Economies of Scope in Transportation and Domestic Trade

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Motivation

- Freight transportation of goods: Economic foundation of a modern economy
- Road freight: Key in developing countries
  - India: 67% of transport sector + 3.1% of GDP
- How transporters leverage geography to gain efficiency?
  $\Rightarrow$ Group deliveries into a single shipment
  $\Rightarrow$ i.e. Trip chaining, **economies of scope**

This Paper

Research questions

- Are there "economies of scope" from exploiting grouped shipments in transportation markets?
- How do economies of scope in transportation affect intensive and extensive margins of domestic trade?

Setting: Freight trucking within India

- Universe of transactions for one large state
- Can trace path trucks take to deliver shipments

Stylized Facts

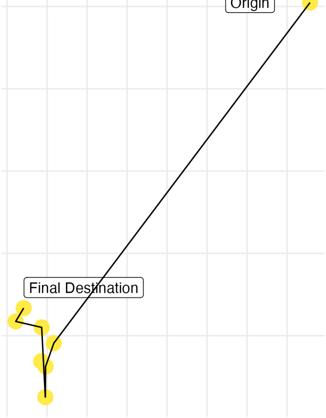
- Grouped shipments common and characterize a large portion of domestic
- Evidence for economies of scope in transportation
  - Around 40% of trade by value

Quantitative Trade Model

- Trade costs *endogenous* to trucker route choices

Counterfactuals

- Role of economies of scope on trade flows
  - Bilateral trade 30% lower due to loss of opportunities to group shipments (partial equilibrium)



Literature and Contributions

- Trade Costs and Economic Geography: Samuelson (1954), Anderson and van Wincoop (2003), Eaton and Kortum (2002), Allen and Arkolakis (2014), Ahlfeldt et al. (2015)
  - **Contribution:** Focus on role of economies of scope and grouped shipments shaping trade costs.
- Transportation Sector in Economic Geography and International Trade: Hummels et al. (2009), Asturias (2020), Brancaccio et al. (2020), Yang (2021), Miyauchi et al. (2022), Wong (2022), Allen and Arkolakis (2022), Allen et al. (2023)
  - **Contribution:** Study effect of grouping shipments (ex ante trip chaining) (Allen et al., 2023).
- Production Location Decisions: Melitz (2003), Tintelnot (2016), Antras et al. (2017), Antras et al. (2022), Alfaro-Urena et al. (2023)
  - **Contribution:** Study role of domestic transportation sector in shaping market entry.

Data and Context

Transaction Data:

- Establishment-to-establishment transactions at the HS-8 level for a large Indian state for 2019.
- Censoring: All transactions that begin or end in the state.
- Key: Data generated when transporter picks up shipment.

Table 1: Example Data

Date	ID	Seller	Seller Pincode	Buyer	Buyer Pincode	Product	Value	Vehicle
2019-01-01-13:01:32	12345	Brian	48104	Gaurav	90210	Shoes	X	**G0 B!U3**
2019-01-01-13:01:32	12346	Brian	48104	Brock	90212	Socks	Y	**G0 B!U3**
2019-01-01-15:00:01	12347	J.J.	48127	Blake	90210	Shirts	Z	**G0 B!U3**

Defining Shipments:

- All uninterrupted transactions fulfilled by a vehicle that originate close together, in both space and time.
- Grouped shipments VS Direct shipments.

Facts 1 + 2: Grouped shipments are common and important

Fact 1: Grouped shipments are common and important

Table 2: Prevalence of Grouped Shipments within the Sample

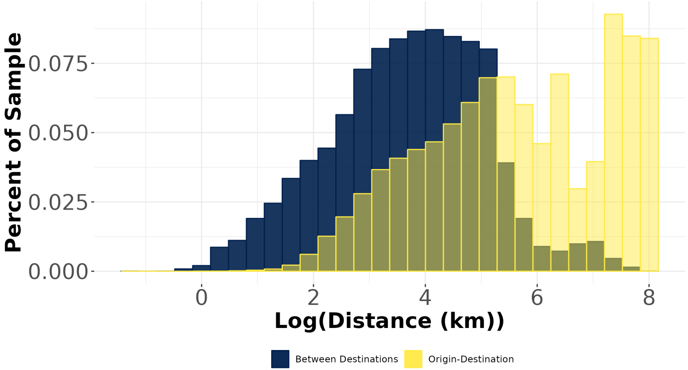
	Transactions	Shipments	Fraction of Trade	Vehicles	Sellers
Direct Shipments	0.4	0.79	0.6	0.96	0.90
Grouped Shipments	0.6	0.21	0.4	0.46	0.63

Fact 2: Sellers of grouped shipments are well-connected

- Sellers ever part of a grouped shipment: Average 13 customers, 12 destination locations.
  - Median: 3 customers, 3 destinations.
- Sellers never part of a grouped shipment: Average 2 customers, 2 destination locations.
  - Median: 1 customer, 1 destination.

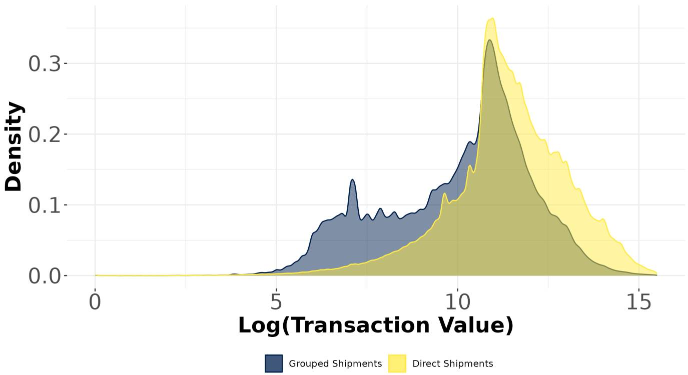
Fact 3: Group shipments' stops are close together

Figure 2: Distance Distribution



Fact 4: Value of transactions in grouped shipments are lower

Figure 3: Transaction Value Distribution



MODEL

Setup: Allen and Arkolakis (2022) + Antras et al. (2022)

- J locations: L_j consumers in j immobile, supply labor inelastically.
- Production: Perfectly competitive final goods firms produce varieties, $\omega \in [0, 1]$.
- Preferences: CES with elasticity of substitution σ across *truckers* (φ) and varieties (ω).

Trade and Transportation Sector:

- Trade between locations requires use of monopolistically competitive truckers, φ.
    - <u>Simplification:</u> truckers *ex ante* homogeneous, not heterog. as in Antras et al. (2022)
- Final goods producer sell output to truckers at marginal cost.
- Truckers deliver j's output via a route: $r \equiv \{j, d_1, d_2, \dots\} \in 2^J$.
- Truckers incur variable trade costs (Allen and Arkolakis, 2022):

$$r^*(\varphi, \omega) = arg \min_{r \in \mathcal{R}_{ji}(\varphi)} \left\{ c_{ji,r}(\varphi, \omega) \right\} = arg \min_{r \in \mathcal{R}_{ji}(\varphi)} \left\{ \frac{1}{\epsilon_r(\varphi, \omega)} \tau(r) \right\}, \quad \epsilon_r(\varphi, \omega) \sim \text{Frechet}(\theta)$$

- And fixed route-entry costs, f_r.
- Set of routes entered between j and i: $\mathcal{R}_{ji}(\varphi)$.

Transportation Sector

Transportation Sector's Problems:

- (1) Enter into routes ($\mathcal{R}_{ji}(\varphi)$), (2) Route assignment ($r^*(\varphi,\omega) \in \mathcal{R}_{ji}(\varphi)$), (3) Pricing ($p_{ji}(\varphi,\omega)$).

Pricing Problem:

- $\pi_{ji,r^*}(\varphi,\omega) = (1+\tau_{ji}(\varphi,\omega))\, p_j(\varphi,\omega)\, q_{ji}(\varphi,\omega) - (1+c_{ji,r^*}(\varphi,\omega))\, p_j(\varphi,\omega)\, q_{ji}(\varphi,\omega)$
- $p_{ji}(\varphi) = \mu p_j \left[\Xi\left(\mathcal{R}_{ji}(\varphi)\right)\right]^{\frac{1}{1-\sigma}}$, $\Xi\left(\mathcal{R}_{ji}(\varphi)\right) \in [0,1]$.
- $\Xi \equiv$ "Efficiency of φ's delivery capabilities."
  - When $\tau \downarrow$ or $\mathcal{R}_{ji}(\varphi) \uparrow \Rightarrow \Xi \to 1$, good for transportation firm given it is now the seller.

Entry Problem:

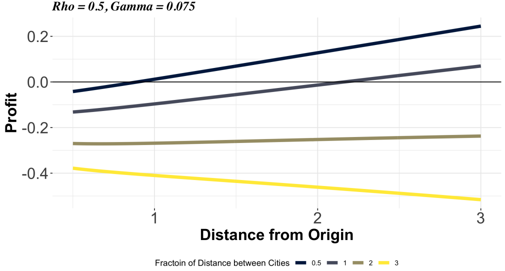
$$\pi_j\left(\varphi, \{\mathcal{R}_{ji}(\varphi)\}_{j=1}^{J}\right) \equiv \kappa \sum_{i\in\mathcal{J}} p_j^{1-\sigma} E_i P_i^{\sigma-1} \Xi\left(\mathcal{R}_{ji}(\varphi)\right) - \sum_{r\in\cup_i \mathcal{R}_{ji}(\varphi)} w_j f_r$$

Economies of Scope?

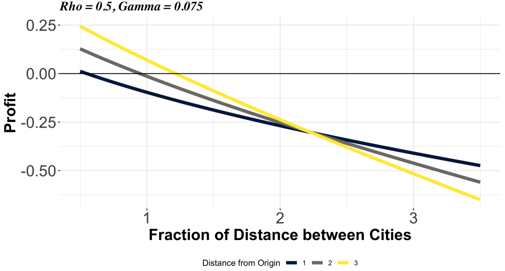
Exercise: Consider shipment from O to d_1 and d_2.

- $dist(\{d_1\}) = dist(\{d_2\}) = z$, where z is distance from origin
- $dist(\{d_1, d_2\}) = z + yz$, where $y \geq 0$ is fraction of distance between cities
- **When is grouped shipment profitable?**

Figure 4: When are Grouped Shipments Preferable



(A) Distance from Origin



(B) Distance between Cities

- Change in profit: $\pi(\{d_1, d_2\}) - \pi(\{d_i\}_{i=1}^2)$

Assumptions | Other Comparative Statics

QUANTIFICATION

Key parameters: Trade elasticity $\tau(r)$ + route choice heterogeneity (θ) + fixed costs of route entry (f_r).

$\tau(r) + \theta$**:** Details

- $\tau(r) = \kappa_0(\text{distance}(r))^{\kappa_1}$.
- Leverage our data, an instrumental variables strategy, and model implied gravity equation.
- $\kappa_1 \approx 0.023$.
- $\theta \approx 1.197$.

Fixed costs:

- $f_r = \gamma \times \text{distance}(r)$.
- Leverage equilibrium conditions:
  - All truckers ex ante identical, $\Omega_{ji} = \Omega_i$.
  - $L_i = \Omega_i \sigma \sum_j \sum_{r \in \mathcal{R}_{ij}} f_r$.

Counterfactuals and Conclusion

Counterfactual: Details

- Effect of grouped shipments on domestic trade (intensive margin).
- Estimate how Ξ would change if no grouped shipments were allowed holding entry into markets constant.
- Find domestic bilateral would fall by about 30% in absence of ability to group shipments (in partial equilibrium).

Conclusion:

- Document presence and prevalence of grouped shipments in domestic trade.
- Develop quantitative model that can rationalize grouped shipments via economies of scope.
- Estimate a substantial degree of heterogeneity in route choices.
- Trade cost benefit from grouping shipments contributes to domestic trade via lower trade costs.

Comparative Static Assumptions

Exercise: Consider shipment from O to d_1 and d_2. When is grouped shipment profitable?

- $\mathcal{J} = \{O, d_1, d_2\}$.
- We consider the route entry decisions for a transporter, φ, located in O.
- The sets of possible routes for each destination are: $\mathcal{R}_{Od_1} \equiv \left\{\{d_1\}, \{d_1, d_2\}\right\}$, $\mathcal{R}_{Od_2} \equiv \left\{\{d_2\}, \{d_1, d_2\}\right\}$.
- The distance of the routes are: distance $(\{d_1\}) =$ dist $(\{d_2\}) = z$, distance $(\{d_1, d_2\}) = z + yz$
- $\tau(r) =$ distance $(r)^\rho$.
- Normalize the following: $E_d P_d^{\sigma-1} = p_O^{1-\sigma} = \kappa\varphi^{\sigma-1} = w_O = 1$, for each $d \in \{d_1, d_2\}$.
- Fixed costs are linear functions of distance: $f_r = \gamma \times$ (distance (r)).
- Finally, $\sigma - 1 < \theta$. More specifically: $\theta = 8$, $\sigma = 2$.

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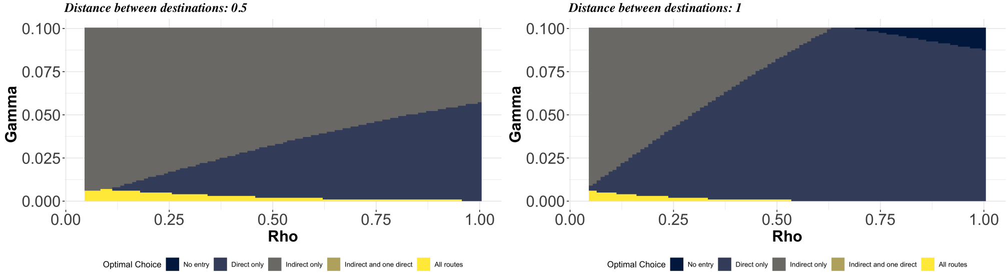
Comparative Statics Continued (2)

Exercise: Consider shipment from O to d_1 and d_2. When is grouped shipment profitable?

Figure 5: Entry Decision as a function of Variable and Fixed Parameters



(a) Close Together

(b) Equal Distance

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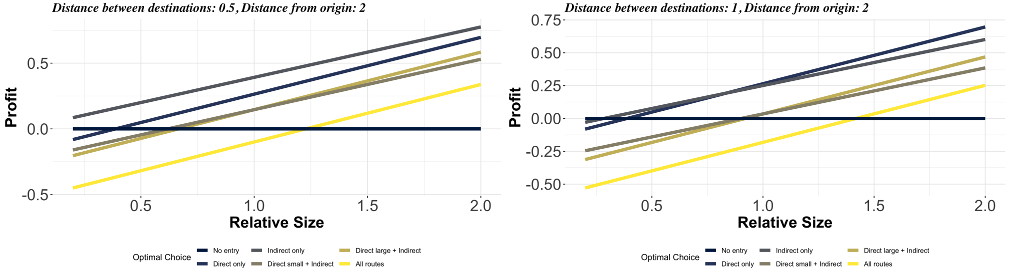
Comparative Statics Continued (3)

Exercise: Consider shipment from O to d_1 and d_2. When is grouped shipment profitable?

FIGURE 6: Dependence on Market Size



(A) Close Together

(B) Equal Distance

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ESTIMATING θ

Estimation Equation (κ_1)**:**

$$\underbrace{\log(p_{sobdtvhi})}_{\log(p_{\boldsymbol{od},\boldsymbol{r}}(\varphi,\omega))} = \underbrace{\kappa_1 \times \log(\text{distance}(r))}_{\tau(r)} + \underbrace{f_{s,o,h,t}}_{\log(p_{\boldsymbol{o}}(\omega))} + \underbrace{f_{\varphi,o,d,h}}_{-\log\left(\epsilon_{\boldsymbol{ji},\boldsymbol{r}}(\varphi,\omega)\right)}$$
$$+ f_{b,d,t} + f_{\text{unit}(hi)} + \beta \log(q_{sobdtvhi}) + \nu_{sobdtvhi}$$

- Note, omitted variable bias due to $\epsilon_{ji,r}(\varphi,\omega)$.
  - Instrument $\log(\text{distance}(r))$ with bilateral distance between seller pincode and buyer pincode.
  - Need that productivity not correlated with the bilateral distance.

Gravity Equation:

$$\log(\lambda_{ji,r}) = -\theta \times \kappa_1 \log(\text{distance}(r)) + \log(\Omega_{ij,r}) + f_{ji} + \nu_{ji,r}$$

- $\lambda_{ji,r} \equiv X_{ji,r}/X_{ji}$, $\Omega_{ji,r}$ entrants into r.

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ESTIMATING κ_1

TABLE 3: Estimation of κ_1

Dependent Variable:	Log(Unit Value)							
	OLS							IV
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables								
I(Shipment includes more than one destination) = 1		-0.0131***	-0.0176***		-0.0117***		-0.0135***	-0.0440***
		(0.0043)	(0.0038)		(0.0039)		(0.0050)	(0.0115)
Log(Bilateral Distance)	0.0072**		0.0071**					
	(0.0031)		(0.0031)					
Log(Route Distance)				-0.0070**	-0.0039			0.0223**
				(0.0033)	(0.0029)			(0.0099)
Log(Added Distance)						-0.0012***	0.0001	
						(0.0004)	(0.0005)	
Fixed-effects								
Unit	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HSN-Seller-Origin Pin-Year-Month	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Vehicle-Origin Pin-Destination Pin-HSN		Yes		Yes	Yes	Yes	Yes	
Buyer-Destination Pin-Year-Month	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Vehicle-HSN	Yes		Yes					Yes
Controls								
Log(Quantity)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics								
R^2	0.91719	0.92794	0.91719	0.92794	0.92794	0.92794	0.92794	0.91719
Observations	11,797,553	11,797,553	11,797,553	11,797,553	11,797,553	11,797,553	11,797,553	11,797,553
Kleibergen-Paap								210

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ESTIMATING θ

TABLE 4: Estimation of θ

Dependent Variable:	$\text{Log}(\lambda)$
Model:	(1)
Variables	
Log(Route Distance)	-0.0267**
	(0.0105)
Log(Number of Vehicles)	1.414***
	(0.0076)
Fixed-effects	
Origin Pin-Destination Pin	Yes
Fit statistics	
R^2	0.84099
Observations	3,285,833

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COUNTERFACTUAL

Goal: Identify how presence of grouped shipments affect bilateral trade flows.
Approach:

- Remove grouped shipments from $\mathcal{R}_{od}$.
- New route-entry sets: $\mathcal{R}^D_{od}$.
- Given estimates* of θ, ζ, construct counterfactual $\Xi(\mathcal{R}^D_{od})$.
  - Effect on $\Xi(\mathcal{R}^D_{od})$ ambiguous. Improves (approaches 1) or worsen (approaches 0), depending on:
    - (1) number of routes (route choice heterogeneity),
    - (2) presence of grouped routes (longer variable trade costs).
- Estimate model's aggregate gravity equation:

$$\log(X_{od}) = f_o + f_d + \log(\Omega_{od}) + \log(\Xi_{od}(\mathcal{R}_{od})) + \epsilon_{od}$$

- Save f_o, f_d and construct counterfactual $\widehat{\log(X_{od})}$ using $\Xi(\mathcal{R}^D_{od})$.

Results: (more details on next slide)

- Bilateral trade declines by about 30% across all od pairs.

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Counterfactual Continued

Figure 7: Difference in Ξ

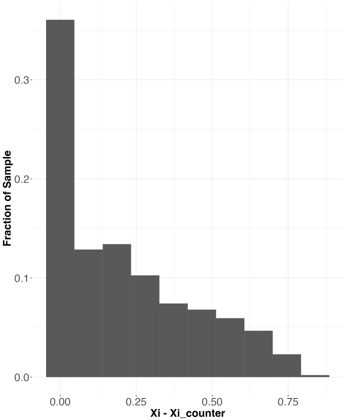

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Table 5: Aggregate Gravity Regression

Dependent Variable:	$\log(X_{od})$
Model:	(1)
Variables	
$\log(\Xi(\mathcal{R}))$	0.6342***
	(0.0351)
$\log(\Omega_{od})$	1.069***
	(0.0184)
Fixed-effects	
Origin Pin	Yes
Destination Pin	Yes
Fit statistics	
R^2	0.70837
Observations	66,098