010-2011	
Route-level variables	mean	std	mean	std
Export	164	2050	989	12100
Total length	20.40	11.60	17.24	10.45
Length of expressway segments	12.93	7.71	16.88	9.72
Expressway share in total length	0.65	0.24	0.99	0.05
Effective length	13.93	9.00	8.80	5.77

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

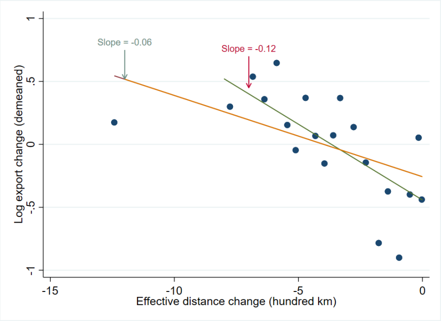
$$\underbrace{\Delta dist_{od}^{t}}_{-513\ km} = \Delta dist_{o\to d}^{L} + 0.5 \times \Delta dist_{o\to d}^{H} = \underbrace{(\Delta dist_{o\to d}^{L} + \Delta dist_{o\to d}^{H})}_{-316\ km\ (60\%)} \quad \underbrace{-0.5 \times \Delta dist_{o\to d}^{H}}_{-196\ km\ (40\%)}$$

Back

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



(a) Cross-section variations

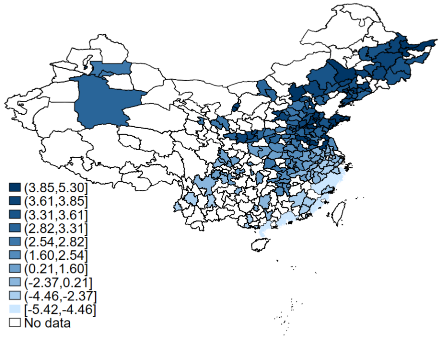


(b) Over-time variations

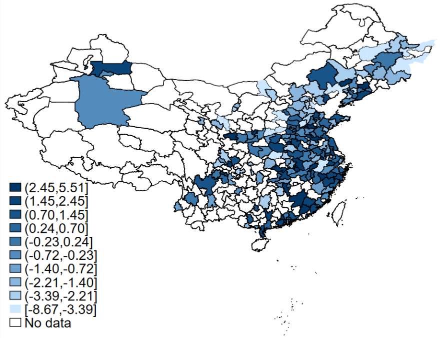
Figure: Bin-scattered Plots of Log(Export) and Route Length

Note: Panel (a) plots the log(export) of routes over the effective length of routes. Panel (b) plots the change in log(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		
$dist^t_{od}$	-0.185***	-0.166***	-0.157***	-0.373***	-0.138***		-0.157***	-0.137***	-0.137***
	(0.049)	(0.041)	(0.041)	(0.017)	(0.044)		(0.041)	(0.039)	(0.039)
- on express						-0.075*			
						(0.039)			
- on regular						-0.137***			
						(0.044)			
log(city export through other routes)		0.171**						0.053**	
		(0.073)						(0.026)	
Specification	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Fixed Effects	og, ot, gt	$od, p_o t, dt$	$od, p_o t, dt$	oti, dti	odi, oti, dti	odi, oti, dti	ogi, oti, gti	$odi, p_o ti, dti$	$odi, p_o ti, dti$
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; $\Rightarrow$ the variations in export mainly come from growth instead of rerouting
- Results are robust when using sectoral data

Robustness: Measuring in Weights

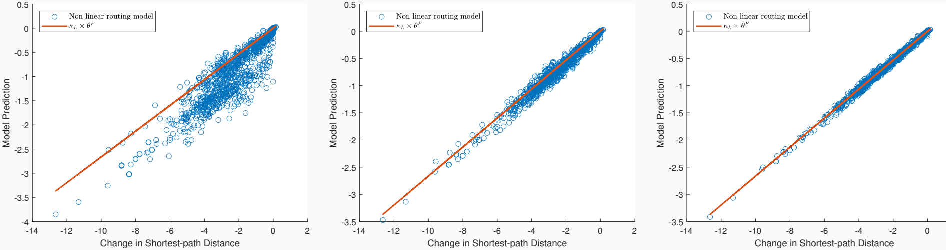
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Effective Route Length and Export						By Type of Road		
	OLS				IV Reduced Form	2SLS	OLS	IV Reduced Form	2SLS
distance_total_w05	-0.363***	-0.412***	-0.191***	-0.217***		-0.231***			
	(0.011)	(0.012)	(0.042)	(0.052)		(0.067)			
iv_distance_total_w05					-0.268***				
					(0.079)				
(first) distance_express_w05							-0.088**		-0.163**
							(0.044)		(0.080)
(first) distance_road_w05							-0.215***		-0.248***
							(0.052)		(0.074)
(first) iv_distance_express_w05								-0.161**	
								(0.063)	
(first) iv_distance_road_w05								-0.285***	
								(0.086)	
Fixed Effects	o, d, t	ot, dt	od, ot, dt	od, ot, dt	od, ot, dt	od, ot, dt	od, ot, dt	od, ot, dt	od, ot, dt
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)** $\theta = 1.5 \times \theta^*$

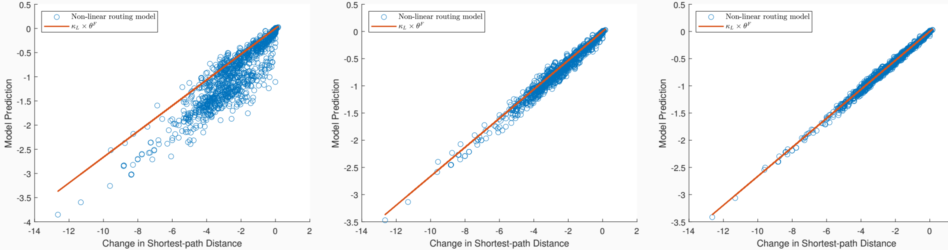
Figure: Model Prediction Varying θ

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



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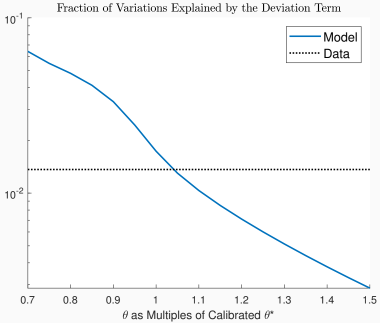
Vertical: Model prediction $\Delta \log \left([\tilde{\mathbb{B}}^t(\kappa^H \theta, \kappa^L \theta)_{(od)}] \right)$

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

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

Model validation: export level

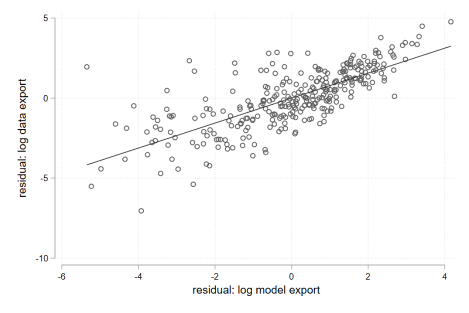


Figure: City-level export in 2010: Model versus Data

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

Back

Model validation: export growth

Table: Predicting Export Growth

	(1)	(2)	(3)
Log(export), model	0.465***	0.953***	0.871***
	(0.048)	(0.189)	(0.199)
Fixed Effects	t	oi, it	oi, it
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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Back

Model validation: transshipment

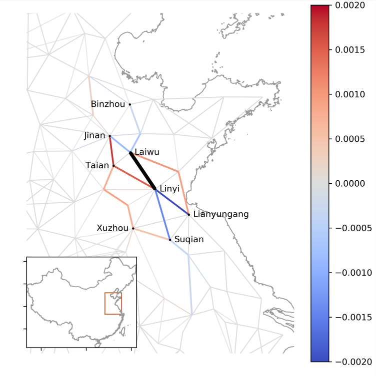
Table: Correlation with Shipment

	(1)	(2)	(3)
Log(shipment), model	0.314***	0.177***	0.176***
	(0.040)	(0.035)	(0.041)
Log(employment)		0.594***	0.587***
		(0.059)	(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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Back

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