Trade Liberalization, Roads and Firm Productivity*

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Abstract

We examine the role of road infrastructure in determining the impact of a reduction in input tariffs on firm productivity. We combine new geo-spatial data on road improvements in Ethiopia with establishment level data on manufacturing firms that allow us to estimate physical productivity. Results show that an input tariff reduction is associated with a larger increase in firm productivity in areas where better roads improve access to other intranational markets. Roads magnify pass-through of tariff reductions to imported input prices and also incentivize firms to exploit this cost advantage to enhance productivity. Road infrastructure hence complements trade liberalization.

Keywords: Input tariffs; transport infrastructure; roads; firms; productivity; Ethiopia
JEL Classification: F14; O14; O18

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1 Introduction

Firms play a crucial role in spurring economic development. Studies exploring the determinants of firm performance have thus retained a prominent place in the literature and have highlighted trade liberalization as a key driver of firm productivity (Lee, 1995; Brandt et al., 2017). Increased competition and better access to intermediate inputs resulting from trade liberalization can encourage innovation, incentivize technology adoption and lead to productivity enhancements (Topalova and Khandelwal, 2011; Bloom et al., 2016; De Loecker, 2011). However, trade liberalization alone may be inadequate to ensure gains to productivity growth and economic development. Pavcnik (2017) points out that the distribution of gains from trade liberalization is far from uniform within countries and depends on complementary domestic conditions, including the flexibility of labor and credit markets, quality of institutions and provision of public goods and infrastructure. Identifying and understanding these complementary conditions and the channels through which they shape the effects of trade liberalization on firms is important to inform domestic policy and achieve economic development.

In this study, we examine the complementary role of road infrastructure in determining the impact of input tariff (the tariff on intermediate inputs) liberalization on firm productivity. We argue that roads matter for productivity gains from input tariff liberalization. Specifically, we propose that improved roads magnify the mechanism whereby a reduction in input tariffs boosts firm productivity, by improving their connectivity to intranational markets. Increased intranational connectivity can not only magnify the pass-through of a tariff reduction to input prices, but by improving market access, can incentivize firms to undertake actions that enhance physical total factor productivity. Such productivity-enhancing actions may include investing in new imported inputs and/or superior technology, all of which can expand the firm's production possibility frontier. Our empirical analysis combines newly constructed geo-spatial data from Ethiopia on road improvements under the Ethiopian Road Sector Development Program (RSDP) with detailed establishment level data on manufacturing firms.

Overlapping trade and road infrastructure reforms make Ethiopia an excellent case study for our purpose. Tariffs were reduced progressively starting in the early 1990s and continuing into our sample period, as part of a trade liberalization agenda initiated externally. Tariff changes were hence largely exogenous to domestic firms. Next, Ethiopia embarked on extensive improvements to roads via the RSDP, aimed at improving connectivity throughout the country. Significant enhancements in road infrastructure were undertaken under this program, including projects to rehabilitate and upgrade the quality of existing roads and to build new ones.

To study the impact of roads, we utilize raw data on the evolution of the Ethiopian road network over time, sourced from the Ethiopian Road Authority (ERA). For each point in time during our sample period, we observe the set of existing road segments, their surface type and their condition. We identify urban areas (towns) using contiguous lit spatial units from high resolution nocturnal satellite images. Road improvements under the RSDP result in differential changes in the quality of road infrastructure across Ethiopian towns over time, either through increases in the quality of the existing road network or through an expansion of the existing network with the construction of new roads. Our primary measure of roads for each Ethiopian town in a given year is its market access, determined by the road network (hereafter referred to simply as market access). This variable captures the intensity of possible road connections between the urban area (town) in which a firm is located and other markets in the country. Furthermore, we employ an additional measure of roads that captures the travel time from each town to Galafi, a small town en route to Ethiopia's primary port in Djibouti.[1] This second measure (hereafter referred to as Galafi) is intended to capture the impact of road infrastructure improvements on the cost of transporting imported inputs intranationally, from (dry) port to destination.

We exploit census data on Ethiopian manufacturing establishments from 1998 through 2009 to construct measures of firm productivity.[2] In addition to information on revenues, the Ethiopian manufacturing census records data on quantities, allowing us to compute unit-values at the firm level. This allows us to build quantity-based physical productivity measures that are not affected by the usual caveats undermining the application of revenue-based productivity in studies of trade liberalization and firm performance. As highlighted by a burgeoning literature, focusing on revenue-based productivity introduces biases in the estimation of production function coefficients and may confound the effects of trade liberalization on physical productivity and firm markups (see for instance De Loecker, 2011; De Loecker et al., 2016).

Our empirical strategy relates firm productivity to input tariffs, roads and an interaction of the two to explore the complementary effect of roads on the relationship between input tariffs and firm productivity. First, we document that a mere reduction in input tariffs has no impact on physical firm productivity, consistent with the idea that a reduction in input prices may not be sufficient for physical productivity enhancements (De Loecker and Goldberg, 2014). Next, we find strong complementarity between market access and input tariff liberalization, especially at lower levels of market access. A one percentage point decrease in the input tariff is associated with a 3.1 percentage point larger increase

[1] About 93% of total Ethiopian trade is estimated to transit through the port of Djibouti, according to the World Bank (World Bank, 2013).

[2] The data, collected by the Ethiopian Central Statistical Agency (CSA), include detailed information at the establishment level on location (town), labor and capital use, usage of imported inputs and exports.

in physical productivity for a firm with median market access relative to a firm with market access at the 5^{th} percentile. A one percentage point decrease in the input tariff is associated with a 0.4 percentage point larger increase in physical productivity for a firm with market access at the 95^{th} percentile relative to a firm with median market access. We find no evidence for complementarity between input tariff liberalization and travel time to Galafi.

We undertake a battery of robustness checks. We address the endogeneity of road investments in two ways. First, we introduce control variables for local road infrastructure improvements and the presence of multinationals that may have been incentivized to locate in specific areas. Second, we adopt an instrumental variable identification strategy that tackles the following two concerns: (i) unobserved local factors, like lobbying by growing firms, drive the construction of local roads and connections between towns and nearby economic hubs; (ii) such political economy efforts to attract a larger share of investments in road infrastructure are correlated across towns. We show that our results survive under both estimation strategies. Our findings are further confirmed with alternative measures of productivity, roads, tariffs and in various cuts of the data. Finally, results endure after we control for the effect of a reduction in output tariffs (the tariff on the final good produced by the firm) on firm productivity that operates by increasing competition.

We explore the channels through which roads complement the relationship between input tariff liberalization and firm productivity. We find that an input tariff reduction is associated with greater pass-through to input prices for firms in areas with better market access. Additionally, better market access is associated with greater perceived competition by firms. Finally, with a fall in the input tariff, firms in towns with better market access are more likely to employ newly imported intermediate inputs and a higher capital-labor ratio. Note that imported intermediate inputs can embody superior technology, while a higher capital-labor ratio is in line with adoption of new technology. These findings provide support for our argument that better market access provides an incentive for firms to invest in total factor productivity enhancements.

In an extension of our empirical analysis, we look at revenue-based firm productivity and the markup charged as additional dependent variables. We find some evidence for complementarity between market access and the impact of input tariff liberalization on revenue-based productivity. However, our results on the markup charged by firms reveal no such complementarity. We argue that two contrasting forces are potentially at work. While amplified gains from an input tariff reduction for firms in towns with better market access mean larger markups, increased competitive pressures from better market access can exert an opposing influence.

Our paper makes several contributions. First, our study broadly relates to the literature emphasizing road infrastructure improvements as crucial for economic development in low-income countries (Storeygard, 2016; Donaldson, 2018). Policy makers have long touted the potential for roads to generate growth and alleviate poverty.[3] While studies have found that good roads are associated with increases in firm activity (Shiferaw et al., 2015), exports (Volpe Martincus and Blyde, 2013; Coşar and Demir, 2016) and employment (Volpe Martincus et al., 2017), recent work casts doubt on the ability of road improvements to substantially transform rural economies in developing countries (Asher and Novosad, 2020). By focussing on inputs and firm productivity, we highlight an important role for roads in ensuring gains from trade liberalization. Our results suggest that initial road investments bring the largest productivity gains for firms, echoing existing work on investment in railroads in Africa (Jedwab and Moradi, 2016).

Second, we contribute to the literature studying infrastructure development in the context of international trade. This literature has embedded intranational trade costs into models of international trade to emphasize that better transport infrastructure can impact interregional and international trade (Donaldson, 2018), shape the pattern of comparative advantage among sub-national entities (Coşar and Fajgelbaum, 2016) and determine the intranational distribution of gains from falling international trade barriers (Atkin and Donaldson, 2015; Allen and Atkin, 2016; Ramondo et al., 2016). However, to date, there has been no formal assessment of the role played by roads in determining the impacts of trade liberalization on physical firm productivity, specifically through firm decisions to import new inputs or upgrade technology. We aim to fill this gap by underscoring the role for transport infrastructure in ensuring productivity gains for domestic firms.

Third, our study contributes to the literature demonstrating that lower input tariffs and the resulting access to cheaper, better quality and a wider variety of intermediate inputs is associated with greater firm productivity (Topalova and Khandelwal, 2011; Bigsten et al., 2016; Halpern et al., 2015; Colantone and Crinò, 2014), higher markups (Brandt et al., 2017), product quality improvements (Amiti and Khandelwal, 2012) and greater product scope (Goldberg et al., 2010). In this context, we argue that the positive effects of an input tariff reduction are augmented when firms are better connected to markets intranationally by quality transport infrastructure. In fact, firms in less connected regions may lose out on gains from trade liberalization because they lack the incentives from better market access to enhance physical productivity.

The remainder of the paper is organized as follows. Section 2 presents our conceptual

[3] The World Bank identified "widespread poverty ... linked to, among others, the constraint imposed by the poor road network on economic and social development and the creation of local employment opportunities" as a concern for Ethiopia (World Bank, 2018).

framework. Section 3 focuses on the empirical analysis. We describe our measures of tariffs and road infrastructure, the data and estimation of physical total factor productivity. We further discuss the empirical specification, identification issues and estimation strategy. Section 4 presents results, robustness checks and extensions to the baseline analysis. Section 5 concludes.

2 Conceptual Framework

The main goal of our study is to analyze the role played by road improvements in determining the impact of an input tariff reduction on physical total factor productivity of firms. In this section, we discuss the channels through which road improvements shape the productivity impacts of trade liberalization. We begin by noting that a reduction in the input tariff can lead to a decrease in input prices, generating a cost advantage for firms. As pointed out by Atkin and Donaldson (2015), the transmission of input tariff reductions to reductions in input prices can be a complex function of the quality of transportation infrastructure. Specifically, the quality of roads can lead to differential pass-through of tariff reductions to input prices, both through its impact on the marginal cost for intermediaries transporting inputs domestically and the demand conditions they face.[4] However, this differential pass-through following a reduction in input tariffs alone is neither necessary nor sufficient for road improvements to generate differential effects of input tariff liberalization on firm physical productivity.

An important contribution we make in this paper is to go beyond pass-through, arguing that roads differentially affects firms' incentives to take productivity-enhancing actions in response to the cost advantage generated by an input tariff reduction. Before discussing this channel in detail, we characterize productivity-enhancing actions. We define productivity-enhancing actions as specific actions firms take that increase physical productivity, thereby enhancing the firm's production possibility frontier. First, a firm might increase its physical productivity by introducing a new imported input. Koren and Tenreyro (2013) argue that imported inputs can embody superior technology. Adoption of a wider variety of imported inputs is tantamount to technological diversification, leading to increases in firm productivity and growth. In fact, their view is that costs of adopting new inputs can be thought of as the cost of research and development of new varieties.[5] This idea is in line with theoretical insights from the endogenous growth literature, where technology embodied in imported inputs can bring

[4] We discuss intermediaries and pass-through of input tariff reductions to domestic prices in Appendix A.

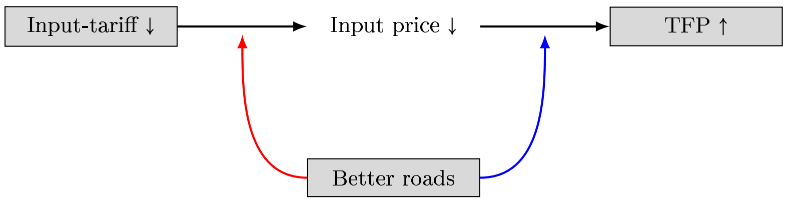
[5] Koren and Tenreyro (2013) cite the example of the entry of new input-producing firms into a (South Korean) conglomerate that increases the productivity of that conglomerate. In farming, inputs that embody technology include high-yielding seeds, chemical fertilizers and cellphones used to transmit weather information.

efficiency gains at the aggregate level (Rivera-Batiz and Romer, 1991; Grossman and Helpman, 1991; Howitt and Aghion, 1998). At the micro level, superior technology embedded in foreign inputs can increase physical productivity, enhancing the production possibility frontier of the firm. Second, the firm might adopt a superior technology that is reflected in a revised input mix observable by the econometrician, such as one with a higher share of high skill workers or capital inputs (Topalova and Khandelwal, 2011; Xu and Wang, 1999; Eaton and Kortum, 2001; Yasar and Paul, 2007).

How do roads result in input tariff reductions triggering productivity-enhancing actions at the firm level? The quality of roads determines the degree of market access in the firm's area (town). Better connectivity to intranational markets means that, on the one hand, firms can access larger demand. Jensen and Miller (2018) show how, when consumers learn about non-local producers, firms gain market share and grow. On the other hand, firms compete more intensively with other final good producers, given that an increase in market access allows consumers to access goods produced by firms in other locations. Greater demand and more competition increase the potential gains for firms from improving physical total factor productivity, increasing incentives to use the cost advantage implied by a reduction in input tariffs to undertake productivity enhancements. This argument is consistent with previous findings in the literature, where larger market share (Lommerud et al., 2009), increased product market competition (De Loecker and Goldberg, 2014) and a combination of the two (Desmet et al., 2020) are associated with improvements in physical productivity. Thus, we argue that firms in locations with better roads have a greater incentive to increase physical productivity with an input tariff reduction.

To summarize, input tariff reductions decrease input prices for firms, incentivizing productivity-enhancing actions that increase firm productivity. Roads can magnify this mechanism in two ways, as illustrated in Figure 1. First, roads shape the pass-through of an input tariff reduction to a decrease in input prices for firms (the red arrow in Figure 1). Second, they influence the incentives faced by firms to take productivity-enhancing decisions in response to the cost advantage generated by these lower input prices (the blue arrow in Figure 1). We wish to reiterate here that the first channel alone only impacts how an input tariff reduction impacts firm profitability, not firm productivity. In other words, the differential pass-through from input tariffs to input prices generated by roads is not sufficient to establish that roads play a role in determining the effects of input tariff liberalization on physical firm productivity. Moreover, it is not a necessary condition either. Even if pass-through does not vary with roads, the incentives to take productivity-enhancing actions in response to an input tariff reduction can vary, leading to a differential effect of input tariff liberalization on productivity. This emphasis on the role played by roads in enhancing physical firm productivity is a crucial contribution of our paper.

Figure 1: The two channels of roads' impact in shaping the effect of input tariffs on productivity



In the empirical analysis that follows, we will estimate the differential effect of an input tariff reduction on the productivity of firms located across urban areas (towns) with varying quality of roads. We will also aim to disentangle the channels through which roads shape the impact of a reduction in input tariffs on firm productivity. Particularly, we will explore differential pass-through of input tariff reductions to input prices and the relationship between market access and competition. We will also examine evidence for potential productivity-enhancing actions that firms take in response to an input tariff reduction, and ask if they vary with road quality.

Finally, we will exploit rich geo-spatial information on the Ethiopian road network to identify whether road improvements matter because they increase connectivity along specific intranational trade routes (the route from each location to Galafi) and/or because they expand the overall degree of market access for firms in an area. We can thus throw light on how new and better roads play a role in determining the productivity impacts of trade liberalization.

3 Empirical Framework

This section presents the ingredients of our empirical framework. Section 3.1 discusses Ethiopian infrastructure and tariff reforms and related measures used in the analysis. Section 3.2 describes the database of Ethiopian firms and the methodology we adopt to estimate total factor productivity. Our preferred approach accounts for both output price and input price biases in addition to the standard endogeneity concerns due to simultaneity in input choices. Section 3.3 introduces the empirical specification used to analyze the role of infrastructure in determining the effect of a reduction in input tariffs on firm productivity and discusses our identification strategy. Finally, Section 3.4 introduces the estimation sample and reports summary statistics.

3.1 Infrastructure and Tariffs in Ethiopia: Reforms and Related Measures

3.1.1 Road infrastructure

Being a landlocked country with a poorly developed railway system, Ethiopian road transport represents the dominant mode for intranational movement of people and goods (Iimi et al., 2017).[6] At the end of the nineties, the deteriorated condition of the existing road network spurred the Ethiopian Government to launch a major infrastructural reform program: the Road Sector Development Programme (RSDP). The first three phases of the program, from July 1997 to June 2010 involved construction, rehabilitation, upgrading and maintenance of federal and regional roads by the Ethiopian Roads Authority (ERA) and the Regional Roads Authorities (RRAs).

The official assessment of the first three phases of the program (Ethiopian Roads Authority, 2011) reveals substantial improvements in road infrastructure along multiple dimensions between 1997 and 2010 (see Table 1).

Table 1: Improvements in road infrastructures during the RSDP

Indicators	1997	2010
Proportion of Asphalt roads in Good Condition	17%	73%
Proportion of Total Road network in Good Condition	22%	56%
Road Density/ 1000 sq. km	24.1	44.4

Notes: Raw data sourced from Ethiopian Roads Authority (2011).

The main source of information on Ethiopian road infrastructure we draw upon in this paper is a proprietary geo-spatial database consisting of coded documents by the ERA and the RRAs reporting on all road construction sites that were opened in the context of the first three phases of the RSDP. The resulting database is a time series of shapefiles of the Ethiopian road network, where for each geo-localized road segment, two main attributes are registered: the type of road surface and the road's condition. There are four types of road surfaces in the data: earth surface, minor gravel (which identifies regional rural roads with a gravel surface), major gravel (federal gravel roads) and asphalt. As for road conditions, the database distinguishes between two categories: (i) not rehabilitated and (ii) new or rehabilitated.[7]

Figure 2a presents the network of federal and regional roads in 1996 by type of surface

[6] The railway connecting Addis to the port of Djibouti was ceased in 2007 in the section between Addis and Dire Dawa. The new railway connecting Addis to Djibouti has been financed by a Chinese concessional loan project and was inaugurated in early 2017, almost ten years after the sample period analyzed in this paper.

[7] Information on road surface and condition are recorded every two years from 1996 to 2010. The raw data were compiled by a local consultant. The consistency and accuracy of the original documents used for the coding exercise were checked by the authors during a field trip in 2017.

and the cities that are covered in our empirical analysis. Figure 2b shows the network of federal and regional roads in 2010, distinguishing between road segments which existed in 1996 and were not rehabilitated by 2010 and roads that were either newly constructed or rehabilitated during the first three phases of the RSDP (red segments on the map). A visual inspection of the two maps shows a substantial expansion of the road network between 1996 and 2010. This data on road improvements can be aggregated to compute the average travel speed for each road segment at each point in time. This is done in accordance with the speed matrix proposed by the ERA and reported in Table 2.[8]

Table 2: The ERA travel speed matrix

Surface	Condition	
	Not rehabilitated	Rehabilitated or new
Asphalt	50	70
Major gravel	35	50
Minor gravel	25	45
Earth	20	30

Notes: The table reports average travel speed as a function of the surface and condition of the road segment. Speed is measured in kilometers per hour.

To identify the role of road improvements in determining the relationship between a reduction in input tariffs and firm performance, we employ two measures of the quality of roads. The first one is an indicator of market access à la Harris (1954). This and alternative versions of the market access indicator have been used by Donaldson and Hornbeck (2016) to measure the economic effects of infrastructural developments in the context of a formal structural gravity trade model. In our context, and similarly to Storeygard (2016), market access captures the structure of road connections between a geographically defined urban area (city or town) where a firm is located and all other urban markets in the country weighted by the intensity of their economic activity.[9]

Formally, we define the indicator Market access$_{rt}$ for each town r at time t as follows:

$$\text{Market access}_{rt} = \log\Big(\sum_{z \neq r} D_{rz,t}^{-1} L_z\Big) \tag{3.1}$$

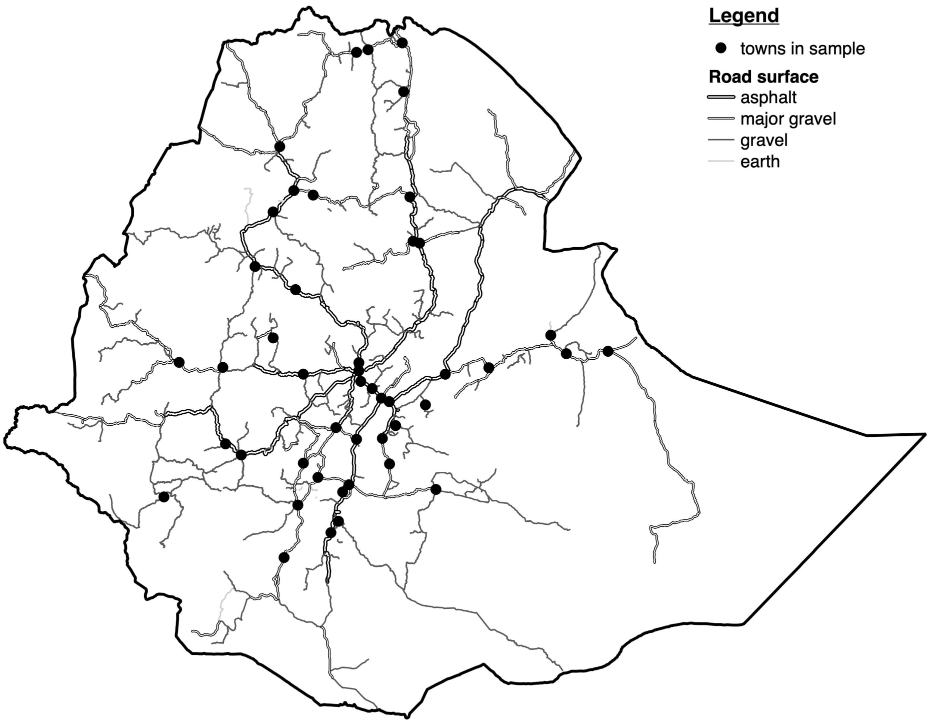
where $D_{rz,t}$ is the minimum distance in hours of travel between town r and town z given the road network in place at t, and L_z is an indicator of economic activity based on night-light intensity in z in the pre-sample period (1996).[10] Bilateral distances in travel

[8] The same speed matrix has been used by Shiferaw et al. (2015) and Jedwab and Storeygard (2020).

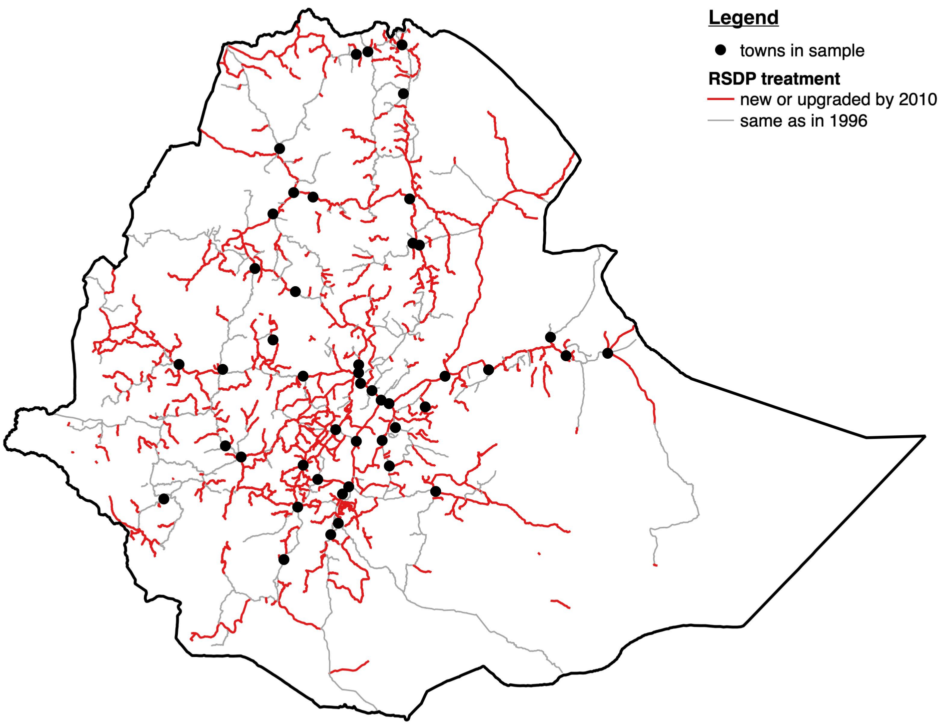
[9] In the computation of market access, we consider all cities recorded as hosting firms in the Ethiopian Census of Large and Medium Manufacturing Firms.

[10] While many papers including Donaldson and Hornbeck (2016) use population data in the computation of market access, we employ night light intensity data as in Storeygard (2016). This is

Figure 2: Federal roads, regional roads and the RSDP



(a) Cities and RSDP roads in 1996 by surface type



(b) New and upgraded RSDP roads between 1996 and 2010

hours are computed applying the Dijkstra algorithm on the network of Ethiopian urban

particularly appropriate, given our interest in supply-side economic activity. In a robustness check, reported in column (3) of Table 8 we show that results do not change if we adopt population weights.

areas (nodes) connected by federal and regional Ethiopian roads (links).[11] Each link is characterized by its average travel speed, a function of the surface type and condition of the road segment(s) in the link (see Table 2). Hence, the variable Market access_{rt} captures the intensity of the road infrastructure reform treatment received by town r at time t as the capacity of such treatment to affect r's contact with intranational markets in the country.

Following Henderson et al. (2011, 2012) we measure town-level economic activity with night light data. More precisely, L_z is given by the sum of the beginning of sample (1996) night light intensity scores provided by NOAA National Geophysical Data Center (2018) over 0.86km^2 grid cells within the urban area corresponding to town z.[12] Urban areas are defined as contiguous lit areas between 1996 and 2010 intersecting with, or situated within a 5 kilometer-ray buffer centered on the town coordinates as reported in the road network database.[13] Note that since L_z is fixed over time, the time variation in Market access_{rt} solely reflects the rehabilitation, upgrading and construction of new roads undertaken during the first three phases of the RSDP.

The market access indicator, Market access_{rt}, captures several dimensions of connectivity that are consistent with the mechanism and channels identified in our conceptual framework. First, it reflects the ease with which intermediate inputs can be transported to Ethiopian firms. As more remote towns are better connected to regional and central economic hubs via the road network, the cost for intermediaries to transport inputs to them is likely to decline. Second, the measure accounts for both increases in market size and competition faced by firms. As discussed in Section 2, we expect market

[11]Starting from the shapefiles with road segments, we create additional ancillary nodes to allow for turns at every intersection between road segments. We have no information on the direction of travel allowed on each road segment. Hence, links are set so that they are not directed, reflecting the underlying assumption that each road segment can be travelled on in both directions. This is a reasonable assumption, given the focus on regional and federal roads which represent the majority of road infrastructure in the country. A road (link) is connected to a town node when it enters the corresponding urban area (definition follows in the main text). Unlike Ethiopian regions (the first level of administrative division in the country), city or town areas are small and relatively homogeneous. For this reason, we assume zero distance for connections between roads and town nodes. Alternative assumptions do not change the resulting market access indicator.

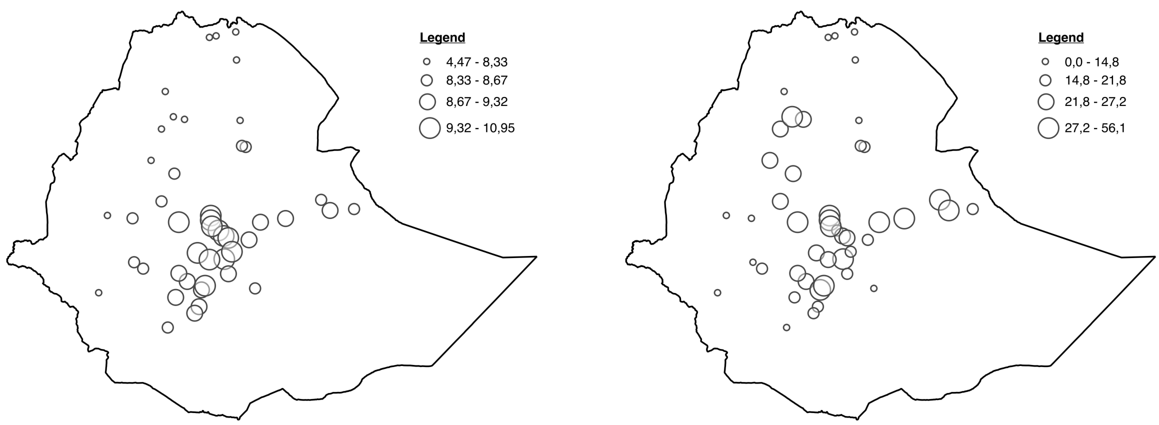
[12]Following Eberhard-Ruiz and Moradi (2019), we use scores from raw satellite images, instead of processed images with stable nightlights, as more reliable proxies of economic activity in small and medium African towns.

[13]This definition of urban areas follows the approach in other studies, as in Henderson et al. (2017) and Eberhard-Ruiz and Moradi (2019). We identify urban areas starting from town coordinates as reported in the Ethiopian Census of Large and Medium Manufacturing Firms. For 6 towns, we do not find any corresponding lit area and we exclude their coordinates from our analysis. Also, the contiguous lit area associated with Addis, the capital city, covers 8 town coordinates: Addis, Burayu, Sululta, Sendafa, Akaki, Sebeta, Bishoftu, Modjo. In order to identify town-specific areas, we partition this contiguous area into 7 sub-areas consisting of the Voronoi polygons defined around town coordinates. This requires merging Addis and Burayu, whose coordinates are too close to each other to allow for the application of the Voronoi partition. Figure B-1 provides a graphical representation of this partition for Addis (including Burayu), Sululta, Akaki, Bishoftu and Modjo, the towns within the contiguous lit area ultimately covered in our baseline estimation sample.

access to play a role in shaping the productivity effect of an input tariff reduction via two channels. First (channel one), market access can affect the pass-through from input tariffs to input prices. Second (channel two), it may influence the incentives of firms across urban areas to take productivity-enhancing decisions. Relevant for the pass-through channel (channel one) is the lower travel cost from intranational markets implied by an increase in market access, and the higher demand and competition faced by intermediaries serving a local market. The combination of these forces leads to a theoretical ambiguity in how Market access_{rt} affects pass-through, and thereby productivity. We derive and discuss this theoretical ambiguity in Appendix A. The role of Market access_{rt} in determining how liberalization affects productivity via channel two is unambiguous. The higher demand and competition faced by firms with an increase in market access boost firm incentives to enhance productivity, magnifying the impact of input tariff liberalization on firm productivity.

Figure 3a plots the value of the market access indicator at the beginning of our baseline estimation sample (1998) for the 46 towns that are covered in the econometric analysis. Figure 3b shows the change in market access between 2010 and 1998 for each town, formally Market $\text{access}_{r,2010}$ − Market $\text{access}_{r,1998}$. Focusing on Figure 3a, bigger circles near the center of the country close to Addis reveal higher market access in this area of the country. Smaller circles away from the center indicate lower market access for these towns. Figure 3b shows a larger increase in market access for less connected towns away from the center, suggesting that they saw improvements in road infrastructure over the time period of our analysis.

Figure 3: Market access (Market access_{rt})



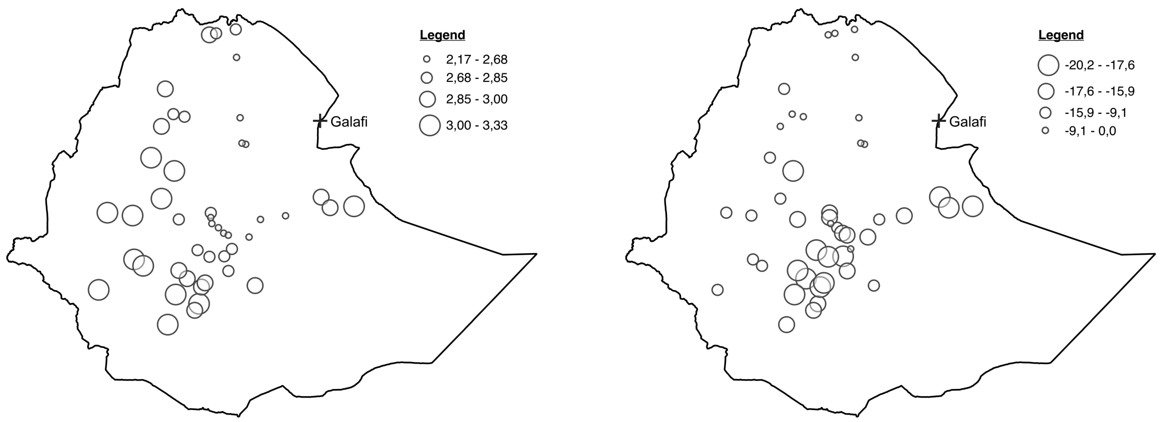
(a) Market $\text{access}_{r,1998}$

(b) Market $\text{access}_{r,2010}$ − Market $\text{access}_{r,1998}$

The second measure that we use to identify the role of road improvements in determining the relationship between a reduction in input tariffs and firm performance is the travel time to Galafi. Galafi is the first node to the border with Djibouti. To reiterate, almost 93% of Ethiopian trade passes through the port of Djibouti and up until the re-establishment of the Djibouti-Addis railway in 2018, all of this trade took place via roads (see World Bank, 2013, for more details). For our empirical analysis we take the log of the minimum travel time in hours from each urban area r to Galafi given the road network in place at time t. Assuming that the resulting variable - Galafi_{rt} - captures the decrease in transport cost incurred by firms importing intermediate inputs more closely than market access, we expect this variable to better pick up the effect of roads on pass-through of input tariff reductions to input prices. On the contrary, we do not expect any impact of Galafi_{rt} on firms' incentives to take productivity-enhancing actions once we control for market access.

Figure 4a plots the value of Galafi_{rt} across the 46 urban areas covered in the estimation sample and for $t = 1998$. Figure 4b instead plots $\text{Galafi}_{r,2010} - \text{Galafi}_{r,1998}$. Note that bigger circles in Figure 4b report negative values since they are associated with larger reduction in travel time.

Figure 4: Travel time to Galafi (Galafi_{rt})



(a) $\text{Galafi}_{r,1998}$ (log of travel time in minutes) (b) $\text{Galafi}_{r,2010} - \text{Galafi}_{r,1998}$ (percentage change)

In Table C-1, we conduct a descriptive analysis of the relationship between market access and relevant firm outcomes measured at the town level. We find that roads are positively correlated with a range of indicators of economic performance and global engagement in manufacturing, like the total number of firms, labor productivity, capital intensity, total sales, import-intensity (defined as the ratio of imports to sales) and the ratio of skilled to unskilled labor . These correlations are consistent with roads broadly benefiting the manufacturing sector in Ethiopia.

3.1.2 Tariffs

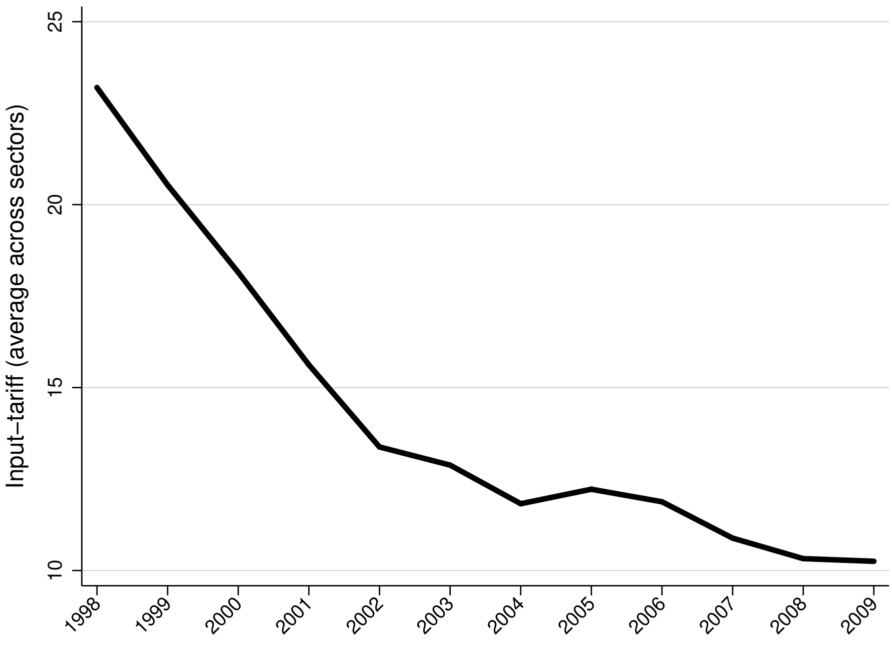
Starting in 1993, the Ethiopian government implemented six rounds of trade reforms, which ended in 2003 with the adoption of a six-band tariff structure with bands now ranging from 0 to 35% (more details are available in World Bank, 2004). We collect data on tariffs from the World Bank's WITS database, which uses the UN's TRAINS database as its source. Data on tariffs for Ethiopia are publicly available for the period 1995-2015, but they report some gaps in coverage, especially for the pre-2000 period. In light of this, we replace missing tariff values with values obtained by linear interpolation.

We construct input tariffs with information on the use of raw materials to construct industry weights. First, we match the code attributed by the CSA to each raw material used by the firm with a (4-digit) HS code[14]. Second, we compute the share of each input in each industry's total input expenditure: we denote as α_{jzt} the share of expenditure on input z in total input expenditures of industry j at time t.[15] Third, we use these shares as industry-specific coefficients to weight output tariffs using the standard approach:

$$\text{Input-tariff}_{jt} = \sum_{z} \alpha_{jzt} \text{Ouput-tariff}_{zt} \tag{3.2}$$

Figure 5 traces changes in the (sector) average input tariff for the period of our estimation sample (from 1998 to 2009). With trade liberalization, input tariffs dropped sharply up to 2003 and more gradually thereafter.

Figure 5: Input tariff reduction



Notes: Authors' calculations from World Bank's WITS data.

[14]Overall, we have 95 different commodities that are used as inputs by firms. On average, for each 4-digit ISIC code (an industry in our sample of firms), 15 different commodities (inputs) were used to calculate the weights.

[15]We construct these cost shares on the basis of total input purchases, including both domestic and imported inputs to avoid endogeneity bias (see discussion in Amiti and Konings, 2007).

3.2 Firm-level Data and the Estimation of Total Factor Productivity

3.2.1 Firm level Data

We use establishment level data from the annual census of Large and Medium Manufacturing Firms, published by the Central Statistical Agency (CSA) of Ethiopia.[16] Data cover all firms with at least 10 persons engaged and that use electricity in their production process.[17] All firms need to comply with CSA requirements, and the census is therefore representative of more structured and formal firms in the country.[18] The dataset includes detailed information on the characteristics of each establishment that are needed to estimate production functions, including output, employment, capital and inputs. Firms belong to the manufacturing sector, and their industry is defined at the 4-digit level according to the ISIC Rev. 3 classification.

Information on sales values and physical quantities is given for (up to eight) specific products produced by each firm. Products are recorded according to a CSA (Ethiopian Statistical Agency) classification and information available includes the value and quantity produced for the domestic and export markets for each product.[19] As discussed earlier in the section on input tariffs, our data also allow us to identify raw materials used at the firm level, sourced domestically and imported, and their share in total firm expenditure.

Finally, and crucially for our focus on roads, we have information on the region, woreda (district) and town for each firm. While firms are located in about 80 towns in the country, their growth is geographically divergent over time. Nevertheless, we register a strong concentration in the capital, Addis Ababa, which hosts 47% of the firms and 54.3% of total observations in our data respectively.[20]

The firm census dataset is an unbalanced panel of 3,551 establishments covering the period 1998-2009, totalling 12,672 observations. Table 3 reports the number of firms for each year, showing strong dynamism in the private sector,[21] which is consistent with

[16]The census data includes information at the level of the single productive establishment. We use the terms establishment and firms interchangeably in the paper.

[17]The number of persons engaged refer to employees as well as working owners.

[18]In 2005, a representative survey of firms was conducted instead of a census. This does not represent a critical bias for our analysis, since we do not focus explicitly on entry and exit rates (except when adjusting our TFP estimates for attrition), or on generating aggregate figures. Yet, we make an adjustment for those firms that are in the data in both 2004 and 2006, but not in 2005, filling in information for all variables as the simple average of the closest years. Results remain robust when dropping 2005 from our data.

[19]The product code necessary to identify products is missing in some cases. On average, across firms and years in our estimation sample, non-identifiable products account for 21% of total firm sales. We therefore opt to conduct our analysis at the firm, rather than at the product level.

[20]Once we collate relevant variables for our analysis, our ultimate baseline estimation sample includes firms located in 46 towns (see Section 3.4).

[21]The sector has experienced rapid growth, with an annual average of 10% over the period considered.

the overall pattern of economic growth experienced by the country over the last decade (Moller, 2015).

Table 3: Number of firms in census years

Year	Firms	Share (%)
1998	701	5.53
1999	712	5.62
2000	704	5.56
2001	732	5.78
2002	866	6.83
2003	923	7.28
2004	980	7.73
2005	978	7.72
2006	1,131	8.93
2007	1,301	10.27
2008	1,696	13.38
2009	1,948	15.37
Total	12,672	100

Notes: Authors' summary of Ethiopian Census Data on firms.

3.2.2 TFP Estimation

To construct our dependent variable, we follow the existing literature and use a measure of firm performance based on estimated Total Factor Productivity (TFP). A large body of research on the nexus between trade liberalization and firm performance has been unable to distinguish improvements in physical efficiency from gains in profitability due to lack of information on firm specific prices. In our study, we exploit information on values and physical quantities to construct a measure of physical productivity at the firm level in the spirit of Eslava et al. (2004) and Smeets and Warzynski (2013).

We start from a basic production function linking the output produced by firm i to inputs adopted in the production process:

$$y_{ijrt} = \beta_1 \; k_{ijrt} + \beta_2 \; l_{ijrt} + \beta_3 \; m_{ijrt} + \omega_{ijrt} + \epsilon_{ijrt} \tag{3.3}$$

where y_{ijrt} denotes the output of firm i producing in sector j, located in town r at time t. k_{ijrt} denotes capital, l_{ijrt} labor and m_{ijrt} intermediate inputs respectively. The random component ω_{ijrt} is unobservable productivity or technical efficiency and ϵ_{ijrt} is an idiosyncratic output shock.

Standard approaches adopt industry price deflators, when available, to adjust both output and inputs for price variation common to all firms in a given industry j. This introduces a so-called output price bias, resulting in a possible downward bias on the input coefficients, which is due to the likely correlation between firm specific variation in output prices and expenditure on inputs (De Loecker and Goldberg, 2014; De Loecker, 2011). For instance, firms producing products of high quality are likely to use high quality inputs that are priced higher. Similarly, lack of information on firm specific variation in input prices can introduce a downward bias in the estimated coefficients, given that higher input prices will raise input expenditure, while not increasing physical output (De Loecker et al., 2016).

Our data allow us to eliminate the output price bias given that we can calculate firm level price indices from information on the quantity and value of a firm's product. We aggregate product-level unit values at the firm level to calculate a firm-level price index P_{it}, using the approach suggested by Eslava et al. (2004) and Smeets and Warzynski (2013). The steps followed to calculate P_{it} are described in Appendix D.[22]

While deflating output with firm specific prices eliminates the output price bias, we follow a simplified version of the approach developed by De Loecker et al. (2016) to address input price bias. The assumption here is that the source of input price variation at the firm level can be captured by the quality of inputs adopted in the production process. Another assumption is that output quality is complementary to input quality and therefore, the quality of inputs is a function of the quality of output. This assumption allows us to control for the input price bias by including the output price index in the control function to account for unobserved input price variation.

We estimate production functions at the sector level (aggregating sectors at the 2 digit of the ISIC classification, and combining sectors sharing similar technologies when sample sizes are too small). Since OLS coefficients will be biased in equation (3.3) due to simultaneity and selection biases, we apply the approach by Levinsohn and Petrin (2003) (LP) that uses the costs of raw material as a proxy for unobservable productivity shocks to correct for simultaneity bias. We also address potential collinearity in the first stage due to simultaneity bias in the labor coefficient by adopting the correction suggested by Ackerberg et al. (2015). Finally, we adjust our estimates for attrition in the second stage of our productivity estimation [23]. Physical output is total production at the level of the firm deflated using the index P_{it} described in Appendix D. We use the book value of fixed assets at the beginning of the year to measure capital stock, the total number of permanent employees to measure labor and the total cost of materials to measure intermediate inputs. Table E-1 in Appendix E reports production function coefficients at the industry level.

[22]This comes with measurement issues, given that product-level prices are measured by unit values. In addition, we make assumptions concerning product homogeneity or the way products are aggregated across firms. See Appendix D for details.

[23]Productivity is estimated using the prodest package in Stata (Rovigatti and Mollisi, 2016)

3.3 Econometric Specification and Identification Strategy

The basic empirical strategy used in this paper consists of a standard interaction model. The main regressors of interest are: (i) the product of the input tariff and the market access indicator; and (ii) the product of the input tariff and the measure of travel time to Galafi. The empirical model is given by

$$\begin{aligned}\log \text{TFP}_{ijrt} = \beta \text{ Input-tariff}_{jt} + \gamma \text{ Input-tariff}_{jt} \times \text{Market access}_{rt} + \\ + \delta \text{ Input-tariff}_{jt} \times \text{Galafi}_{rt} + \boldsymbol{\eta}' \mathbf{z}_{ijrt} + \mu_i + \nu_{rt} + \varepsilon_{ijrt}\end{aligned} \tag{3.4}$$

The dependent variable is the natural logarithm of TFP estimated for firm i active in sector j, town r at time t. Input tariffs in equation (3.4) vary at the industry-year level. The second regressor consists of the interaction between the input tariff and the measure of market access determined by the road network as described in Section 3.1. The latter varies at the town level and over time. The third regressor is the interaction between the input tariff and the rt-specific travel time to Galafi. The model includes a vector of firm-specific characteristics varying over time ($\mathbf{z}_{ijrt}$): this includes a control for the firm's age (age_{ijrt}), a dummy for exporter status ($\text{Exporter dummy}_{ijrt}$) and one for foreign ownership ($\text{Foreign ownership dummy}_{ijrt}$). The baseline specification also contains firm fixed effects (μ_i), town-year fixed effects (ν_{rt}) and the idiosyncratic error term (ε_{ijrt}). Standard errors are clustered at the level of the (four-digit) industry-town pair.

Consistent with the large literature on the productivity effects of tariff liberalization, lower tariffs are expected to have a positive impact on TFP at the average quality of roads. This would be reflected in a negative sign for the coefficient β when the variables $\text{Market access}_{rt}$ and Galafi_{rt} are demeaned. By construction, the proposed specification allows the productivity effect of the input tariff to vary linearly with the quality of roads as reflected in the two metrics of market access and travel time to Galafi. The role of roads in shaping the effect of tariff liberalization is identified by the coefficients γ and δ. A negative sign for γ would indicate that the negative relationship between input tariffs and TFP is magnified for firms in towns where better roads generate a higher market access. Similarly, a positive sign for δ would reveal that the linkage from lower input tariffs to higher productivity is amplified for firms where better roads imply a lower travel time to Galafi.

Identification in this empirical setting requires the policy treatment (input tariffs in our case) to be as good as randomly assigned. The included battery of fixed effects account for any confounding heterogeneity originating from firm specific as well as town and year specific shocks/characteristics. In sections below, we address further concerns pertaining to endogeneity.

3.3.1 Endogeneity of Tariffs

A standard argument in the literature has to do with the potential endogeneity of trade policy. Phenomena related to political economy (Grossman and Helpman, 1994), including the targeting of more (or less) productive industries for protection or lobbying by firms and industries might influence both the timing and the size of trade protection, introducing a bias in our estimates. In the case of Ethiopia, trade reforms were largely exogeneous, shaped by international institutions under liberalization programs implemented beginning in the early '90s (Jones et al., 2011; Bigsten et al., 2016). Nevertheless, we tackle this potential concern in two main ways.

First, as in Topalova and Khandelwal (2011), Ahsan (2013) for India and Bas (2012) for Argentina, we aggregate our firm data at the industry level to test for the political protection argument. Specifically, we construct aggregates of production, employment, exports, capital intensity and agglomeration for each 4-digit industry and test the correlation among pre-sample levels (1996) of these variables and changes in the input tariff between 1996 and 2003.[24] Results from these regressions are reported in Appendix F and show that there is hardly any correlation between changes in input tariffs and pre-sample industry characteristics, bolstering our argument that tariff reform in Ethiopia was largely exogeneous to firm outcomes.

Second, following Topalova and Khandelwal (2011) and Brandt et al. (2017), we check whether input tariff adjustments were made in response to productivity levels. To do this we regress input tariffs at time $t+1$ on firm productivity at t, controlling for firm and year fixed effects. We repeat the same exercise using levels of productivity at $t-5$. Results of these exercises show that changes in input tariffs were not correlated with previous levels of firm productivity, implying that policy makers did not adjust trade policy in response to observed productivity levels. Due to space considerations, we present and discuss results from these exercises in Appendix F. Overall, we find strong empirical support against endogeneity of input tariff liberalization in Ethiopia.

[24]For this exercise we use the change in input tariffs between 1996 and 2003, since this is the year of the latest trade reform. Results do not change if we replicate the same exercise using the change in tariffs from 1996 to 2009.

3.3.2 Endogeneity of Roads

In this section, we address potential endogeneity of Market access_{rt} and Galafi_{rt}.[25] Specifically, unobserved local factors may drive investments in road improvements systematically across towns. For instance, the high costs and potential benefits of road improvements can lead policy makers to select locations in which they will have the biggest economic impact (Coşar and Demir, 2016; Duflo and Pande, 2007; Asher and Novosad, 2020). In our specific context, a concern is that road improvement decisions were related to the time-contingent activities of more/less productive firms if they systematically lobbied for local infrastructure development. A mitigating factor in the Ethiopian context, as argued by Shiferaw et al. (2015), is that road improvement plans under the program were made on a 5-year basis. It is hence unlikely that they were affected by annual changes in firm performance. Alternatively, policy makers may want to connect growing/declining towns to nearby economic hubs. Additionally, polical economy efforts to attract larger shares of investment in road infrastructure may be correlated across towns.

We proceed to address these concerns in four steps. First, we regress town-specific changes (log differences) in Market access_{rt} and Galafi_{rt} during each phase of the RSDP against town-level average productivity at the beginning of each phase and we find no significant relationship between the two variables. We replicate the exercise after replacing average TFPQ with the town-level proxy for economic activity based on night-light data (L_{rt} defined above). Again, there is no strong evidence that suggests that towns with higher economic performance as captured by night light intensity receive disproportionate infrastructure investments in the context of the RSDP. Results of these exercises are reported in Appendix G.

Second, we check whether investments in roads are correlated with government decisions regarding provision of incentives to foreign investors (multinational firms) to locate in

[25] Note that while the text of this Section discusses potential endogeneity of Market access_{rt} and Galafi_{rt}, endogeneity itself could represent a less relevant threat to the consistent estimation of our parameter of interest - the coefficient of the interaction between roads and tariffs. Recent work by Nizalova and Murtazashvili (2016) shows that in estimating the coefficient of an interaction between an exogenous treatment (in our case input tariff reduction) and an endogenous moderator (market access and/or travel time to Galafi), consistent OLS estimates are obtained when the moderator and the unobservable omitted variable determining the endogeneity of the moderator (firms' lobbying capacity, for instance) are jointly independent of the treatment. Given exogeneity of tariffs discussed above, the absence of any correlation between roads and tariffs would guarantee consistent estimates for γ (as well as for β). This is strongly the case in our exercise, where exogenous tariff policy action at the national level is independent of town level infrastructure improvements. Indeed, in our setting, the correlation between roads and tariffs is very close to zero. Computed on firm-year observations, the correlation between Market access and Input-tariff is equal to -0.032 on the estimation sample defined below, and equal to -0.005 on all available observations. Similarly, the correlation between Galafi and Input-tariff is .14 on the estimation sample and 0.096 on the available data. A similar discussion of the implications of Nizalova and Murtazashvili (2016) can be found in Beverelli et al. (2018).

specific areas. In some cases, when negotiating new FDI projects, the Ethiopian Government assigned land to new entrants. An ad-hoc survey run by Abebe et al. (2019) asks foreign investors if their location was allocated by the authorities. This choice is clearly not random and likely reflects local political-economy forces. Knowing whether an FDI location was targeted by the government allows us to identify areas where factors capable of shaping government decisions (including lobbying) were more likely to be present. We hence test whether FDI allocation correlates with improvements in roads. To do this, we regress the increase in market access between 1996 and 2014 on an indicator variable that equals one if the location was selected by the government to host an FDI project.[26] We do not find a statistically significant difference in road investments across locations receiving government-supported FDI (the coefficient on the FDI indicator is -0.033 with a standard error of 0.0289).

Third, as in Donaldson and Hornbeck (2016), we exploit the fact that variation in each town's market access is determined by improvements to the whole road network in the country. Therefore we can partial out the facilitating role of changes in local roads, the source of the endogeneity concern. We do this by augmenting the baseline model (3.4) with an additional interaction between $\text{Input-tariff}_{jrt}$ and a measure of the quality of local road infrastructure at the town level. There are two limitations to this strategy. First, one might argue that controlling for local changes in road infrastructure (changes that potentially reflect town-specific lobbying efforts endogenous to the productivity of local firms) fails to account for the eventuality that given the national framework of the infrastructure reform under analysis, endogenous local lobbying efforts to attract a larger share of the national investment in roads may be correlated with lobbying efforts in other locations. In other words, we cannot exclude that endogenous political economy motives are correlated across Ethiopian cities. Second, local road improvements might be correlated with faraway road improvements if the goal is to connect towns to regional economic hubs.

To tackle both these limitations, our fourth exercise applies an instrumental variable identification strategy that builds on Jedwab and Storeygard (2020).[27] We construct instruments for $\text{Market access}_{rt}$ and Galafi_{rt} using a new set of bilateral distances. These new distances only reflect changes in the road network outside appropriately defined exclusion zones, where investment in road infrastructure is more likely to reflect endogeneous factors. For each city r we create an exclusion zone consisting of the area within a circular buffer centered on r's coordinates, extended to cover the trajectory

[26] We conduct this analysis for 174 districts, rather than at the town level, since our data on FDI, sourced from Abebe et al. (2019), are at the district level. Furthermore, given that most FDI projects covered in Abebe et al. (2019) are in more recent years, we extend this analysis to the year 2014, for which we have road information.

[27] Similar instrumental variable identification strategies are discussed in the review by Redding (2020) and implemented in Jaworski and Kitchens (2019).

toward the nearest large city. Defining the exclusion zone in this manner helps us account not only for endogeneous local road improvements but also improvements targeted at connecting towns to hubs.

In addition, while Jedwab and Storeygard (2020) compute the distance between an origin o and a destination d only accounting for road improvements outside the exclusion zone around origin o, our approach further excludes road changes within d's exclusion zone, as well as within the exclusion zone around any other city with at least one firm. This modification of the original approach reflects the nature of our empirical exercise, which is a country case study. Our analysis studies the effect of a single national infrastructural reform, which necessitates accounting for correlated endogeneous political economy motives across urban areas.[28]

Formally, we partition the area within the Ethiopian national borders into two sets. The first one, denoted as $LOCAL$, consists of the union of all exclusion zones around each urban area r. For each r, the exclusion zone is identified as the convex hull of a circular buffer with radius of 20 kilometers centered on r's coordinates and the nearest city with a population in 1994 strictly bigger than 50 thousands people.[29] The second one – $LOCAL^C$ – equals to the complement of the first set. Figure G-1 in the Appendix offers a graphical representation of these sets displayed on the 1996 road network. Shaded areas reflect exclusion zones. Our instruments exclude any road improvements in the exclusion zones, which represent the likeliest source of endogeneity, thus isolating arguably exogenous improvements to the road network. We proceed to create a new time series of road network shape files N_t^* for $t > 1996$, where the road segments in $LOCAL$ are fixed at the pre-sample year 1996, while other roads and their speed-relevant parameters are free to vary for t.[30] For each pair (o, d) of urban areas with $o \neq d$, we define $D_{od,t}^*$ as the minimum distance in hours of travel between o and d given the new road network N_t^*. Finally, we construct measures of market access and distance to Galafi using these new bilateral distances:

$$\text{Market access}_{rt}^* = \log\Big(\sum_{z \neq r} L_z / D_{rz,t}^*\Big) \tag{3.5}$$

$$\text{Galafi}_{rt}^* = D_{r\text{Galafi},t}^* \tag{3.6}$$

We use the interaction between input tariffs and Market access$_{rt}^*$, and between input

[28] This is not an issue in the empirical framework of Jedwab and Storeygard (2020). In fact, that paper considers the effect of transportation investments across 39 African countries and the concern that political economy forces are correlated across urban areas is absent.

[29] The resulting shape on the plane consists of a standard circular buffer with radius of 20 kilometers centered on r extended with an isosceles triangle whose base lies within the buffer and whose apex is set at the coordinates of the nearest large city.

[30] Whenever a road segment in the original road network shape file is not fully contained in $LOCAL$ or in its complement, we split it up into multiple connected sub-segments so that the resulting network only consists of road segments fully contained in $LOCAL$ or in its complement.

tariffs and Galafi^*_{rt} as excludable instruments for the two interaction terms of interest. Results from including the additional interactions and the instrumental variable exercises are presented after a discussion of our baseline estimates.

3.4 Estimation Sample

We assemble data from the sources described to obtain our final estimation sample. The final sample consists of an unbalanced panel covering up to 1544 establishments located in 46 towns and observed across the period 1998-2009, yielding a total of 7740 observations. Summary statistics for the variables used to obtain baseline results are reported in Table 4.

Table 4: Summary statistics

Variable	mean	median	sd	min	max
log TFP_{ijrt}	2.484	2.267	1.518	-4.999	9.081
$\text{Input-tariff}_{jrt}$	14.376	10.032	9.480	0	60.236
Market Access_{rt}	9.188	9.463	1.060	4.470	11.004
Galafi_{rt}	2.647	2.667	0.154	0	3.425
Night light intensity_{rt}	8.802	9.669	1.461	3.807	10.035
$\log(\text{age}_{ijrt}+1)$	2.436	2.398	0.891	0	4.736
Exporter dummy_{ijrt}	0.045	0	0.208	0	1
Foreign ownership dummy_{ijrt}	0.040	0	0.196	0	1

Notes: The table reports summary statistics for the main variables used in the analysis as described in equation 3.4.

4 Results

4.1 Baseline Results

Section 2 outlines our hypothesis that road infrastructure, by improving connectivity, shapes the relationship between input tariff reductions and firm productivity. We examine this hypothesis in our empirical analysis. We report our main estimation results in Table 5. Column (1) presents a simple relationship between the input tariff and firm productivity. Column (2) includes our road variables - market access and travel time to Galafi - and their interactions with the input tariff. Models in columns (1) and (2) do not control for potentially confounding heterogeneity across towns, but only for firm and year fixed effects. Column (3) reports estimates for the specification in column (2) with town-year fixed effects introduced to account for unobserved time-contingent, town-specific shocks correlated with firm productivity. Note that in this case we cannot estimate the impact of market access and travel time to Galafi on firm productivity, since these effects are subsumed by the town-year effects. Column (3) is our preferred specification and we employ it for all subsequent estimations.

Column (1) shows a negative relationship between the input tariff and firm productivity,

Table 5: Main Estimation Results

Dependent variable:	log TFP$_{ijrt}$		
	(1)	(2)	(3)
Input-tariff$_{jt}$	-0.008	-0.008	-0.008
	(0.007)	(0.007)	(0.007)
Input-tariff$_{jt}$×Market access$_{rt}$		-0.007**	-0.009**
		(0.003)	(0.004)
Input-tariff$_{jt}$×Galafi$_{rt}$		-0.006	-0.025
		(0.020)	(0.023)
Market access$_{rt}$		0.408***	
		(0.115)	
Galafi$_{rt}$		0.513	
		(0.770)	
Observations	7740	7740	7740
Adjusted R^2	0.664	0.664	0.663
Firm FE	√	√	√
Year FE	√	√	
Town-year FE			√
Firm-year controls	√	√	√

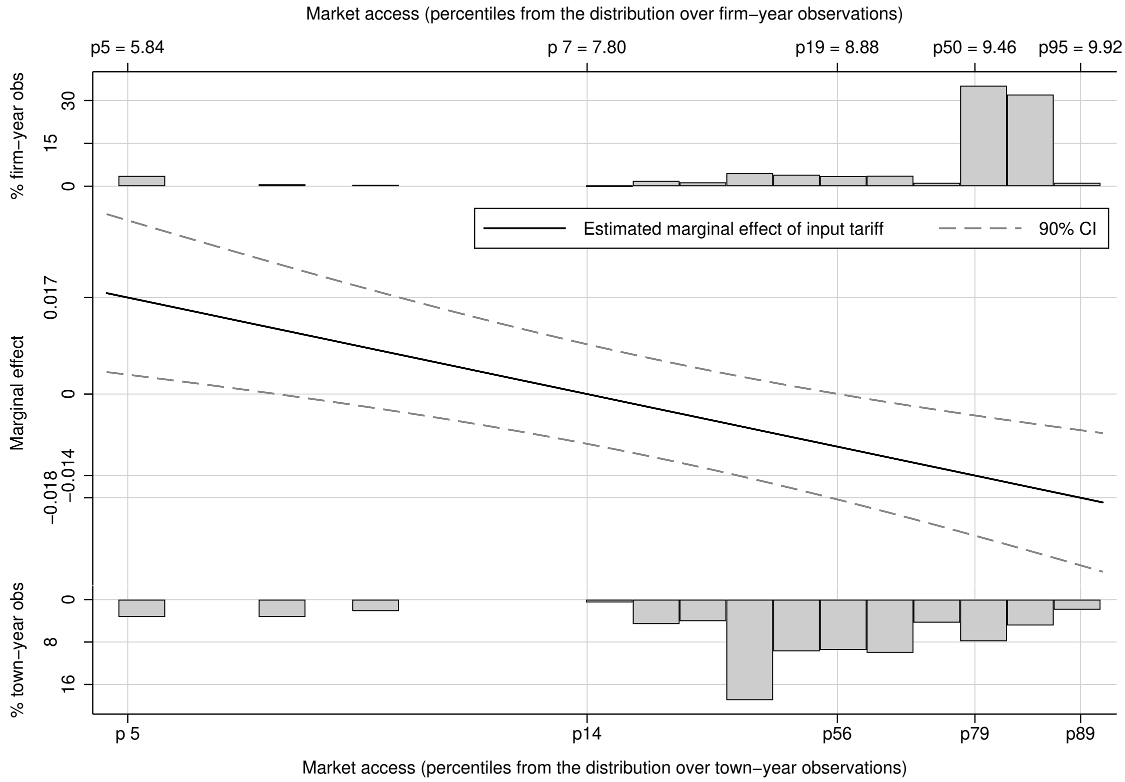
Notes: Market access$_{rt}$ and Galafi$_{rt}$ are demeaned using the mean computed on the estimation sample. Firm-time controls include exporter and FDI dummies and firm age. Standard errors in parentheses are clustered at the town-sector level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

however, this effect is not statistically significant. In column (2), we find that the interaction term between the input tariff and market access is negative and statistically significant. A decrease in the input tariff is associated with a larger increase in productivity in firms located in towns with better market access. The interaction between the input tariff and travel time to Galafi is negative, but not statistically different from zero. Put together, these results highlight two aspects related to the role of road infrastructure improvements in the context of trade liberalization. First, without quality roads, there is no evidence that a reduction in the input tariff is associated with gains in total factor productivity for Ethiopian firms. Next, road improvements complement an input tariff reduction not primarily by lowering the cost of transporting intermediate inputs from port to destination regions, but by endowing firms with greater intranational market access. Results continue to hold in column (3), which includes town-year fixed effects to account for time-varying town-specific heterogeneity. Overall, these results emphasize the role for roads in determining the effects of a reduction in the input tariff on firm productivity [31].

[31] To explore whether changes to market access or input tariffs, as opposed to initial levels, drive impacts on firm productivity, we estimate two additional specifications building on the baseline specification in column (3). In column (1) of Appendix Table H-1, we present results from estimating the baseline specification with an added interaction term of the input tariff and an indicator variable for higher-than-

Figure 6 plots the effect of the input tariff on firm productivity at various levels of market access with 90 percent confidence intervals on each side. The effect is computed by estimating the same specification as for column (3) of Table 5 without demeaning Market access$_{rt}$ nor Galafi$_{rt}$. The horizontal axis presents percentiles of market access in the data based on firm-year and town-year observations.

Figure 6: The effect of input tariffs moderated by road infrastructures (market access)



Notes: The central panel in this figure plots the estimated marginal effect of input tariffs on log TFP$_{ijrt}$ (on the vertical axis) as a function of Market access$_{rt}$ (on the horizontal axis) and fixing the value of Galafi$_{rt}$ at its sample median level denoted by $\overline{\text{Galafi}}$. The estimated marginal effect in the figure is computed using the same estimating equation as the one used for column (3) of Table 5 but without demeaning Market access$_{rt}$ nor Galafi$_{rt}$. Considering the regression equation (3.4), the point estimate plotted as a solid black line in the figure is given by $\hat{\beta} + \hat{\gamma} \times$ Market access$_{rt}$ + $\hat{\eta} \times \overline{\text{Galafi}}$. The upper and lower panel of the figure plot the distribution of Market access$_{rt}$ over firm-year observations and town-year observations respectively. Point estimates for the marginal effect of the input tariff are negative for values of Market access$_{rt}$ bigger than 7.8. 93% (86%) of firm-years (town-years) covered in the estimation sample score a value of Market access$_{rt}$ bigger than that threshold. After the 19$^{\text{th}}$ (56$^{\text{th}}$) percentile of the distribution of Market access$_{rt}$ over firm-years (town-years), the estimated marginal effect is negative and also statistically different from zero.

median initial town market access. In column (2), we add an interaction of an indicator variable for higher-than-median initial input tariff for the sector and the original market access variable. We find that the coefficient on our interaction term of interest between the input tariff and market access remains negative, statistically significant and similar in magnitude to the baseline result in both cases. This is suggestive evidence that our key result is not simply driven by initial levels of input tariffs and market access.

We make the following observations from Figure 6. First, the downward sloping line at the center of the figure shows that the coefficient on the input tariff is more negative for larger values of market access. In other words, a fall in the input tariff is associated with a larger increase in firm productivity as market access from better roads improves. From the figure, a one percentage point decrease in the input tariff is associated with a 3.1 percentage point larger increase in productivity for a firm with median market access relative to a firm with market access at the 5^{th} percentile. A one percentage point decrease in the input tariff is associated with a 0.4 percentage point larger increase in productivity for a firm with market access at the 95^{th} percentile relative to a firm with median market access. Note from the confidence intervals in Figure 6 that moving from roads at the 5^{th} percentile to the median level of market access results in a statistically larger effect of an input tariff reduction on firm productivity. This is not true for moving from the median to the 95^{th} percentile of market access.

Our results hence suggest that roads built to increase market access of towns at the left tail of the distribution can bring larger gains to firm productivity from input tariff liberalization. Second, the estimated marginal effect of the input tariff is negative and statistically significant for 81% of firm-year observations and 44% of town-year observations. This suggests that for a majority of firms in our data (but not for all firms), a fall in the input tariff is associated with an increase in productivity since they are located in urban areas with adequate market access.

4.2 Identification and Robustness

In this section, we address several empirical concerns. First, we present results from the various exercises to tackle endogeneity of roads discussed in Section 3.3.2. Next, we test for robustness of our results to alternative productivity, road and tariff measures. Finally, we ask if our results are robust to cuts of the sample and controlling for the effect of the output tariff (the tariff on the final good produced by the firm) on productivity and its complementarity with road infrastructure. We find that our baseline results endure qualitatively across all of these tests.

4.2.1 Addressing Endogeneity of Road Infrastructure

The quality of road infrastructure might be endogenous to firm productivity. Even though descriptive evidence discussed in Section 3.3.2 suggests that this is unlikely in our empirical setting, we present results from a number of additional exercises to address endogeneity of roads in Table 6 and Table 7.

In Column (1) of Table 6 we augment the baseline model with an additional interaction between input tariffs and a measure of the quality of local (town-level) roads denoted as

Table 6: Additional interactions

Dependent variable:	log TFP_{ijrt}	
	(1)	(2)
Input-tariff$_{jt}$	-0.007	-0.009
	(0.007)	(0.007)
Input-tariff$_{jt}$×Market access$_{rt}$	-0.008**	-0.010***
	(0.003)	(0.003)
Input-tariff$_{jt}$×Galafi$_{rt}$	-0.009	-0.009
	(0.022)	(0.023)
Input-tariff$_{jt}$×Local roads$_{rt}$	0.013	0.009
	(0.009)	(0.017)
Input-tariff$_{jt}$×Night light intensity$_{rt}$		0.013
		(0.010)
Input-tariff$_{jt}$×Log number of firms$_{rt}$		-0.012
		(0.011)
Input-tariff$_{jt}$×Production$_{rt}$		0.004
		(0.005)
Input-tariff$_{jt}$×FDI town$_{rt}$		0.002
		(0.008)
Input-tariff$_{jt}$×Export town$_{rt}$		0.011*
		(0.007)
Observations	7740	7740
Adjusted R^2	0.663	0.664
Firm FE	√	√
Town-time FE	√	√
Firm-time controls	√	√

Notes: Local roads$_{rt}$ measures the sum of all distances that can be travelled in an hour from a town node over all possible road links connected to that node; Night light intensity$_{rt}$ is the average light intensity within a circle of a 10 kilometer ray centered around the point coordinate associated with each town in our sample; Log number of firms$_{rt}$ is the log number of firms in town r at time t; Production$_{rt}$ is the (log) total value of real production of firms based in town r at time t; FDI town$_{rt}$ is a dummy that equals one if the town hosts a foreign-owned firm in year t; Export town$_{rt}$ is a dummy that equals one if the town hosts at least one exporting firm at time t. All variables, except the last two, are demeaned using the mean over the estimation sample. Firm-time controls include exporter and FDI dummies and firm age. Standard errors in parentheses are clustered at the town-sector level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Local roads$_{rt}$. We construct this variable as the sum of all distances that can be travelled in an hour from a town node over all possible road links connected to that node. As argued by Donaldson and Hornbeck (2016) in their seminal contribution, partialling out the local component of the market access measure would not undermine its variability, which crucially depends on the whole road network. However, it will help to purge it of local variation that is the source of endogeneity. We find that after partialling out the facilitating role of improvements to local road infrastructure, the market access indicator capturing road infrastructure retains its role in shaping the effect of an input tariff reduction on firm productivity.

In the spirit of Ahsan (2013), column (2) augments the specification with additional interactions between the input tariff and measures of economic performance at the town level, in particular the number of firms and total production. We also include measures of multinational and export presence at the local level. Note that the two latter variables will also account for state support for special industrial zones to a certain extent, since multinationals in Ethiopia are incentivized to locate in them (Abebe et al., 2019). This exercise reinforces our interpretation of γ as the productivity premium due to better road connectivity with intranational markets, given that it controls for a host of other town-level factors that might generate differential effects of input tariff liberalization.

Results based on the instrumental variable exercise discussed in Section 3.3.2 are reported in Table 7. The instruments for the two variables of interest are constructed, as described in equations (3.5) and (3.6), by removing improvements in appropriately defined exclusion zones around each town in our sample, thereby isolating exogeneous improvements to the road network. Column (1) reports results from a model in which both road variables are instrumented, while columns (2) and (3) report estimates from instrumenting the variables of interest one at a time. First stage statistics are strong, supporting the relevance of both instruments. Our baseline estimates are confirmed by this exercise, confirming our main results both qualitatively and quantitatively.[32]

4.2.2 Robustness Checks

Finally, we undertake a series of checks to ensure the robustness of our results to (1) an alternative measure of the dependent variable; (2) an alternative measure of market access; and (3) a firm-level, instead of an industry-level tariff.

First, we calculate an alternative measure of firm productivity, to check if results are affected by the TFP estimation method used and described in Section 3.2. In column (1) of Table 8, we present results for the baseline model with productivity estimated after accounting for a range of variables in the control function.[33]

Second, results may be affected by the manner in which we construct the market access variable measuring roads. We use an alternative measure of market access that draws upon the model-based formula derived in Donaldson and Hornbeck (2016) and applied to the East African context by Eberhard-Ruiz and Moradi (2019) (henceforth ERM). Using

[32] In additional exercises, we have experimented with alternative definitions of the instruments, e.g. by increasing the buffers (up to 150km) around each town. These alternative instruments do not affect the results qualitatively. Results are available upon request.

[33] The control function approach is based on the methodology proposed by De Loecker et al. (2016), and consists of augmenting the set of variables affecting a firm's demand for materials. We do this by adding the input tariff as well as the export status of the firm in the control function.

Table 7: IV Results- Second stage

Dependent variable:	log TFP_{ijrt}		
	(1)	(2)	(3)
Input-tariff$_{jt}$	-0.008	-0.008	-0.009
	(0.007)	(0.007)	(0.007)
Input-tariff$_{jt}$×Market access$_{rt}$	-0.013**	-0.014**	-0.008**
	(0.005)	(0.005)	(0.004)
Input-tariff$_{jt}$×Galafi$_{rt}$	-0.027	-0.035	-0.015
	(0.023)	(0.024)	(0.022)
Observations	7740	7740	7740
Adjusted R^2	0.320	0.320	0.319
Firm FE	√	√	√
Town-year FE	√	√	√
Firm-year controls	√	√	√
KP LM stat	14.143	14.559	27.016
P-val	0.000	0.000	0.000
KP F stat	20.621	43.908	150.269

Notes: The instruments are constructed recalculating the two variables of interest after removing all the improvements in properly defined exclusion zones around each town in our sample where manufacturing firms are located. Column (1) reports the results of a model in which both Market access$_{rt}$ and Galafi$_{rt}$ are instrumented using the variables constructed following (3.5) and (3.6); column (2) reports results in which only Market access$_{rt}$ is instrumented using the variable constructed following (3.5); column (3) reports results in which only Galafi$_{rt}$ is instrumented using the variable constructed following (3.6). Market access$_{rt}$ and Galafi$_{rt}$ are demeaned using the mean computed on the estimation sample. Firm-time controls include exporter and FDI dummies and firm age. Standard errors in parentheses are clustered at the town-sector level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

the night-light intensity variable L and bilateral travel times D, the model-based formula of market access for town r can be written as $\sum_{z \neq r} L_z / \exp\{\sigma D_{rz,t}\}$, where σ is a distance decay parameter and captures the non-linear impact of distance on trade. We follow the parametrization in ERM where σ is the product of trade elasticity - fixed at 8.4 - and the average per unit cost of transporting a good for one hour over the road network relative to the good's overall value. The value of this latter parameter has been estimated by ERM at 0.005 using monthly petrol prices for seven Ugandan cities. We plug the resulting value (0.042) of the distance decay parameter σ in the market access formula, take the log and denote it as Roads(ERM)$_{rt}$. We present results in column (2) of Table 8.

Results from columns (1) and (2) confirm our baseline patterns. A reduction in the input tariff is associated with a larger increase in firm productivity for firms in regions with better market access. The coefficient on the interaction term between the input tariff and travel time to Galafi is negative but not statitsically significant.

Third, we address the concern that night lights data poorly capture local economic development. Measuring economic activity via night lights has been subject to criticism in the literature. (Asher et al., 2021; Gibson et al., 2021) raise and summarize concerns related to the use of night lights data in Economics. They point out that night lights lack temporal consistency and are thus less suited for time-series analyses. In addition,

Table 8: Robustness checks

Exercise:	Control F	Alt Mkt Acc	Pop wgts	Firm tariff
	(1)	(2)	(3)	(4)
Input-tariff$_{jt}$	-0.008	-0.008	-0.009	
	(0.007)	(0.007)	(0.007)	
Input-tariff$_{jt}$×Market access$_{rt}$	-0.008**			
	(0.003)			
Input-tariff$_{jt}$×Market access (ERM)$_{rt}$		-0.009**		
		(0.004)		
Input-tariff$_{jt}$×Galafi$_{rt}$	-0.026	-0.013	-0.020	
	(0.023)	(0.022)	(0.023)	
Input-tariff$_{jt}$×Market access (population)$_{rt}$			-0.009***	
			(0.003)	
Input-tariff$_{it}$				-0.005
				(0.004)
Input-tariff$_{it}$×Market access$_{rt}$				-0.005*
				(0.003)
Input-tariff$_{it}$×Galafi$_{rt}$				-0.002
				(0.020)
Observations	7740	7740	7740	7202
Adjusted R^2	0.635	0.663	0.663	0.669
Firm FE	√	√	√	√
Town-time FE	√	√	√	√
Firm-time controls	√	√	√	√

Notes: Market access$_{rt}$ and Galafi$_{rt}$ are demeaned using the mean over the estimation sample. The dependent variable in column (1) is TFP estimated with a modified control function; in column (2) we use a definition of market access based on the approach by Eberhard-Ruiz and Moradi (2019); column (3) reports estimates based on a definition of market access using pre-sample population weights. Population data are sourced from 1994 national population census. Finally, column (4) reports our baseline estimates using input tariffs calculated at the firm level, rather than at the sector level. The number of observations in this column drops slightly since some firms do not report product codes to identify products. Firm-time controls include exporter and FDI dummies and firm age. Standard errors in parentheses are clustered at the town-sector level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

light sources used in areas of low population density are often not picked up, making the data a poor source for studies focussing on rural areas. We note that these concerns are mitigated in our case, since we use cross-section variation in night lights to weight our market access measure and focus on towns. However, due to 'blurring', the sensor and data processing attribute light to different places than where it was emitted, leading to spatial inaccuracies that can also show up in the cross-section. Finally, very high light intensities are top-coded in the data. The last two concerns are relevant in our case.

To address these concerns, we follow (Donaldson and Hornbeck, 2016) and construct an alternative measure of market access that uses initial total population sourced from the 1994 census as weights in equation (3.1), instead of night lights. We then use this alternate measure to capture market access in column (3). We find that the interaction between the input tariff and market access is negative, statistically significant and of roughly the same magnitude as the baseline. Finally, in column (4), we use firm-level input tariffs instead of industry-level tariffs[34] and show that results remain qualitatively unaffected.

As a final step, we include output tariffs in our estimation. In fact, it is conceivable that the output tariff (the tariff on the final product produced by firms) is correlated with the input tariff and independently affects firm productivity by spurring firms to improve efficiency in the face of competition. If this is true, our estimates of the effect of the input tariff on firm productivity and its complementarity with roads will not be consistently estimated without accounting for output tariff effects. In addition, some of the mechanisms linking infrastructure development to trade liberalization could also work through changes in the output tariff. We thus introduce controls for the output tariff and its interaction with roads in our baseline regression. Results are presented in Table 9. The qualitative story on the input tariff remains. However, we do not find a significant interaction effect between the output tariff and road variables.

Table 9: Output tariff

Dependent variable:	log TFP_{ijrt}	
	(1)	(2)
Input-tariff$_{jt}$		-0.007
		(0.006)
Input-tariff$_{jt}$×Market access$_{rt}$		-0.007**
		(0.003)
Input-tariff$_{jt}$×Galafi$_{rt}$		-0.043
		(0.028)
Output-tariff$_{jt}$	-0.009	-0.006
	(0.010)	(0.010)
Output-tariff$_{jt}$×Market access$_{rt}$	-0.012*	-0.010
	(0.006)	(0.007)
Output-tariff$_{jt}$×Galafi$_{rt}$	0.023	0.043
	(0.042)	(0.043)
Observations	7740	7740
Adjusted R^2	0.662	0.662
Firm FE	√	√
Town-time FE	√	√
Firm-time controls	√	√

Notes: Market access$_{rt}$ and Galafi$_{rt}$ are demeaned using the mean over the estimation sample. Firm-time controls include exporter and FDI dummies and firm age. Standard errors in parentheses are clustered at the town-sector level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Overall, our analyses in this section show that our results are robust to a range of checks,

[34]Firm level tariffs are calculated as described in Section 3.1.2 with the only difference that weights are firm, and not industry, specific.

boosting confidence in our baseline finding.

4.3 Mechanism and Channels

We have so far established a significant facilitating role for roads in determining the impact of input tariff reductions on firm productivity. In this section, we explore evidence for the mechanism that underlies the impact of an input tariff reduction on firm productivity and the channels through which roads magnify these impacts. We leverage the strength of our data, which allows us to differentiate between domestic and intermediate inputs, calculate the price (unit-value) of imported inputs and track their use over time.[35]

We argue in our conceptual framework that in response to input tariff reductions, better roads magnify the incentives for firms to undertake productivity-enhancing actions that increase their physical total factor productivity. Such actions can range from the use of imported intermediate inputs that embody superior technology to the adoption of differential production techniques. We now explore evidence for this mechanism. First, we study the relationship between input tariffs and the likelihood that a firm employs a new imported input in production in column (1) of Table 10. We find a negative and statistically significant coefficient on the interaction between market access and the likelihood of a firm using a new imported input. This provides strong support for the idea that roads differentially afford firms with the opportunity to utilize new imported inputs following a reduction in input tariffs. In a framework where imported intermediates embody superior technology, improved access to foreign intermediate inputs is a plausible explanation for the differential gains in total factor productivity from input tariff liberalization experienced by firms in towns with better market access from roads.

Second, we ask if an input tariff reduction is associated with differential use of production techniques by firms in areas with better roads. Columns (2) focuses on the capital-labor ratio, while columns (3) looks at the employment of non-production workers. Both these variables can also signal a shift in technology.[36] From column (2), we find that a reduction in the input tariff is associated with greater capital-intensity among firms in areas with better market access. From column (3), we see a negative coefficient on the interaction between the input tariff and market access, though this result is not statistically significant. Broadly, results from columns (1) - (3) offer

[35] A limitation of our data is that firms are asked to report their seven most important intermediate inputs. This means that we are unable to accurately capture changes in the scope or variety of intermediate inputs used by firms following input tariff liberalization.

[36] Note however that owing to the lack of information on the specific functions of non-production workers within the firm, their share in the total is only a rough proxy for skill intensity. This category is open enough to include both high skilled managers and technicians as well as less skilled administrative assistants.

support for our proposition that market access incentivizes firms to undertake actions that improve physical productivity, including adopting new inputs and production technology.

Finally, we delve into the channels through which roads magnify the impact of an input tariff reduction on firm productivity. The first channel is differential pass-through of a reduction in the input tariff to imported input prices for firms across areas with varying quality of roads. We consider the price (unit-value) of imported intermediate inputs at the firm level as our dependent variable. Note that the role of roads in determining the relationship between input tariffs and input prices is nuanced. Consider for instance a framework of intranational trade with imperfectly competitive intermediaries importing intermediate inputs at the world price and transporting them to firms across locations (Atkin and Donaldson, 2015). Prices that firms pay for their inputs in each location are a function of intermediaries' markups, which in turn depend on their marginal costs (including the cost of acquiring the input and intranational transport costs), competition faced (like the number of intermediaries serving the same location with the same intermediate input) and local demand conditions. All these elements depend upon road infrastructure quality. For instance, intermediaries' marginal costs should respond negatively to the quality of roads connecting economic hubs such as dry ports or border towns with locations where firms (demand) are located. Furthermore, the number of intermediaries serving a local market, and therefore competition among them, should increase with the quality of road infrastructure. Finally, location specific demand conditions (number of firms demanding a particular intermediate input and its quantity) may be a positive function of the extent of market access from better roads.

A priori, it is ambiguous whether roads magnify or attenuate pass-through of input tariff reductions to local input prices. Appendix A offers a simple model à la Atkin and Donaldson (2015) that illustrates this point. The role of roads in determining the relationship between input tariffs and input prices for firms is thus an empirical question that we explore in column (4). We find that a reduction in the input tariff is associated with lower input prices for firms in regions with better market access. Thus, pass-through of input tariff reductions to input prices is magnified by better market access from good roads.

The second channel operates through an increase in market size and competition from improved market access, resulting from better connectivity. The idea is that with a reduction in input tariffs, firms located in towns with better market access can not only exploit a larger market (by definition), but also face greater competition. This leads to firms undertaking productivity-enhancing actions that increase physical productivity. To bolster this idea, we use self-reported information from firms when they are asked to rank their main reasons for capacity underutilization. One reason provided in the

Table 10: Mechanism and Channels

Roads magnify:	firms' actions			pass-through
Dependent variable:	new input	K/L	non-prod wks	input price
	(1)	(2)	(3)	(4)
Input-tariff$_{jt}$	-0.031	-0.013	-0.010	0.019
	(0.021)	(0.013)	(0.006)	(0.013)
Input-tariff$_{jt}$×Market access$_{rt}$	-0.020*	-0.016***	-0.006	0.049***
	(0.011)	(0.006)	(0.007)	(0.017)
Input-tariff$_{jt}$×Galafi$_{rt}$	0.011	-0.041	-0.015	0.123
	(0.070)	(0.043)	(0.019)	(0.117)
Galafi$_{rt}$	-0.991			
	(2.325)			
Market access$_{rt}$	0.274			
	(0.439)			
Observations	5043	7740	7423	1755
Adjusted R^2		0.607	0.478	0.297
Firm FE	√	√	√	√
Year FE	√			
Town-year FE		√	√	√
Firm-year controls	√	√	√	√

Notes: Market access$_{rt}$ and Galafi$_{rt}$ are demeaned using the sample mean over the estimation sample. The dependent variable in column (1) is a dummy variable that equals one each time a new variety of an imported input is reported by the firm. The model is estimated using a conditional logit and only includes firms that switch status between importing a new input and not, across years. The dependent variable in column (2) is the log of the capital labour ratio, measured as the book value of fixed assets divided by the number of employees. The dependent variable in column (3) measures the ratio of non-production workers to production workers. The dependent variable in column (4) is the price index of imported inputs. Column (4) only includes firms that employ imported inputs. Firm-time controls include exporter and FDI dummies and firm age. Standard errors in parentheses are clustered at the town-sector level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

survey is market shortage because of competition. We generate a dummy variable that equals one if competition is listed as the main motivation by a firm, and zero otherwise[37]. Because firm responses are recorded each year and can differ across years, we can link within-firm changes in whether competition is ranked as the premier reason for capacity underutilization to changes in our market access measure. We present results in Table 11. Columns (1) and (2) show that an increase in market access is positively related to the likelihood that Ethiopian firms mention competition as the main reason for capacity underutilization. Column (2) shows that this result persists after controlling for changes in the distance to Galafi. Results in this section thus provide supportive evidence for both channels underlying the facilitating role of roads.

[37]We drop a small number of firms that did not respond to this specific question.

Table 11: Roads and competition

Dependent variable:	Competition	
	(1)	(2)
Market access$_{rt}$	0.0934**	0.111**
	(0.0418)	(0.0430)
Galafi$_{rt}$		0.252
		(0.365)
Constant	-0.721*	-1.544
	(0.399)	(1.159)
Observations	6504	6504
R-squared	0.474	0.474
Firm FE	√	√
Time FE	√	√
Firm-time controls	√	√

Notes: The dependent variable is a dummy variable, taking the value of 1 when firms indicate competition as the main reason for capacity underutilization. Firm-time controls include exporter and FDI dummies and firm age. Standard errors in parentheses are clustered at the town-sector level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.4 Extensions

In an extension of our analysis, we ask how our interaction effect of interest affects productivity of firms that enter, exit and survive. We present results for our baseline equation, estimated separately for entering, exiting and surviving firms in Table 12, columns (1), (2) and (3) respectively. Entering firms are firms that enter after the initial year in our sample and that do not exit until the last year. Exiting firms are those that exit before the final year in our sample. Surviving firms are those that exist in each year of our sample, in other words, firms that form a balanced panel. From columns (1) through (3), we find that the coefficients on the interaction between the input tariff and market access are all negative and of roughly the same magnitude. However, the coefficients in columns (1) and (2) are not statistically significant, while the one for the balanced panel in column (3) is. In addition, the coefficient in column (3) is slightly larger in magnitude than in the full, unbalanced panel. The evidence thus indicates that our key result is concentrated among surviving firms.

Next, a key contribution of this study is our ability to analyze gains in physical total factor productivity (denoted as TFP in our paper but often called TFPQ in the literature) from input tariff liberalization. A growing body of research has emphasized the need to focus on physical total factor productivity as opposed to revenue-based total factor productivity (TFPR), which conflates impacts on productivity and the markup. Furthermore, there is rising interest in looking at the how firms' pricing strategies respond to trade liberalization, including via input tariff reductions (Brandt et al., 2017; Fan et al., 2018).

In a second extension of our analysis, we probe the effects of input tariff liberalization

Table 12: Entry, exit and surviving firms

Sub-population:	Entrants	Exiters	Survivors
	(1)	(2)	(3)
Input-tariff$_{jt}$	0.0145	-0.000981	-0.00819
	(0.0141)	(0.0116)	(0.00985)
Input-tariff$_{jt}$×Market access$_{rt}$	-0.00822	-0.0139	-0.0146**
	(0.00970)	(0.0159)	(0.00650)
Input-tariff$_{jt}$×Galafi$_{rt}$	0.0170	-0.149**	-0.0157
	(0.0737)	(0.0705)	(0.0367)
Constant	1.719***	2.727***	3.675***
	(0.416)	(0.435)	(0.758)
Observations	2604	2136	2255
Adjusted R^2	0.739	0.810	0.710
Firm FE	✓	✓	✓
Town-time FE	✓	✓	✓
Firm-time controls	✓	✓	✓

Notes: Market access$_{rt}$ and Galafi$_{rt}$ are demeaned using the mean over the estimation sample. Firm-time controls include exporter and FDI dummies and firm age. Standard errors in parentheses are clustered at the town-sector level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

and the complementary role of roads on the markup charged by firms and on TFPR.[38]

We hypothesize that by reducing marginal cost, an input tariff reduction will ceteris paribus result in an increase in the markup charged by firms (as found, for instance, by De Loecker et al., 2016). Whether this increase in the markup resulting from input tariff liberalization is exacerbated or attenuated in areas with better road infrastructure is less clear. On the one hand, a reduction in marginal cost from the input tariff reduction is likely to result in a smaller increase in the markup in areas with better roads due to stronger competitive pressures. On the other hand, the fact that these firms can also access a larger market and have a greater incentive to employ imported inputs and increase TFPQ may influence markups in the opposite direction. The direction in which roads affect the impact of input tariff liberalization on markups will depend on the effect that dominates, with the possibility of observing no role for roads if these effects play out

[38] We calculate price-cost margin following the approach by De Loecker and Warzynski (2012), which rests on the idea that markups generate a wedge between an input's elasticity and revenue share. The markup μ_{it} is calculated as the ratio of price to marginal cost, $\mu_{it} = \frac{P_{it}}{\lambda_{it}}$, where P_{it} is the firm's output price. We can derive an expression for markup as:

$$\mu_{it} = \beta_{it}^{m}(\alpha_{it}^{m})^{-1},$$

in which $\beta_{it}^{m} = \frac{\partial Q_{it(.)}}{\partial M_{it}}\frac{M_{it}}{Q_{it}}$ is the output elasticity of material inputs and $\alpha_{it}^{m} = \frac{p_{it}^{m} M_{it}}{P_{it}Q_{it}}$ is the share of expenditure in materials in total revenue. We recover the output elasticity of materials β_{it}^{m} directly from the production function estimated in equation (3.3) and then adjust the share of expenditure on materials, α_{it}^{m} to account for productivity shocks to revenue, $\alpha_{it}^{m} = \dfrac{exp(m_{it})}{exp(r_{it} - \hat{\epsilon}_{it})}$.

equally.

We present results for TFP, TFPR and the markup (μ) in Table 13. All columns estimate the baseline specification with firm and town-year fixed effects and firm controls. Columns (1) and (4) replicate columns (1) and (3) of our baseline table Table 5 [39]. Columns (2) and (5) and columns (3) and (6) look at the relationship between the input tariff and TFPR and the markup and the facilitating role of roads in each instance, respectively. As hypothesized, from column (3), we confirm that a reduction in the input tariff is associated with higher markups charged by firms. From column (6), we find no facilitating role for roads in determining the relationship between the input tariff and the markup. This is consistent with the two forces in areas with better road infrastructure acting in opposite directions - more competition in connected regions exerts downward pressure on the markup, while better market access and efficiency gains from physical productivity (TFP) enhancements work the other way. Finally, columns (2) and (4) focus on revenue productivity (TFPR) and show that a reduction in the input tariff is associated with an increase in TFPR, driven by the reduction in marginal cost for firms. The increase is magnified in cities with better road infrastructure, driven primarily by gains in TFP.

Table 13: Extentions - Revenue productivity and markups

Dependent variable:	log TFP	log TFPR	μ	log TFP	log TFPR	μ
	(1)	(2)	(3)	(4)	(5)	(6)
Input-tariff$_{jt}$	-0.009	-0.024*	-0.010***	-0.008	-0.025*	-0.010***
	(0.007)	(0.014)	(0.003)	(0.007)	(0.014)	(0.003)
Input-tariff$_{jt}$×Market access$_{rt}$				-0.009**	-0.011**	-0.001
				(0.004)	(0.005)	(0.002)
Input-tariff$_{jt}$×Galafi$_{rt}$				-0.025	-0.003	-0.008
				(0.023)	(0.055)	(0.011)
Observations	7740	7740	7567	7740	7740	7567
Adjusted R^2	0.663	0.704	0.390	0.663	0.705	0.390
Firm FE	√	√	√	√	√	√
Town-year FE	√	√	√	√	√	√
Firm-year controls	√	√	√	√	√	√

Notes: Market access$_{rt}$ and Galafi$_{rt}$ are demeaned using the sample mean over the estimation sample. TFPR is computed following the procedure described in Section 3.2.2, the only difference being that output is now deflated using the country-wide deflator (sourced from the IMF). Markups (μ) are estimated following the approach by De Loecker and Warzynski (2012), which is described earlier in this Section, and are expressed in logs. Firm-time controls include exporter and FDI dummies and firm age. Standard errors in parentheses are clustered at the town-sector level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Overall, our results in this section are consistent with the idea that while input tariff liberalization is associated with greater improvements in efficiency in areas with better roads, it is not associated with equivalent increases in the markup charged by firms. The latter finding can be explained by the presence of competitive pressures from economic

[39] The minor difference between column (1) of Table 13 and column (1) of Table 5 is due to the inclusion of town-year fixed effects (instead of year fixed effects only)

dynamism spurred by better roads. The flavour of these results underscores the important role for improved roads in delivering gains from trade liberalization to local firms.

5 Conclusion

In this paper, we examine the role of roads in determining the effect of a reduction in input tariffs on the productivity of Ethiopian firms. We find that a reduction in input tariffs is associated with a larger increase in productivity for firms in towns with better market access from roads that connect them to other intranational markets. We find supportive evidence that road improvements facilitate adoption of new imported intermediate inputs and capital-intensive production techniques from a reduction in input tariffs. We observe greater pass-through of input tariff reductions to input prices and greater perceived competition among firms in locations with better market access. Finally, results suggest that increased competition from better connectivity to other markets can ensure that increases in firm markups are not differentially larger in towns with better roads.

We belive that our analysis has implications for both trade and infrastructure policy in developing economies. While trade liberalization can improve firm performance by affording domestic firms better access to intermediate inputs, poor infrastructure can mitigate these gains from trade, particularly for very remote regions. This may exacerbate regional inequality with trade liberalization. Road improvements can complement the beneficial effects of trade liberalization on firm performance. An interesting and related question is whether, and to what extent, misallocation of road infrastructure can hamper productivity gains from trade liberalization. There is scope for future research to delve into this question by studying the impact of trade liberalization on firms if roads were built optimally (Graff, 2019).[40]

[40] We thank an anonymous referee for this idea.

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Appendix for Online Publication

Trade Liberalization, Roads and Firm Productivity by Fiorini, Sanfilippo and Sundaram

A Roads and the pass-through from input tariffs to input prices

In this Appendix we propose a stylized model to analyze the differential impact of a decrease in the input tariff on input prices in towns with varying quality of road infrastructure. Our theory draws from the model introduced by (Atkin and Donaldson, 2015).

Suppose that intermediaries transport an imported product from the border (or dry port) to the final destination (Ethiopian towns, indexed by r).[1] Intermediaries obtain the product at the port for a price of $p^w + t$ where t is a specific tariff on imports of the product. They incur a transport cost to transport the product from the origin to the destination market. For simplicity, we assume that this transport cost is a per-unit cost $\tau(x_r)$ that is related to x_r, the quality of road infrastructure in town r. Better roads lead to a lower transport cost and hence, $\tau'(x_r) < 0$. Intermediaries then sell the product to firms to be used as an intermediate input in production at a price p_r. We conceptualize Ethiopian towns as local markets. This is consistent with anecdotal evidence from the ground, which documents how firms operate in local markets given high intranational transport costs.

We assume that the number of intermediaries competing in each town r is given by n_r and it is a positive function of the quality of local infrastructure x_r. Formally, $n_r'(x_r) > 0$, capturing the fact that better infrastructure induces greater competition among intermediaries. The number of intermediaries in each town is fixed (we rule out entry), which is plausible in the Ethiopian context (Atkin and Donaldson, 2015).

Consider the location specific demand function

$$Q_r = a(x_r) - bp_r \tag{A-1}$$

Demand in the town depends on roads via $a(x_r)$, with $a'(x_r) > 0$. This is a core

[1]The relevance of different types of intermediaries - from companies managing international and domestic transport, to agents dealing with customs clearance procedures - is high in the context of Ethiopia. This has been confirmed in a series of field interviews with various officials at the Ethiopian Customs Authority and with experts of the trade facilitation and logistics division at the Ethiopian office of the World Bank.

assumption, unique to our framework. The rationale behind is that low cost conditions generated by better access to roads might generate firm entry (or at least reduce firm exit), generate agglomeration economies and more economic dynamism that increases demand for intermediate inputs from firms.

Denote with q_{kr} the quantity sold by intermediary k in location r. The profit function of intermediary k in location r is given by

$$\Pi_{kr}(q_1, \ldots, q_{n_r}) = q_{kr} p_r \Big(\sum_{i=1}^{n_r} q_{ir} \Big) - c_{jr}(q_{jr}) \tag{A-2}$$

where $\sum_{i=1}^{n_r} q_{ir}$ can be denoted as q_r. Location specific marginal cost is given by

$$c'_r(q_{kr}) = p^w + t + \tau(x_r) \tag{A-3}$$

Necessary conditions for the Cournot-Nash equilibrium can be identified in the following system of first order conditions (FOCs):[2]

$$p_r(Q_r) - \frac{1}{b} q_{kr} - p^w - t - \tau(x_r) = 0 \qquad \forall j = 1 \ldots n_r(x_r) \tag{A-4}$$

Summing FOCs across intermediaries, we get

$$n_r(x_r) p_r(Q_r) - \frac{1}{b} q_r - n_r(x_r)\Big(p^w + t + \tau(x_r)\Big) = 0 \tag{A-5}$$

Imposing market clearing $Q_r = q_r$ and using the expression for demand, (A-5) can be rewritten as an expression in p_r. That expression can be solved to obtain the location-specific equilibrium price

$$p_r^* = \frac{a(x_r)}{b(n_r(x_r) + 1)} + \frac{n_r(x_r)}{(n_r(x_r) + 1)} \Big(p^w + t + \tau(x_r)\Big) \tag{A-6}$$

We can now derive a workable expression for $\partial \Big(\frac{\partial p}{\partial t} \frac{1}{p} \Big) / \partial x$ where, for the sake of simplicity, we ignore the r subscript since everything is now intended to be location-specific. We also write p^* as p. This expression tells us how does the proportionate change in the equilibrium price associated with a change in tariffs varies with the quality of road infrastructure. In other words, it is the moderating effect of roads on the transmission of tariff changes to price changes.

$$\frac{\partial \Big(\frac{\partial p}{\partial t} \frac{1}{p} \Big)}{\partial x} = \frac{b}{[a + bn(p^w + t + \tau)]^2} (an' - bn^2 \tau' - na') \tag{A-7}$$

[2]Functions' differentiability and concavity of the payoff functions make FOCs also sufficient.

The sign of this expression is determined by the term in the numerator in brackets.

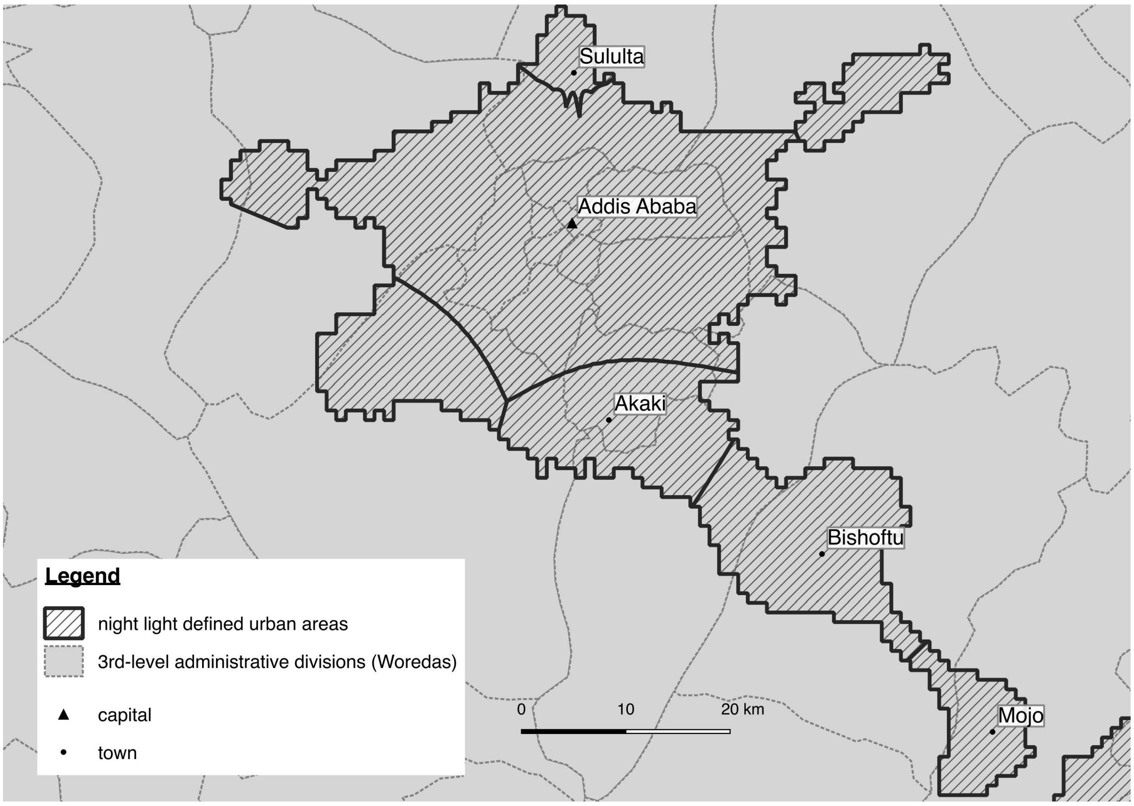
$$\frac{\partial\left(\frac{\partial p}{\partial t}\frac{1}{p}\right)}{\partial x} < 0 \iff an' - bn^2\tau' - na' < 0 \iff \frac{n'}{n} - \frac{b}{a}n\tau' < \frac{a'}{a} \qquad \text{(A-8)}$$

Hence, for a large enough proportional shift in demand due to better roads, $\partial\left(\frac{\partial p}{\partial t}\frac{1}{p}\right)/\partial x < 0$, suggesting that towns with better roads may see a weaker transmission of tariff declines to price declines. On the other hand, a larger competition effect among intermediaries captured by n'/n, or a larger effect of roads on the transport cost captured by $-(b/a)n\tau'$ will result in $\partial\left(\frac{\partial p}{\partial t}\frac{1}{p}\right)/\partial x > 0$ so that towns with better roads will see a stronger transmission of tariff declines to price declines. Finally, if these various effects offset each other, we may observe no moderating effect of roads on the impact of a tariff decrease on the destination price.

From our analysis above we conclude that the effect of road infrastructure in shaping the pass-through from input tariffs to input prices faced by the firms in different areas of the national market is ambiguous and depends on the relative strength of the three channels (demand, competition and transport cost) discussed above. If the latter two forces dominate, $\partial\left(\frac{\partial p}{\partial t}\frac{1}{p}\right)/\partial > 0$. If instead the "demand" force dominates, we would expect $\partial\left(\frac{\partial p}{\partial t}\frac{1}{p}\right)/\partial x < 0$. This theoretical ambiguity generates the empirical question of what the net moderating role of road infrastructure on input prices actually is. The empirical analysis conducted in the paper contributes to answer this question for the case of Ethiopia. We discuss results from the empirical estimation in Table 10.

B Ethiopian towns within a contiguous lit area

Figure B-1: Voronoi partition of the contiguous lit area



Notes: The figure plots urban areas defined by night-lights corresponding to Addis (including Burayu), Sululta, Akaki, Bishoftu and Modjo, all lying within a contiguous lit area. We partition the area into sub-areas consisting of the Voronoi polygons defined around town coordinates.

C Roads and aggregate firm performance

Table C-1: Correlation between roads and town-level aggregate firm performance

Dep var:	N firms_{rt}	Lab prod_{rt}	Capital intensity_{rt}	Sales_{rt}	Import/sales_{rt}	Skill ratio_{rt}
	(1)	(2)	(3)	(4)	(5)	(6)
Roads_{rt}	0.019*	0.108***	0.143***	0.127***	0.011***	0.050***
	(0.011)	(0.028)	(0.021)	(0.038)	(0.004)	(0.013)
Observations	638	591	624	638	635	615
R^2	0.903	0.490	0.568	0.719	0.416	0.383
Town FE	√	√	√	√	√	√
Year FE	√	√	√	√	√	√

Notes: The dependent variables are constructed by adding up firm level information at the town and year level. N firms_{rt} is the log number of firms; Lab prod_{rt} is the log of labor productivity, constructed as total value added divided by total number of employees; Capital intensity_{rt} is the log of the share of total fixed assets in total number of employees; Sales_{rt} is the log of total sales; Import/sales_{rt} measures the value of imported raw materials as a share of total sales; and the Skill ratio_{rt} is the share of the total number of administrative (and other non-production) workers in the total number of production workers. Robust standard errors in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

D Firm-level price index

The estimation of firm level productivity in the present paper builds on Eslava et al. (2004) and Smeets and Warzynski (2013). These two studies propose an empirical model of the production function where, instead of deflating revenues with the standard vector of sector-level price indices, a firm-level price index P_{it} is used. This Appendix discusses the procedure to adapt the methodology applied in Eslava et al. (2004) and Smeets and Warzynski (2013) to the specificities of our data.

Step 1

First, we account for the fact that in the Ethiopian firm census data, many products within firms are not consistently identifiable across time due to the lack of a product category as identifier. Second, multiple line entries within a firm-year record the same product code and unit measure. The solution we adopt is as follows. All products with missing product code are grouped in an aggregate product category (denoted with nim 'non identifiable missing'). Products within a firm-year that have the same values for both product code and unit measure are grouped in aggregate product categories depending on their product code ($onih$ 'other non identifiable with product code h').

Next, we derive a product-level price index as a weighted average of the prices of domestic sales and exports:

$$P_{hit} = \sum_{\nu=d,x} s^{\nu}_{hit} P^{\nu}_{hit} \tag{D-1}$$

where the superscripts d and x stand respectively for the domestic and export market, and s^{ν}_{hit} is the share of market ν in the total sales of product h by firm i at time t.

We deal with missing information in line with Eslava et al. (2004). In a nutshell: we compute sector-year level averages of P^{ν}_{hit} for $\nu \in \{d, x\}$ and we replace missing values of P^{ν}_{hit} with the respective sector-year average in case of a zero or missing value for sales or export quantity (value) and a non-missing, strictly positive value for sales or export value (quantity). Notice that when the value is missing (this is actually a minority of cases) the shares s^{ν}_{hit} cannot be computed. We correct for this by replacing the missing value of domestic and/or export sales for a product-firm-time level observation with the average value of domestic and/or export sales across available observations of the same product in the same firm but in alternate years.

Finally, we compute $P_{nim,it}$ and $P_{onih,it}$ as the weighted average of P_{hit} for all h belonging to the respective group of non-identifiable products, with weights computed as the h share of the total value (sales value plus export value) in the group. In this newly created database, these product-aggregates will be treated as individual products.

Step 2

We focus on product-level observations with perfectly identifiable products. We compute P_{hit} as before and append the results to the database created in Step 1. Then, we apply a Tornqvist formula to obtain firm-level prices. Notice that the dynamic structure of the Tornqvist formula requires that each product h is perfectly identifiable across time.

$$\Delta log(P_{it}) = \sum_h \frac{s_{hit} + s_{hi(t-1)}}{2} \times \left[log(P_{hit}) - log(P_{hi(t-1)})\right] \tag{D-2}$$

where s_{hit} is the share of product h total (both domestic and export) sales value over total sales value of the firm i at time t.

Finally, we select 2009 as our base year (the number of active firms is at its maximum in this year) and set $P_{i,2009} = 1$. We then proceed recursively (backward) to retrieve firm-level prices:

$$log(P_{i(t-1)}) = log(P_{it}) - \Delta log(P_{it}) \;\; \forall t \leq 2009 \tag{D-3}$$

We first apply (D-3) only for those firm-year pairs (i, t) such that, for every year $t \leq k \leq 2009$, $\Delta log(P_{it})$ is non missing.

There are two potential computational caveats that we address following the approach laid out by Eslava et al. (2004). First, a firm might not be observed in the base year. Consider the following example which illustrates the proposed solution. Take firm i and assume that the last year where it is observed is 2006. In that case the last $\Delta log(P_{it})$ that we can compute using (D-2) is $\Delta log(P_{i2006})$. We will set $log(P_{i2006})$ as the sector-level average for 2006, i.e. $\sum_j log(P_{j2006})/|J^{S(i)_{2006}}|$, where $|\cdot|$ is a cardinality operator, J^{k_t} is the set of firms j belonging to sector k for which we were able to retrieve $log(P_{jt})$, and $S(i)$ is the sector to which firm i belongs. Second, a firm i might have a missing value for $\Delta log(P_{it})$ at a certain time t in between two time intervals where it is potentially possible to apply the recursive formula (D-3). This would cause a break in the formula (this is the case for year 2004 and panel_id 6 for instance). Again, we solve this issue by replacing the missing observation of $log(P_{i(t-1)})$ with the sector-level average for that year. The result is a series of firm-level price indices P_{it} which will be used to deflate firm-level revenues.

E TFP coefficients

Table E-1: TFP coefficients

Sector	Labor	Capital	Materials
15	0.4126489	0.0486334	0.8142029
17	0.0830094	0.0317496	0.6806585
18	0.1221208	-0.0289049	0.9153442
19	0.0679566	0.0752514	0.8331738
20	0.4058325	0.0115141	0.7583169
22	0.4919236	-0.010469	0.5968748
24	0.0809411	0.1088803	0.8244199
25	0.4396779	0.0269117	0.7720901
26	0.3447249	0.0431832	0.6823554
28	0.1844413	0.1293488	0.7633256
34	0.3015625	0.0996745	0.7081328
36	0.1963425	0.038197	0.8051757

Notes: The table reports coefficients of the production function estimated for each 2-digit industry following the methodology described in Section 3.2.2. Sectors are specified as 2-digit ISIC Rev 3 categories.

F Addressing potential endogeneity of tariff reforms

In this section, we ensure that input tariff changes are largely exogenous to initial industry characteristics. If input tariff changes are endogenous to initial industry characteristics, it is possible that our results on the impact of input tariff reductions on firm productivity are inconsistently estimated. To do this, we estimate relationships between initial sector characteristics in 1996 including production, employment, exports, capital intensity and agglomeration and input tariff changes at the sector level between 1996 and 2003. Results are presented in Table F-1. Across columns, we find no statistically significant relationship between initial sector characteristics and input tariff changes, assuring us that tariff changes are plausibly exogenous.

Table F-1: Correlation between initial sectoral characteristics and trade policy change

Dependent variable:	Production	Employment	Export	Capital intensity	Agglomeration
	(1)	(2)	(3)	(4)	(5)
ΔInput-tariff	-1.005	-1.093*	-1.085	0.514	0.008
	(1.243)	(0.547)	(3.219)	(0.811)	(0.025)
Observations	36	41	41	41	41
R^2	0.020	0.081	0.003	0.015	0.005

Notes: The dependent variables are constructed by aggregating firm level data at the 4-digit sector and year level and using pre-sample information from the census year 1996. Variables "Production", "Employment" and "Export" are the sum of the values of output, employees and exports of the firm by sector and year; "Capital Intensity" is constructed as the sum of fixed asset divided by the total employment by sector and year; "Agglomeration" is given by the number of firms in each sector and year. After aggregation, all variables have then been transformed in logs. Input tariffs are computed at the 4-digit sector level and the variable report their changes between 1996 and 2003. Robust standard errors in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Next, we ask if input tariff changes are related to initial performance, measured by productivity. If they are, then the relationship we estimate between reductions in input tariffs and firm productivity might be driven by how tariff reforms were targeted across sectors. In Table F-2, we estimate correlations between lagged values of productivity and input tariff changes in each year in our sample period. Again, we find no evidence of a strong correlation between initial performance and subsequent changes in input tariffs, lending further credence to our claim that input tariff changes are exogenous to firm performance.

Table F-2: Correlation between initial sectoral performance and trade policy change

Dependent variable:	Input-tariff$_{jt}$	
	(1)	(2)
log TFP$_{ijt-1}$	-0.038	
	(0.063)	
log TFP$_{ijt-5}$		-0.024
		(0.055)
Observations	7367	3107
R^2	0.456	0.055
Firm FE	√	√
Year FE	√	√

Notes: The dependent variable in both regressions is the input tariff computed at the industry level. The regressors are firm productivity lagged one and five years respectively. All regressions include firm and year fixed effects. Robust standard errors clustered at the sector level are reported in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

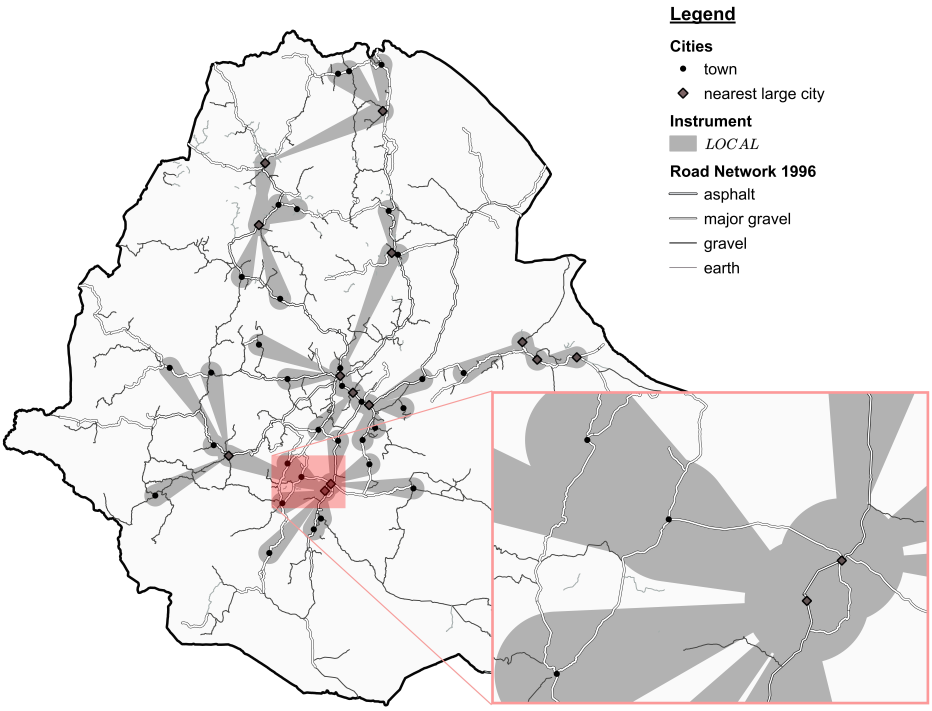
G Addressing potential endogeneity of roads

Table G-1: Correlation between town-level economic outcomes and change in roads

Panel A:	Dep var: ΔMarket access$_{rp}$					
	(1)	(2)	(3)	(4)	(5)	(6)
log TFP$_{rp}$	0.016		0.016	-0.004		-0.004
	(0.010)		(0.010)	(0.013)		(0.013)
Night light intensity$_{rp}$		0.007	0.003		0.013	-0.007
		(0.009)	(0.011)		(0.073)	(0.080)
Observations	117	138	117	109	138	109
Adjusted R^2	0.012	-0.003	0.004	0.350	0.328	0.341
Town FE				$\surd$	$\surd$	$\surd$
RSDP phase FE				$\surd$	$\surd$	$\surd$
Panel B:	Dep var: ΔGalafi$_{rp}$					
	(1)	(2)	(3)	(4)	(5)	(6)
log TFP$_{rp}$	-0.009		-0.009	0.003		0.002
	(0.007)		(0.007)	(0.007)		(0.008)
Night light intensity$_{rp}$		0.002	0.003		0.093*	0.097*
		(0.006)	(0.006)		(0.047)	(0.049)
Observations	112	115	112	103	109	103
Adjusted R^2	0.007	-0.008	0.000	0.413	0.444	0.439
Town FE				$\surd$	$\surd$	$\surd$
RSDP phase FE				$\surd$	$\surd$	$\surd$

Notes: The dependent variables ΔMarket access$_{rp}$ and ΔGalafi$_{rp}$ are constructed as the difference between the value of Market access$_{rt}$ and Galafi$_{rt}$ at the end and beginning of each of the three phases (indexed by p) of the RSDP covered in our sample. log TFP$_{rp}$ is constructed by averaging firm level data at the town level for the year at the beginning of each RSDP phase. Night light intensity$_{rp}$ is also measured at the town level for the year at the beginning of each RSDP phase. Robust standard errors in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Figure G-1: Partition of the area within Ethiopian borders



Notes: The set $LOCAL$ is constructed as the union of all 20km radius buffers centered on the coordinates of urban areas extended to cover the trajectory toward the nearest large city.

H Additional Tables

Table H-1: Initial values

Dependent variable:	log TFP_{ijrt}	
	(1)	(2)
Input-tariff$_{jt}$	-0.0353**	-0.00856
	(0.0167)	(0.00798)
Input-tariff$_{jt}$×Market access$_{rt}$	-0.0155***	-0.00708*
	(0.00522)	(0.00366)
Input-tariff$_{jt}$×Galafi$_{rt}$	-0.0381	0.0239
	(0.0243)	(0.0226)
Input-tariff$_{jt}$×High-Market access$_{rt}$	0.0310	
	(0.0199)	
High-tariff$_{jt}$×Market access$_{rt}$		-0.208
		(0.316)
High-tariff$_{jt}$×Galafi$_{rt}$		-2.022***
		(0.738)
Constant	2.599***	2.660***
	(0.294)	(0.304)
Observations	7740	7535
Adjusted R^2	0.745	0.745
Firm FE	√	√
Town-time FE	√	√
Firm-time controls	√	√

Notes: Market access$_{rt}$ and Galafi$_{rt}$ are demeaned using the mean over the estimation sample. The variable High-Market access$_{rt}$ is a dummy taking 1 if the pre-sample value of a town market access was higher than the median market access calculated on the whole sample of towns. The variable High-tariff$_{jt}$ is a dummy taking 1 if the pre-sample value of an industry's input tariff was higher than the median input tariff calculated on the whole sample of industries. Firm-time controls include exporter and FDI dummies and firm age. Standard errors in parentheses are clustered at the town-sector level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.