European Bank
for Reconstruction and Development

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

Banu Demir, Beata Javorcik, Piyush Panigrahi

Abstract
This paper explores how improved internet infrastructure impacts supply chains and economic activity, focusing on Türkiye. Using the expansion of fiber-optic networks and firm-to-firm transaction data, we find that better connectivity shifts input sourcing to well-connected regions and diversifies supplier networks. We estimate a spatial equilibrium model with endogenous network formation and rational inattention and find that high-speed internet reduced information acquisition and communication costs. Enhanced connectivity increased real income by 2.2% in the median province. Our findings underscore the importance of digital infrastructure investments in fostering economic growth by improving supply chain efficiency and broadening firms' access to suppliers.

Keywords: Supply chain networks, internet infrastructure, firm-to-firm trade.

JEL classification numbers: L14; O33; R12

Contact details: Banu Demir is a Professor of Economics at Oxford University. Beata Javorcik is Chief Economist at EBRD and Professor of Economics at Oxford University (email: javorcib@ebrd.com). Piyush Panigrahi is an economist at the International Finance Corporation.

Working Paper No 299 **Prepared in January 2025**

1 Introduction

Technological progress has made communication faster, more convenient, and more accessible, allowing people to connect with others in ways that were previously impossible. The availability of high-speed internet enabled remote face-to-face meetings among participants from multiple locations, exchanging large files, or simultaneous working on data located on shared drives or in the cloud. Teams consisting of people working for different companies and located in different places can seamlessly collaborate facilitating business-to-business transactions, exchange of information and troubleshooting, joint design, electronic billing, etc. Around the world, governments and multilateral development banks see digitalization, including investment in high-speed internet connectivity, as a powerful tool for promoting economic growth and development.

This paper studies empirically and theoretically the effects of the rollout of fast and reliable internet access on input sourcing and hence economic growth across space. To the best of our knowledge, it is the first study using microdata on firm-to-firm transactions to assess the impact of ICT infrastructure improvements on firms' input sourcing patterns and quantifying the resulting welfare gains in a general equilibrium setting. It is also the first study quantifying the contribution of two distinct channels affected by communications infrastructure: the cost of acquiring information about potential suppliers and the cost of communications in the course of running business operations.

Our study is based on the empirical context of Türkiye, a country that has invested heavily in high-speed internet infrastructure and significantly expanded its optical fiber cable network between 2012 and 2019. Leveraging extensive microdata on firm-to-firm transactions and the deployment of optical fiber cables across Turkish provinces, we find that firms exhibit a stronger propensity to acquire inputs from regions with superior internet connectivity. Further, firms diversify their input sourcing by engaging with a larger number of suppliers and distributing their sourcing more equitably among suppliers located in provinces with improved internet connectivity. We rationalize these findings with a spatial equilibrium model that incorporates rationally inattentive input sourcing by firms. We structurally estimate the model and show that internet connectivity not only reduces the cost of obtaining information about potential suppliers but also reduces costs of synchronous communication with suppliers. Using the estimated model, we further show that the gains from improvement in the high-speed internet infrastructure in real income amount to 2.2% in the median Turkish province with comparable contribution of both channels.

Our analysis centers around the construction of an extensive administrative microdata set from Türkiye, which comprises the following key components: i) microdata covering a quasi-comprehensive set of firm-to-firm transactions, complemented by essential firm characteristics such as location (province) and industry of operation, along with balance sheet information including gross sales, employment figures, and wage information, obtained from the Ministry of Industry and Technology, spanning the period of 2012 to 2019; ii) province-level data on fiber cable length for 2012 to 2019, obtained from the Information and Communication Technologies Authority; and iii) the GIS database of information on the BOTAS natural gas and oil pipeline network, which serves as the backbone for the optical fiber cable network.

Armed with this database, the analysis proceeds in two parts. In the first part, we provide empirical evidence on the effect of the roll-out of optical fiber cables on firms' input sourcing at across Turkish provinces. The roll-out of optical fiber cables across Türkiye over 2012-2019 was staggered across provinces albeit with a secular increase in the length of optical fiber cables rolled out in the median province. The roll-out of cables was accompanied by uniform adoption of high-speed internet by firms across all sectors. In this context, our empirical strategy aims to use the temporal variation in high-speed internet access across the cross-section of Turkish provinces to capture the effects on firms' input sourcing both across provinces and within provinces across individual suppliers. To do so, we postulate that to engage in high-quality communication and remote collaboration, both parties require access to high-speed internet. Using data on the length of optical fiber cables rolled out, we construct bilateral measures of internet connectivity across pairs of Turkish provinces for each year that captures this complementarity between internet speeds at both provinces.

In reduced form regressions, the identifying assumption is that the higher proximity to the optical fiber network does not affect input sourcing of firms at a destination province from an origin province except through their effect on better internet connectivity at both provinces. We assess the validity of this assumption in several ways. We report how point estimates are affected by the inclusion of a variety of controls across origin-destination province pairs, both time-varying and time-invariant, as well as by using alternative specifications of our bilateral measure. To address concerns that the roll-out of optical fiber cables was correlated with province pairs which were predisposed to trade more a priori, we employ estimation using instrumental variables.

Our instrumental variable is motivated by the context in which Türkiye's massive expansion of optical fiber network occurred starting late 2011. On October 3, 2011, the government made a significant decision regarding fiber access services, stipulating their exemption from regulations for a span of five years or until the proportion of fiber internet subscribers reached 25% of the fixed broadband subscriber base. The ensuing growth in optical fiber network was facilitated by the government's decision to grant private internet providers the authority to utilize optical fiber cables laid out by BOTAS, the local natural gas and oil distributor in Türkiye, to connect to farther locations. Optical fiber cables are typically laid out along with oil and gas pipelines to enable close monitoring and detection of faults. The BOTAS optical fiber network was laid out for pipeline monitoring before the expansion was set in motion. Since the BOTAS network was not laid out to facilitate internet connectivity across provinces, we are able to exploit plausibly exogenous variation in the distance of individual districts in Türkiye to the BOTAS network to construct our instrument for internet connectivity.

Using this design, we find that better internet connectivity has strong and significant positive effects on input sourcing by firms at a destination province from an origin province. That is, firms reallocate their input purchases towards provinces with better internet connectivity. Furthermore, they diversify their input sourcing by engaging with more suppliers and sourcing more equitably across suppliers, conditional on the reallocation across origins.

In the second part of the paper, we shed light on the aggregate implications through a quantitative spatial equilibrium model featuring endogenous formation of input-output linkages between firms under rational inattention. We build on the theoretical framework developed in Oberfield (2018) and Panigrahi (2022), and extend it in several dimensions to capture economic forces that are relevant in our context. In the model, firms' production processes consist of multiple input requirements, and firms select the most attractive suppliers for their production requirements. However, firms operate with imperfect information regarding the attractiveness of potential suppliers. A potential supplier is considered more attractive if it (a) possesses a higher match-specific productivity with the buyer, (b) has lower production costs, and (c) is geographically closer thus implying lower trade costs. Acquiring information about potential suppliers is costly. The firm is only privy to the distribution from which match-specific productivities are drawn and does not know the marginal cost of potential suppliers. However, it can opt to invest attention resources to gather information about potential suppliers, akin to the approach employed by Dasgupta and Mondria (2018). The presence of internet connectivity influences both the cost of information acquisition and the cost of communication within buyer-supplier pairs. Where both origin and destination provinces have relatively better internet connectivity, costs of gathering information are lower and match-specific productivities are being drawn from a stochastically better distribution in a first-order sense. The former implies that firms diversify their supplier base more extensively in provinces with superior internet access, while the latter implies that firms reallocate their input purchases towards provinces with better internet connectivity.

To quantify these forces, we estimate the model parameters, and calibrate the model to the 2012 Turkish economy as a reference equilibrium. In particular, we estimate the elasticity of firm-to-firm trade with respect to internet connectivity using an approach that combines model-based maximum likelihood with the exclusion restrictions of our IV through control functions. We find that the estimated elasticities are statistically significant. This indicates that improved fiber connectivity reduces both communication and information acquisition costs.

Armed with the calibrated model, we proceed to explore general equilibrium counterfactuals. We find that better access to high-speed internet led to a 2.2% annualized increase in real income in the median Turkish province. This gain is driven by a dual mechanism: improved internet connectivity lowers information costs, enabling firms to assess and engage with a wider range of suppliers, and reduces communication frictions, promoting smoother interactions and transactions over long distances. Our paper is the first study assessing the welfare gains resulting from ICT infrastructure improvements in a general equilibrium setting, incorporating granular data on the domestic production network. It is also the first study focusing on the two distinct channels.

Our paper contributes to several strands of literature. First, it is closely related to the literature examining the impact of internet on various economic outcomes (see Hjort and Tian (2024) for a comprehensive review), especially international trade. In a cross-country study, Freund and Weinhold (2004) find that increase in the number of web hosts led to export growth. Fernandes, Mattoo, Nguyen, and Schiffbauer (2019) show evidence that internet roll-out in China increased firm-level exports, while Malgouyres, Mayer, and Mazet-Sonilhac (2021) use the staggered roll-out of broadband internet in France to show its positive effect on firm-level imports. Hjort and Poulsen (2019) find evidence of a notable increase in direct exports when submarine internet cables reach Africa. Exploiting the roll-out of the global telegraph network, Juhász and Steinwender (2018) show evidence that improvements in ICT increased trade in intermediates whose specifications can easily be communicated at a distance. In another study, Akerman, Leuven, and Mogstad (2022) exploit the roll-out of broadband internet in Norway and show that availability of internet increases the sensitivity of trade to distance. Jiang (2023) finds that firms that adopt more advanced technology have both higher within-firm communication and larger geographic coverage. We contribute to this literature by highlighting the importance of bilateral communication costs working through two distinct channels and by showing that access to fast internet enhances firms' ability to access a wider variety of inputs also within national borders. Unlike the other studies, we rely on a quasi-universe of firm-to-firm transactions.

Second, our paper is related to the literature that studies the propagation of shocks in production networks (Acemoglu, Carvalho, Ozdaglar, and Tahbaz-Salehi (2012); Baqaee and Farhi (2019, 2024, 2020); Bigio and LaO (2020); Demir, Javorcik, Michalski, and Ors (2024b)), and in particular ones that model endogenous formation of production networks (Chaney (2014); Lim (2018); Oberfield (2018); Huneeus (2020); Acemoglu and Azar (2020); Demir, Fieler, Xu, and Yang (2024a); Eaton, Kortum, and Kramarz (2022); Bernard, Dhyne, Magerman, Manova, and Moxnes (2022); Panigrahi (2022); Miyauchi (2023); Arkolakis, Huneeus, and Miyauchi (2023)). Our contribution extends the framework outlined in Panigrahi (2022) in two crucial ways. First, we introduce match-specific productivities among buyer-seller pairs that can stochastically vary contingent on the availability of high-speed internet access between the provinces where these firms are located. Second, we incorporate rationally inattentive behavior into firms' decisions regarding input sourcing. This means that firms endogenously determine the amount of information to acquire, with information acquisition costs being lower for province pairs with better internet connectivity.

Third, our paper is also related to papers studying information frictions in trade models. Rauch and Trindade (2003) augment a conventional trade model with informational trade barriers to demonstrate how the Internet and other ICT technologies can enhance the compatibility of international trade partners. This, in turn, leads to a greater integration of labor markets. In a similar vein, Allen (2014) introduces information frictions into a trade model, positing that diverse producers undertake a costly, sequential search process to determine optimal markets for their goods. His findings suggest that information frictions play a crucial role and help explain observed trading patterns in empirical data. Dickstein and Morales (2018) provide evidence that exporters operate without complete information sets, with larger firms possessing superior knowledge of foreign market conditions. They observe that improved access to information leads to an increase in total exports, even as the number of exporters decreases. Meanwhile, Dasgupta and Mondria (2018) endogenize information within a trade model, revealing that information costs exert non-monotonic and asymmetric impacts on bilateral trade flows. Our model is closest in this literature to Dasgupta and Mondria (2018) in that we introduce information costs and rationally inattentive behavior in firms' input sourcing decisions but extend the formulation of information costs to allow for more flexible patterns of substitution across suppliers.

Finally, our paper contributes the growing literature on market integration (Bernard, Moxnes, and Saito (2019, 2020); Donaldson (2015, 2018); Cristea (2011)) in quantitative spatial economics (Allen and Arkolakis (2014); Redding (2016); Caliendo, Parro, Rossi-Hansberg, and Sarte (2017a); Redding and Rossi-Hansberg (2017); Redding (2022); Cosar, Demir, Ghose, and Young (2021)). While this literature has focused on the impact of technology and transportation cost shocks on the spatial economy, we utilize the broader framework to assess the quantitative impact of reduction in communication costs due to high-speed internet access on the spatial distribution of economic activity. Cristea (2011), Bernard, Moxnes, and Saito (2019), and Bernard, Moxnes, and Saito (2020) show that lower transportation costs facilitate creation of new business relationships. Our contribution lies in demonstrating that access to fast internet connections can have similar effect on facilitating firm-to-firm interactions as lower transport costs.

The remainder of the paper proceeds as follows. Section 2 describes the background of optical fiber cable rollout in Türkiye and the data. Section 3 presents the empirical evidence on the effects of fiber cable rollout on firms' input sourcing patterns. Section 4 describes our model of input sourcing under rational inattention. Section 5 describes our estimation framework, presents results of structural estimation and quantitative assessment of the effects of optical fiber cable roll-out in Türkiye. Section 6 concludes.

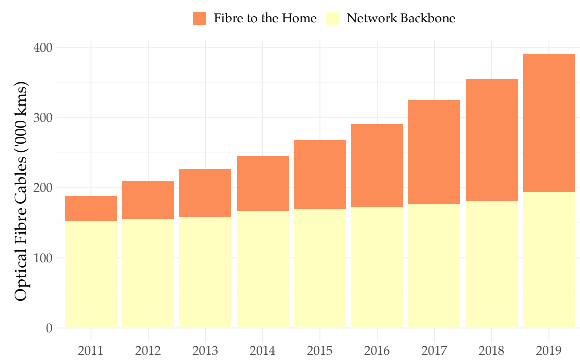
2 Background & Data

2.1 Rollout of Fiber Optic Infrastructure in Türkiye

Prior to 2010, Türkiye's internet infrastructure was extensive but had limited speed. In 2011, Türkiye's Information and Communication Technologies Authority (ICTA) decided not to regulate the incumbent fixed operator, Turk Telekom, for a period of five years or until fiber subscribers represented less than 25% of total fixed broadband subscribers. Turk Telekom agreed to offer wholesale access (Re-sale and Bit-Stream Access) to its fiber network under equal and non-discriminatory conditions. Additionally, to protect the rights of competing ISPs, ICTA mandated that Turk Telekom continue providing wholesale services on its existing network in areas undergoing fiber transition.

During the following eight years, from 2011 to 2019, the fiber network expanded extensively, covering a remarkable distance of 390.8 thousand kilometers, equivalent to an impressive 0.48 kilometers per square kilometer of land area. This remarkable growth was facilitated by the government's decision to grant private internet providers the authority to utilize the existing fiber cables owned by BOTAS, the local natural gas and oil distributor. This played a pivotal role in accelerating the rollout of fiber connectivity across the country. Figure 1 shows that the length of optical fiber cables rolled out in Türkiye almost doubled from 2012 to 2019. It also shows that investment in fiber optic infrastructure was primarily directed towards rolling out fiber internet to farther locations (i.e. fiber to the home, FTTH) and less towards the backbone of the fiber optic network. Figure 2 shows that, between 2012 and 2019, not only has the number of subscribers (both households and firms) to

Figure 1: **Optical Fiber Cable Roll-out in Türkiye**



Note: This figure depicts the roll-out of optical fiber cables and its breakdown between the backbone of the network and peripheral fibers laid to reach farther locations (fiber to the home) across Turkish provinces during the period 2012-2019. It is based on data obtained from the ICT Authority in Türkiye. Over 2012-2019, the length of optical fiber cables rolled out increased by 85% with the network backbone increasing by 33% and that of cables rolled out to expand the network increasing by 375%

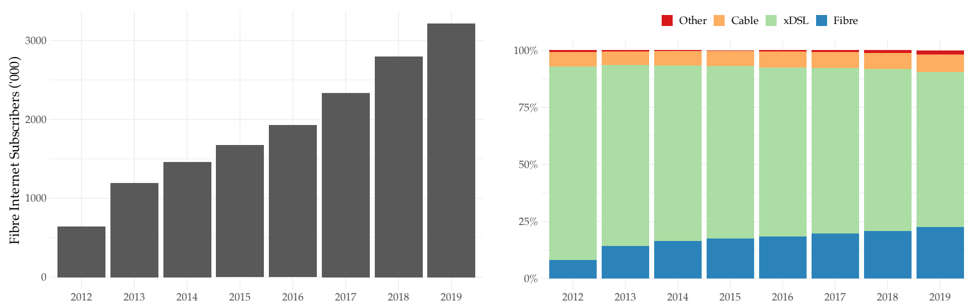
fiber internet lines increased fivefold, but their share in all fixed broadband connections has also been steadily rising. As of 2020, the fiber internet lines accounted for 23.9% of all fixed broadband connections in Türkiye, converging to the OECD average of 30.6%.

2.2 Data

This subsection provides a brief overview of the main datasets used in the analysis. We combine data from multiple sources. Broadly, they fall into four categories: (a) data on firm-to-firm transactions and other firm-level outcomes, (b) data relating to internet availability and usage across Turkish provinces, (c) regional economic data, (d) other data.

Firm-to-Firm Trade & Firms' Balance Sheet Data We combine three data sets covering all formal firms in Türkiye from 2012 through 2019. The Ministry of Industry and Technology (MoIT) in Türkiye maintains all the data sets and uses the same firm identifier, allowing us to merge them. The data sets are as follows. First, the VAT data report the value of all domestic firm-to-firm trade that exceeds 5,000 Turkish liras (about US$840 in 2019) in a given year. Second, from the income statements, we use the yearly gross sales, employment, and wage bill of each firm. Third, from the firm registry, we extract each firm's province and 4-digit NACE code, the stan-

Figure 2: **Fiber Internet Subscribers**



Note: The left panel depicts the evolution of the number of fiber internet subscribers in Türkiye during the period 2012-2019. The right panel shows the breakdown of fixed broadband connections into fiber, xDSL, Cable TV and others. Over 2012-2019, not only did the number of subscribers increase five-fold, but the share of broadband subscriptions due to fiber internet also increased.

dard industry classification in the European Union. The full sample consists of about 1.5 million unique firms operating in 494 distinct industries and forming a network of over 27 million business links.

We restrict the analysis to firms in the manufacturing sector, covering 226 four-digit NACE codes, unless otherwise noted. The baseline sample has just under 265,000 unique firms, forming a network of about 4 million business links. On average, each buyer has 9.3 suppliers, with 4.7 suppliers per buyer-origin province.

Regional Economic Data We obtain data on economic outcomes such as sectoral GDP, population, employment rate, urbanization rate etc from TUIK both at the province and district level. Türkiye has 81 provinces which are further subdivided into 973 districts. We use this data as controls for spatial and temporal variation in province and district characteristics.

High-Speed Internet Data For the period 2012-2019, we have province-level information on length of optical fiber cables rolled out as well as number of fixed broadband, mobile and cable TV subscribers. The data is obtained from the Information and Communication Technologies Authority (ICTA) in Türkiye. We use data on cable roll-out to construct measures of fiber internet connectivity across province-years.[1]

[1] We use data on cable TV subscriptions to construct a measure of cable TV connectivity across province-years in a falsification exercise as discussed later in Section 3.

Other Data We digitize the map of BOTAS' oil and gas pipeline network in 2011 which also forms the backbone of the optical fiber network. Using this GIS data, we measure distance of Turkish districts to the pipeline network to construct our instruments for fiber connectivity. We also obtain the GIS database of the road network in Türkiye to measure travel times between Turkish provinces in 2005 and 2010 (as in Cosar et al. (2021)). We use travel time data as a control variable in some of our empirical specifications.

For the period 2012-2019, we have micro-level data on ICT usage by businesses from a survey conducted annually by the Turkish Statistical Institute (TUIK) since 2005. The survey includes approximately 10,000 firms annually, comprising all firms with over 250 employees and a representative sample of smaller firms. We use the survey data on ICT usage to assess firm-level adoption of high-speed internet which is defined as connections with internet speeds exceeding 100Mbps.

For a shorter period 2016-2019, we also obtain data on upload and download speeds across finer locations in Türkiye which we aggregate to the province-level to concord with the rest of the analysis. This data is obtained from Ookla, a private internet speed testing firm.

2.3 Spatial Variation in Fiber Internet Rollout

To capture spatial variation in roll-out of fiber optic infrastructure across Turkish provinces and years, we construct a measure of fiber intensity for each province and year. In particular, we measure fiber intensity as the length of fiber optic cables rolled out in a province normalized by its land area. Formally, for a province d in year t, fiber intensity $I_{d,t}$ is calculated as:

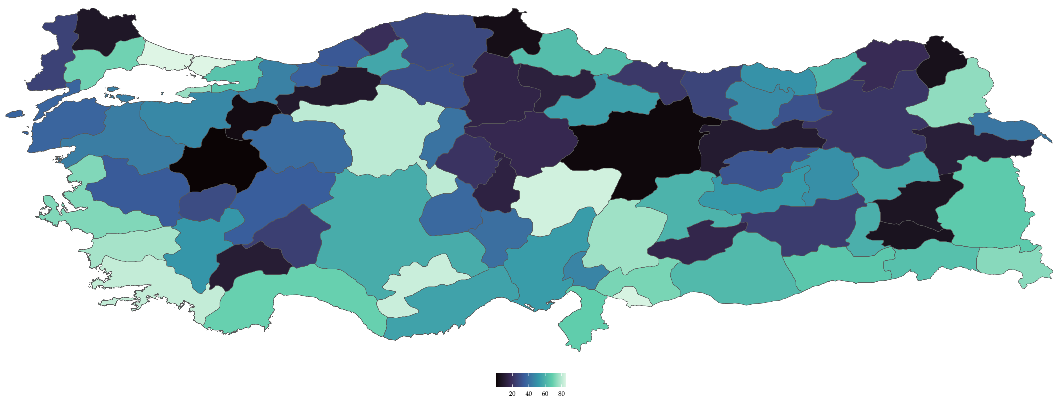
$$I_{dt} = \ln\left(1 + \frac{L_{dt}}{A_d}\right),$$

where L_{dt} denotes the length of optical fiber cables (in kms) rolled out in province d in year t and A_d is the surface area of the province (in km^2). Figure 3 depicts the change in fiber intensity across Turkish provinces between 2012 and 2019.[2]

We assess whether more fiber optic cables translate to better internet connectivity in Turkish provinces. To do so, we obtain upload and download speeds reported

[2]Figure A1 shows the annual variation in the length of optical fiber cables rolled out and the corresponding fiber intensity.

Figure 3: **Change in Optical Fiber Length**



Note: This figure depicts the spatial variation in optical fiber cable roll-out across Turkish provinces during the period 2012-2019. The median Turkish province saw a 68% increase in optical fiber roll-out, with a maximum of 177% for Istanbul and a minimum of 31% for Kutahya.

across provinces for years 2016-2019. Figure A2 shows that change in our measure of fiber intensity correlates positively with both upload and download speeds.

2.4 Fiber Internet Adoption by Firms

The roll-out went hand-in-hand with high take-up by firms. Figure A3 shows that the share of firms with high-speed internet followed the trend in roll-out and increased drastically since 2011.[3] The fraction of firms with high-speed internet increased from zero in 2011 to about 30% by the end of 2019.

To investigate how strongly adoption responded to the roll-out of fiber internet, we estimate the following equation for the 2012-2019 period:

$$\text{Adoption of High-Speed Internet}_{ft} = \gamma I_{dt} + \alpha_d + \alpha_{st} + \text{Size}_{ft} + e_{ft} \tag{1}$$

where the dependent variable takes on the value one if firm f adopts high-speed

[3] We consider a firm to have access to high-speed internet if it reports internet speed over 100Mbps in the ICT Survey.

internet in year t, and zero otherwise. The specification controls for firm size in terms of employment and includes province as well as sector-year fixed effects.[4] In Table A1, column (1), the parameter of interest, which captures the adoption rate by firms, is positive and statistically significant, suggesting that firms adopted high-speed internet as it became available in their provinces. The magnitude of the estimate implies that a 1 percent increase in fiber cable length to area is associated with a 0.017 percentage-point increase in the share of firms with high-speed internet access, which corresponds to a 8.7 percent increase relative to the mean value the dependent variable over the sample period.

In column (2), we estimate the effect of the availability of high-speed internet on firm-level adoption by sector. The results imply that firm-level adoption of high-speed internet as a response to its availability does not vary significantly across sectors.

3 Empirical Evidence

Türkiye witnessed a massive investment in fiber optic infrastructure during 2012-2019. This resulted in staggered roll-out of optical fiber cables across Turkish provinces. In this context, our aim is to exploit both temporal and cross-sectional variation in fiber connectivity across province pairs to capture the consequences of high-speed internet access on input sourcing patterns and hence supply chain organization across Turkish provinces. This section uses the datasets described above to estimate the effects of high-speed internet access on the spatial distribution of firms' intermediate input purchases.

3.1 Why Fiber Infrastructure Matters

Fiber-optic internet is often considered superior to other broadband technologies like DSL (Digital Subscriber Line) or cable internet for several reasons. First, fiber internet offers faster download and upload speeds compared to many other broadband technologies. It can provide symmetrical speeds, meaning the upload speed is as fast as the download speed. This makes fiber-optic internet ideal for bandwidth-intensive activities like high-definition streaming and large file transfers. Second,

[4] Sectors are aggregated from 2-digit NACE industries as listed in the second column of Table A1.

fiber-optic connections generally have lower latency compared to some other broadband options. Low latency is crucial for real-time applications like video conferencing, as it reduces delays and lag in communication. Third, fiber-optic cables are less susceptible to interference from electrical and radio frequency sources, making them more reliable than some other broadband technologies, especially in areas with high levels of electromagnetic interference. Finally, fiber internet offers a more consistent and reliable speed experience compared to other technologies like DSL or cable. While internet speed with DSL or cable may be influenced by factors like distance from the provider's equipment or network congestion, fiber provides a more stable and predictable performance.[5]

For synchronous communication to work effectively, whether it is in the form of a video call, voice call, online chat, or any other real-time interaction both parties typically require a good internet connection. Synchronous communication involves the exchange of data in real-time. A stable and sufficiently fast internet connection is necessary to transmit this data smoothly. A good internet connection ensures that messages or signals are sent and received promptly. With a poor connection, there can be delays in sending and receiving messages, audio dropouts, video stuttering, which can disrupt the flow of conversation and make it less effective. A weak or unreliable connection can also lead to disconnects, dropped calls, or interrupted chats, which can be frustrating and disruptive to the communication process. Different forms of synchronous communication have varying bandwidth requirements. For example, video calls and high-quality voice calls require more bandwidth than text-based chat. If one party has limited bandwidth, it may struggle to handle the data requirements of the chosen communication method, leading to a suboptimal experience. For smooth and effective synchronous communication, both parties should ideally have good internet connections. Based on this rationale, we construct a bilateral measure of connectivity across Turkish province pairs o and d that aims to capture this strong complementarity of internet speed in both provinces. In particular, we proxy for fiber connectivity between provinces as the minimum of fiber intensity between both provinces, that is,

$$\text{Fiber Connectivity } I_{o,d,t} = \min\{I_{o,t}, I_{d,t}\}$$

[5] According to a survey conducted by *Which* magazine among 3,000 participants, 63% reported faster speeds, 49% experienced fewer connection dropouts, and 39% reported fewer prolonged outages.

where $I_{p,t}$ is a measure of fiber intensity in province p in year t. Figure A4 shows the change in bilateral fiber connectivity across province pairs over the 2012-2019 period.

3.2 Empirical Strategy

To estimate the effect of fiber connectivity on firms' input sourcing strategy across province pairs over time, we estimate the following baseline specification:

$$\ln y_{o,b,t} = \beta \ln \text{Fiber Connectivity}_{o,d(b),t} + \alpha_{b,t} + \alpha_{o,t} + \alpha_{o,d(b)} + \alpha' X_{o,d,t} + \epsilon_{o,b,t} \tag{2}$$

where o indexes origin provinces, b indexes buyer firms, $d(b)$ indexes destination province where b is located and t indexes years. In our baseline specification, we regress origin-buyer-year level outcomes $y_{o,b,t}$ on our bilateral measure of fiber connectivity, buyer-year fixed effects, origin-year fixed effects, and origin-destination fixed effects. To address concerns about auto-correlated error terms for the same province pair over time, we cluster standard errors two-way at the origin and destination level. After reporting the reduced-form estimation results, we then estimate IV point estimates using an instrument for fiber connectivity. Subsequently, to account to the substantial number of zero observations at the origin-buyer-year levels, we estimate the specification using PPML and also report point estimates obtained via a control function approach to address endogeneity concerns. The identifying assumption in specification (2) is that length of fiber cable rolled out affect buyer-origin level outcomes relative to other buyer-origin pairs only through their effect of internet connectivity from fiber internet. To assess this assumption, as we discuss in detail below, we also report a number of additional robustness checks as part of the reduced-form and IV estimation.

3.3 Reduced-Form Estimation

Reallocation across Origins We begin by estimating the effect of improvements in fiber connectivity on firms' input sourcing strategy across provinces. To do so, for each buyer firm and year, we compute the share of its material costs that is due to purchases from suppliers from each origin province in that particular year. Using data on firm-to-firm transactions that we obtain from the Ministry of Industry and Technology in Türkiye, the cost share of a firm b located in province d due to purchases from suppliers at province o in year t is calculated as:

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

where Purchases(s,b,t) denotes the value of purchases by firm b from supplier s.

We estimate specification (2) with these cost shares on the left-hand side. Table 1 Panel A, column (1) presents the reduced-form results. We find that the effect of fiber connectivity on cost share from origin is positive and statistically significant at the 1% level. This implies that Turkish firms sourced inputs relatively more from provinces for which fiber connectivity improved.

Diversification across Suppliers within Origins To further investigate the effect of fiber connectivity on input sourcing, we explore the effect of fiber connectivity on input sourcing across suppliers within an origin province. We consider three outcomes. First, we estimate the effect of fiber connectivity on the number of suppliers at province o that firm b in province d sources from in year t. Table 1 Panel A, column (2) reports the reduced-form results. We find that fiber connectivity between provinces o and d has a positive and statistically significant positive effect on the number of suppliers that b engages with in o.

Second, we estimate the effect of fiber connectivity on the concentration of input purchases across suppliers within an origin province. To do so, for each buyer firm and year, we compute the Herfindahl-Hirschmann index of its share of material costs that is due to purchases from suppliers from each origin province in that particular year. In particular, the cost share HHI of a firm b located in province d due to purchases from suppliers at province o in year t is calculated as:

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

We estimate specification (2) with these cost share HHIs on the left-hand side. Table 1 Panel A, column (3) presents the reduced-form results. We find that the effect of fiber connectivity on cost share HHI from origin is negative and statistically significant at the 1% level.

Finally, we estimate the effect of fiber connectivity on the number of new connections that a firm makes at an origin province in a given year relative to the year before. Table 1 Panel A, column (4) presents the reduced-form results. We find the effect to be positive and statistically significant at the 1% level.

These results imply that not only do Turkish firms reallocate their input purchases towards provinces with better internet connectivity but they also diversify their input sourcing strategy conditional on reallocation. They source from more suppliers and do so more equitably across suppliers.

Table 1: **Reallocation and Diversification in Input Sourcing**

Dependent Variable:	Cost Share (1)	No. Suppliers (2)	Cost Share HHI (3)	New Connections (4)
Panel A: OLS				
Fibre Connectivity	0.510***	0.325***	-0.107***	0.0632***
	(0.0549)	(0.0297)	(0.0136)	(0.0196)
Panel B: 2SLS				
Fibre Connectivity	0.498***	0.309***	-0.102***	0.0629***
	(0.0577)	(0.0310)	(0.0139)	(0.0197)
KP test stat.	31.9	31.9	31.9	31.9
Fixed Effects:				
Buyer×Year	✓	✓	✓	✓
Origin×Year	✓	✓	✓	✓
Origin×Destination	✓	✓	✓	✓
Observations	2,230,473	2,230,473	2,230,473	2,230,473

Note: Each observation pertains to a buyer firm, an origin province and a year. All variables are in natural logarithms. Cost Share is the fraction of purchases of a buyer from the origin province. No. Suppliers is the number of suppliers of the buyer firm located in a given origin province. Cost Share HHI is the Herfindahl-Hirschman Index of cost shares of suppliers of a buyer, which are located in a given origin province. New Connections is the number of new suppliers relative to the year before. * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at origin and destination level, are reported in parentheses.

Robustness Checks Table 1 Panel A documents strong effects of fiber connectivity on firms' spatial distribution of input purchases captured by cost share from origin, number of suppliers, cost share HHI across provinces. One potential concern is that other correlated factors that simultaneously affect fiber connectivity and firms' input sourcing might affect our estimates. We subject our estimates in Table 1 to a battery of robustness checks.

With the inclusion of buyer-year, origin-year, and origin-destination fixed effects, any potential threat to identification would come from time-varying factors pertaining to an origin-destination pair. In Table A2, we include (a) absolute difference in GDP per capita at origin and destination to account for the fact that similar provinces are likely to trade more and (b) mobile connectivity between origin and destination provinces to account for other forms of connectivity that might make it more likely for origin and destination provinces to trade more. The results show that our baseline estimates are robust to omission of such variables.

In Table A3, we use an alternative measure of fiber connectivity computed as the negative absolute difference of fiber intensity at origin and destination provinces. We find that the coefficients are still statistically significant and of the same sign as the baseline estimates. In Table A4 we conduct a placebo test where we replace our fiber connectivity variable with the minimum value of the ratio of cable TV subscribers per capita at origin and destination. While both require similar infrastructure, cable TV does not provide direct benefits to firms. To the extent that our results reflect the adoption of high-speed internet by businesses rather than improvements in regional infrastructure over the sample period, the extent of cable TV subscription should not affect trade-related outcomes. The results confirm our conjecture. In Table A5, we also include purchases from non-manufacturing suppliers and find that our results still hold in sign and statistical significance.

In Table A6, we look into the source of variation in our bilateral connectivity measure. Our measure is dominated by the trade partner whose fiber connectivity is of lower quality than the other. Therefore, we expect that improvements in fiber connectivity of a trade partner have an effect on our bilateral connectivity measure when the other trade partner's connectivity measure is in the higher quartiles of the respective distribution. The results presented in Table A6 confirm our predictions.

In addition to the analysis presented here, we present further robustness results in the IV estimation that follows.

3.4 IV Estimation

One potential concern is that FTTH predominantly reached economically attractive locations or locations that are predisposed to trade more a priori. To address this, we employ instrumental variables estimation.

Construction of IV Our choice of instrumental variable is driven by the context in which Türkiye witnessed a substantial expansion of its optical fiber network, commencing in late 2011. The deregulation of broadband services paved the way for the subsequent growth in the optical fiber network, as it empowered private internet providers to utilize optical fiber cables laid out by BOTAS, the local natural gas and oil distributor in Türkiye, to establish connections to more distant locations (see Figure A5).

Optical fiber cables are commonly installed alongside oil and gas pipelines to serve as reliable communication infrastructure. These fiber cables are used by operators to detect potential leaks or damages, identify security breaches or any attempts to tamper with the pipeline infrastructure and effectively manage the substantial volumes of data generated by sensors and monitoring equipment distributed along the length of the pipeline. The BOTAS optical fiber network was laid out for before the expansion of the optical fiber network set in motion. Since the BOTAS network was not laid out to facilitate internet connectivity across provinces, we are able to exploit plausibly exogenous variation in the distance of individual districts in Türkiye to the BOTAS network to construct our instrument for internet connectivity.

The 81 provinces of Türkiye are further subdivided into 973 districts. For each district m, we calculate the minimum distance from the district center to the BOTAS pipeline network, Z_m. We then compute the average distance for each province to the pipeline network as the weighted average distance of its districts with weight pertaining to each district's share of the province's total population in 2011 (see Figure A6). In particular, the weighted distance of province o to the pipeline network is calculated as:

$$Z_o = \sum_{m \in o} \frac{\text{Population}_{m,2011}}{\text{Population}_{o,2011}} \times Z_m.$$

We show that these distance measures across provinces are not correlated with a series of initial province characteristics, such as GDP, area, population, manufacturing share of GDP, urbanization rate, and employment rate, pertaining to the year 2011. Figure A7 shows that the corresponding estimates are not significantly different from zero.

To capture the notion of strong complementarity in internet speed for synchronous communication, we construct the IV for fiber connectivity for each province pair as:

$$Z_{od} = \max\{Z_o, Z_d\}.$$

Since this bilateral measure is time-invariant, we use its interactions with year dummies for years 2012 through 2019 in our first-stage regression. One would expect a negative correlation between this measure and our bilateral fiber connectivity measure, and also that the magnitude of the correlation to increase over time. The results presented in Figure A8 are consistent with our prior: relative to the year 2012, distance to the BOTAS pipeline network is negatively related to high-speed internet connectivity across all years with the effect increasing over time. The interaction terms are jointly significant, with an F-statistic above 500.

IV Estimation Results Table 1, Panel B presents IV point estimates of the effect of fiber connectivity on cost share, number of suppliers, cost share HHI, and number of new connections. In the IV estimation, the effect of fiber connectivity is positive and statistically significant for firms' cost share from origin, number of suppliers and new connections while negative and statistically significant for cost share HHI among suppliers at origin. Reassuringly, the IV point estimates are close to the OLS estimates.

3.5 Event Study Estimates

Finally, we conduct an event-study analysis of the improvements in fiber connectivity. Our setting deviates from a standard one for two reasons. First, our treatment variable is a continuous one. Second, regardless of how treatment is defined, time of treatment varies across units, i.e. province pairs. To address the former issue, we define a binary treatment status variable as follows. We calculate the median of the fiber intensity variable across all provinces and years. Then we define the year of "treatment" for a province pair as the year when the fiber intensity of both provinces is above the sample median. Needless to say, the timing of the treatment status changes across province pairs. We address the staggered nature of treatment using the approach proposed by Callaway and Sant'Anna (2021). Right panel of Figure A9 presents the event-study estimates for the three main outcomes of interest. It is reassuring that none of the variables exhibit any significant pre-trend in the years up until the year of treatment. While the estimates are not directly comparable to our baseline estimates, the two sets of estimates are qualitatively similar.

We repeat the event study exercise described above also using a binary treatment variable based on our instrumental variable. In particular, we regress fiber intensity, I_{dt}, on the instrumental variable interacted with annual dummies, controlling for province and year fixed effects. We recover the projected values $\hat{I}_{dt}$ and calculate their median. As before, the year of "treatment" for a province pair is when the projected fiber intensity of both provinces is above the sample median. The event study estimates based on our instrumental variable, as presented in the left panel of Figure A9, are very close to their OLS counterparts.

4 A Model of Input Sourcing under Rational Inattention

With these empirical results in hand, we now lay out a spatial equilibrium framework that features heterogeneous input sourcing by imperfectly informed firms. Our main objectives are twofold. First, estimation of the model would allow us to shed light on the aggregate implications of access to high-speed internet arising from its effects on input sourcing patterns that we observe in the previous section. Since we employ variation over time and across province pairs, our empirical estimates are by construction based on relative changes in sourcing patterns across provinces and hence cannot directly speak to aggregate effects. Second, the model allows us to shed additional light on the underlying channels. The previous section suggests that firms not only reallocate more purchases towards provinces with better access to high-speed internet but they also source more equitably across suppliers in such provinces.

What are the welfare effects of access to reliable high-speed internet? The model incorporates distinct channels through which access to high-speed internet affects firm-to-firm trade across space and leads to the observed reduced form effects. In the model, better access reduces the costs of acquiring information about potential suppliers and the costs of synchronous communication between suppliers and buyers. While the lower cost of acquiring information results in a more informed choice of the lowest-cost supplier, and the lower cost of synchronous communication reduces the costs of purchasing goods from any chosen supplier. This reduces input costs, and hence the cost of goods produced. However, whether these reductions in input costs help to increase outward market share across provinces depends on two factors. First, for firms in a relatively expensive province, lower information acquisition costs might result in loss of market share and vice versa. Second, the general equilibrium effects on local factor prices can dampen the effect of reduced input prices. Thus, the aggregate welfare effect is a priori unclear as it depends on the strength of each of the two channels.

4.1 Model Setup

The theoretical framework is a model of trade between provinces in Türkiye in the spirit of Eaton and Kortum (2002), with endogenous formation of firm-to-firm linkages as in Panigrahi (2022) and input sourcing under rational inattention as in Dasgupta and Mondria (2018). The resulting framework has three key features that capture the important empirical patterns presented so far. First, the cost of synchronous communication plays a role in firms' decisions of where to source inputs from, in addition to standard iceberg trade costs of shipping goods from one province to another. Second, firms are imperfectly informed about potential suppliers when deciding whom to source inputs from. However, firms can acquire more information about potential suppliers. Third, access to better internet influences both the cost of synchronous communication and the cost of acquiring further information about suppliers. The model economy consists of multiple provinces that trade goods with each other. Provinces are indexed by o, d. Each province has a positive and exogenously given measure of firms and households. The model is static and aims to capture the long-run steady state of the economy.

Production Function Firms differ ex ante in their idiosyncratic productivity, and each produces a differentiated good using labor supplied by households and intermediate inputs sourced from potentially different sets of suppliers spread across multiple provinces. Their production processes involve combining labor and performing a set of tasks using intermediate inputs obtained from other firms. The production function features constant returns to scale. In what follows, we suppress the identity of the buyer for simplicity of notation and describe the production process for an anonymous firm located in province d. The production function for any firm, defined over labor and a discrete number of tasks (indexed by k), is:

$$y = z\left(\frac{l}{1-\alpha}\right)^{1-\alpha}\left(\frac{\prod_{k=1}^{K} m(k)^{1/K}}{\alpha}\right)^{\alpha},$$
$$m(k) = \sum_{s} m(s,k),$$

where y is the output of firm, l is the amount of labor input used, $m(s,k)$ is the quantity of materials purchased from supplier s to accomplish task k, z is the idiosyncratic Hicks-neutral productivity with which the firm produces, α is the materials share of costs, and K is the number of tasks in the production function. For accomplishing any task, the outputs of potential suppliers are perfectly substitutable. This formulation of the production function in terms of the tasks performed by intermediate inputs is similar to that proposed by Eaton, Kortum, and Kramarz (2022). As in Panigrahi (2022), the outputs of potential suppliers are perfectly substitutable within tasks of a firm, and the outputs of the same supplier can be used across multiple tasks by the same firm.

Supplier Choice & the Role of High-Speed Internet Access To accomplish a task a firm chooses whom to source inputs from and how much, given the costly information it chooses to acquire. For the cost-minimizing firm, the supplier choice depends on three factors: (a) the marginal cost of production of supplier $c(s)$, (b) the iceberg trade cost of shipping goods from o_s, the supplier province, to the destination province d, denoted by $\tau_{o_s d}$ and (c) the match-specific productivity $a(s,k)$. Since tasks enter symmetrically in the production function, we suppress the index k for tasks in the rest of the section for simplicity.

The firm has, however, imperfect information when making this choice. While iceberg trade costs are common knowledge, the firm is imperfectly informed about the marginal costs and the associated match-specific productivities with potential suppliers for any particular task. We assume that high-speed internet access affects synchronous communication costs and information acquisition costs.

First, communication costs are likely to be lower when both parties have access to high-speed internet. To model this relationship, we assume that match-specific productivities are drawn independently for all potential suppliers involved in each of the tasks within a firm's production function. In particular, match-specific productivity $a(s)$ for firms at province o for tasks of firms at d are drawn independently according to the following Fréchet distribution:[6]

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

where o_s denotes the province where s is located. We specify that the scale parameter of the Fréchet distribution has a constant elasticity concerning fiber connectivity:

$$\ln \phi_{od} = \bar{\gamma} + \gamma \ln I_{od}.$$

This means that the better the quality of internet access between the origin and destination provinces, the more likely it is that match-specific productivities are higher. In other words, when the scale parameter ϕ_{od} is higher, communication costs tend to be lower. When making their supplier choice decision, while ϕ_{od} is common knowledge across all province pairs, the exact realization of match-specific productivities between a buyer-seller pair across tasks would be unknown ex ante.

Second, costs of acquiring information about potential suppliers are lower when both the origin and destination provinces have better access to high-speed internet. We model the firm as being rationally inattentive. The firm has some prior knowledge about the options available and can choose to expend costly attention to obtain further information on marginal costs. The firm chooses the amount of information to acquire optimally based on the expected decrease in the cost of production. We follow Sims (2003) and model the rationally inattentive firm's problem as one of directly choosing the probability of choosing a supplier conditional on prior knowledge. Formally, the firm's supplier choice problem for any given task is:

$$\log p = \max_{\boldsymbol{\pi}} \left\{ -\mathbb{E}_{\mu} \left[\sum_{s} \pi(s) \ln(c(s) \tau_{o_s d} a(s)) \right] - \psi(\boldsymbol{\pi}, \mu) \right\}, \tag{3}$$
$$\text{subject to} \quad \pi(s) \geq 0 \text{ for all } s, \quad \sum_{s} \pi(s) = 1$$

where p is the effective price of the task, $\pi(s)$ denotes the probability of choosing

[6]Note that match-specific components vary by task within a buyer's production function, thus a single supplier may not be best for all tasks.

supplier s for the task conditional on prior knowledge, μ is the probability measure that denotes prior knowledge of the firm and $\psi(\boldsymbol{\pi},\mu)$ denotes the cost of acquiring information.

As in the existing literature on rational inattention (Sims (2003); Matejka and McKay (2015)), we specify information costs as proportional to the decline in uncertainty due to the additional information relative to prior knowledge. In particular, information acquisition cost $\psi(\boldsymbol{\pi},\mu)$ is given by:

$$\psi(\boldsymbol{\pi},\mu)=\Omega\big(\mathbb{E}_{\mu}[\boldsymbol{\pi}]\big)-\mathbb{E}_{\mu}[\Omega(\boldsymbol{\pi})],$$

where the level of uncertainty $\Omega(\cdot)$ for a vector of choice probabilities is the associated generalized entropy as defined in Fosgerau, Melo, de Palma, and Shum (2020). In particular, the level of uncertainty associated with a vector of supplier choice probabilities for tasks of firms at d is:

$$\Omega(\boldsymbol{\pi})=-\sum_{s}\pi(s)\left(\lambda_{o_s d}\ln\pi(s)+(1-\lambda_{o_s d})\ln\left(\sum_{s'\in o_s}\pi(s')\right)\right),$$

In this formulation, for a firm at d, the cost of acquiring information about potential suppliers at o is captured by λ_{od}. For province pairs where λ_{od} is high, the costs are higher. We specify that the inverse of this parameter is related to fiber connectivity with constant elasticity:

$$\frac{1}{\lambda_{od}}=\bar{\eta}+\eta\ln I_{od}.$$

This expression captures in a reduced-form way the effect of access to high-speed internet on information acquisition costs. In other words, when $\eta>0$ the better the access to high-speed internet, the lower is the cost incurred by a buyer firm in the destination province to obtain additional information about potential suppliers at the origin province. Our formulation also implies that acquiring more information about a potential supplier reduces the cost of obtaining information about other suppliers in the same province.

Household Preferences

Each household supplies one unit of labor inelastically to firms in its province and earns labor income. Household preferences are modeled analogously to production functions, with tasks in their utility function. The utility function for any household, defined over a discrete number of tasks (indexed by k), is:

$$u = \prod_{k=1}^{K} \left(\sum_{s} q(s,k) \right)^{1/K},$$

where $q(s,k)$ is the quantity of goods purchased from supplier s to accomplish task k, and K is the number of tasks in the utility function. Similar to firms, they are imperfectly informed but rationally inattentive and choose the vector of optimal conditional choice probabilities.

4.2 Equilibrium

With these model primitives in hand, we now turn to characterizing equilibrium in the model economy. An equilibrium in the model economy is a system of allocations and prices such that (a) households maximize their utility subject to budget constraints, (b) firms decide on optimal input sourcing to minimize costs of production, and (c) goods and labor markets clear. We begin by characterizing expressions for firm-to-firm trade that arise from firms' optimal input choice. These expressions are novel to our setup and assist in transparent estimation of our model using microdata on firm-to-firm transactions, as we will describe in Section 5. Then, we describe how these expressions feed into labor market clearing conditions and determine wages in general equilibrium, allowing us to conduct counterfactual experiments.

Firm-to-Firm Trade We characterize firm-to-firm trade through posterior probabilities of supplier choice. These probabilities are conditional on marginal costs of potential suppliers but in expectation over match-specific productivities that are unknown at the time of supplier choice. Since match-specific productivities are independent and identically distributed across tasks, the probability of firm s getting selected for any one of the tasks is the same as for any other. Given the firms' rationally inattentive supplier choice problem (3) and the functional form assumptions for communication costs and information acquisition costs, we can characterize, for any firm located in province d, the conditional probabilities of choosing a supplier

s as stated in the following proposition.

Proposition 1. *Conditional on the marginal cost of production for firm s being $c(s)$, the probability with which any firm located in d selects supplier s for any given task is*

$$\pi(s,d) = \pi(s \,|\, o_s,d) \times \pi(o_s,d),$$

$$\pi(s \,|\, o_s,d) = \frac{\mathbb{E}_\mu[\pi(s \,|\, o_s,d)]c(s)^{-\zeta/\lambda_{o_s d}}}{\sum_{s' \in o_s} \mathbb{E}_\mu[\pi(s' \,|\, o_s,d)]c(s')^{-\zeta/\lambda_{o_s d}}}, \tag{4}$$

$$\pi(o,d) = \frac{\mathbb{E}_\mu[\pi(o,d)]\tau_{od}^{-\zeta}\phi_{od}\left(\sum_{s' \in o} \mathbb{E}_\mu[\pi(s' \,|\, o,d)]c(s')^{-\zeta/\lambda_{od}}\right)^{\lambda_{od}}}{\sum_{o'} \mathbb{E}_\mu[\pi(o',d)]\tau_{o'd}^{-\zeta}\phi_{o'd}\left(\sum_{s' \in o'} \mathbb{E}_\mu[\pi(s' \,|\, o',d)]c(s')^{-\zeta/\lambda_{o'd}}\right)^{\lambda_{o'd}}}, \tag{5}$$

where $\pi(o,d)$ denotes the probability of choosing a supplier from province o and $\pi(s \,|\, o_s,d)$ the probability of choosing supplier s conditional on having chosen to source from the province where it is located, o_s

Proof. See Section C.1. □

The above expressions for posterior choice probabilities have a structure similar to nested logit, except that they are adjusted by prior probabilities $\mathbb{E}_\mu[\boldsymbol{\pi}]$. As can be expected, prior probabilities positively influence posterior probabilities. Equation (4) provides the probability of choosing a supplier within a province while equation (5) provides the probability of choosing a province. Equation (4) shows that firms with lower marginal costs are more likely to get selected. Furthermore, $|\frac{\partial \ln \pi(s|o)}{\partial \ln c(s)}| = \frac{\zeta}{\lambda_{od}}$, i.e., these probabilities are less sensitive to marginal costs if the parameter λ_{od} associated with information acquisition costs is higher. In other words, with better fiber connectivity, information costs are lower and the choice of supplier is more sensitive to marginal cost. Equation (5) shows that province pairs trade more intensively when the scale parameter associated with match-specific productivities are higher, i.e., $\frac{\partial \ln \pi(o,d)}{\partial \ln \phi_{od}} = 1$. In other words, with better fiber connectivity (and hence higher ϕ_{od}), communication costs tend to be lower which makes it more likely for a supplier to be chosen from province o.

Labor Market Clearing At equilibrium, for all provinces o:

$$w_o L_o = \sum_d \pi(o,d) w_d L_d \tag{6}$$

Equation (6) is the labor market clearing condition for each province. It equates the labor income (total wage bill of all firms) in o to expenditure of goods produced at o, coming from final consumption and intermediate input usage in all provinces.

Comparative Statics The choice probabilities stated above map directly to data on firm-to-firm sales and hence transparently show how comparative statics arising from the model deliver the reduced-form results we presented in Section 3. The elasticity of $\pi(o,d)$ with respect to fiber connectivity I_{od} is γ. For positive values of γ , this implies that firms in a destination province tend to reallocate a larger proportion of their input purchases from suppliers in province o when fiber connectivity between these provinces improves and communication costs decline. Furthermore, for positive values of η, when fiber connectivity improves, information acquisition costs fall and λ_{od} decreases. Recall that λ_{od} regulates the level of sensitivity of the choice of a supplier within its province to its marginal cost. For a given distribution of marginal costs in a province, this implies that when information acquisition costs decline, choice probabilities become more equitable across suppliers.

4.3 Welfare Impact of High Speed Internet Access

We use as a measure of welfare in a province the average utility level enjoyed by households who reside there. Given households' utility maximization, changes in this welfare level for households in province d can be expressed as:

$$\widehat{V}_d = \frac{\widehat{w}_d}{\widehat{P}_d}, \tag{7}$$

where w_d denotes the wage, P_d the price index, and V_d the indirect utility, all for province d, and $\widehat{\cdot}$ denotes the change in a variable. Equation (8) shows that change in average welfare level across households depends on (i) changes in labor income (common across all households) $\widehat{w}_d$ and (ii) changes in price index of the average household $\widehat{P}_d$. Change in price index is defined recursively as:

$$\widehat{P}_d = \left(\sum_o \pi(o,d) \widehat{\phi}_{od} \widehat{\omega}_{od} \left(\widehat{w}_o^{1-\alpha} \widehat{P}_o^{\alpha} \right)^{-\zeta} \right)^{-1/\zeta},$$

$$\omega_{od} = \left(\sum_{s \in o} \mathbb{E}_{\mu}[\pi(s \mid o,d)] \left(\frac{c(s)^{-\zeta}}{\sum_{s' \in o} c(s')^{-\zeta}} \right)^{1/\lambda_{od}} \right)^{\lambda_{od}}. \tag{8}$$

The above expression implies that the change in the price index in a province d is a weighted power mean of changes in wages $\widehat{w}_o$, prices indices $\widehat{P}_o$, synchronous communication costs (captured by $\widehat{\phi}_{od}$) and information acquisition costs (captured by $\widehat{\omega}_{od}$) in all provinces, weighted by trade shares $\pi(o,d)$.

To quantify the welfare gains brought about by high-speed internet access in Türkiye, we conduct the following thought experiment. We compare the level of welfare in Türkiye prior to the expansion of optical fiber network to what it would have been in a counterfactual equilibrium where only the fiber cable network expansion had occurred, holding all other factors constant. By doing so, we aim to measure the welfare gains that the Turkish economy had incurred on account of the fiber cable roll-out.

Counterfactual Equilibria To create the counterfactual equilibrium, we model the Turkish economy with the exact same exogenous determinants as in 2012 prior to expansion of the optical fiber cable network, except that we assume the fiber cable network differs by the average annual change across the years 2012-2019. This approach provides a natural measure of the gains from rollout of optical fiber cables, ceteris paribus. Through the lens of our model, this measures the combined effect of reallocation and diversification in input sourcing. In the counterfactual equilibrium, firms and households face lower communication and information frictions on account of better access to high-speed internet. This, ceteris paribus, leads to more efficient input sourcing for firms by lowering their cost of intermediate use. At the same time, general equilibrium response leads to differential change in nominal wages across provinces.

To solve for the counterfactual equilibrium, we follow the methodology developed by Dekle, Eaton, and Kortum (2008) as adapted to settings with granular data in Dingel and Tintelnot (2020) and Panigrahi (2022), and express the equilibrium conditions of the model in changes relative to their baseline values. This allows us to solve for a counterfactual equilibrium of the economy corresponding to an improvement in fiber internet connectivity, as captured by a change in communication and information costs, given the parameters of the model and the values of the endogenous variables in the baseline equilibrium. However, in our model, changes in fiber connectivity affect the elasticity of firm-to-firm trade with respect to marginal costs. Since the elasticity is non-constant, we cannot use their methodology as is. Therefore, unlike their methodology, where all model primitives cancel out when evaluating counterfactuals, we explicitly utilize model primitives that we back out from our estimated model to construct shocks that capture changes in information acquisition costs ($\widehat{\omega}_{od}$).

5 Estimation and Quantification

To conduct quantitative analysis using the model, we proceed in four steps. First, we estimate key parameters through which access to high-speed internet affects communication and information acquisition costs (γ, $\bar{\eta}$, η). Second, we calibrate endogenous quantities such as firm-to-firm trade in the baseline equilibrium using model-predicted values and use as wages the set of values that satisfy labor market clearing conditions. We also calibrate the shape parameter of match-specific productivities ζ and materials share of costs α. Third, we construct shocks to communication and information acquisition costs using annualized changes in fiber connectivity and our estimated parameters. Finally, we follow the procedure described in the previous section to evaluate welfare changes across provinces owing to these shocks.

5.1 Estimation of Communication and Information Acquisition Costs

To estimate key elasticities of communication and information acquisition costs with respect to fiber connectivity, we operationalize expressions in Proposition 1 as a nested logit model of supplier choice. Estimation relies on variation of fiber connectivity across time. Therefore, it is useful to emphasize that the expressions hold for every period. We index observations across years by t to emphasize the panel nature of the data. Estimation of the nested logit model entails controlling for several unobserved variables, chiefly the unconditional choice probabilities for each seller and destination province as well as marginal cost of production for each seller in each year. From a fixed effects perspective, these are very high-dimensional. To tame the computational difficulties associated with such an effort, we take the sequential approach to estimating the nested logit model. That is, first, we estimate the inner nest associated with choice of suppliers within a province via multinomial logit using suitable summary statistics at the seller-destination and seller-year levels. Then, we estimate the outer nest associated with the choice of the province, again as a multinomial logit but while controlling for the inclusive values estimated in the previous step.

We next utilize the first order conditions implied by the joint likelihood maximization problem to derive dependent variables to be used for estimation of the inner and outer nests. The first order conditions implied by the likelihood maximization problem can be solved to obtain the appropriate dependent variables as described in the following proposition.

Proposition 2. *For a firm located in province d, the maximum likelihood estimate of the probability of choosing a supplier from province o satisfies:*

$$\left(\frac{c_{o,t}^{-\zeta}\mathbb{E}_{\mu}[\pi(o,d)]\tau_{od}^{-\zeta}\phi_{od,t}\omega_{od,t}}{\sum_{o'}c_{o',t}^{-\zeta}\mathbb{E}_{\mu}[\pi(o',d)]\tau_{o'd}^{-\zeta}\phi_{o'd,t}\omega_{o'd,t}}\right)^{*}=\frac{1}{M_d}\sum_{b\in d}\sum_{s\in o}Cost\ Share(s,b,t)\quad\forall o,d.\tag{9}$$

Further, the maximum likelihood estimate of the probability of choosing a supplier s conditional on choosing the province o_s where it is located satisfies:

$$\left(\frac{\mathbb{E}_{\mu}[\pi(s\,|\,o_s,d)]\widetilde{c}(s,t)^{-\zeta/\lambda_{od,t}}}{\sum_{s'\in o}\mathbb{E}_{\mu}[\pi(s'\,|\,o_s,d)]\widetilde{c}(s',t)^{-\zeta/\lambda_{od,t}}}\right)^{*}=\frac{1}{M_d}\sum_{b\in d}\frac{Cost\ Share(s,b,t)}{\sum_{s'\in o}Cost\ Share(s',b,t)}\quad\forall s,d.\tag{10}$$

Here $\cdot^*$ denotes the maximum likelihood estimate and $Cost\ Share(s,b,t)=\frac{Purchases(s,b,t)}{\sum_{s'}Purchases(s',b,t)}$.

Proof. See Section C.2. □

The proposition above provides expressions useful for the sequential estimation of the nested logit model of supplier choice. Specifically, equation (9) identifies the dependent variable for estimating the outer nest as the *average trade share*, calculated as the origin province's cost share averaged across firms in the destination province. In turn, equation (10) suggests that the dependent variable for the inner nest estimation is the *average relative cost share*, calculated as a supplier's cost share relative to the total cost share of all suppliers within its province, also averaged across destination firms.

Estimating the inner nest using equation (10) yields an estimate for $\eta/\bar{\eta}$. This estimation equation includes unobserved factors, specifically the marginal costs of suppliers $\tilde{c}(s,t)$ and the unconditional choice probabilities of selecting a supplier, conditional on its province of location $\mathbb{E}_{\mu}[\pi(s\,|\,o_s,d)]$. Estimating these as two-way fixed effects, with both seller-year and seller-destination fixed effects, would be computationally prohibitive. Thus, we proxy for these two-way fixed effects by using estimates that would have been obtained from separate inclusion of each set of fixed effects. Specifically, we estimate the following specification:

$$\frac{\exp(\kappa_0\delta(s,d)+\kappa_1\delta(s,t)+\kappa_2\delta(s,t)\times\ln I_{od,t})}{\sum_{s'\in o}\exp(\kappa_0\delta(s',d)+\kappa_1\delta(s',t)+\kappa_2\delta(s',t)\times\ln I_{od,t})}=\mathbb{E}\left[\frac{1}{M_d}\sum_{b\in d}\frac{\text{Cost Share}(s,b,t)}{\sum_{s'\in o}\text{Cost Share}(s',b,t)}\right] \tag{11}$$

where $\delta(s,d)$ and $\delta(s,t)$ are proxy variables at the seller-destination and seller-year levels. The ratio κ_2/κ_1 provides an estimate of $\eta/\bar{\eta}$.

Estimating the outer nest equation (9) provides estimates for γ and $\bar{\eta}$. This estimation requires controlling for the inclusive value obtained in the inner nest estimation. Specifically, the coefficient on fiber connectivity offers an estimate of γ, while the coefficient on the inclusive value provides an estimate of $\bar{\eta}$. We estimate the following specification:

$$\frac{\exp(\delta(o,t)+\delta(o,d)+\gamma\ln I_{od,t}+\bar{\eta}\ln\omega_{od,t})}{\sum_{o'}\exp(\delta(o',t)+\delta(o,d)+\gamma\ln I_{o'd,t}+\bar{\eta}\ln\omega_{o'd,t})}=\mathbb{E}\left[\frac{1}{M_d}\sum_{b\in d}\sum_{s\in o}\text{Cost Share}(s,b,t)\right] \tag{12}$$

where $\delta(o,t)$ and $\delta(o,d)$ are fixed effects at the origin-time and origin-destination levels, and $\omega_{od,t}$ denotes the inclusive value obtained from estimation of the inner nest. The fixed effects capture time-varying factors specific to the origin, as well as time-invariant factors at the province-pair level, including transportation costs and the unconditional probability of choosing the origin.

To address endogeneity concerns, we include the residual obtained from first stage regressions, using our instrumental variable outlined in Section 3, as a control function. We present the results of the estimation from the inner nest specification (11) and outer nest specification (12) in columns (1) and (2) of Table 2, respectively. Our estimates suggest the following values for structural parameters: $\gamma=0.465$, $\bar{\eta}=1.501$, and $\eta=0.060$.

Table 2: **Estimation of Information Acquisition and Communication Costs**

Dependent Variable:	Average Relative Cost Share	Average Trade Share
	(1)	(2)
Fibre Connectivity × Seller×Year Proxy	0.00744***	
	(0.00282)	
Seller×Year Proxy	0.187***	
	(0.00238)	
Seller×Destination Proxy	0.840***	
	(0.00319)	
Fibre Connectivity		0.465***
		(0.110)
Inner Nest Incl. Value		1.501***
Fixed Effects:		
Origin×Year		✓
Destination×Year		✓
Origin×Destination		✓
R^2	0.678	0.989
Observations	72,233,694	45504

Note: In column (1), each observation pertains to a supplier firm, a destination province, and a year. In column (2), each observation pertains to an origin province, a destination province, and a year. To address endogeneity concerns, estimation is done though a control function approach by including predicted residuals obtained from the first-stage regression. * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at origin and destination level, are reported in parentheses.

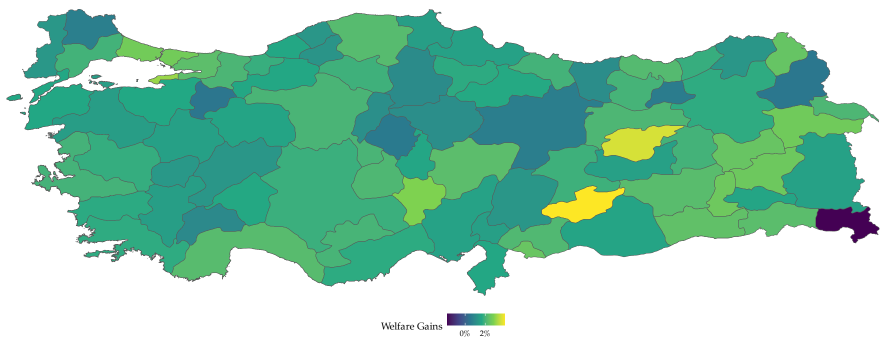
5.2 Calibration

Equation (5) indicates that the shape parameter ζ of the distribution of match-specific commmunication costs coincides with the trade elasticity. Therefore, we calibrate the shape parameter ζ to 5 based on the median estimate of trade elasticities reported in Head and Mayer (2014). We set the material share α to 0.7, based on the average material share among all firms in our data. For counterfactual experiments, we calibrate endogenous quantities such as firm-to-firm trade in the baseline equilibrium using model-predicted values and use as wages the set of values that satisfy labor market clearing conditions.

5.3 Welfare Effects of High-Speed Internet Infrastructure

Our objective is to conduct a quantitative assessment of the effect of optical fiber rollout in Türkiye. To achieve this, we begin by selecting the Turkish economy in 2012 as our reference point. We construct shocks to the economy using actual annualized changes in fiber rollout between 2012 and 2019 and evaluate how much annual real income would have changed across Turkish provinces if the 2012 economy had been subject to these shocks, ceteris paribus. This is the first exercise in the literature that assesses the welfare gains resulting from improvements in ICT infrastructure in a general equilibrium setting.

Figure 4: **Welfare Effects across Turkish Provinces**



Note: This figure depicts the welfare impact of high-speed internet roll-out across Turkish provinces.

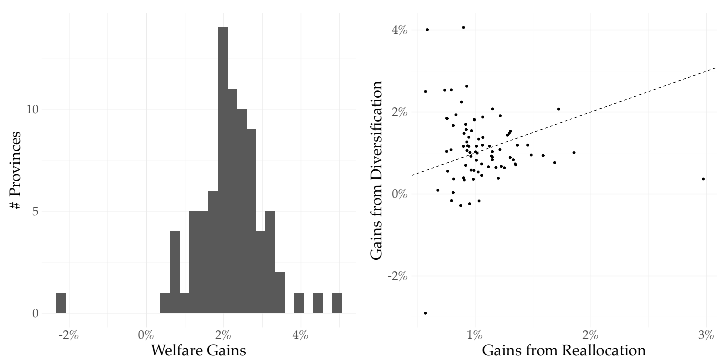
To examine the distinct roles of communication and information acquisition costs, we consider two additional counterfactual equilibria. First, to isolate the effect of reallocation across provinces in input sourcing, we compute welfare changes between the baseline and a counterfactual equilibrium in a version of our model where the diversification channel (i.e., changes within a province) is absent (i.e., $\eta = 0$). The summary statistics indicate a median gain of 1%, with an interquartile range from 0.9% to 1.2%. Similarly, to capture the effect of diversification in input sourcing, we compute welfare changes in a version of our model where the reallocation channel is absent (i.e., $\gamma = 0$). The summary statistics for this scenario show a median gain of 1.03%, with an interquartile range from 0.66% to 1.53%. Figure 5 decomposes welfare changes into reallocation and diversification channels. Both channels significantly contribute to overall welfare gains, with the diversification channel exhibiting more variation across provinces.

The results of our quantification exercise are displayed in Figure 4, which depicts a map of welfare gains across Turkish provinces, revealing considerable heterogeneity in gains among them. The summary statistics show a median gain of

2.2%, with an interquartile range from 1.8% to 2.6%.

The reallocation channel captures the gains arising from reduced synchronous communication costs between buyers and suppliers, resulting in lower costs of intermediate goods for all. Although the general equilibrium effects on local wages dampen the effect of reduced input prices, the welfare effects due to the reallocation channel are positive for all provinces. The diversification channel captures the gains arising from reduced information acquisition costs. While it also leads to lower production costs, the effect on sales is ambiguous: the sales effect is positive for a province that is relatively cheaper but was perceived as a high-cost source, and negative for one that is relatively expensive but was perceived as a low-cost source of inputs. Consistent with this intuition, the gains due to the diversification channel are larger for smaller and relatively remote provinces, where information frictions are initially expected to be higher.

Figure 5: **Welfare Effects: Comparison of Reallocation and Diversification Channels**



Note: The left panel presents the distribution of welfare gains from high-speed internet roll-out across Turkish provinces, and the right panel their breakdown into the reallocation and diversification channels.

6 Conclusion

This study explores the substantial effect of high-speed internet infrastructure on economic activity, particularly focusing on how it reshapes firms' input sourcing strategies and the resulting implications for regional economic growth. By analyzing the extensive rollout of fiber-optic internet across Turkish provinces from 2012 to 2019 and utilizing rich microdata on firm-to-firm transactions, we provide empirical evidence that highlights how enhanced internet connectivity significantly transforms the way firms interact within supply chains.

Our findings show that improved internet access encourages firms to reallocate their purchases towards suppliers in regions with better connectivity, fostering a more robust and diversified input sourcing strategy. Specifically, firms do not merely shift their sourcing to regions with better internet; they also increase their number of suppliers and distribute their purchases more evenly across these suppliers. This pattern of diversification suggests that better internet infrastructure lowers both the cost of obtaining information and the cost of maintaining synchronous communication, which are crucial for managing complex supply chains.

To rationalize these empirical observations, we develop and estimate a spatial equilibrium model incorporating rational inattention in the endogenous formation of production networks. Our model provides an understanding of how high-speed internet reduces information acquisition and communication costs, driving firms to make more informed choices regarding their suppliers and enabling more efficient and resilient supply chains.

The quantitative findings suggest that improvements in high-speed internet connectivity contribute significantly to economic welfare. We estimate that the rollout of fiber-optic networks led to a 2.2% increase in real income in the median Turkish province, illustrating the tangible economic benefits that stem from investments in digital infrastructure. This gain is attributed to a dual mechanism – enhanced internet reduces information costs, allowing firms to evaluate and engage with a broader pool of suppliers, and decreases communication frictions, facilitating smoother interactions and transactions over distance.

In conclusion, our findings highlight that by reducing communication and information costs, digital infrastructure investments can lead to far-reaching improvements in business operations, supply chain efficiency, and overall economic resilience, ultimately promoting higher welfare and sustainable development.

References

ACEMOGLU, D. AND P. D. AZAR (2020): "Endogenous Production Networks," *Econometrica*, 88, 33–82.

ACEMOGLU, D., V. M. CARVALHO, A. OZDAGLAR, AND A. TAHBAZ-SALEHI (2012): "The Network Origins of Aggregate Fluctuations," *Econometrica*, 80, 1977–2016.

AKERMAN, A., E. LEUVEN, AND M. MOGSTAD (2022): "Information Frictions, Internet, and the Relationship between Distance and Trade," *American Economic Journal: Applied Economics*, 14, 133–63.

ALLEN, T. (2014): "Information Frictions in Trade," *Econometrica*, 82, 2041–2083.

ALLEN, T. AND C. ARKOLAKIS (2014): " Trade and the Topography of the Spatial Economy," *The Quarterly Journal of Economics*, 129, 1085–1140.

ARKOLAKIS, C., F. HUNEEUS, AND Y. MIYAUCHI (2023): "Spatial Production Networks," Working Paper 30954, National Bureau of Economic Research.

BAQAEE, D. R. AND E. FARHI (2019): "The Macroeconomic Impact of Microeconomic Shocks: Beyond Hulten's Theorem," *Econometrica*, 87, 1155–1203.

——— (2020): "Productivity and Misallocation in General Equilibrium," *The Quarterly Journal of Economics*, 135, 105–163.

——— (2024): "Networks, Barriers, and Trade," *Econometrica*, 92, 505–541.

BERNARD, A. B., E. DHYNE, G. MAGERMAN, K. MANOVA, AND A. MOXNES (2022): "The Origins of Firm Heterogeneity: A Production Network Approach," *Journal of Political Economy*, 130, 1765–1804.

BERNARD, A. B., A. MOXNES, AND Y. U. SAITO (2019): "Production Networks, Geography, and Firm Performance," *Journal of Political Economy*, 127, 639–688.

——— (2020): "The Geography of Knowledge Production: Connecting Islands and Ideas," Working Paper, Dartmouth College.

BIGIO, S. AND J. LAO (2020): "Distortions in Production Networks," *The Quarterly Journal of Economics*, 135, 2187–2253.

CALIENDO, L., F. PARRO, E. ROSSI-HANSBERG, AND P.-D. SARTE (2017a): "The Impact of Regional and Sectoral Productivity Changes on the U.S. Economy," *The Review of Economic Studies*, 85, 2042–2096.

CALLAWAY, B. AND P. H. SANT'ANNA (2021): "Difference-in-Differences with multiple time periods," *Journal of Econometrics*, 225, 200–230.

CHANEY, T. (2014): "The Network Structure of International Trade," *American Economic Review*, 104, 3600–3634.

COSAR, A. K., B. DEMIR, D. GHOSE, AND N. YOUNG (2021): "Road Capacity, Domestic Trade and Regional Outcomes," *Journal of Economic Geography*, 22, 901–929.

CRISTEA, A. D. (2011): "Buyer-Seller Relationships in International Trade: Evidence from U.S. States' Exports and Business-Class Travel," *Journal of International Economics*, 84, 207–220.

DASGUPTA, K. AND J. MONDRIA (2018): "Inattentive Importers," *Journal of International Economics*, 112, 150–165.

DEKLE, R., J. EATON, AND S. KORTUM (2008): "Global Rebalancing with Gravity: Measuring the Burden of Adjustment," *IMF Staff Papers*, 55, 511–540.

DEMIR, B., A. C. FIELER, D. Y. XU, AND K. K. YANG (2024a): "O-Ring Production Networks," Tech. Rep. 1.

DEMIR, B., B. JAVORCIK, T. K. MICHALSKI, AND E. ORS (2024b): "Financial Constraints and Propagation of Shocks in Production Networks," *The Review of Economics and Statistics*, 106, 437–454.

DICKSTEIN, M. J. AND E. MORALES (2018): "What do Exporters Know?" *The Quarterly Journal of Economics*, 133, 1753–1801.

DINGEL, J. I. AND F. TINTELNOT (2020): "Spatial Economics for Granular Settings," Working Paper 27287, National Bureau of Economic Research.

DONALDSON, D. (2015): "The Gains from Market Integration," *Annual Review of Economics*, 7, 619–647.

——— (2018): "Railroads of the Raj: Estimating the Impact of Transportation Infrastructure," *American Economic Review*, 108, 899–934.

EATON, J. AND S. KORTUM (2002): "Technology, Geography, and Trade," *Econometrica*, 70, 1741–1779.

EATON, J., S. S. KORTUM, AND F. KRAMARZ (2022): "Firm-to-Firm Trade: Imports, Exports, and the Labor Market," Working Paper 29685, National Bureau of Economic Research.

FERNANDES, A. M., A. MATTOO, H. NGUYEN, AND M. SCHIFFBAUER (2019): "The Internet and Chinese Exports in the Pre-Ali Baba Era," *Journal of Development Economics*, 138, 57–76.

FOSGERAU, M., E. MELO, A. DE PALMA, AND M. SHUM (2020): "Discrete Choice and Rational Inattention: A General Equivalence Result," *International Economic Review*, 61, 1569–1589.

FREUND, C. L. AND D. WEINHOLD (2004): "The Effect of the Internet on International Trade," *Journal of International Economics*, 62, 171–189.

HEAD, K. AND T. MAYER (2014): "Gravity Equations: Workhorse,Toolkit, and Cookbook," in *Handbook of International Economics*, ed. by G. Gopinath, E. Helpman, and K. Rogoff, Elsevier, vol. 4 of *Handbook of International Economics*, 131 – 195.

HJORT, J. AND J. POULSEN (2019): "The Arrival of Fast Internet and Employment in Africa," *American Economic Review*, 109, 1032–79.

HJORT, J. AND L. TIAN (2024): "The Economic Impact of Internet Connectivity in Developing Countries," Working Paper, INSEAD.

HUNEEUS, F. (2020): "Production Network Dynamics and the Propagation of Shocks," Working Paper, Central Bank of Chile.

JIANG, X. (2023): "Information and Communication Technology and Firm Geographic Expansion," Working Paper, University of California - Davis.

JUHÁSZ, R. AND C. STEINWENDER (2018): "Spinning the Web: The Impact of ICT on Trade in Intermediates and Technology Diffusion," NBER Working Papers 24590, National Bureau of Economic Research, Inc.

LIM, K. (2018): "Endogenous Production Networks and the Business Cycle," Working Paper, University of Toronto.

MALGOUYRES, C., T. MAYER, AND C. MAZET-SONILHAC (2021): "Technology-induced Trade Shocks? Evidence from Broadband Expansion in France," *Journal of International Economics*, 133, 103520.

MATEJKA, F. AND A. MCKAY (2015): "Rational Inattention to Discrete Choices: A New Foundation for the Multinomial Logit Model," *American Economic Review*, 105, 272–98.

MIYAUCHI, Y. (2023): "Matching and Agglomeration: Theory and Evidence from Japanese Firm-to-Firm Trade," Working Paper, Boston University.

OBERFIELD, E. (2018): "A Theory of Input-Output Architecture," *Econometrica*, 86, 559–589.

PANIGRAHI, P. (2022): "Endogenous Spatial Production Networks: Quantitative Implications for Trade & Productivity," Working Paper, Johns Hopkins University.

RAUCH, J. E. AND V. TRINDADE (2003): "Information, International Substitutability, and Globalization," *American Economic Review*, 93, 775–791.

REDDING, S. J. (2016): "Goods Trade, Factor Mobility and Welfare," *Journal of International Economics*, 101, 148 – 167.

——— (2022): "Trade and Geography," in *Handbook of International Economics: International Trade, Volume 5*, ed. by G. Gopinath, E. Helpman, and K. Rogoff, Elsevier, vol. 5 of *Handbook of International Economics*, 147–217.

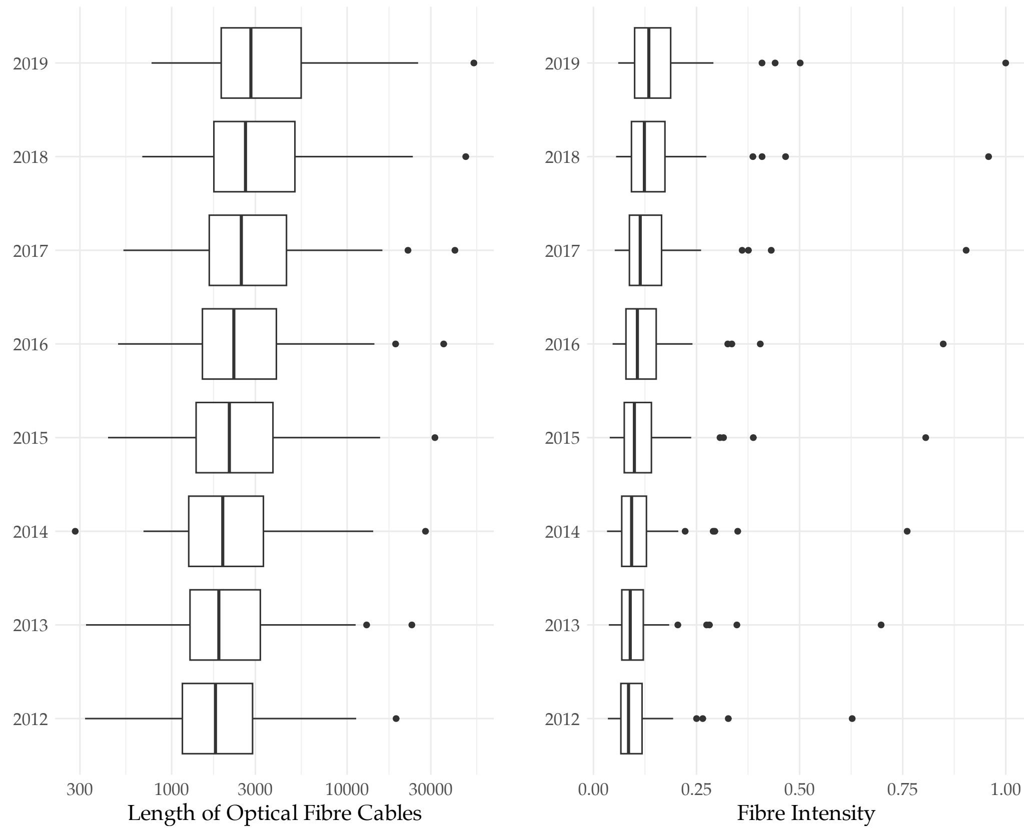
REDDING, S. J. AND E. ROSSI-HANSBERG (2017): "Quantitative Spatial Economics," *Annual Review of Economics*, 9, 21–58.

SIMS, C. A. (2003): "Implications of Rational Inattention," *Journal of Monetary Economics*, 50, 665–690.

Online Appendix

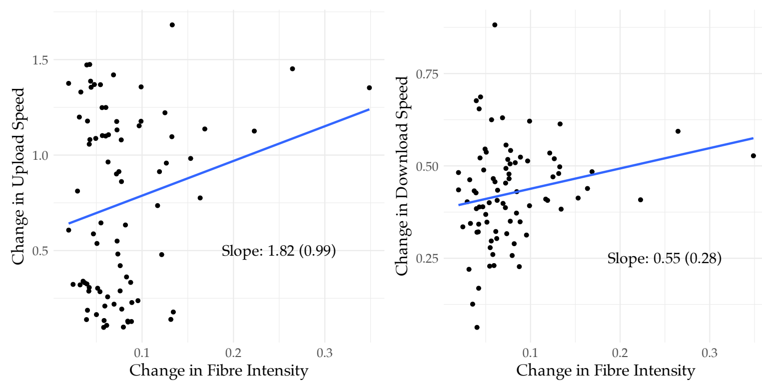
A Appendix: Background & Data

Figure A1: **Change in fiber cable length between 2012-2019**



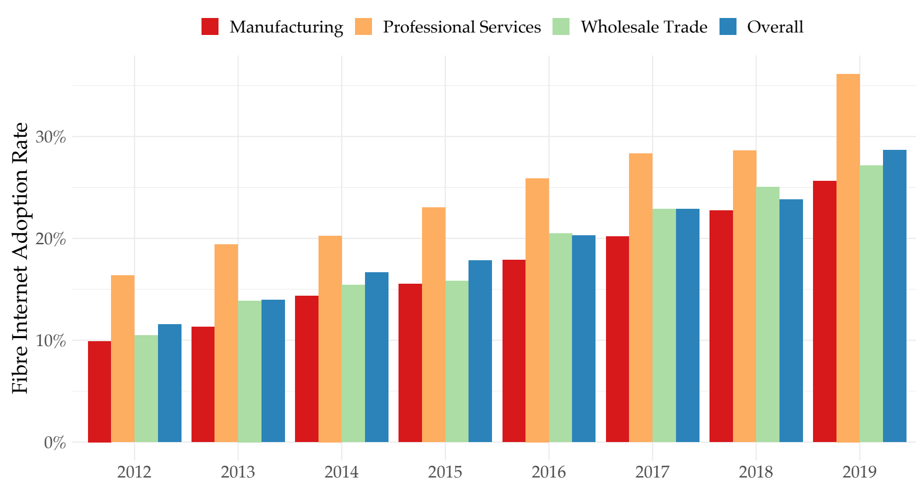
Note: The left panel is a box and whiskers plot of length of optical fibre cables rolled out across Turkish provinces over years. The right panel is a box and whiskers plot of fibre intensity across Turkish provinces over the years.

Figure A2: **Correlation of Fiber Intensity with Upload and Download Speeds**



Note: The left panel depicts how change in measured fiber intensity correlates with change in reported upload speeds during the period 2016-2019. The right panel depicts correlation of fiber intensity with reported download speeds. Data on upload and download speeds across Turkish districts, which we aggregate to the level of provinces, during 2016-2019 was obtained from Ookla.

Figure A3: **Firms' Adoption of High-Speed Internet in Türkiye**



Note: This figure depicts the evolution of firms' adoption of high-speed internet across broad sectors (manufacturing, professional services and wholesale trade) and for the overall economy. During 2012-2019, firms in all sectors increasingly adopt high-speed internet. The fraction of firms with high-speed internet increased from zero in 2011 to about 30% by the end of 2019.

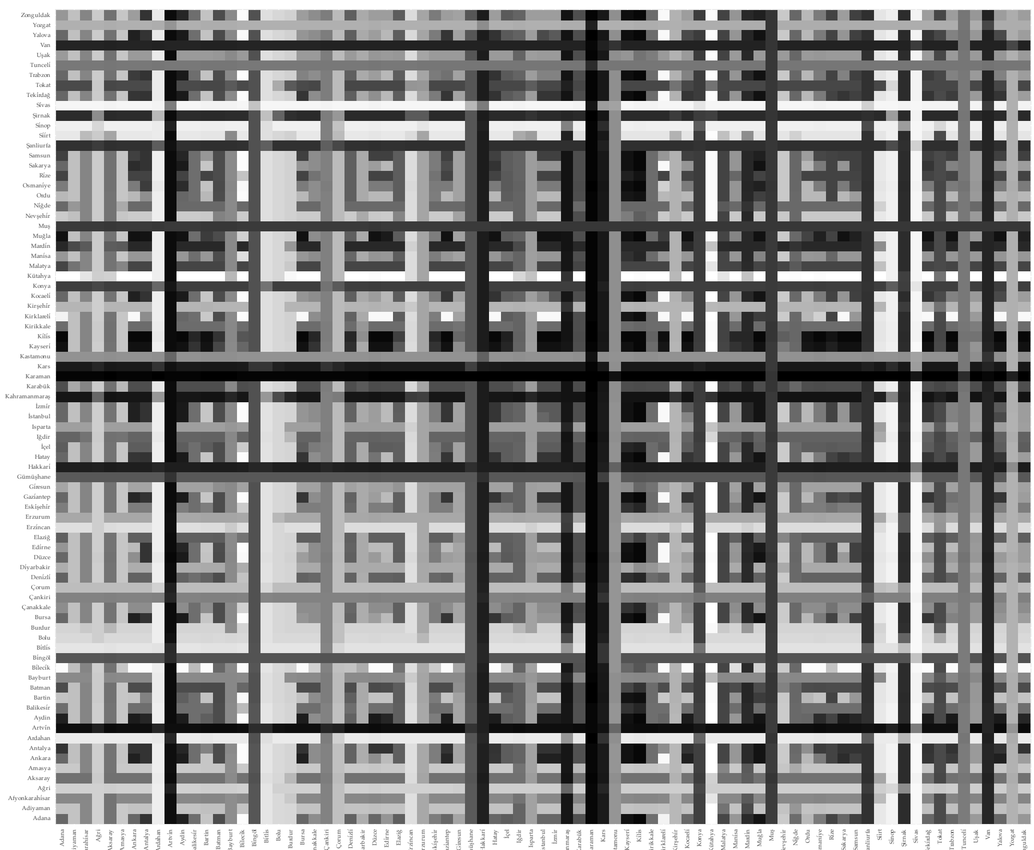
Table A1: **Firms' adoption of high-speed internet**

	(1)	(2)
Fibre Intensity	1.660**	
	(0.648)	
Fibre Intensity ×		
Food, beverages, and tobacco		1.648**
		(0.661)
Textiles, clothing, and footwear		1.637**
		(0.647)
Wood and paper products		1.666**
		(0.657)
Coke, petroleum, chemical products, and pharmaceuticals		1.668**
		(0.648)
Plastics and non-metallic mineral products		1.683**
		(0.644)
Basic metals		1.361**
		(0.651)
Fabricated metal products and general-purpose machinery		1.611**
		(0.644)
Computer, electronic, electrical and optical products		1.713**
		(0.665)
Manufacture of motor vehicles and ships		1.603**
		(0.651)
Furniture and other manufacturing		1.736**
		(0.650)
Trade		1.614**
		(0.643)
Professional services		1.629**
		(0.650)
Observations	3337	3337

Note: * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered by province, in parentheses. All columns include firm size (measured in terms of employment) as a control. The corresponding specification is in (1). Column (1) presents results at the province-year level and column (2) at the province-firm size-year level. The latter includes dummies for each firm size.

B Appendix: Empirical Evidence

Figure A4: **Change in Bilateral Fibre Connectivity**

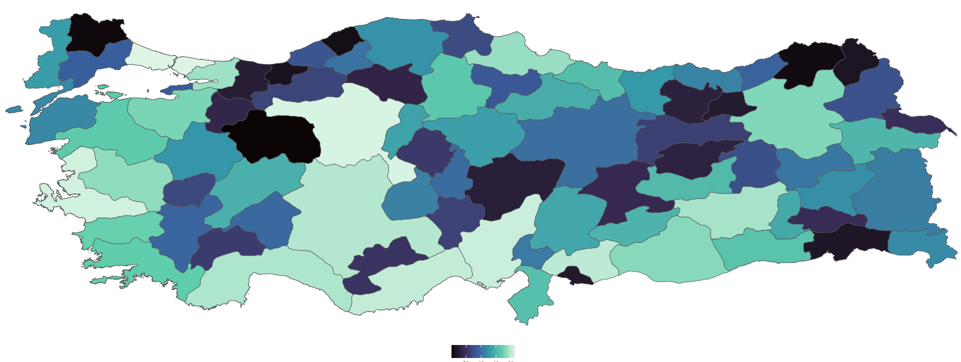


Note: This figure depicts the change in fibre connectivity between each pair of Turkish provinces during the period 2012-2019. Fibre Connectivity is measure as the minimum of fibre intensity between provinces in a pair. Darker shades represent higher values.

Figure A5: **BOTAS Oil and Gas Pipeline Network**

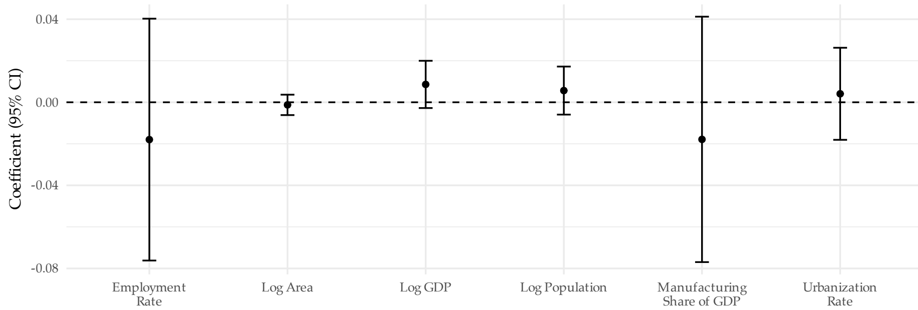
Note: This map shows the gas pipeline network of BOTAS.

Figure A6: **Distance to BOTAS Pipeline Network**



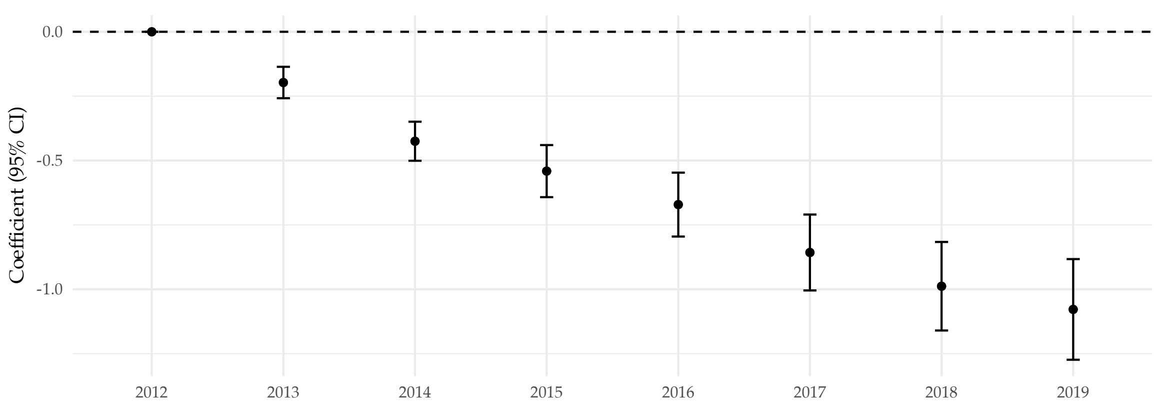
Note: This map depicts the spatial variation in weighted distance of provinces to the BOTAS pipeline network. The distance of a province to BOTAS pipeline is calculated as the weighted average of the shortest distance of its districts to the pipeline where each district is weighted by its population. Lighter shades represent higher percentiles.

Figure A7: **Distance to BOTAS pipelines and Initial Province Characteristics**



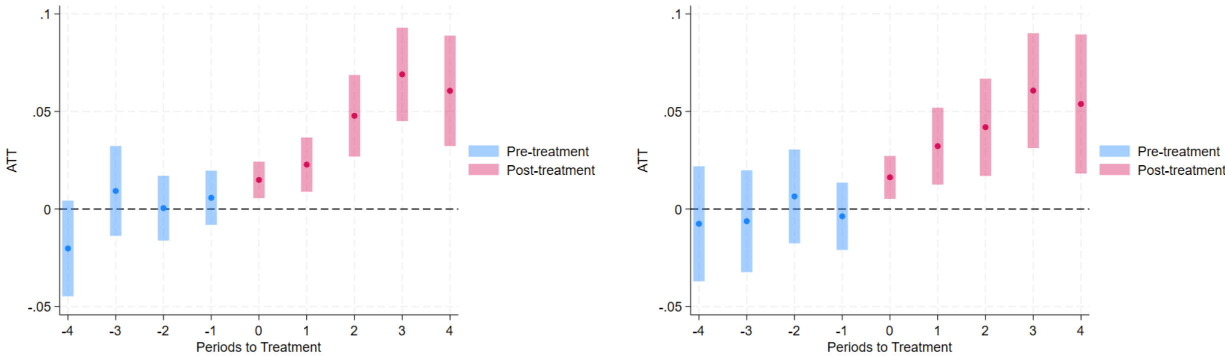
Note:See Section 3.4 for discussion. The distance of a province to BOTAS pipelines is constructed as the weighted average of the distances of districts within the province where the district population are used as weights. This figure plots the coefficient estimates and the corresponding 95% confidence intervals obtained from regressing this distance on initial provincial characteristics (pertaining to 2011), controlling for NUTS2 level fixed effects.

Figure A8: **Distance to BOTAS pipelines and First Stage Estimates**

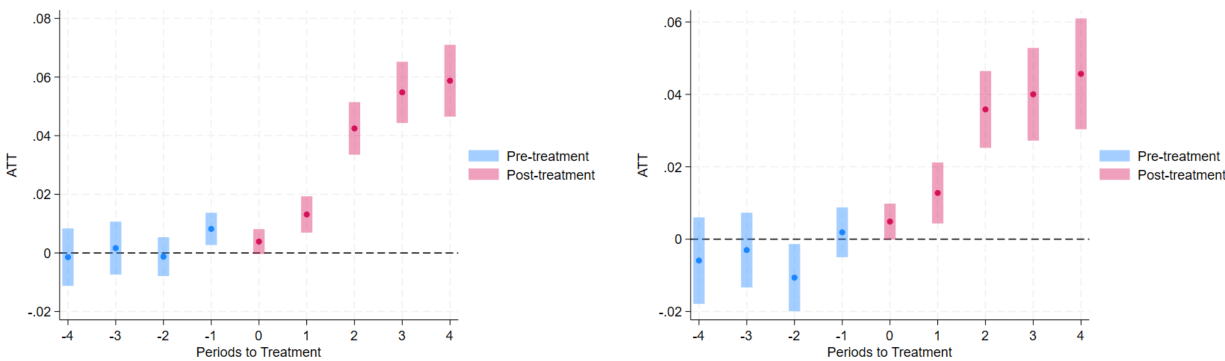


Note: See Section 3.4 for discussion. The distance of a province to BOTAS pipelines is constructed as the weighted average of the distances of districts within the province where the district population are used as weights. This figure plots the coefficient estimates and the corresponding 95% confidence intervals obtained from first-stage regression of fibre connectivity on distance to BOTAS pipelines interacted with year dummies.

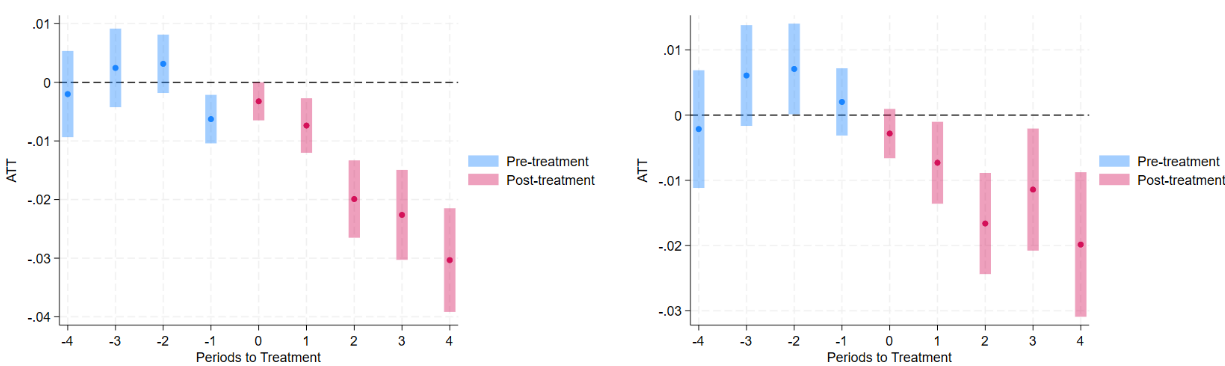
Figure A9: **Event study estimates**



(a) Cost Share



(b) No. Suppliers



(c) Cost Share HHI

Note: The figures show the event study estimates based on a binary treatment variable defined in Section 3.5. The specification includes firm-source province fixed effects. Left panel plots the 2SLS estimates, and the right panel OLS estimates.

Table A2: **Reallocation and Diversification in Input Sourcing: Additional Controls**

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

Note: See Section 3.3 for discussion. Each observation pertains to a buyer firm, an origin province and a year. All variables are in natural logarithms. No. Suppliers is the number of suppliers of the buyer firm located in a given origin province. Cost share is the fraction of purchases of a buyer from a given source province. Cost Share HHI is the Herfindahl-Hirschman Index of cost shares of suppliers of a buyer, which are located in a given origin province. New Connections is the number of new suppliers relative to the year before. For a pair of origin and destination provinces in a given year, difference in GDP p.c. is the absolute difference in GDP per capita and mobile connectivity is computed as the minimum of 3G/4G mobile subscribers per capita between both provinces. * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at origin and destination level, are reported in parentheses.

Table A3: **Reallocation and Diversification in Input Sourcing: Alternative Measure of Bilateral Connectivity**

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

Note: See 3.3 for discussion. Each observation pertains to a buyer firm, an origin province and a year. All variables are in natural logarithms. No. Suppliers is the number of suppliers of the buyer firm located in a given origin province. Cost share is the fraction of purchases of a buyer from a given source province. Cost Share HHI is the Herfindahl-Hirschman Index of cost shares of suppliers of a buyer, which are located in a given origin province. New Connections is the number of new suppliers relative to the year before. Fibre connectivity is measured as the negative absolute difference of fiber intensity at origin and destination provinces:$-|I_{o,t} - I_{d,t}|$. * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at origin and destination level, are reported in parentheses.

Table A4: **Reallocation and Diversification in Input Sourcing: Placebo Test**

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

Note: See Section 3.3 for discussion. Each observation pertains to a buyer firm, an origin province and a year. All variables are in natural logarithms. Cable TV connectivity is computed as the minimum of cable TV subscribers per capita between both provinces. No. Suppliers is the number of suppliers of the buyer firm located in a given origin province. Cost share is the fraction of purchases of a buyer from a given source province. Cost Share HHI is the Herfindahl-Hirschman Index of cost shares of suppliers of a buyer, which are located in a given origin province. New Connections is the number of new suppliers relative to the year before. All columns also include interactions of bilateral travel time between source and destination with annual dummy variables. * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at origin and destination level, are reported in parentheses.

Table A5: **Reallocation and Diversification in Input Sourcing: Including Non-Manufacturing Suppliers**

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

Note: See Section 3.3 for discussion. Each observation pertains to a buyer firm, an origin province and a year. All variables are in natural logarithms. No. Suppliers is the number of suppliers of the buyer firm located in a given origin province. Cost share is the fraction of purchases of a buyer from a given source province. Cost Share HHI is the Herfindahl-Hirschman Index of cost shares of suppliers of a buyer, which are located in a given origin province. New Connections is the number of new suppliers relative to the year before. * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at origin and destination level, are reported in parentheses.

Table A6: **Reallocation and Diversification in Input Sourcing: Source of Variation in Fibre Intensity**

Dependent Variable:	Cost Share (1)	No. Suppliers (2)	Cost Share HHI (3)	New Connections (4)
Panel A				
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)
Panel B				
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

Note: See Section 3.3 for discussion. Each observation pertains to a buyer firm, an origin province and a year. All variables are in natural logarithms. No. Suppliers is the number of suppliers of the buyer firm located in a given origin province. Cost share is the fraction of purchases of a buyer from a given source province. Cost Share HHI is the Herfindahl-Hirschman Index of cost shares of suppliers of a buyer, which are located in a given origin province. New Connections is the number of new suppliers relative to the year before. * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at origin and destination level, are reported in parentheses.

Table A7: **Reallocation and Diversification in Input Sourcing: Controlling for Travel Time Interactions**

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

Note: See Section 3.3 for discussion. Each observation pertains to a buyer firm, an origin province and a year. All variables are in natural logarithms. No. Suppliers is the number of suppliers of the buyer firm located in a given origin province. Cost share is the fraction of purchases of a buyer from a given source province. Cost Share HHI is the Herfindahl-Hirschman Index of cost shares of suppliers of a buyer, which are located in a given origin province. New Connections is the number of new suppliers relative to the year before. All columns also include interactions of bilateral travel time between origin and destination with annual dummy variables. Travel time is calculated using the road network in 2010. * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at origin and destination level, are reported in parentheses.

Table A8: **Reallocation and Diversification in Input Sourcing: Excluding Origin-Destination Fixed Effects**

Dependent Variable:	Cost Share (1)	No. Suppliers (2)	Cost Share HHI (3)	New Connections (4)
Fibre Connectivity	0.485***	0.264***	-0.114***	0.140
	(0.155)	(0.115)	(0.056)	(0.092)
Travel Time	-0.224***	-0.198***	0.102***	-0.107
	(0.019)	(0.015)	(0.008)	(0.011)
Fixed Effects:				
Buyer×Year	✓	✓	✓	✓
Origin×Year	✓	✓	✓	✓
Observations	3,362,435	3,362,435	3,362,435	3,362,435

Note: See Section 3.3 for discussion. Each observation pertains to a buyer firm, an origin province and a year. All variables are in natural logarithms. No. Suppliers is the number of suppliers of the buyer firm located in a given origin province. Cost share is the fraction of purchases of a buyer from a given source province. Cost Share HHI is the Herfindahl-Hirschman Index of cost shares of suppliers of a buyer, which are located in a given origin province. New Connections is the number of new suppliers relative to the year before. All columns also include interactions of bilateral travel time between origin and destination with annual dummy variables. Travel time is calculated using the road network in 2010. * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at origin and destination level, are reported in parentheses.

Table A9: **Reallocation and Diversification in Input Sourcing: Interaction between Travel Time and Connectivity**

Dependent Variable:	Cost Share (1)	No. Suppliers (2)	Cost Share HHI (3)	New Connections (4)
Fibre Connectivity	0.294***	0.176***	-0.056***	0.0319
	(0.056)	(0.025)	(0.013)	(0.0197)
Travel Time × Fibre Connectivity	-0.093***	-0.064***	0.022***	-0.0134**
	(0.018)	(0.0095)	(0.0039)	(0.0056)
Fixed Effects:				
Buyer×Year	✓	✓	✓	✓
Origin×Year	✓	✓	✓	✓
Origin×Destination	✓	✓	✓	✓
Observations	3,362,435	3,362,435	3,362,435	3,362,435

Note: Each observation pertains to a buyer firm, an origin province and a year. All variables are in natural logarithms. No. Suppliers is the number of suppliers of the buyer firm located in a given origin province. Cost share is the fraction of purchases of a buyer from a given source province. Cost Share HHI is the Herfindahl-Hirschman Index of cost shares of suppliers of a buyer, which are located in a given origin province. New Connections is the number of new suppliers relative to the year before. Travel time is calculated using the road network in 2010. * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at origin and destination level, are reported in parentheses.

C Theoretical Appendix

C.1 Proof of Proposition 1

The firm makes its information acquisition decision in expectation over match-specific productivities which are independently and identically distributed across tasks and potential suppliers. Using properties of the Fréchet distributional assumptions for match-specific productivities, we can reformulate the firm's supplier choice problem (3) as:

$$\log p = \max_{\boldsymbol{\pi}} \left\{ \mathbb{E}_{\mu} \left[\sum_{s} \pi(s) \ln\left(c(s)^{-\zeta} \tau_{o_s d}^{-\zeta} \phi_{o_s d} \right) \right] - \psi(\boldsymbol{\pi}, \mu) \right\},$$
$$\text{subject to } \pi(s) \geq 0 \text{ for all } s, \sum_{s} \pi(s) = 1.$$

An application of Proposition 4(ii) in Fosgerau et al. (2020) under the functional form assumptions for information acquisition costs to the above problem then leads to the desired result.

C.2 Proof of Proposition 2

We define a normalized version of the scaled marginal costs as $\tilde{c}(s)^{-\zeta} = \frac{c(s)^{-\zeta}}{c_{o_s}^{-\zeta}}$ where o_s denotes the province where s is located and for any origin province o, $c_o^{-\zeta} = \sum_{s \in o} c(s)^{-\zeta}$. Let d_b denote the province where b is located. The log-likelihood function for the inner nest of supplier choice conditional on an origin province is proportional to the following expression:

$$\begin{aligned}
\mathcal{L}_{\text{inner}} &\propto \left(\sum_{b} \sum_{s} \left(\frac{\text{Cost Share}(s,b)}{\sum_{s' \in o_s} \text{Cost Share}(s',b)} \right) \ln \left(\frac{\mathbb{E}_{\mu}[\pi(s \mid o_s, d_b)] \tilde{c}(s)^{-\zeta/\lambda_{o_s d_b}}}{\sum_{s' \in o} \mathbb{E}_{\mu}[\pi(s' \mid o_s, d_b)] \tilde{c}(s')^{-\zeta/\lambda_{o_s d_b}}} \right) \right) \\
&= \sum_{d} \sum_{s} \left(\sum_{b \in d} \left(\frac{\text{Cost Share}(s,b)}{\sum_{s' \in o_s} \text{Cost Share}(s',b)} \right) \right) \ln \left(\mathbb{E}_{\mu}[\pi(s \mid o_s, d)] \tilde{c}(s)^{-\zeta/\lambda_{o_s d}} \right) \\
&\quad - \sum_{d} M_d \left(\sum_{o} \ln \left(\sum_{s' \in o} \mathbb{E}_{\mu} \left[\pi(s' \mid o, d) \right] \tilde{c}(s')^{-\zeta/\lambda_{od}} \right) \right)
\end{aligned}$$

The maximum of the log-likelihood must satisfy first order conditions with respect to $\tilde{c}(s)^{-\zeta}$ and λ_{od}. The first order condition with respect to $\tilde{c}(s)^{-\zeta}$ can be simplified as follows:

$$
\begin{aligned}
&\frac{\partial \mathcal{L}_{\text{inner}}}{\partial \tilde{c}(s)^{-\zeta}} = 0 \\
\implies &\sum_d \left(\sum_{b \in d} \left(\frac{\text{Cost Share}(s,b)}{\sum_{s' \in o_s} \text{Cost Share}(s',b)} \right) \right) \left(\frac{1/\lambda_{o_s d}}{\tilde{c}(s)^{-\zeta}} \right) = \sum_d M_d \left(\frac{1/\lambda_{od} \mathbb{E}_\mu[\pi(s \mid o_s,d)] \left(\tilde{c}(s)^{-\zeta}\right)^{1/\lambda_{o_s d}-1}}{\sum_{s' \in o_s} \mathbb{E}_\mu[\pi(s' \mid o_s,d)] \tilde{c}(s')^{-\zeta/\lambda_{o_s d}}} \right) \\
\implies &\sum_d \left(\sum_{b \in d} \left(\frac{\text{Cost Share}(s,b)}{\sum_{s' \in o_s} \text{Cost Share}(s',b)} \right) \right) (1/\lambda_{o_s d}) = \sum_d M_d \left(\frac{\mathbb{E}_\mu[\pi(s \mid o_s,d)] \tilde{c}(s)^{-\zeta/\lambda_{od}}}{\sum_{s' \in o_s} \mathbb{E}_\mu[\pi(s' \mid o_s,d)] \tilde{c}(s')^{-\zeta/\lambda_{od}}} \right) (1/\lambda_{o_s d})
\end{aligned}
$$

Clearly, the following solution satisfies the above equation:

$$
\left(\frac{\mathbb{E}_\mu[\pi(s \mid o_s,d)] \tilde{c}(s)^{-\zeta/\lambda_{o_s d}}}{\sum_{s' \in o_s} \mathbb{E}_\mu[\pi(s' \mid o_s,d)] \tilde{c}(s')^{-\zeta/\lambda_{o_s d}}} \right)^* = \frac{1}{M_d} \sum_{b \in d} \left(\frac{\text{Cost Share}(s,b)}{\sum_{s' \in o_s} \text{Cost Share}(s',b)} \right) \tag{13}
$$

For this to be the maximum likelihood estimate, this solution must also simultaneously satisfy the first order condition with respect to $\lambda_{o_s d}$. The first order conditions with respect to $\lambda_{o_s d}$ can be simplified as follows:

$$
\begin{aligned}
&\frac{\partial \mathcal{L}_{\text{inner}}}{\partial \lambda_{o_s d}} = 0 \\
&\implies \sum_d \left(\sum_s \left(\frac{\text{Cost Share}(s,b)}{\sum_{s' \in o_s} \text{Cost Share}(s',b)} \right) \ln\left(\tilde{c}(s)^{-\zeta} \right) \left(-1/\lambda_{o_s d}^2 \right) \right) \\
&= \sum_d M_d \left(\sum_o \frac{\partial \ln\left(\sum_{s \in o} \mathbb{E}_\mu[\pi(s \mid o_s,d)] \tilde{c}(s)^{-\zeta/\lambda_{o_s d}} \right)}{\partial \lambda_{o_s d}} \right) \\
&= \sum_d M_d \left(\sum_o \sum_{s \in o} \frac{\mathbb{E}_\mu[\pi(s \mid o_s,d)] \tilde{c}(s)^{-\zeta/\lambda_{o_s d}} \ln \tilde{c}(s)^{-\zeta}}{\sum_{s' \in o_s} \mathbb{E}_\mu[\pi(s' \mid o_s,d)] \tilde{c}(s')^{-\zeta/\lambda_{o_s d}}} \left(-1/\lambda_{o_s d}^2 \right) \right) \\
&= \sum_d M_d \left(\sum_s \frac{\mathbb{E}_\mu[\pi(s \mid o_s,d)] \tilde{c}(s)^{-\zeta/\lambda_{o_s d}} \ln \tilde{c}(s)^{-\zeta}}{\sum_{s' \in o_s} \mathbb{E}_\mu[\pi(s' \mid o_s,d)] \tilde{c}(s')^{-\zeta/\lambda_{o_S d}}} \left(-1/\lambda_{o_s d}^2 \right) \right)
\end{aligned}
$$

Clearly, the solution in equation (13) also satisfies this first order condition with respect to $\lambda_{o_s d}$. This proves the first part of the proposition.

Next, note that the log-likelihood of the outer nest of choice of origin province is proportional to:

$$
\mathcal{L}_{\text{outer}} \propto \sum_s \left(\sum_b \text{Cost Share}(s,b) \right) \ln\left(c_o^{-\zeta} \tau_{od}^{-\zeta} \phi_{od} \mathbb{E}_\mu[\pi(o,d)] \right)
$$

$$-\sum_{d\in\mathcal{J}} M_d \ln\left(\sum_{o'} c_{o'}^{-\zeta}\tau_{o'd}^{-\zeta}\phi_{o'd}\mathbb{E}_\mu\left[\pi\left(o',d\right)\right]\right)$$

The likelihood equations for $c_o^{-\zeta}\tau_{od}^{-\zeta}\phi_{od}\omega_{od}\mathbb{E}_\mu\left[\pi(o,d)\right]$ can be simplified as follows:

$$\begin{aligned}
&\frac{\partial\mathcal{L}_{\text{outer}}}{\partial\left(c_o^{-\zeta}\tau_{od}^{-\zeta}\phi_{od}\omega_{od}\mathbb{E}_\mu[\pi(o,d)]\right)} = 0\\
&\implies \frac{\sum_{b\in d}\sum_{s\in o}\text{Cost Share}(s,b)}{c_o^{-\zeta}\tau_{od}^{-\zeta}\phi_{od}\omega_{od}\mathbb{E}_\mu[\pi(o,d)]} = \frac{M_d}{\sum_{o'} c_{o'}^{-\zeta}\tau_{o'd}^{-\zeta}\phi_{o'd}\omega_{o'd}\mathbb{E}_\mu[\pi(o',d)]}\\
\implies &\left(\frac{c_o^{-\zeta}\tau_{od}^{-\zeta}\phi_{od}\omega_{od}\mathbb{E}_\mu[\pi(o,d)]}{\sum_{o'} c_{o'}^{-\zeta}\tau_{o'd}^{-\zeta}\phi_{o'd}\omega_{o'd}\mathbb{E}_\mu[\pi(o',d)]}\right)^* = \frac{1}{M_d}\sum_{b\in d}\left(\sum_{s\in o}\text{Cost Share}(s,b)\right)
\end{aligned}$$

This proves the second part of the proposition.