Breaking Invisible Barriers: Does Fast Internet Improve Access to Input Markets?

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Motivation

- Global spending on digital transformation projected to reach $3.4 tn by 2026
- Availability of **high-speed reliable** internet has changed how people interact and do business:
  - conduct face-to-face meetings remotely
  - provide remote support and troubleshoot on the production line
  - share large files with product specifications, designs, photos
- Penetration of high speed internet strongly correlated with economic growth
- Governments eager to promote the diffusion of broadband technologies

This Paper

Impact of Fast Internet Access

- Firms' Input Sourcing Strategy
- Supply Chain Networks
- Regional Trade in Input Markets
- Spatial Distribution of Economic Activity

This Paper

FAST INTERNET, FIRMS' INPUT SOURCING, & ECONOMIC ACTIVITY ACROSS SPACE

- **Setting**:
  - broadband deregulation in Turkey in 2011
  - massive expansion of optical fibre networks during 2012-2019
  - staggered rollout of optical fibre cables across provinces
  - high take-up of fibre internet; uniform adoption across sectors
- **Data**:
  - domestic firm-to-firm transactions
  - province-level deployment of optical fibre cables

▸ Details

This Paper

FAST INTERNET, FIRMS' INPUT SOURCING, & ECONOMIC ACTIVITY ACROSS SPACE

- Construct **bilateral measure of internet connectivity** for province pairs
  - synchronous communication feasible if both parties have good internet
  - measure captures strong complementarity in internet quality
- Estimate **impact on firms' input sourcing strategy**
  - firms **reallocate** input purchases towards provinces with better internet
  - firms **diversify** their input sourcing in provinces with better internet
    - **number of domestic suppliers** ↑
    - **concentration of purchases** ↓

This Paper

FAST INTERNET, FIRMS' INPUT SOURCING, & ECONOMIC ACTIVITY ACROSS SPACE

- Build **tractable spatial equilibrium model** featuring
  - **endogenous formation** of firm-to-firm linkages
  - **rationally inattentive** behavior in input sourcing

- In the model, better internet connectivity leads to
  - stochastically **better match productivity** with potential suppliers
    $\Longrightarrow$ firms reallocate purchases towards provinces with better internet
  - **lower cost of obtaining information** about potential suppliers
    $\Longrightarrow$ firms diversify input sourcing in provinces with better internet

This Paper

FAST INTERNET, FIRMS' INPUT SOURCING, & ECONOMIC ACTIVITY ACROSS SPACE

- Model delivers **nested logit estimating equations**
  - outer nest for choice of province
  - inner nest for choice of supplier within province
- Outer nest analogous to **structural gravity specification**
  - trade between provinces **depends on internet connectivity and trade costs**
  - elasticity wrt internet connectivity is **0.5**; wrt travel time is **1.6**
- Quantify real income gains due to access to high-speed internet:
  - **increase in real income** in the median Turkish province is **2%**
  - large but smaller than gains from improvement in transportation infrastructure

▸ Literature

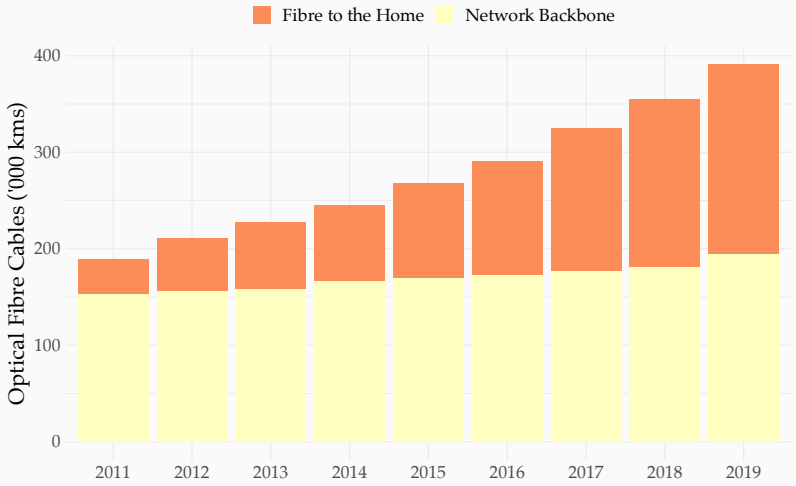
Broadband Deregulation in Turkey in 2011

Role of Turkish ICT Authority (ICTA)

- ICTA decided in 2011 not to regulate incumbent fixed operator Turk Telekom *"for a five year period or as long as the ratio of fiber subscribers is lower than 25% of the total of fixed broadband subscribers"*
- Turk Telekom committed to provide wholesale access to its fiber network on equal conditions and non-discriminatory basis
- Roll-out kicked off after private ISPs granted access to BOTAS network
- Investments in fibre rose quickly, fibre subscribers grew 5x in 8 years

Optical Fibre Cable Rollout 2012-2019

Length of cable doubled, Investment concentrated in FTTH



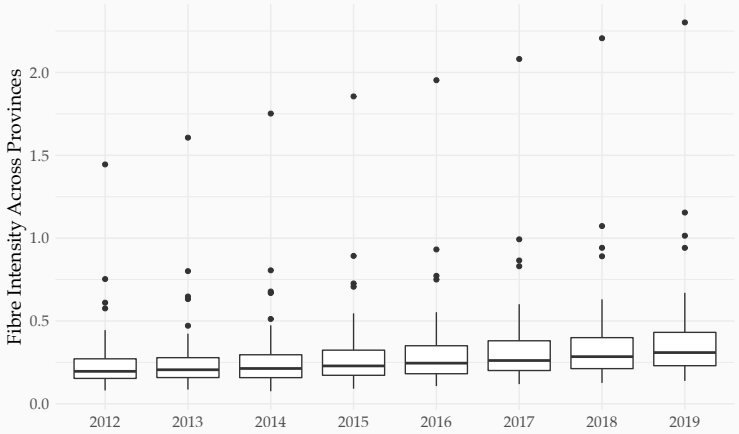
Optical Fibre Cable Rollout 2012-2019

ROLLOUT STAGGERED BUT SECULAR INCREASE IN FIBRE INTENSITY

▸ Rollout Length

For province d in year t:

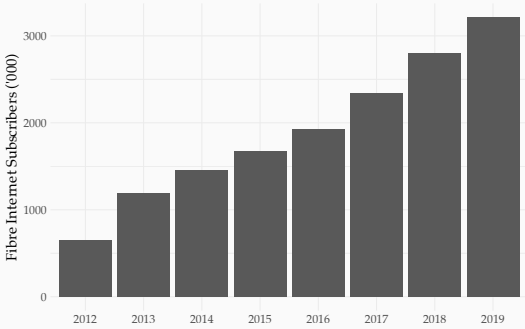
$$\text{Fibre Intensity}, I_{dt} = \ln\left(1 + \frac{\text{Fibre Cable Length}(d,t)}{\text{Area}(d)}\right)$$

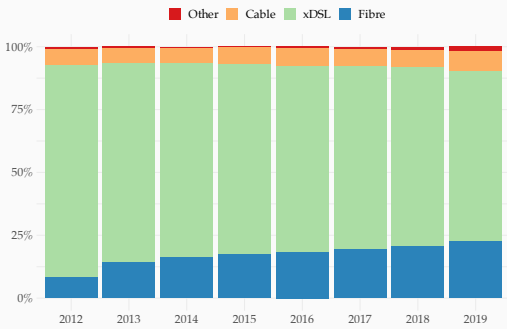


▸ Speed

Adoption of Fibre Internet

HIGH TAKE-UP; ACCOUNTED FOR 24% OF BROADBAND CONNECTIONS IN 2020

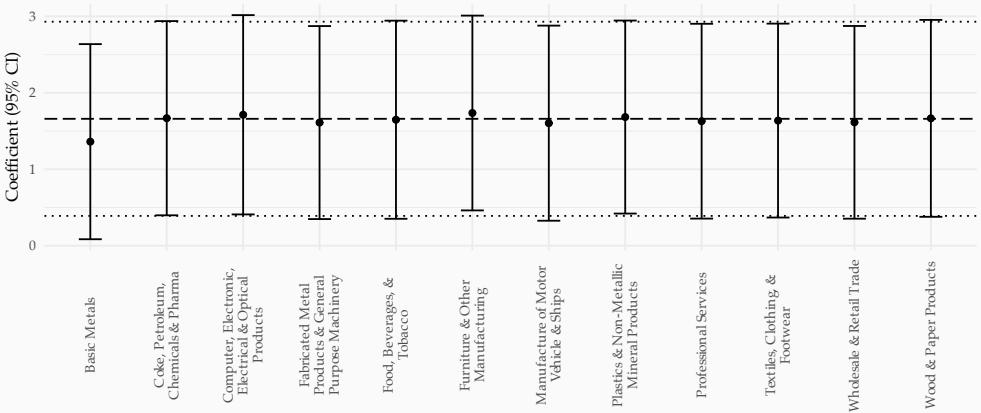




Adoption of Fibre Internet

FIRM-LEVEL RESPONSE UNIFORM ACROSS SECTORS

Specification | Broad Sectors



Benefits of Fibre Internet

Comparison to ADSL

- Compared to ADSL, fibre-style broadband:
  - is faster
  - is more reliable
  - has less fluctuation in speed and service
- Among 3000 participants in a *Which* survey:
  - 63% report faster speeds
  - 49% report fewer connection dropouts
  - 39% report fewer long outages

▸ Wiedmann (2023)

Measuring Bilateral Internet Connectivity

SYNCHRONOUS COMMUNICATION AND HIGH-SPEED INTERNET

- Synchronous communication involves the exchange of data in real-time.
- With poor internet connection:
  - delays in sending and receiving messages
  - audio dropouts
  - video stuttering
- For effective synchronous communication, both parties require good internet
- Measure of bilateral connectivity captures this strong complementarity
- For provinces o and d in year t:

$$\text{Fibre Connectivity}, I_{od,t} = \min \{\text{Fibre Intensity}_{ot}, \text{Fibre Intensity}_{dt}\}$$

Reallocation of Firm-Level Purchases across Origins

IMPACT OF FIBRE CONNECTIVITY

- **Outcome Variable**:
  fraction of input purchases of buyer firm b located in destination province d from origin province o in year t

$$\text{Cost Share}(o,b,t) = \frac{\sum_{s \in o} \text{Purchases}(s,b,t)}{\sum_{o'} \sum_{s' \in o'} \text{Purchases}(s',b,t)}$$

- **Specification**:

$$\ln \text{Cost Share}(o,b,t) = \beta \ln \text{ Fibre Connectivity}(o,d,t) + \alpha_{od} + \alpha_{ot} + \alpha_{bt} + \epsilon_{obt}$$

  - Fixed Effects: Origin-Destination, Buyer-Year, Origin-Year
  - Standard errors are clustered at the origin and destination province levels

Reallocation of Firm-Level Purchases across Origins

PURCHASES REALLOCATED TOWARDS PROVINCES WITH BETTER CONNECTIVITY

Dependent Variable:	Cost Share	
	(1)	(2)
Fibre Connectivity	0.510***	0.485***
	(0.0549)	(0.155)
Travel Time		-0.224***
		(0.019)
Fixed Effects:		
Buyer × Year	✓	✓
Origin × Year	✓	✓
Origin × Destination	✓	
R^2	0.588	0.470
Observations	2,230,473	2,230,473

Diversification of Firm-to-Firm Purchases within Origins

IMPACT OF FIBRE CONNECTIVITY

- **Outcome Variables**:
  for buyer b located in destination d pertaining to origin o in year t: $y(o,b,t)$

  1. Number of Suppliers
  2. Hirschmann-Herfindahl Index for Concentration of Cost Shares

$$\text{Cost Share HHI}(o,b,t) = \sum_{s \in o} \left(\frac{\text{Purchases}(s,b,t)}{\sum_{s' \in o} \text{Purchases}(s',b,t)} \right)^2$$

  3. Number of New Connections (relative to the past two years)

- **Specification**:

$$\ln y(o,b,t) = \beta \ln \text{ Fibre Connectivity}(o,d,t) + \alpha_{od} + \alpha_{ot} + \alpha_{bt} + \epsilon_{obt}$$

Diversification of Firm-to-Firm Purchases within Origins

INCREASED DIVERSIFICATION FROM PROVINCES WITH BETTER CONNECTIVITY

Dependent Variable:	No. Suppliers	Cost Share HHI	New Connections
	(1)	(2)	(3)
Fibre Connectivity	0.325***	-0.107***	0.0632***
	(0.0297)	(0.0136)	(0.0196)
Fixed Effects:			
Buyer × Year	✓	✓	✓
Origin × Year	✓	✓	✓
Origin × Destination	✓	✓	✓
Observations	2,230,473	2,230,473	2,230,473

Impact of Fibre Connectivity on Firms' Input Sourcing

Robustness Checks

- 2SLS using distance to BOTAS network as IV — ▸ 2SLS
- Additional Controls: — ▸ Additional Controls
  - Difference in GDP per capita
  - 3G/4G Mobile Connectivity
- Alternative Measure of Connectivity: $-|I_{ot} - I_{dt}|$ — ▸ Alternative Connectivity
- Exploiting Source of Variation in Fibre Connectivity — ▸ Source of Variation
- Including Non-Manufacturing Suppliers — ▸ All Suppliers
- Interactions between Travel Time and Year Dummies — ▸ Control for Travel Time
- Cable TV Rollout as Placebo Test — ▸ Placebo Test

Model of Rationally Inattentive Input Sourcing

In a Nutshell

- Provinces, indexed by $o, d \in \{1, \cdots, J\}$
- Firms, indexed by $s, b \in [0, M]$
- Positive measure of firms and households at each location
- Firms combine labour and tasks via a Cobb-Douglas aggregator
- Trade between provinces is costly, $\tau_{od} \geq 1$

▸ Details

Model of Rationally Inattentive Input Sourcing

Imperfect Information in Supplier Choice

- Supplier choice depends on
  - marginal cost of supplier, $c(s)$
  - iceberg trade cost, τ_{od}
  - match productivity, $a(s, b, k)$
- Firm has prior beliefs about these factors, given probability measure ν
- Firm chooses the most cost effective supplier for each task but has
  - imperfect information about marginal cost of a potential supplier
  - no information about match productivity with a potential supplier but imperfect info. about its distribution

▸ Details

Model of Rationally Inattentive Input Sourcing

Implications connecting to Empirical Evidence

- Firm reallocates purchases towards provinces with better fibre connectivity

$$\pi(o, d) \propto \text{match scale } \phi_{od}$$

- Firm diversifies input purchases in provinces with better fibre connectivity

$$\lambda_{od} \text{ decreases from } \infty \implies HHI(\{\pi(s \mid o, d) : s \in o\}) \downarrow$$

▸ Details

Estimation Results

Robustness

Choice of Origin: Impact of Internet Connectivity on Regional Trade

Dependent Variable:	Average Cost Share					
	Manufacturing			Overall		
	(1) PPML	(2) PPML:CF	(3) PPML:CF	(4) PPML	(5) PPML	(6) PPML:CF
Fibre Connectivity	0.629***	0.421***	0.421**	0.470***	0.594***	0.277***
	(0.143)	(0.107)	(0.182)	(0.115)	(0.118)	(0.0672)
Travel Time				-1.550***		
				(0.0112)		
Fixed Effects:						
Origin × Year	✓	✓	✓	✓	✓	✓
Destination × Year	✓	✓	✓	✓	✓	✓
Origin × Destination	✓	✓	✓		✓	✓
R^2	0.986	0.986	0.986	0.842	0.994	0.996
Observations	45504	45504	45504	51840	51840	51840

Welfare Effects of High-Speed Internet Infrastructure

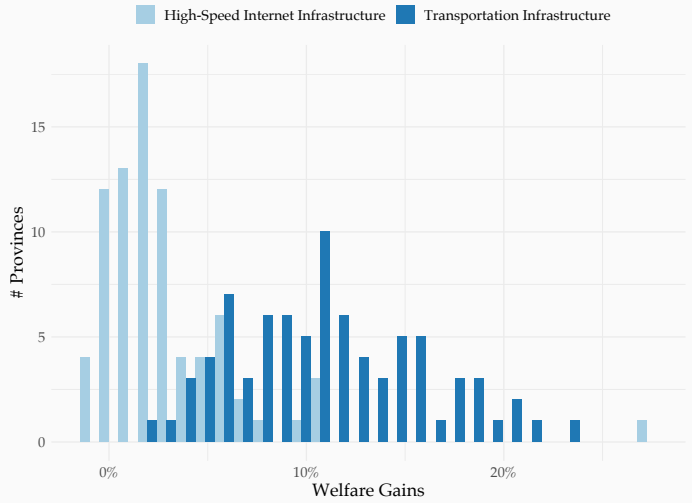
Road Network

COMPARISON WITH TRANSPORTATION INFRASTRUCTURE IMPROVEMENTS

- Conduct a hypothetical experiment where the 2012 Turkish economy had experienced the same large-scale transport infrastructure improvements as between 2005-2010.
- Investment program:
  - Upgraded the quality and/or lane-capacity of existing paved roads
  - Generated significant reduction in travel times with no change in bilateral distances
- Travel times between provinces in 2005 and 2010 calculated using digitized maps and speed assumptions by Cosar, Demir, Ghose, and Young (2021, *JoEG*)

Welfare Effects of High-Speed Internet Infrastructure

COMPARISON OF WELFARE GAINS



Conclusion

- Improved internet connectivity matters for firm-to-firm linkages
  - firms reallocate purchases towards provinces with better internet
  - firms diversify input sourcing more in provinces with better internet

- Estimated (model-consistent) elasticity of input purchases with respect to internet connectivity is 0.5, compared to the travel time elasticity of 1.6

- Estimated welfare gains from high-speed internet access are large but smaller in magnitude than the gains from improvement in transportation infrastructure

Thank You!

Data

- **Province-Level Internet Penetration Data** [ICT Authority]
  - length of optical fibre cables
  - broadband subscribers
  - GIS information on network backbone
- **Firm-to-Firm Transactions Data** [Ministry of Industry & Technology]
  - business-to-business transaction values based on VAT records
  - balance sheet/income statement and customs records
  - firm registry: location and industry of operation
- $\approx$ 150K firms; focus (mainly) on manufacturing sector

Back

Literature

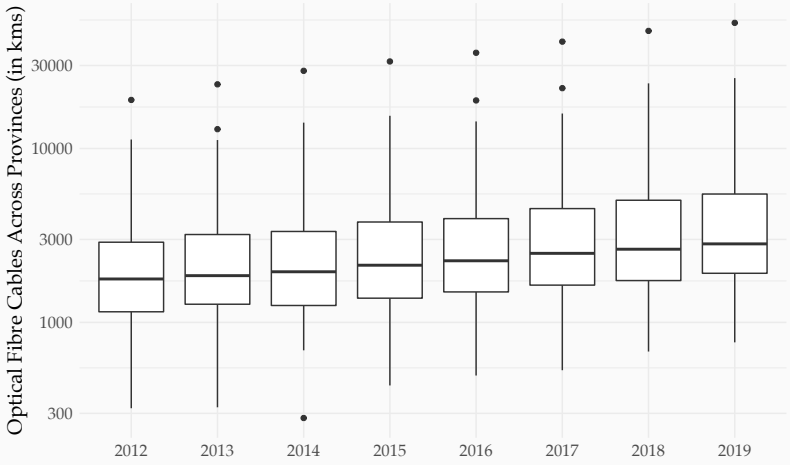
- **Internet and International Trade:** Freund and Weinhold (2004, *JIE*); Fernandes, Mattoo, Nguyen, and Schiffbauer (2019, *JDE*); Hjort and Poulsen(2019, *AER*); Malgouyres, Mayer, Mazet, and Sonilhac (2021, *JIE*); Akerman, Leuven, and Mogstad (2022, *AEJ:Policy*)
- **Information Frictions in Trade:** Rauch and Trindade (2003, *AER*); Chaney (2014, *AER*); Allen (2014, *ECMA*); Dickstein and Morales (2018, *QJE*); Dasgupta and Mondria (2018, *JIE*)
- **Market Integration and Quantitative Spatial Economics:** Allen and Arkolakis (2014, *QJE*); Donaldson (2015, *ARE*); Redding (2016, *JIE*); Cosar, Demir, Ghose, and Young (2021, *JoEG*); Cristea (2011, *JIE*); Bernard, Moxnes, and Saito (2019, *JPE*; 2020)
- **Endogenous Production Networks:** Oberfield (2018, *ECMA*); Lim (2018); Acemoglu and Azar (2020, *ECMA*); Huneeus (2020); Arkolakis, Huneeus, and Miyauchi (2021); Bernard, Dhyne, Magerman, Manova, and Moxnes (2022, *JPE*); Eaton, Kortum, and Kramarz (2022); Panigrahi (2022); Demir, Fieler, Xu, and Yang (Forthcoming, *JPE*)

▸ Back

Optical Fibre Cable Rollout 2012-2019

ROLLOUT STAGGERED ACROSS PROVINCES BUT SECULAR INCREASE

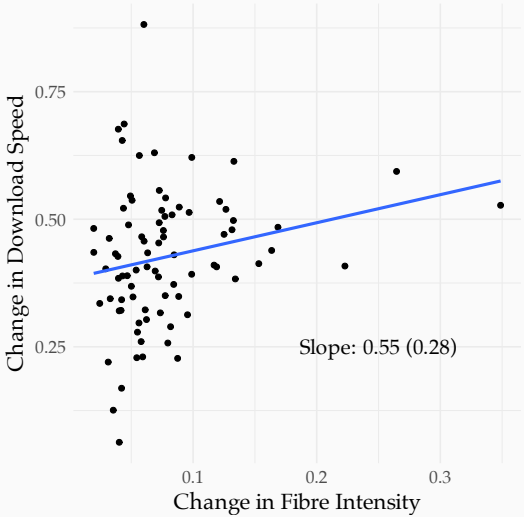
Back

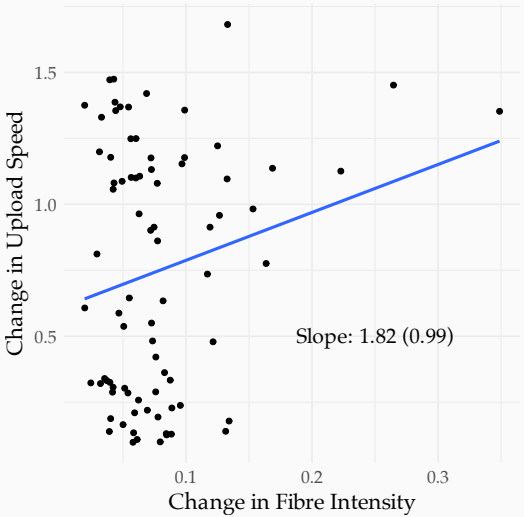


Optical Fibre Cable Rollout 2012-2019

REPORTED INTERNET SPEEDS INCREASED

Back





Adoption of Fibre Internet

ESTIMATING FIRM-LEVEL RESPONSE

Back

- **Outcome Variable**:

$$H_{st} = \mathbb{I}\{\text{firm } s \text{ of sector } i \text{ in province } d \text{ has high-speed internet in year } t\}$$

- **Specification**:

$$H_{st} = \iota_i \times \text{Fibre Intensity}_{dt} + \alpha_d + \alpha_{it} + \text{Size}_{st} + \epsilon_{st}$$

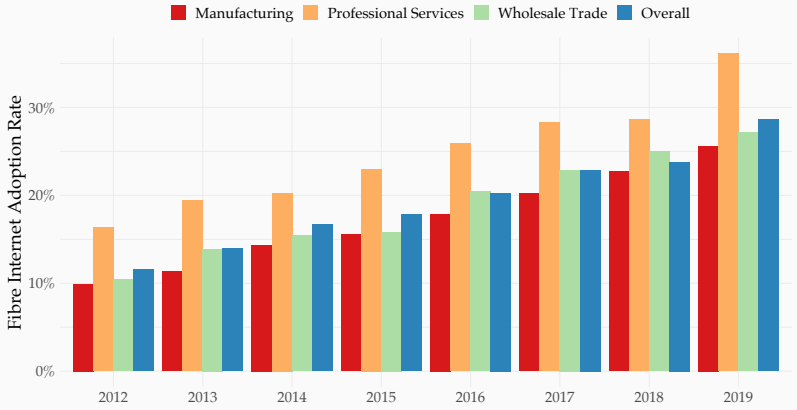
  - Fixed Effects: Province, Sector-Year
  - Controls: Size measured as employment
  - Standard errors clustered by province

- **Data**: Annual Firm-Level Survey on ICT Usage

Adoption of Fibre Internet

INCREASE IN ADOPTION ACROSS BROAD SECTORS

Back



Note: Adoption Rate is fraction of firms with speed higher than 100Mbps

Impact of Fibre Connectivity on Firms' Input Sourcing

Additional Controls

Back

Dependent Variable:	Cost Share		No. Suppliers		Cost Share HHI		New Connections	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fibre Connectivity	0.467***	0.515***	0.291***	0.323***	-0.0916***	-0.105***	0.0531***	0.0549***
	(0.0559)	(0.0590)	(0.0316)	(0.0280)	(0.0129)	(0.0144)	(0.0198)	(0.0196)
Difference in GDP p.c.	0.208**		0.165***		-0.0735***		0.0483**	
	(0.0808)		(0.0393)		(0.0195)		(0.0242)	
Mobile Connectivity		-0.0615		0.0255		-0.0174		0.0981
		(0.231)		(0.105)		(0.0626)		(0.0667)
Fixed Effects:								
Buyer×Year	✓	✓	✓	✓	✓	✓	✓	✓
Origin×Year	✓	✓	✓	✓	✓	✓	✓	✓
Origin×Destination	✓	✓	✓	✓	✓	✓	✓	✓
Observations	2,230,473	2,230,473	2,230,473	2,230,473	2,230,473	2,230,473	2,230,473	2,230,473

Benefits of Fibre Internet

Qualitative Survey by Wiedemann (2023) in Kenya

Back

- Majority of surveyed firms stated:
  "... they rely on [online] services to communicate with their buyers and/or suppliers...key advantage is that they allow firms to send photos of goods and/or invoices"
- A retailer of construction materials and hardware notes:
  "... sending photos results in fewer mistakes, such as sending a product with the wrong specifications."
- Internet can improve the match quality of firms of any size with their buyers and suppliers.

Addressing Endogeneity of Cable Rollout

Distance from BOTAS Pipeline Network

- Optical fibre cables commonly installed alongside oil and gas pipelines
  - to detect damages, security breaches or tampering
  - to effectively manage voluminous data generated by monitoring equipment
- Turkish oil and gas distributor BOTAS also laid out fibre cables
- BOTAS fibre network laid out before deregulation, formed the backbone
- Roll-out kicked off after private ISPs granted access to BOTAS network
- Distance of individual districts from BOTAS network plausibly exogenous

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Addressing Endogeneity of Cable Rollout

BOTAS Pipeline Network: Backbone of Optical Fibre Cable Network

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Addressing Endogeneity of Cable Rollout

Distance from BOTAS Pipeline Network

- For each province o, calculate initial population weighted average distance of districts m to BOTAS network:

$$\overline{\text{Distance}}_o = \sum_{m \in o} \frac{\text{Population}_{m,2011}}{\text{Population}_{o,2011}} \times \text{Distance}_m$$

- Weighted distance uncorrelated with initial province characteristics

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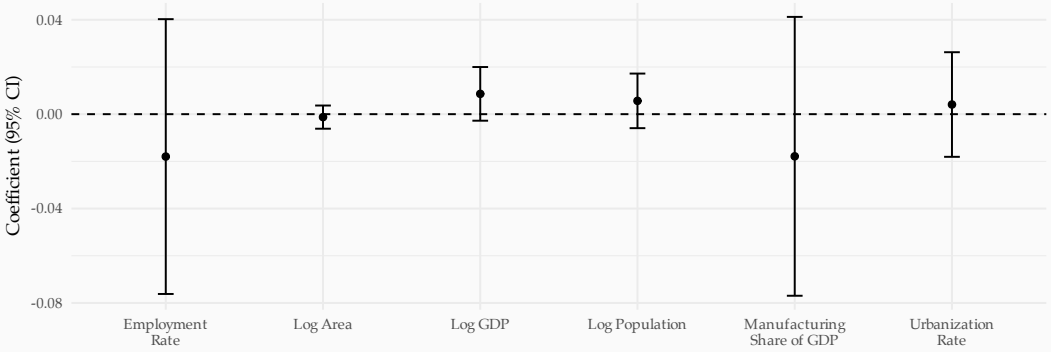
Addressing Endogeneity of Cable Rollout

Distance to BOTAS pipelines and Initial Province Characteristics

▸ Back



Addressing Endogeneity of Cable Rollout

IV Based on Distance from BOTAS Network

- For each province pair, o and d in year t,

$$Z_{od,t} = \max\left\{\overline{\text{Distance}}_o, \overline{\text{Distance}}_d\right\} \times \mathbb{I}(t)$$

- More costly to deploy cables at farther places
- IV negatively correlated with fibre connectivity

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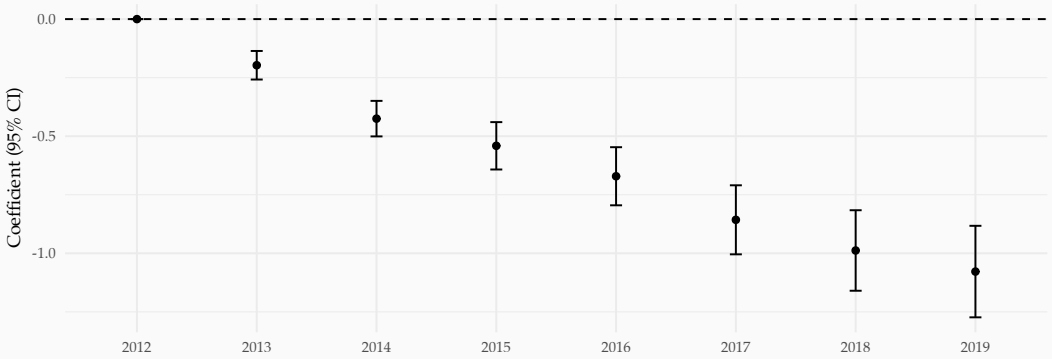
Addressing Endogeneity of Cable Rollout

IV Based on Distance from BOTAS Network: First Stage



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Addressing Endogeneity of Cable Rollout

2SLS ESTIMATES

Dependent Variable:	Cost Share (1)	No. Suppliers (2)	Cost Share HHI (3)	New Connections (4)
Fibre Connectivity	0.498***	0.309***	-0.102***	0.0629***
	(0.0577)	(0.0310)	(0.0139)	(0.0197)
Fixed Effects:				
Buyer × Year	✓	✓	✓	✓
Origin × Year	✓	✓	✓	✓
Origin × Destination	✓	✓	✓	✓
Observations	2,230,473	2,230,473	2,230,473	2,230,473
KP test stat.	31.9	31.9	31.9	31.9

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Impact of Fibre Connectivity on Firms' Input Sourcing

Alternative Connectivity Specification

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Dependent Variable:	Cost Share (1)	No. Suppliers (2)	Cost Share HHI (3)	New Connections (4)
Fibre Connectivity, Alternative	0.255***	0.163***	-0.0534***	0.0316***
	(0.0274)	(0.0148)	(0.00682)	(0.00981)
Fixed Effects:				
Buyer × Year	✓	✓	✓	✓
Origin × Year	✓	✓	✓	✓
Origin × Destination	✓	✓	✓	✓
Observations	2,230,473	2,230,473	2,230,473	2,230,473

Impact of Fibre Connectivity on Firms' Input Sourcing

Source of Variation in Fibre Connectivity

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Dependent Variable:	Cost Share (1)	No. Suppliers (2)	Cost Share HHI (3)	New Connections (4)
Origin Fibre Intensity × Destination Fibre Intensity in:				
2^{nd} Quartile	-0.121	-0.155	0.168	-0.0501
	(0.477)	(0.218)	(0.118)	(0.139)
3^{rd} Quartile	0.213	0.172**	-0.0735*	0.0119**
	(0.173)	(0.0709)	(0.0387)	(0.0463)
4^{th} Quartile	0.519***	0.331***	-0.108***	0.0637***
	(0.0541)	(0.0295)	(0.0137)	(0.0196)
Fixed Effects:				
Buyer × Year	✓	✓	✓	✓
Origin × Year	✓	✓	✓	✓
Origin × Destination	✓	✓	✓	✓
Observations	2,230,473	2,230,473	2,230,473	2,230,473

Impact of Fibre Connectivity on Firms' Input Sourcing

Source of Variation in Fibre Connectivity

Back

Dependent Variable:	Cost Share (1)	No. Suppliers (2)	Cost Share HHI (3)	New Connections (4)
Destination Fibre Intensity × Origin Fibre Intensity in:				
2^{nd} Quartile	-0.267	-0.238	0.0933	-0.139
	(0.443)	(0.123)	(0.209)	(0.143)
3^{rd} Quartile	0.181	0.173**	-0.0483	0.0191
	(0.159)	(0.0695)	(0.0395)	(0.0485)
4^{th} Quartile	0.517***	0.330***	-0.109***	0.0649***
	(0.0549)	(0.0296)	(0.0137)	(0.0192)
Fixed Effects:				
Buyer × Year	✓	✓	✓	✓
Origin × Year	✓	✓	✓	✓
Origin × Destination	✓	✓	✓	✓
Observations	2,230,473	2,230,473	2,230,473	2,230,473

Impact of Fibre Connectivity on Firms' Input Sourcing

Including All Suppliers

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Dependent Variable:	Cost Share (1)	No. Suppliers (2)	Cost Share HHI (3)	New Connections (4)
Fibre Connectivity	0.691***	0.398***	-0.122***	0.145***
	(0.0613)	(0.0338)	(0.0129)	(0.0182)
Fixed Effects:				
Buyer × Year	✓	✓	✓	✓
Origin × Year	✓	✓	✓	✓
Origin × Destination	✓	✓	✓	✓
Observations	3,362,435	3,362,435	3,362,435	3,362,435

Impact of Fibre Connectivity on Firms' Input Sourcing

Controlling for Travel Time

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Dependent Variable:	Cost Share (1)	No. Suppliers (2)	Cost Share HHI (3)	New Connections (4)
Fibre Connectivity	0.288***	0.183***	-0.0653***	0.0530***
	(0.0501)	(0.0255)	(0.0137)	(0.0199)
Fixed Effects:				
Buyer × Year	✓	✓	✓	✓
Origin × Year	✓	✓	✓	✓
Origin × Destination	✓	✓	✓	✓
Observations	2,230,473	2,230,473	2,230,473	2,230,473

Impact of Fibre Connectivity on Firms' Input Sourcing

Placebo Test

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Dependent Variable:	Cost Share (1)	No. Suppliers (2)	Cost Share HHI (3)	New Connections (4)
Cable TV Connectivity	-2.210	-0.375	-0.0624	-0.315
	(1.754)	(0.906)	(0.441)	(0.487)
Fixed Effects:				
Buyer × Year	✓	✓	✓	✓
Origin × Year	✓	✓	✓	✓
Origin × Destination	✓	✓	✓	✓
Observations	2,230,473	2,230,473	2,230,473	2,230,473

Model of Rationally Inattentive Input Sourcing

Technology

- **Production Function**
  [technology consists of labor and multiple input requirements]

$$\text{output}(b) = \text{productivity}(b) \left(\frac{\text{labor}(b)}{1-\alpha} \right)^{1-\alpha} \left(\frac{\prod_{k=1}^{K} \overbrace{\text{task}(b,k)^{\frac{1}{K}}}^{\text{symmetric}}}{\alpha} \right)^{\alpha}$$

$$\text{task}(b,k) = \underbrace{\sum_{s} \text{materials}(s,b,k)}_{\text{substitutes}}$$

  - α, materials share
  - K, # tasks

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Imperfect Information in Supplier Choice

Match Productivity

- Match productivity is stochastic:
  [Fréchet Distribution]

$$\mathbb{P}\left(a(s,b,k) \leq a\right) = \exp\left(-\phi_{od} a^{-\zeta}\right)$$

  - $a(s,b,k)$: match productivity of supplier s for task k
  - ϕ_{od}: match scale parameter for suppliers at o and buyers at d
- Better internet at o and $d \rightarrow$ Stochastically better match productivity

$$\phi_{od} = \exp\left(\bar{\gamma} + \gamma \ln I_{od}\right)$$

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Imperfect Information in Supplier Choice

Information Costs

- Information about marginal costs of potential suppliers is costly [generalized entropy based on Bregman divergence]

$$\text{Information Cost, } \psi(b) = -\bar{\boldsymbol{\pi}}(b) \cdot \log \boldsymbol{S}\left(\bar{\boldsymbol{\pi}}(b)\right) + \mathbb{E}_v\left[-\boldsymbol{\pi}(b) \cdot \log \boldsymbol{S}\left(\boldsymbol{\pi}(b)\right)\right]$$

$$S\left(\pi(s,b)\right) = \lambda_{od} \ln \pi(s,b) + (1-\lambda_{od}) \ln \left(\sum_{s' \in o} \pi(s',b) \right)$$

  - $\boldsymbol{\pi}(b) \equiv \{\pi(s,b)\}_s$ where $\pi(s,b)$ is probability of choosing supplier s
  - $\bar{\boldsymbol{\pi}}(b) = \mathbb{E}_v\left[\boldsymbol{\pi}(b)\right]$ are the choice probabilities based on priors
  - λ_{od}: information cost scale parameter for buyers at d across suppliers at o
- Better internet at o and d $\rightarrow$ information costs are lower

$$\lambda_{od} = \frac{1}{(1 + \eta \ln I_{od})}$$

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Imperfect Information in Supplier Choice

Firm's Problem

- Firm chooses most cost effective supplier subject to information costs

$$\max_{\boldsymbol{\pi}(b,k)} \quad \mathbb{E}_v \left[\sum_s \left(\ln a(s,b,k) - \ln c(s) - \ln \tau_{od} \right) \pi(s,b,k) \right] - \psi(b)$$

$$\text{subject to } \pi(s,b,k) \geq 0$$

$$\sum_s \pi(s,b,k) = 1$$

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Model of Rationally Inattentive Input Sourcing

Nested Logit Choice Probabilities

$$\pi(s,d) = \underbrace{\pi(s \mid o,d)}_{\text{Choice of Supplier within Origin}} \times \underbrace{\pi(o,d)}_{\text{Choice of Origin}}$$

$$\pi(s \mid o,d) = \frac{\bar{\pi}(s \mid o,d)c(s)^{-\zeta/\lambda_{od}}}{\sum_{s' \in o} \bar{\pi}(s' \mid o,d)c(s')^{-\zeta/\lambda_{od}}}$$

$$\pi(o,d) = \frac{\bar{\pi}(o,d)c_o^{-\zeta}\tau_{od}^{-\zeta}\phi_{od}}{\sum_{o'} \bar{\pi}(o',d)c_{o'}^{-\zeta}\tau_{o'd}^{-\zeta}\phi_{o'd}}$$

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Taking Model to Data

Nested Logit Estimation: Sequential Approach

- Choice of Origin Province [**outer nest**]

$$\mathbb{E}\left[\underbrace{\frac{1}{M_d}\sum_{b\in d}\sum_{s\in o}\text{Cost Share}(s,b,t)}_{\text{Average Cost Share}(o,d,t)}\right] = \frac{\exp\left(\delta_{o,t}+\delta_{od}+\gamma\ln I_{od,t}\right)}{\sum_{o'}\exp\left(\delta_{o',t}+\delta_{o'd}+\gamma\ln I_{o'd,t}\right)}$$

- Choice of Supplier within Origin Province [**inner nest**]

$$\mathbb{E}\left[\underbrace{\frac{1}{M_d}\sum_{b\in d}\frac{\text{Cost Share}(s,b,t)}{\sum_{s'\in o}\text{Cost Share}(s',b,t)}}_{\text{Relative Average Cost Share}(s,d,t)}\right] = \frac{\exp\left(\delta_{s,t}+\eta\ln I_{od,t}\times\delta_{s,t}+\delta_{sd}\right)}{\sum_{s'\in o}\exp\left(\delta_{s',t}+\eta\ln I_{od,t}\times\delta_{s',t}+\delta_{s'd}\right)}$$

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Taking Model to Data

Nested Logit Estimation

$$\mathbb{E}\left[\text{Cost Share}(s,b,t)\right] = \pi(s,d)$$

- $\text{Cost Share}(s,b,t) = \frac{\text{Purchases}(s,b,t)}{\sum_{s'} \text{Purchases}(s',b,t)}$
- Estimands: Elasticity w.r.t Fibre Connectivity
  - Match Scale γ
  - Information Cost η

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Inner Nest Elasticity

- Model implies the following specification for the inner nest:

$$\mathbb{E}\left[\sum_{b\in d}\frac{\pi_{od}(s\mid o,b)}{M_d}\right]=\exp\left(-\zeta\ln\tilde{c}_o(s)+\eta I_{od}(-\zeta\ln\tilde{c}_o(s))\right)$$

- $\ln\tilde{c}_o(s)$ is a high-dimensional fixed effect. For feasible estimation, we concentrate it out – make an educated guess by PPML :

$$\widehat{\tilde{c}_o(s)^{-\zeta}}=\sum_{d'\in\mathcal{J}}\sum_{b\in d'}\frac{\pi_{od'}(s\mid o,b)}{M_{d'}}$$

- So, we can run the following Poisson specification :

$$\mathbb{E}\left[\frac{\frac{\sum_{b\in d}\pi_{od}(s|o,b)}{M_d}}{\sum_{d'}\sum_{b\in d'}\frac{\pi_{od'}(s|o,\bullet)}{M_{d'}}}\right]=\exp\left(\eta\ln I_{od,t}\times\ln\left[\sum_{d'}\sum_{b\in d'}\frac{\pi_{od'}(s\mid o,b)}{M_{d'}}\right]\right)$$

Estimation Results

Choice of Origin: Robustness Checks

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Dependent Variable:	Average Cost Share				
	(1)	(2)	(3)	(4)	(5)
Fibre Connectivity	0.344**	0.548***	0.593***		
	(0.147)	(0.122)	(0.119)		
(Alternative) Fibre Connectivity				0.297***	
				(0.059)	
Cable TV Connectivity					0.150
					(0.124)
Fixed Effects:					
Origin×Year	✓	✓	✓	✓	✓
Destination×Year	✓	✓	✓	✓	✓
Origin×Destination	✓	✓	✓	✓	✓
Controls:					
Travel Time ×Year	✓				
Diff. in GDP p.c.		✓			
Mobile Connectivity			✓		
R^2	0.994	0.994	0.994	0.994	0.984
Observations	45,504	45,504	45,504	45,504	45,504

Estimation Results

Choice of Supplier within Origin

Dependent Variable:	Relative Average Cost Share	
	(1) PPML	(2) PPML:CF
Fibre Connectivity × Seller×Year FE	0.007*** (0.002)	0.007*** (0.003)
Fixed Effects:		
Seller×Year	✓	✓
Seller×Destination	✓	✓
R^2	0.684	0.678
Observations	72,233,694	72,233,694

Welfare Effects of High-Speed Internet Infrastructure

Computation of Counterfactual Outcomes

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For any change in aggregate state, equilibrium change in wages $\widehat{\boldsymbol{w}} \equiv \{\widehat{w}_d : d \in \mathcal{J}\}$ and welfare $\widehat{\boldsymbol{V}} \equiv \left\{\widehat{V}_d : d \in \mathcal{J}\right\}$ are characterized by:

$$\widehat{A}_d = \sum_o \pi_{od} \widehat{\tau_{od}}^{-\zeta} \widehat{\phi_{od}} \widehat{w}_o^{-\zeta(1-\alpha_o)} \widehat{A}_o^{\alpha_o}$$

$$\widehat{\pi_{od}} = \frac{\widehat{\tau_{od}}^{-\zeta} \widehat{\phi_{od}} \widehat{w}_o^{-\zeta(1-\alpha_o)} \widehat{A}_o^{\alpha_o}}{\widehat{A}_d}$$

$$\frac{\widehat{w}_o w_o L_o}{1-\alpha_o} = \sum_d \widehat{\pi_{od}} \pi_{od} \frac{\widehat{w}_d w_d L_d}{1-\alpha_d}$$

$$\widehat{V}_d = \widehat{w}_d \widehat{A}_d^{\frac{1}{\zeta}}$$

where $\widehat{\boldsymbol{\delta}} \equiv \left\{\widehat{\delta}_{od} : (o,d) \in \mathcal{J}^2\right\}$ is function of shocks that capture the resultant effect of change from σ_0 to σ_0'.

Comparison with Transportation Infrastructure Improvements

Road Network in 2005 and 2010

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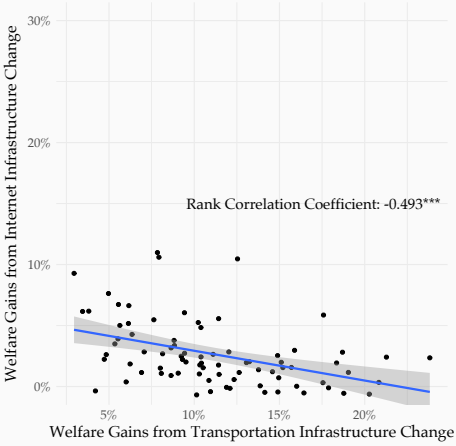
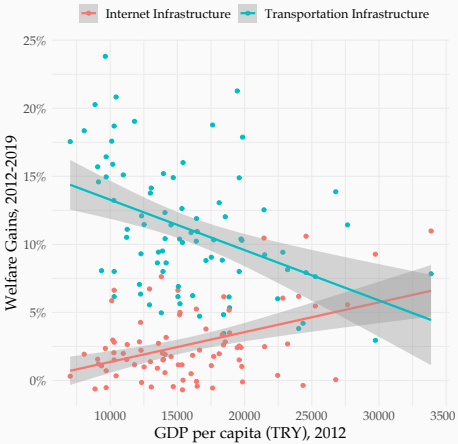
Welfare effects of high-speed internet vs transportation infrastructure: Excluding Istanbul





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