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Trade Liberalization, Infrastructure and Firm Performance: Evidence from Ethiopia*

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Abstract

This paper investigates the role of road infrastructure in shaping the effects of trade liberalization on firm performance. We conceive of a framework where intermediaries transport goods to local markets. Better infrastructure decreases intra-national transport costs, improves competition among intermediaries and increases demand in local markets. Depending on the relative strengths of these channels, improving infrastructure can either amplify or attenuate the positive effects of tariff reductions on firm productivity. We aim to resolve this ambiguity by exploiting census data on Ethiopian manufacturing firms combined with information on tariff reform and improvements in road infrastructure at the town level to empirically explore the complementarity between trade liberalization effects and road infrastructure. We show that a reduction in the output and input tariff has a strong positive effect on productivity for firms located in towns with better road infrastructure. Our study underlines the importance of domestic transport infrastructure in ensuring that gains from trade are spread uniformly within developing countries.

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

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1 Introduction

A large literature in international trade focuses on gains from trade liberalization for domestic firms. Trade liberalization is associated with greater firm productivity (Pavcnik, 2002; Amiti and Konings, 2007; Topalova and Khandelwal, 2011; Bigsten et al., 2016), higher markups (Brandt et al., 2017), quality improvements (Amiti and Khandelwal, 2012) and greater product scope (Goldberg et al., 2010). Similarly, there is substantial evidence that better transport infrastructure can decrease trade costs and increase interregional and international trade (Donaldson, forthcoming). Better road infrastructure can spur firm activity, encourage the entry of new firms (Shiferaw et al., 2015), facilitate exports (Volpe Martincus and Blyde, 2013; Coşar and Demir, 2016) and increase employment (Volpe Martincus et al., 2017). Moreover, recent research has embedded intranational trade costs (encompassing access and quality of road infrastructure) into models of international trade and estimated the role of these intra-national barriers in shaping the pattern of comparative advantage among sub-national entities (Coşar and Fajgelbaum, 2016) as well as the intra-national distribution of the gains from falling international trade barriers (Atkin and Donaldson, 2015).

However, little has been done in the way of a formal assessment of the complementarity between road infrastructure and trade liberalization effects on firm productivity and performance. In this paper, we analyze the role played by road infrastructure in moderating the effects of a fall in import tariffs on the productivity of firms. We focus on both output and input tariffs, capturing a fall in the tariff on the final product produced by the firm and intermediate inputs used in production respectively. Reductions to output and input tariffs affect domestic product prices and hence firm productivity. While output tariff reductions lead to a lower price for the final good, spurring competition and leading to efficiency improvements, a reduction in the input tariff is associated with lower prices for intermediate inputs, allowing firms access to better quality and a wider range of inputs, boosting productivity.

We propose a framework where intermediaries operating in an imperfectly competitive market transport goods from the port to local regions in the country. Intermediaries charge a local price that includes a mark-up. In this framework, we argue that on the one hand, better road infrastructure is associated with better transmission of tariff reductions to domestic prices at the local level and hence productivity of firms in that region. Or, better road infrastructure amplifies trade liberalization effects on firm productivity. On the other hand, better road infrastructure may be associated with greater competition among intermediaries and better demand conditions in the local region. While the former amplifies trade liberalization effects on firm productivity (via its effect on the price charged by the intermediary), the latter (demand) effect operates in the opposite direction, leading to weaker transmission of tariff reductions to the local product price because the intermediary can charge a higher mark-up. To summarize, the net effect of road infrastructure in moderating the impact of an import tariff reduction is theoretically ambiguous and depends on how each of these three channels play out.

We use census data on Ethiopian manufacturing firms from 1998 through 2009.[1] The detail in

[1] The data, collected by the Ethiopian Central Statistical Agency (CSA), include detailed information at the

our data allows us to construct measures of physical productivity at the firm level. Specifically, the availability of price data at the firm level allows us to build quantity-based productivity measures, which are not affected by the usual caveats undermining the application of revenue-based productivity in studies of the effects of trade liberalization on firm performance (see for instance De Loecker, 2011; De Loecker et al., 2016). We combine this data with a measure of road infrastructure quality at the town-level. This is computed as the sum of the estimated travel distance that can be covered in an hour from a particular town across all roads departing from it and accounts for road quality as well as the impact of road construction and rehabilitation over time.[2]

Simultaneous trade and road infrastructure reforms make Ethiopia an excellent case study for our purpose. Tariffs were reduced progressively starting in the early 1990s continuing into our sample period as part of a trade liberalization agenda initiated externally. Hence, we argue (and check) that tariff reductions were largely exogeneous to domestic firms. Next, Ethiopia embarked on extensive improvements to road infrastructure via the Road Sector Development Programme, aimed at improving connectivity through out the country. Significant enhancements in road infrastructure were undertaken under this program, including projects to rehabiliatate and upgrade the quality of existing roads and to build new ones. The Ethiopian case thus offers an excellent setting to explore the role of road infrastructure in moderating the effects of trade liberalization.

Exploiting tariff reductions over time and improvements in road infrastructure that vary over time and across towns, our empirical strategy relates firm productivity to input and output tariffs, road infrastructure and an interaction of the two to capture the moderating effect of road infrastructure on the relationship between tariffs and firm productivity. We find strong complementarity between trade liberalization effects and road infrastructure. A ten percentage point fall in the input tariff is associated with a 11 percentage point greater increase in productivity for a firm in the 41^{st} percentile of access to road infrastructure relative to a firm in the 31^{st}. A ten percentage point fall in the output tariff is associated with a 12 percentage point greater increase for a firm in the 41^{st} percentile of access to road infrastructure relative to a firm in the 35^{th}. Additionally, for a majority of firm-years in our data (59%), a 10 percentage point fall in the input (output) tariff is associated with an increase in firm productivity of at least 8% (12%). This is primarily because most firms are located in the few Ethiopian towns with adequate access to road infrastructure. However, for almost 80% town-years in our data, a reduction in tariffs would not result in an increase in firm productivity due to lack of access to road infrastructure. Results are robust to an instrumental variables estimation strategy, alternative measures of both productivity and road infrastructure and various cuts of the data.

Our study contributes to the literature in several ways. First, our analysis employs measures of physical firm productivity, relating to the burgeoing literature emphasizing the need to use quantity-based, rather than revenue-based measures of productivity to study the impacts of trade

establishment level, including on location (town), labor use, capital, usage of imported inputs and exports.

[2] We construct this and other measures by employing GIS techniques on raw data gathered by the Ethiopian Road Authority (ERA), which include information on the type and quality of roads and on traffic volumes (classified according to the type and capacity of vehicles) on roads connecting Ethiopian towns.

liberalization on firm performance. Focusing on revenue-based productivity introduces biases in the estimation of production function coefficiences and may confound the effects of trade liberalization on physical productivity and firm mark-ups. By estimating physical productivity, we are able to tackle some of these concerns. Second, we confirm the positive impact of a reduction in tariffs on intermediate inputs on physical firm productivity for firms in developing countries like Ethiopia. Third, we underscore the role for domestic transport infrastructure in ensuring gains from trade liberalization for domestic firms. Finally, we posit that in an environment where intranational trade is carried out by intermediaries with market power, the role played by road infrastructure in moderating trade liberalization effects may operate via numerous channels exerting opposing influences on local product prices and hence firm productivity.

Our paper is organized as follows. Section 2 presents our conceptual framework. Section 3 describes the empirical strategy. We describe our measures of tariffs and road infrastructure, the data and productivity estimation. We also discuss the empirical specification, identification issues and strategy. Section 4 and Section 5 present the results while Section 6 concludes.

2 Conceptual Framework

Our goal is to analyze the differential impact of a decrease in the output and input tariff on firm productivity in regions with differential quality of road infrastructure. We hypothesize that the impact of tariff declines on firm productivity work via two channels. First, a fall in the output tariff is associated with a fall in the product price in the local region, which results in improvements in efficiency at the firm level due to increased competition. Second, a fall in the input tariff lowers the cost of obtaining inputs (the intermediate input price), resulting in better and wider access to inputs, which boosts firm productivity. Since both channels operate via their effect on product prices, we propose a stylyzed framework to analyze the impact of tariff declines on the product price in local regions (towns in our data) in Ethiopia.

We posit a framework where intermediaries transport an imported product from the port to the final destination (Ethiopian towns, indexed by r).[3] 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 region r. Better roads lead to a lower transport cost and hence, $\tau'(x_r) < 0$. Intermediaries then sell the product to households for consumption or to both households and firms (where the product is 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 households and firms operate in local markets given high intra-national transport costs.

We assume that the number of intermediaries competing in each region 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

[3] Atkin and Donaldson (2015) propose a similar framework in their analysis of intra-national pass-through of world prices.

fact that better infrastructure induces greater competition among intermediaries. The number of intermediaries in each region is fixed (we rule out entry), which is plausible in the Ethiopian context (Atkin and Donaldson, 2015).

Consider the location specific demand function

$$Q_r = a(x_r) - bp_r \tag{2.1}$$

Demand in the region depends on roads via $a(x_r)$, with $a'(x_r) > 0$. This is a key assumption, unique to our framework. Our rationale behind this assumption is that with an improvement in local roads, households that were earlier unable to access this product at a nearby grocery store may now be able to access it due to a reduction in transport costs in their neighborhood. Similarly, low cost conditions generated by better access to roads might generate firm entry (or at least reduce firm exit), increasing demand for products also used as intermediate inputs in production 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

$$\Pi_{kr}(q_1, \ldots, q_{n_r}) = q_{kr} p_r\Big(\sum_{i=1}^{n_r} q_{ir}\Big) - c_{jr}(q_{jr}) \tag{2.2}$$

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

$$c_r'(q_{kr}) = p^w + t + \tau(x_r) \tag{2.3}$$

Necessary conditions for the Cournot-Nash equilibrium can be identified in the following system of first order conditions (FOCs):[4]

$$p_r(Q_r) - \frac{1}{b} q_{kr} - p^w - t - \tau(x_r) = 0 \qquad \forall j = 1 \ldots n_r(x_r) \tag{2.4}$$

Summing FOCs across intermediaries, we get

$$n_r(x_r) p_r(Q_r) - \frac{1}{b} q_r - n_r(x_r)\Big(p^w + t + \tau(x_r)\Big) = 0 \tag{2.5}$$

Imposing market clearing $Q_r = q_r$ and using the expression for demand, (2.5) can be rewritten as an expression in p_r. That expression can be solved to obtain the location-specific equilibrium price

$$p_r^* = \frac{a(x_r)}{b(n_r(x_r) + 1)} + \frac{n_r(x_r)}{(n_r(x_r) + 1)}\Big(p^w + t + \tau(x_r)\Big) \tag{2.6}$$

Notice that the equilibrium price is equal to the marginal cost when intermediaries in the location are infinitely many. 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

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

words, it is the moderating effect of roads on the transmission of tariff changes to price changes.

$$\frac{\partial\left(\frac{\partial p}{\partial t}\frac{1}{p}\right)}{\partial x} = \frac{b}{[a + bn(p^w + t + \tau)]^2}(an' - bn^2\tau' - na') \tag{2.7}$$

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

$$\frac{\partial\left(\frac{\partial p}{\partial t}\frac{1}{p}\right)}{\partial x} < 0 \iff an' - bn^2\tau' - na' < 0 \iff \frac{n'}{n} - \frac{b}{a}n\tau' < \frac{a'}{a} \tag{2.8}$$

Hence, for a large enough proportional shift in demand due to better roads (the "demand" effect), $\partial\left(\frac{\partial p}{\partial t}\frac{1}{p}\right)/\partial x < 0$, suggesting that regions with better roads may see a weaker transmission of tariff declines to price declines. On the other hand, a larger competition effect among intermediaries (the "intermediary competition" effect) captured by n'/n, or a larger effect of roads on the transport cost (the "transport cost" effect) 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 regions 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 and the fact that we expect impacts on firm productivity to occur through product prices, we conclude that the moderating effect of road infrastructure on the impact of trade liberalization on productivity is ambiguous and depends on the relative strenghts of the "demand", "intermediary competition" and "transport cost" effects on product prices. If the "intermediary competition" and "transport cost" effects dominate, $\partial\left(\frac{\partial p}{\partial t}\frac{1}{p}\right)/\partial > 0$ and hence $\partial\left(\frac{\partial \omega}{\partial t}\right)/\partial x < 0$ where ω denotes firm productivity. If the "demand" effect dominates, we would expect $\partial\left(\frac{\partial p}{\partial t}\frac{1}{p}\right)/\partial x < 0$ and $\partial\left(\frac{\partial \omega}{\partial t}\right)/\partial x > 0$. This theoretical ambiguity generates the question of what is the net moderating role of infrastructure. We now turn to the empirical framework used to craft our answer.

3 Empirical Framework

This section presents the ingredients of our empirical framework. As a first step, Section 3.1 discusses Ethiopian infrastructure and tariff reforms and related measures used in the analysis. Second, 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. Third, Section 3.3 introduces the empirical specification used to analyze the role of infrastructure in moderating the effects of tariffs on firms 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 Infrastructure

Being a landlocked country with a poorly developed railway system (mainly connecting Addis Ababa to the port of Djibouti), road infrastructure represents the prevailing dominant transport mode for goods transported within Ethiopia (Iimi et al., 2017).[5] Recognizing this, Ethiopia has planned and implemented various sectoral infrastructure development programmes over the last 15 years. A major such programme is the Road Sector Development Programme (RSDP), which started in 1997 and was implemented in three phases, the last of which ended in 2011. A recent 13-year assessment by the Ethiopian Road Authority (ERA) reveals that the programme resulted in substantial improvements in road infrastructure (see Table 1).

Table 1: Number of firms in census years

Indicators	1997	2010
Proportion of Asphalt roads in Good Condition	17%	73%
Proportion of Gravel roads in Good Condition	25%	53%
Proportion of Rural roads in Good Condition	21%	53%
Proportion of Total Road network in Good Condition	22%	56%
Road Density/ 1000 sq. km	24.1	44.4
Road Density/ 1000 Population	0.46	0.58
Road Density/ 1000 sq. km (incl. community roads)	24	136.6
Road Density/ 1000 Population (incl. community roads)	0.49	1.83
Proportion of area more than 5 km from all weather road	79%	64.20%
Average distance to all weather road, km	21.4	11.3

Notes: Raw data sourced from RSDP 13 Years Performance and Phase IV: January 2011.

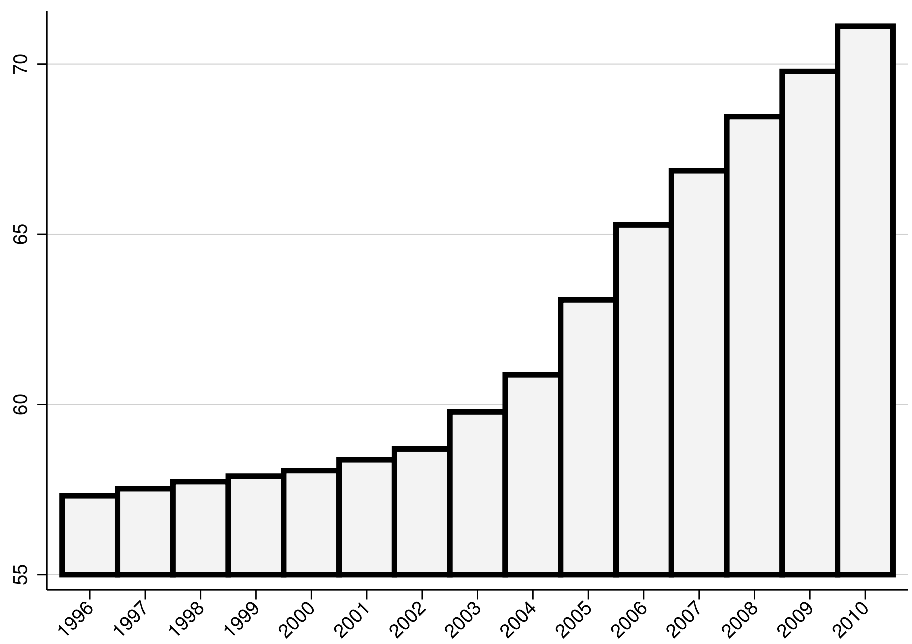
To identify the role of improvements in road infrastructure in moderating the relationship between trade liberalization and firm performance, we develop measures of improvements in the accessibility of select economic nodes (towns hosting firms in the census data) due to the rehabilitation, upgrading and construction of new roads from 1996 through 2009 (the start of the programme to the last year of our census data).

We construct measures of road infrastructure and improvements therein using data collected and updated from different sources. The main source is the 19 Year RSDP programme document, which includes a list of federal roads that were rehabilitated, upgraded or newly constructed in the past 19 years. The document includes a list of trunk roads in the rehabilitation and upgrading programme, and a list of link roads and new roads for different types of work categories such as asphalt concrete, bituminous treatment surface and gravel surface. We extract information on the year of construction and completion of each road project from physical and financial disbursement documents. Roads are classified by their pavement type such as Asphalt Roads, Major Gravel Roads (Federal Gravel Roads), Minor Gravel Roads (Regional Rural Roads) and Earth surfaced roads. The ERA's design documents provide the target speed for different road classes.

[5] The railway connecting Addis to Djibouti has been temporary 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.

The methodology implemented relies on standard tools of GIS analysis. In particular we use service coverage analysis, which tracks improvements in travel time and distance using the expected changes in travel speed due to changes in road quality. Each town included in the census data of firms represents an analysis node. We are then able to calculate the effects of road projects (new roads or road rehabilitation and upgrading) implemented on roads around the node in a particular amount of time T. We calculate the main indicator used in the empirical analysis as follows. First, for each time period (year) t we estimate the distance that can be covered in one hour's time from a node (town) to neighbouring areas using one particular road. This accounts for the quality of the road in year t. Second, we sum the estimated distance across all roads that branch out from the node at time t. The resulting town-year specific measure is taken as a proxy of quality of road infrastructure. Figure 1 shows the overall (summing across all towns) improvement in travel distance in an hour from nodes covered in the firm census data over the sample period.

Figure 1: Increase in Total Travel Distance (Thousand Km) for 1hr Travel Time from Firm Node



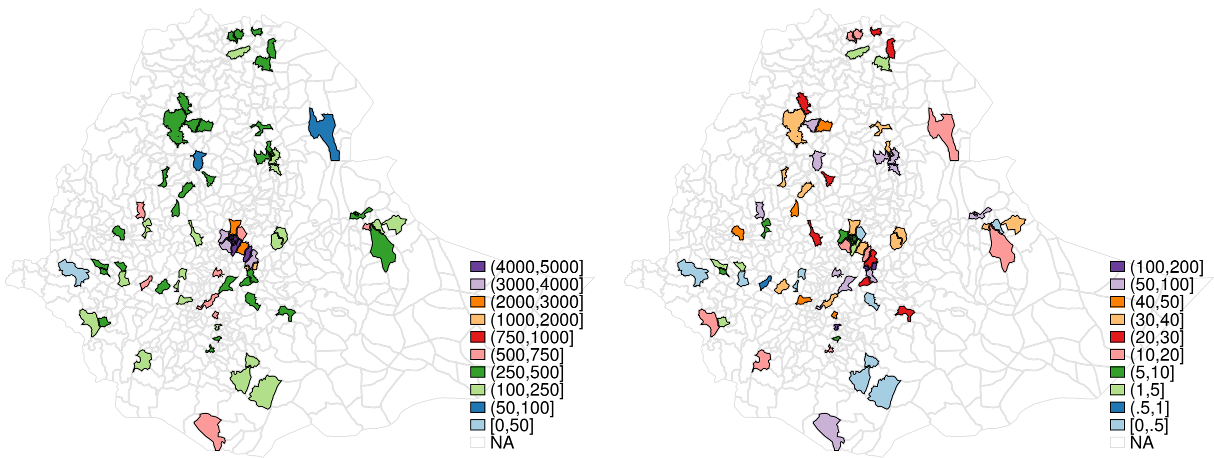
Notes: Authors' elaboration using GIS.

To summarize, the measure we use as our baseline proxy for the quality of road infrastructure in town r at time t is the travel distance that can be covered in an hour departing from r, summed over all roads which are accessible from r in a given year t. We denote the natural log of this measure as $\text{Infrastructure}_{rt}$.

3.1.2 Tariffs

Starting in 1993, the Government of Ethiopia 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

Figure 2: Road infrastructure



(a) Total travel distance (km) in 1998

(b) % increase from 1998 to 2009

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.

Figure 3 documents the changes in input and output tariffs for firms and sectors included in our sample from 1995 to 2009. With trade liberalization, tariffs dropped consistently up to 2003 and get more stable after.

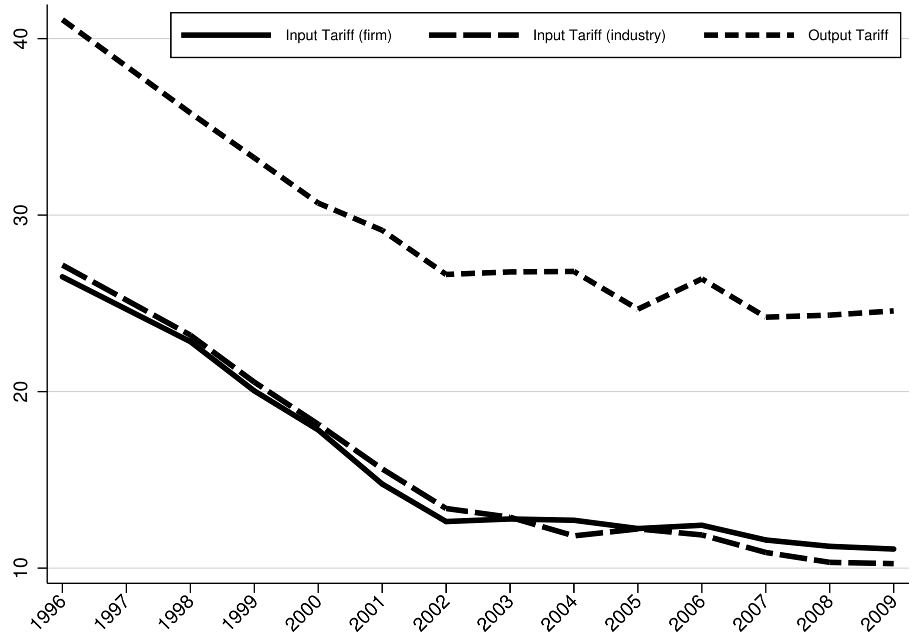
We construct input tariffs directly at the firm level, using information on the use of raw materials to construct weights. First, we match the code attributed by the CSA to each raw material used by the firm with a (4-digit) HS code. Second, we compute the share of each sector in each firm's total input expenditure: we denote as α_{ijt} the share of sector j input expenditure for firm i at time t.[6] Third, we use these shares as firm-specific coefficients to weight output tariffs using the standard approach.

$$\text{Input-tariff}_{it} = \sum_{j} \alpha_{ijt} \text{Ouput-tariff}_{jt} \tag{3.1}$$

Input tariffs at the firm-time level and Output tariffs at the sector-time level are the trade policy variables used in the empirical analysis.

[6] Importantly, we have constructed the cost shares on the basis of total input purchases, i.e. including both domestic and imported inputs, to avoid endogeneity bias (see discussion in Amiti and Konings, 2007).

Figure 3: Changes in tariffs during the sample period



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

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

3.2.1 Firm level Data

We use establishment level[7] data from the annual census of Large and Medium Manufacturing firms, published by the Central Statistica Agency (CSA) of Ethiopia. Data cover all firms that employ at least 10 workers and that use electricity in their production process. All firms need to comply with CSA requirements, and the census is therefore representative of more structured and formal firms in the country.[8] The dataset includes detailed information on the characteristics of each establishment, including on production, employment, capital and inputs, which are needed to estimate production functions. Firms belong to the manufacturing sector, and their industry is defined according to their 4-digit level of the ISIC Rev. 3 classification.

A key feature of the dataset is that it includes detailed information on (up to 8) specific products produced by each firm. Products are recorded following a classification made by the CSA, and for each product, information available includes the value and the quantity produced, both for the domestic and the export market. As anticipated in the discussion of tariff, our data allows to identify raw materials used at the level of the firm and their share in total firm's expenditures.

[7] The census data includes information at the level of the single productive establishment. In the rest of the paper we use the terms establishment and firms interchangeably.

[8] In 2005, a representative survey of firms was conducted instead of a census. This does not represent a huge 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 the variables as the simple average of the closest years. Results remain robust when dropping 2005 from our data.

This information have been used for the construction of the input tariff variable.

Finally, and importantly for our focus on infrastructure, for each firm we have information on its region, woreda (district) up to the level of the town. While firms are located in about 90 towns in the country, and their growth is geographically diversifying over time (Mukim, 2016), we register a strong concentration in the capital, Addis Ababa, which hosts 45.7% of the firms and 52% of the total observations, respectively.

We use an unbalanced panel of 3,551 establishments covering the period 1998-2009, totalling 12,672 observations. Table 2 reports the number of firms for each year of the sample, showing strong dynamism of the private sector,[9] which is consistent with the overall pattern of economic growth experienced by the country during the last decade (Moller, 2015).

Table 2: 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' elaboration on Ethiopian Census Data.

While presenting a multi-product structure, the database has a limitation which undermines the application of a multi-product empirical framework in the analysis. In particular, the product code which is necessary to identify the observation at the product-time level is missing in almost 59% of the product-time level observations in the whole sample. Other products which are not perfectly identifiable across time are those that have the same product code and the same unit of measure within a firm-year pair. These observations account for another 20% in the whole sample. On average across firms and years, non-identifiable products account for 63% of total firm sales. This would make a product-level analysis significantly non-representative.[10] For this reason we choose to conduct the TFP estimation and the subsequent econometric analysis at the level of the firm, making the necessary assumptions to exploit all the product-level information contained in the dataset. These will be discussed in the next section.

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

[10] A similar issue of non-identifiability applies to raw materials which are identified with a code similar to that used for products. About 56% of all raw-material-time level observations have a missing raw material code and therefore are non identifiable across time. Moreover 12% of the observations have the same (non-missing) raw material code and the same unit measure within a firm-year pair. Fortunately the problem here is less relevant from an economic point of view as non-identifiable raw materials account only for about 30% of all raw material expenditures on average across firms and years. This is why the input tariff variable at the firm-level built on these data remains our preferred measure of input tariffs.

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). Due to the lack of information on firm specific prices, it has been argued that a large body of research on the nexus between trade liberalization and firm performance has been unable to capture improvements in physical efficiency, but mostly captures gains in profitability. In our study, we exploit information on values and physical quantities at the product level to construct a measure of physical productivity (Eslava et al., 2004; Smeets and Warzynski, 2013).

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

$$y_{ijrt} = \beta_1 \, k_{ijrt} + \beta_2 \, l_{ijrt} + \beta_3 \, m_{ijrt} + \omega_{ijrt} + \epsilon_{ijrt} \tag{3.2}$$

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} labour and m_{ijrt} the costs of materials, respectively. The random component ω_{ijrt} is the unobservable productivity or technical efficiency and ϵ_{ijrt} is an idiosyncratic output shock distributed as white noise.

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 downward bias of the input coefficients, which is due to the likely correlation between the firm-specific variation in output prices and expenditures on inputs (De Loecker and Goldberg, 2014; De Loecker, 2011). Similarly, lack of information on input price variation 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 prices at the product level, since firms report information on quantity and values of products they produce (see Section 3.2.1 above).[11] We aggregate product prices at the firm level calculating 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 the Appendix A.

While deflating output with firm specific prices eliminates the output price bias and allows us to compute physical TFP more precisely, to address the input price bias we follow a simplified version of the approach developed by De Loecker et al. (2016). 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. With this assumption, the input price bias can be controlled by including the output price index in the control function to account for unobserved input price variation.

[11] This comes with measurement issues, given that prices are measured by unit values. In addition, we make assumptions concerning product homogeneity or the way products are aggregated across firms (see De Loecker and Goldberg, 2014, for more discussion).

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 (3.2) 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 the simultaneity bias. We also address potential collinearity in the first stage due to simultaneity bias of the labour 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. Physical output is the total production at the level of the firm deflated using P_{it} described in the Appendix A. We use the book value of fixed assets at the beginning of the year to estimate the capital coefficient, the total number of permanent employees for labour and the total cost of raw materials for intermediate inputs.

3.3 Econometric Specification and Identification Strategy

The basic empirical strategy used in this paper consists of a standard interaction model, where the main regressor of interest is the product of the policy treatment (output or input tariff) and a moderator variable (quality of insfrastructure). The specification varies depending on the policy instrument considered, whether it is input or the output tariff. The two respective empirical models are given by

$$\log \text{TFP}_{ijrt} = \beta \text{ Input-tariff}_{ijrt} + \gamma \text{ Input-tariff}_{ijrt} \times \text{Infrastructure}_{rt} + \boldsymbol{\delta}' \mathbf{z}_{ijrt} + \mu_i + \nu_{rt} + \varepsilon_{ijrt} \quad (3.3)$$

$$\log \text{TFP}_{ijrt} = \beta \text{ Output-tariff}_{jt} + \gamma \text{ Output-tariff}_{jt} \times \text{Infrastructure}_{rt} + \boldsymbol{\delta}' \mathbf{z}_{ijrt} + \mu_i + \nu_{rt} + \varepsilon_{ijrt} \quad (3.4)$$

The dependent variable in both equations is the natural logarithm of TFP estimated for firm i active in sector j, town r at time t. Input tariffs in equation (3.3) vary at the firm level. Instead, output tariffs in equation (3.4) are specific to the sector j and do not vary across firms within the sector. The second regressor in both specifications consists of the interaction between the respective policy treatment and our measure of the quality of infrastructure. The latter varies at the town level and over time. Both models feature 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 ($\text{Foreign ownership dummy}_{ijrt}$). All specifications also contain firm fixed effects (μ_i), town-time fixed effects (ν_{rt}) and the idiosyncratic error term (ε_{ijrt}). Standard errors are clustered at the level of the industry.

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 infrastructure. This would be reflected in a negative sign for the coefficient β when the moderator variable $\text{Infrastructure}_{rt}$ is demeaned. By construction, the proposed specifications allow the productivity effect of the respective policy instrument to vary linearly with the quality of infrastructure. The role of infrastructure in shaping the effect of tariff liberalization is identified by the coefficient γ. As discussed in Section 2, the different theoretical channels determining the moderating role of infrastructure exert opposing influences. As a consequence, the sign of γ is ultimately an empirical matter. To reiterate, if the “transport cost” and “interemediary competition” effects of road infrastructure dominate the “demand” effect, the sign of γ will be negative. If the “demand” effect offsets the two other effects or if it dominates, we may observe a zero or positive sign for γ.

Identification in this empirical setting requires the policy treatments to be as good as randomly assigned in each equation. The included battery of fixed effects accounts for any confounding heterogeneity originating from firm-specific as well as town-time-specific shocks/characteristics. In sections below, we address further concerns pertaining to our empirical strategy.

3.3.1 Endogeneity of Infrastructure

The literature has long debated the potential endogeneity of infrastructure investments, claiming that new infrastructure is often placed where it will have the biggest economic impact (Coşar and Demir, 2016; Duflo and Pande, 2007). The endogeneity concern in our specific context is that the decision on where to place new roads or to improve existing ones is somehow related to the presence of more productive firms in given towns. If this were the case, the moderating effect of roads on the relationship between tariff reductions and firm productivity would be confounded with the effects of related but unobserved town-specific factors, including economic and political conditions, correlated with firm productivity. We do not expect potential endogeneity of road placement to present a significant concern in our context. While the economic potential of the area is, along with other criteria, among the priorities listed by the Ethiopian Road Authority (ERA) for allocating new infrastructure investments, there is little evidence on the effective criteria used to determine investments in practice. As Shiferaw et al. (2015) who use the same data we employ point out, the risk of endogenous road placement decisions should be marginal given that plans of road constructions are taken on a 5-year basis and this can hardly affect annual changes in firm performance. In addition, given the small weight of the manufacturing sector in the Ethiopian economy, it is hard to speculate that its current performance could affect long term investment decisions in the road sector.

Yet, for robustness, we account for the potential endogeneity of road infrastructure by employing an instrumental variable (IV) approach. First, note that we do not look at the direct effect of road infrastructure on firm productivity, since our focus is on its moderating role. Hence, we account for time-varying town-specific shocks with town-year fixed effects in our baseline regressions, thereby ruling out potential simultaneity bias between firm productivity and road construction. Next, we address the endogeneity in the moderating role of road infrastructure. Following recent studies (Duflo and Pande, 2007; Iimi et al., 2017; Wang et al., 2016), we use the geophysical condition of the terrain as a plausible exogenous proxy for the higher costs of building road infrastructure. We use the slope of the terrain in the district in which each town is based, weighted by the distance of each town to the capital as an instrument for road infrastructure. The assumption here is that investing in new roads in areas more isolated from Addis (the capital and geographical center) is more costly. We use interactions of this instrument with tariffs for our two interaction terms of interest. Given that we use the instrument interacted with the tariff variables that vary by year, we do not worry about the time invariant nature of the proposed instrument.

We present the results from this IV exercise after the discussion of our baseline estimates.

3.3.2 Endogeneity of Tariffs

A standard argument in the literature has to do with the potential endogeneity of trade policy. Political economy mechanisms (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, we are confident about the exogeneity of trade policy since, as also argued by Jones et al. (2011) and Bigsten et al. (2016), trade reforms were largely shaped by international institutions under liberalization programmes in the early '90s. Yet, since we cannot completely rule out endogeneity of tariffs on the basis of this argument, we try to address 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, export, 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 and output tariffs between 1996 and 2003.[12] Results of these regressions show that there is hardly any correlation between changes in 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 tariff adjustments were made in response to productivity levels. To do this we regress input tariffs (calculated at the firm level) at time $t+1$ on firm productivity at t, controlling for firm and year fixed effects. We do the same for output tariffs, regressing their level at $t+1$ on an indicator of average industry productivity, weighted by the share of firm total output and controlling for industry and year fixed effects. We repeat the same exercise using levels of productivity at $t-5$. Results of these exercises show that changes in tariffs were not correlated to previous levels of productivity of firms and industries, thus implying that policymakers did not adjust trade policy in response to observed productivity levels of local firms and industries.

For space considerations we present and discuss results from these exercises in Appendix B. Overall, we find strong empirical support against endogeneity of tariffs reforms in Ethiopia.

[12] To do this exercise we use input tariffs computed at the industry, rather that at the firm level. We use the change until 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.

3.4 Estimation Sample

Assembling data from the different sources we obtain the estimation sample which consists of an unbalanced panel covering up to 1537 establishments located in 56 towns and observed across the period 1998-2009, yielding a total of 7527 observations. Summary statistics for the variables used to obtain the baseline results are reported in Table 3.

Table 3: Summary statistics

Variable	mean	median	sd	min	max
log TFP$_{ijrt}$	2.490	2.267	1.507	-4.999	9.081
Input-tariff$_{ijrt}$	13.964	10	9.924	0	66.667
Output-tariff$_{jt}$	27.182	29.460	9.750	5	65.347
Infrastructure$_{rt}$	7.604	8.330	1.086	4.361	8.423
$\log(\text{age}_{ijrt} + 1)$	2.423	2.398	0.894	0	4.736
Exporter dummy$_{ijrt}$	0.048	0	0.213	0	1
Foreign ownership dummy$_{ijrt}$	0.039	0	0.193	0	1

Notes: The table reports summary statistics for the main variables used in the analysis.

4 Results

4.1 Baseline Results

Section 2 outlines our hypothesis that the role of road infrastructure in moderating the relationship between tariff reductions and firm productivity that operates through product prices is ambiguous and depends on the relative strenghts of the “trasnport cost” and “intermediary competition” effects on the one hand and the “demand” effect on the other. If the first two effects dominate, we expect coefficients on the interaction terms between tariffs and road infrastructure to be negative, suggesting that a reduction in tariffs is associated with relatively higher productivity for firms in towns with better road infrastructure. If the latter effect dominates, we expect coefficients on the interaction terms between tariffs and road infrastructure to be positive. We also expect the likelihood of the “demand” effect dominating to be higher in the case of the input tariff relative to the output tariff, since demand for inputs comes from households and firms.

We report the main estimation results in Table 4. Columns (1) through (4) present results for preliminary versions of our baseline models. The first two columns exclude interactions of tariffs and road infrastructure, which are then included in Columns (3) and (4). These models do not control for potentially confounding heterogeneity across towns, but only for firm and year fixed effects. Columns (5) and (6) report estimates for the baseline equations (3.3) and (3.4), where town-year fixed effects are introduced to account for unobserved town-specific shocks correlated with firm productivity. Finally, column (7) includes both input and output tariffs and their interactions with road infrastructure in a single regression as a first robustness test.

From Columns (1) and (2), we find that reductions in the input and output tariffs are associated with an increase in firm productivity. However, the coefficient is statistically significant only in case of the input tariff. A ten percentage point fall in the input tariff is associated with a seven percent increase in firm productivity. Consistent with the literature, this result lends support to the idea that better access to intermediate inputs through lower prices is associated with productivity improvements for firms. From Columns (3) and (4), negative coefficients on the interaction terms suggest that reductions in the input and output tariffs are associated with higher productivity for firms in towns with better road infrastructure. Our results hence point to a key role for road infrastructure in moderating the effects of trade liberalization on firm productivity. This pattern is confirmed and reinforced by the estimates from our baseline models in columns (5) and (6). This emphasizes the role for road infrastructure in ensuring gains from trade liberalization for firms. In Column (7), we find that the signs and magnitudes of our coefficients of interest remain remarkably consistent with those in previous columns.

Table 4: Main estimation results

Dependent variable:	log TFP_{ijrt}						
					Baseline models		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Input-tariff$_{ijrt}$	-0.007**		-0.006**		-0.003		-0.004
	(0.003)		(0.003)		(0.003)		(0.003)
Output-tariff$_{jt}$		-0.010		-0.008		0.003	0.003
		(0.006)		(0.006)		(0.007)	(0.007)
Input-tariff$_{ijrt}$×Infrastructure$_{rt}$			-0.005**		-0.006**		-0.005*
			(0.003)		(0.003)		(0.003)
Output-tariff$_{jt}$×Infrastructure$_{rt}$				-0.009*		-0.018**	-0.017**
				(0.005)		(0.008)	(0.008)
Infrastructure$_{rt}$			0.065	0.263			
			(0.111)	(0.179)			
Observations	7527	7527	7527	7527	7527	7527	7527
Adjusted R^2	0.673	0.673	0.673	0.673	0.671	0.671	0.671
Firm FE	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓			
Town-year FE					✓	✓	✓
Firm-year controls	✓	✓	✓	✓	✓	✓	✓

Notes: Data are for the years 1998 through 2009. Input and Output tariffs are constructed as outlined in Section 3.1.2. Variable Infrastructure refers to distance covered in 1hr travel time around firm node. Firm-time controls include exporter and FDI dummies and firm age. Standard errors in parenthesis are clustered at the sector level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Figure 3 plots the effect of the input tariff on firm productivity at various levels of road infrastructure quality with 90 percent confidence intervals on each side. The top and bottom axes present percentiles of road infrastructure in the data based on town-year and firm-year observations respectively. The histograms at the top and bottom show the distribution of town-year and firm-year observations at various percentiles of road infrastructure in the data. We make the following observations from Figure 3. 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 road infrastructure. In other words, a fall in the input tariff is associated with a greater increase (or smaller decrease) in firm productivity as the quality of road infrastructure improves. From the figure, a ten percentage point decrease in the input tariff is associated with a 11 percentage point greater increase in productivity for a firm in the 41st percentile of access to road infrastructure relative to a firm in the 31st. Second, the coefficient on the input tariff is negative for 65% of firm-year observations and 20% of town-year observations. This suggests that for a majority of firm-years in our data, a fall in the input tariff is associated with an increase in productivity since they are located in regions with quality access to road infrastructure. Specifically, for 59% of firm-years in our data, a 10 percentage point fall in the tariff is associated with an increase in productivit of at least 8%. However, very few town-years have the level of infrastructure that would be associated with an increase in firm productivity with a fall in the input tariff. Figure 4 presents results for the output tariff. A ten percentage point fall in the output tariff is associated with a 12 percentage point greater increase for a firm in the 41st percentile of access to road infrastructure relative to a firm in the 35th. Like in the case of the input tariff, a fall in the output tariff is associated with an increase in firm productivity for a majority of firm-years, but for very few town-years. For 59% of firm-years in our data, a 10 percentage reduction in the output tariff is associated with an increase of at least 12% in firm productivity. To summarize, both figures highlight two key points. There is a strong moderating role for road infrastructure under trade liberalization and there is substantial scope to improve local road infrastructure in Ethiopia, thereby spurring firm activity and performance uniformly across towns.

4.2 Identification and Robustness

In this section, we address endogeneity concerns in our key independent variable using an instrumental variable estimation strategy. We then test for robustness of our results to alternate productivity and road infrastructure measures. Our results qualitatively support baseline results.

4.2.1 Instrumental Variables Estimation

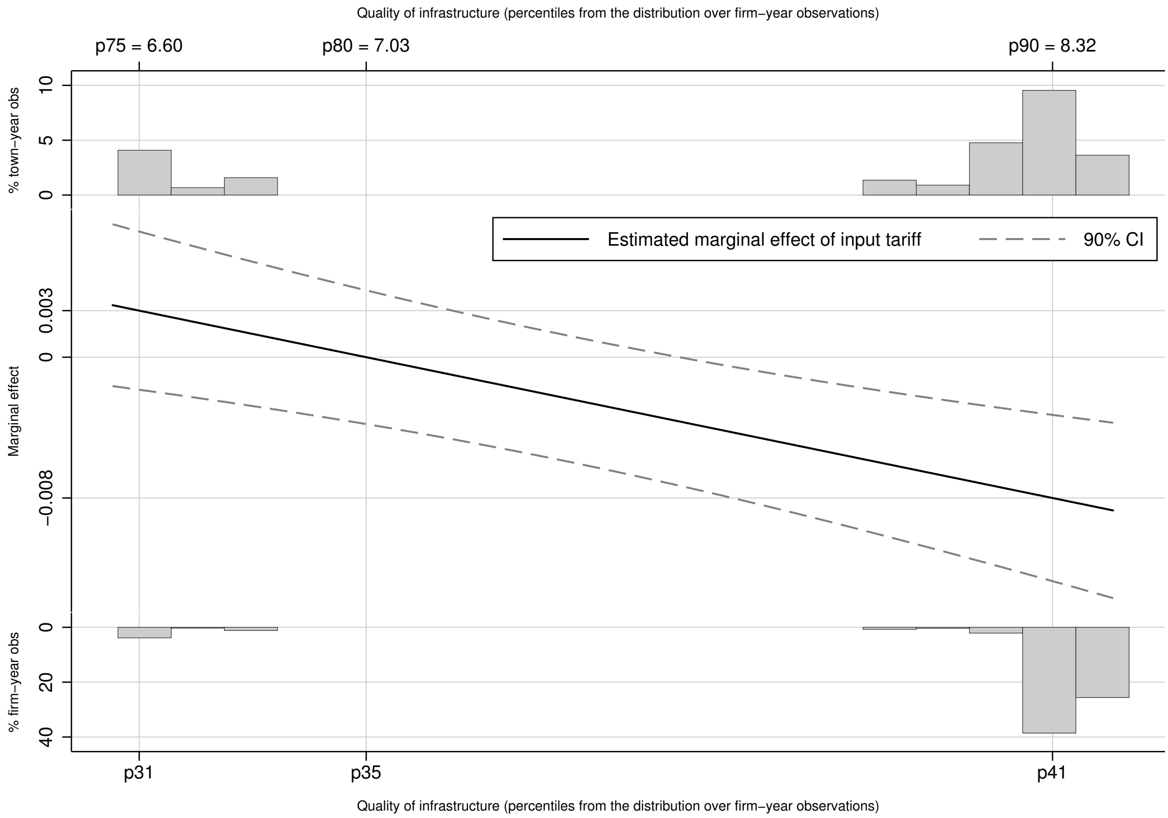
As we argue in Section 3.3.1, the quality of road infrastructure might be endogeneous to firm productivity. To tackle this concern, we instrument for road infrastructure in the interaction terms with tariffs with the slope of the terrain in the district that the firm is located in, weighted by the distance to Addis, the capital city. Our IV is composed of geographical factors that we argue are largely exogeneous. We present results in Table 5. First-stage statistics reported in the table assure us that our instrument is strong and we find that it is negatively related to our road infrastructure variable as expected. From Table 5, we find that second-stage results closely match our baseline results presented in columns (5) and (6) of Table 4.

4.2.2 Robustness Checks

Finally, we undertake a battery of checks to ensure the robustness of our results to (1) alternative measures of the dependent variable; (2) alternative measures of road infrastructure; (3) alternative sub-samples.

First, we calculate alternative measures of firm productivity, to check if results are affected by the TFP estimation methods used and described in Section 3.2. In Columns (1) through (4) of

Figure 4: The effect of input tariffs moderated by the quality of infrastructure



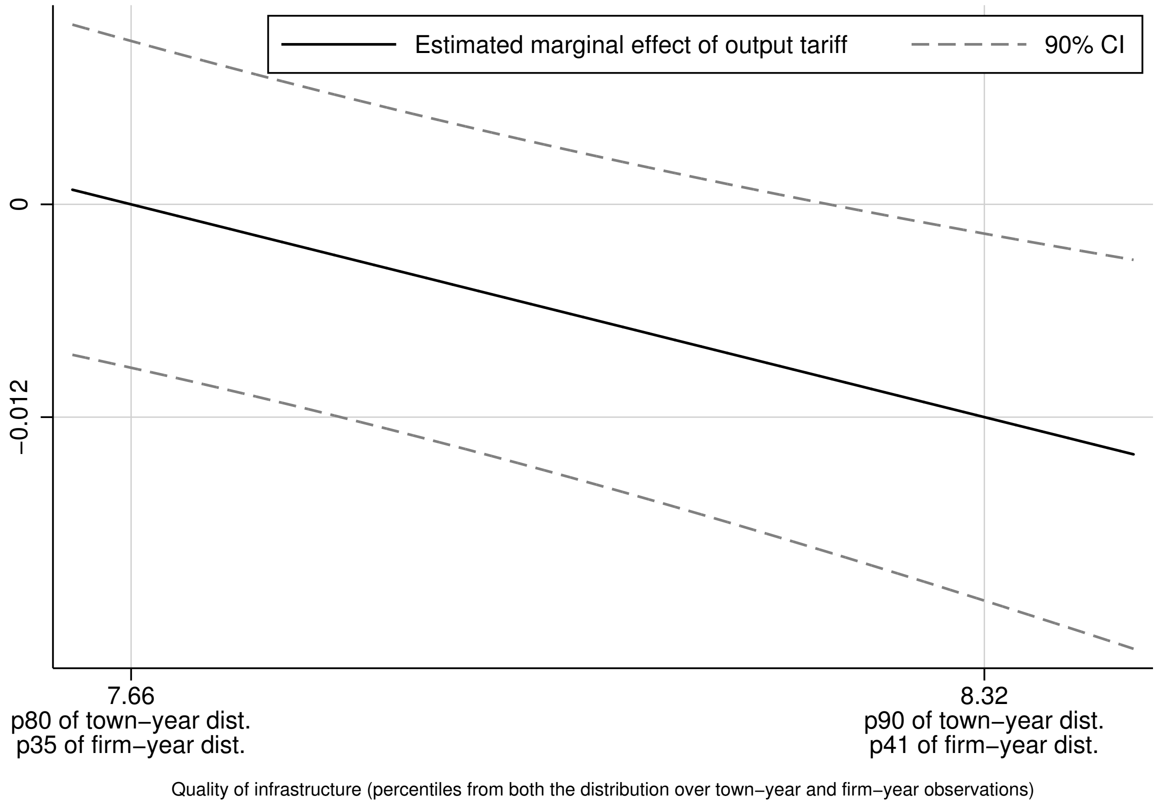
Notes: The central panel of this figure plots the estimated marginal effect of input tariffs on log TFP_{ijrt} from column (5) of Table 4 (on the vertical axis) as a function of $\text{Infrastructure}_{rt}$ (on the horizontal axis). Using the notation in equation (3.3), the point estimate plotted as a solid black line in the figure is given by $\hat{\beta} + \hat{\gamma} \times \text{Infrastructure}_{rt}$. Corresponding confidence intervals at the 90% level of statistical significance have been estimated for each value of $\text{Infrastructure}_{rt}$ in the estimation sample of 7527 observations used in Table 4. The upper panel of the figure plots the histogram reflecting the distribution of $\text{Infrastructure}_{rt}$ over 440 town-year pairs covered in the estimation sample. More precisely it plots a portion of it: the right tale of the distribution from the 75^{th} percentile onward. Point estimates for the marginal effect of input tariff are smaller than 0 for values of $\text{Infrastructure}_{rt}$ bigger than 7.03. Only 20% of the town-year pairs covered in the estimation sample score a value of $\text{Infrastructure}_{rt}$ bigger than that threshold. At the 90^{th} percentile of the distribution of $\text{Infrastructure}_{rt}$ over town-year pairs the estimated marginal effect of input tariff is equal to -0.008 and it is statistically different from zero. The bottom panel of the figure reports the histogram reflecting the distribution of $\text{Infrastructure}_{rt}$ over the 7527 firm-year observations of the estimation sample. For 65% of the observations the estimated marginal effect of input tariff is negative. Moreover, the 90^{th} percentile of the distribution over town-year pairs corresponds to the 41^{st} percentile of quality of infrastructure as distributed on firms-year observations. This means that 59% of the sample observations represent firms observed in a context whose quality of infrastructure is such that a 10 percentage point decrease in input tariffs increases firm's productivity by at least 8 percentage points.

Table 6, we estimate productivity using accounting for a range of variables in the control function[13] (first two Columns) and a one-step GMM method proposed by Wooldrigde (Wooldridge, 2009) (last two Columns). Across the four Columns, we find that our results remain stable and consistent with the baseline.

Second, results may be affected by the choice of variable measuring road infrastructure. We use two alternate measures of road infrastructure and present the results in Table 7. First, we use

[13] 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 both input and output tariffs as well as the status of exporter of the firm.

Figure 5: The effect of input tariffs moderated by the quality of infrastructure



Notes: The figure plots the estimated marginal effect of output tariffs on log TFP_{ijrt} from column (6) of Table 4 (on the vertical axis) as a function of $\text{Infrastructure}_{rt}$ (on the horizontal axis). Using the notation in equation (3.4), the point estimate plotted as a solid black line in the figure is given by $\hat{\beta} + \hat{\gamma} \times \text{Infrastructure}_{rt}$. Corresponding confidence intervals at the 90% level of statistical significance have been estimated for each value of $\text{Infrastructure}_{rt}$ in the estimation sample of 7527 observations used in Table 4. Percentiles on the horizontal axis are computed from both the distribution of $\text{Infrastructure}_{rt}$ over the 440 town-year pairs and over the 7527 firm-year observations in the estimation sample. Point estimates for the marginal effect of output tariff are smaller than 0 for values of $\text{Infrastructure}_{rt}$ bigger than 7.66. 20% of the town-year pairs covered in the estimation sample score a value of $\text{Infrastructure}_{rt}$ bigger than that threshold. 65% of firm are observed in these environments. At the 90^{th} percentile of the distribution of $\text{Infrastructure}_{rt}$ over town-year pairs the estimated marginal effect of input tariff is equal to -0.012 and it is statistically different from zero. 59% of the sample observations represent firms observed in a context whose quality of infrastructure is such that a 10 percentage point decrease in output tariffs increases firm's productivity by at least 12 percentage points.

the total area accessible by road in one hours travel time (computed using a buffer zone of 5 kilometers on both sides of a road) as an alternative indicator of local accessibility and report results in Columns (1) and (2). We call this variable 'Area' Second, in Columns (3) and (4) we use an alternative indicator of road infrastructure that we construct using a different GIS tool: Origin-Destination (O-D) matrix analysis. The O-D matrix analysis is a tool used to test the impact of road construction or rehabilitation and upgrading on travel time to a specific destination. In the service coverage analysis described earlier, the impact of road infrastructure can only be observed if roads around the selected node are improved. The O-D matrix analysis can capture improvements in road infrastructure along road segments between the node and economic hubs. Specifically, we measure improvements in travel time to Addis, the capital city. For firms in Addis we measure improvements in travel time to the town of Galafi (the last

Table 5: Instrumenting for Road Infrastructure

Dependent variable:	log TFP$_{ijrt}$	
	(1)	(2)
Input-tariff$_{ijrt}$	-0.003	
	(0.003)	
Output-tariff$_{jt}$		0.003
		(0.008)
Input-tariff$_{ijrt}$×Infrastructure$_{rt}$	-0.006*	
	(0.003)	
Output-tariff$_{jt}$×Infrastructure$_{rt}$		-0.016*
		(0.009)
Observations	7225	7225
Adjusted R^2	0.667	0.668
Firm FE	√	√
Town-year FE	√	√
Firm-year controls	√	√
KP LM stat	8.943	11.748
P-val	0.003	0.001
KP F stat	822.82	961.073

Notes: Data are for the years 1998 through 2009. Input and Output tariffs are constructed as outlined in Section 3.1.2. Variable Infrastructure refers to distance covered in 1hr travel time around firm node. Firm-time controls include exporter and FDI dummies and firm age. The instrument for Infrastructure is terrain slope weighted by distance to Addis. Standard errors in parenthesis are clustered at the sector-year level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The Kleibergen-Paap (KP) LM statistic and related p-value allow to test for under-identification under the assumption of heteroskedasticity. Weak identification is tested with the KP Wald F test.

Table 6: Robustness to Alternative Measures of Productivity

Productivity measure (in logs):	Control F		W-GMM	
	(1)	(2)	(3)	(4)
Input-tariff$_{ijrt}$	-0.003		-0.002	
	(0.003)		(0.004)	
Output-tariff$_{ijrt}$		0.001		0.006
		(0.007)		(0.009)
Input-tariff$_{ijrt}$×Infrastructure$_{rt}$	-0.006**		-0.005*	
	(0.003)		(0.003)	
Output-tariff$_{ijrt}$×Infrastructure$_{rt}$		-0.018**		-0.017*
		(0.008)		(0.008)
Observations	7527	7527	7527	7527
Adjusted R^2	0.579	0.580	0.983	0.983
Firm FE	√	√	√	√
Town-time FE	√	√	√	√
Firm-time controls	√	√	√	√

Notes: Data are for the years 1998 through 2009. The dependent variables in Columns (1) through (4) are TFP estimated with a modified control function and with the Wooldridge GMM approach respectively. Input and Output tariffs are constructed as outlined in Section 3.1.2. Variable Infrastructure refers to distance covered in 1hr travel time around firm node in Columns (1) through (4). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Ethiopian town by road to the port of Djibouti, which handles most of Ethiopia's trade). We call the resulting variable 'Distance'. With this variable, we are able to capture connectivity to a major port for imports, an additional dimension of road infrastructure relevant to international trade. This analysis complements our baseline focus on road improvements occurring in the immediate surroundings of a firm. Results in both Columns confirm our baseline results. Note that the coefficient on the interaction term between the import tariffs and Distance is positive and statistically significant in Column (6) as expected, since greater distance to Galafi in this case measures lower connectivity.

Table 7: Robustness to Alternative Measures of Quality of Infrastructure

Dependent variable:	log TFP$_{ijrt}$			
	(1)	(2)	(3)	(4)
Input-tariff$_{ijrt}$	-0.004		-0.008**	
	(0.003)		(0.004)	
Output-tariff$_{ijrt}$		-0.007		-0.014
		(0.008)		(0.009)
Input-tariff$_{ijrt}$×Area$_{rt}$	-0.014*			
	(0.008)			
Output-tariff$_{ijrt}$×Area$_{rt}$		-0.056**		
		(0.026)		
Input-tariff$_{ijrt}$×Distance$_{rt}$			0.004**	
			(0.002)	
Output-tariff$_{ijrt}$×Distance$_{rt}$				0.012*
				(0.006)
Observations	7527	7527	6964	6964
Adjusted R^2	0.671	0.672	0.669	0.669
Firm FE	√	√	√	√
Town-time FE	√	√	√	√
Firm-time controls	√	√	√	√

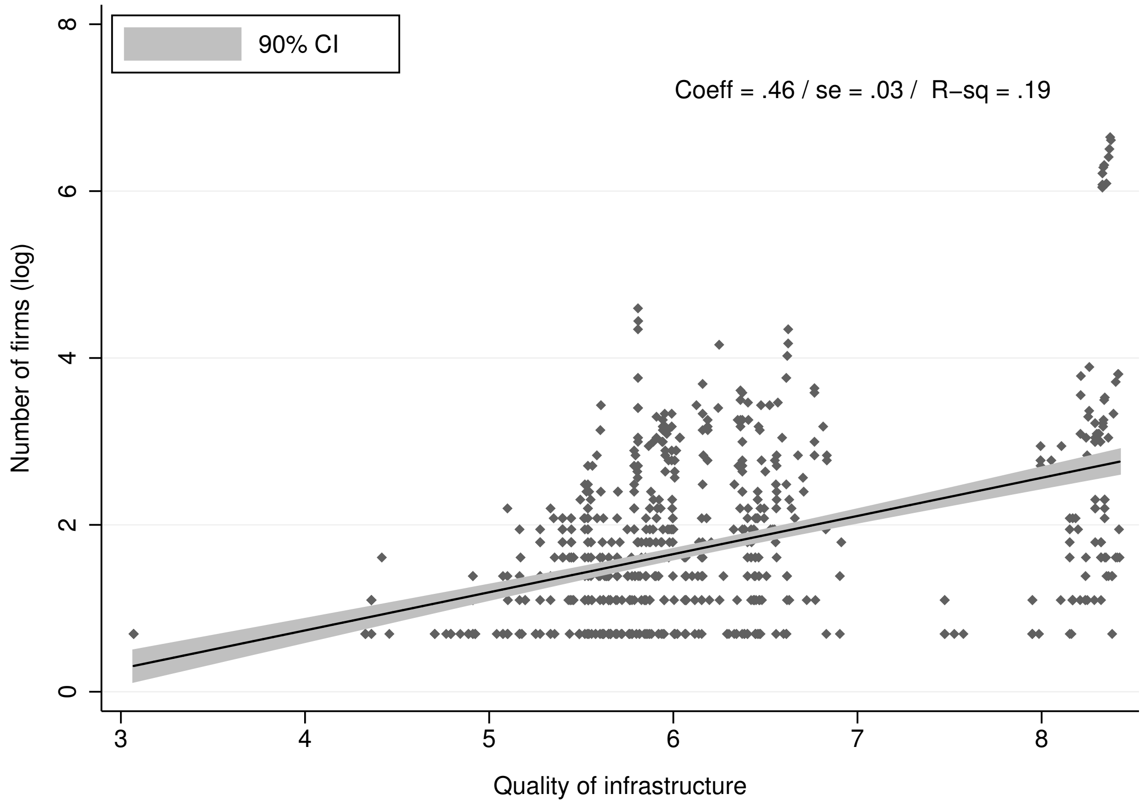
Notes: Data are for the years 1998 through 2009. Input and Output tariffs are constructed as outlined in Section 3.1.2. Variable Area refers to area covered in 1hr travel time around firm node. Variable Distance refers to the travel distance to Addis for all Ethiopian towns different from Addis and distance to Galafi (border with Djibouti and port) for Addis. Firm-time controls include exporter and FDI dummies and firm age. Standard errors in parenthesis are clustered at the sector-year level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Finally, we estimate our regressions without the year 2005, when the census was run as a representative survey, as discussed in Section 3.2. We also exclude years for which tariffs were imputed rather than directly obtained from the source. Our results in both cases remain qualitatively robust. Overall, our analysis in this section shows that our results are robust to alternate measures and samples, increasing confidence in our baseline results.

5 Testing the Demand Effect

This extension to the core analysis in the paper offers an empirical assessment of the "demand" effect discussed in Section 2 affecting the way road infrastructure moderates the effects of tariff liberalization on firm productivity. We argued in Section 2 that better infrastructure improves economic dynamism in a town encouraging greater firm activity via entry or expansion of firms and greater household demand. Overall, better infrastructure is likely to be correlated with greater aggregate demand at the local level. Intermediaries can take advantage of higher local demand to internalize some of the gains from lower trade barriers without passing them on to firms and households in local markets. This can result in better infrastructure jeopardizing/attenuating the positive effects of trade liberalization on firm productivity. To empirically examine this channel, we utilize data on the number of firms active in a town in each year as a proxy for aggregate demand. Figure 6 shows a positive correlation between quality of infrastructure and local demand as measured by this proxy. We then replicate the baseline estimation augmented with the interaction between import tariffs and the number of firms in a town-year. This additional term should control for the moderating role of infrastructure operating through higher local demand. In other words, it should control for the "demand" effect, isolating the moderating role of infrastructure operating through the "transport cost" and "intermediary competition" channels. Table 8 presents results and directly compares them with baseline estimates from Table 4. In particular Columns (1) and (3) of Table 8 report the estimates of Table 4 Columns (5) and (6) respectively.

Figure 6: Quality of infrastructure and number of firms



Notes: The figure plots the logarithm of the number of firms against the quality of infrastructure as captured by the variable Infrastructure for each town-year environment where both variables take a non missing value (734 town-year observations). The figure also reports the fit from a linear regression model. The estimated slope of the linear fit is 0.46 with standard error equal to 0.03.

Results show that consistent with our conceptual framework, after controlling for the moderating

Table 8: Assessing the demand effect

Dependent variable:	log TFP$_{ijrt}$			
	(1)	(2)	(3)	(4)
Input-tariff$_{ijrt}$	-0.003	-0.024**		
	(0.003)	(0.011)		
Output-tariff$_{jt}$			0.003	-0.035**
			(0.007)	(0.015)
Input-tariff$_{ijrt}$×Infrastructure$_{rt}$	-0.006**	-0.012***		
	(0.003)	(0.004)		
Output-tariff$_{jt}$×Infrastructure$_{rt}$			-0.018**	-0.028***
			(0.008)	(0.009)
Input-tariff$_{jt}$×Log number of firms$_{rt}$		0.004*		
		(0.002)		
Output-tariff$_{jt}$×Log number of firms$_{rt}$				0.009***
				(0.003)
Observations	7527	7527	7527	7527
Adjusted R^2	0.671	0.671	0.671	0.672
Firm FE	√	√	√	√
Town-time FE	√	√	√	√
Firm-time controls	√	√	√	√

Notes: Data are for the years 1998 through 2009. Input and Output tariffs are constructed as outlined in Section 3.1.2. Variable Infrastructure refers to distance covered in 1hr travel time around firm node. Variable Log number of firms is the natural logarithm of the number of firms observed in each town-year environment. Firm-time controls include exporter and FDI dummies and firm age. Standard errors in parenthesis are clustered at the sector level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

role of infrastructure through higher demand at the local level, the effect of infrastructure in shaping the impact of tariff reductions on firm productivity is indeed amplified. By adding the new control, the magnitude of the point estimate of the regressor of interest (interaction between the tariff and road infrastructure) doubles (increases by a 100%) for the input tariff and increases by 56% for the output tariff. Our results in this section hence confirm that the "demand" effect of road infrastructure attenuates its role in complementing the effects of trade liberalization on firm productivity. Finally, as expected, the "demand" effect seems stronger in the case of the input rather than the output tariff.

6 Conclusion

In this paper, we examine the role of road infrastructure in moderating the effect of reductions in the input and output tariffs on the productivity of Ethiopian firms. We show that a reduction in the input tariff is associated with an increase in firm productivity. Hence, we confirm the existing finding that better access to intermediate inputs through a fall in the tariff can benefit domestic firms. We find that a reduction in both the input and output tariffs is associated with higher productivity for firms in towns with better road infrastructure. Our results thus emphasize a role for transport infrastructure in ensuring gains from trade. Finally, in an environment where access to goods in local regions depends on intermediaries or transport agents with market power, better road infrastructure, by invigorating local demand may provide incentives for agents to capture and retain some of the gains from trade liberalization, mitigating benefits for firms. Transmission of tariff reductions to domestic prices may not necessarily be stronger with better road infrastructure.

We belive that our analysis has implications for both trade and infrastructure policy in developing economies. While trade liberalization can improve firm performance by fostering competition and affording domestic firms better access to intermediate inputs, poor infrastructure can lead to weak transmission of tariff reductions to domestic prices. This may hamper gains from trade, particularly for remote regions, exacerbating concerns of regional inequality. Our study suggests that road infrastructure can complement the effects of trade liberalization on firm performance. Finally, greater competition in the intermediary sector can yield better transmission of tariff reductions to domestic prices, ensuring that the benefits of trade are spread more uniformly.

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Appendices

A Firm-level price index

Eslava et al. (2004) and Smeets and Warzynski (2013) propose an empirical model of the production function where firm-level revenues are used in the left hand side. Instead of deflating revenues with the standard vector of sector-level price indexes, these author propose a firm-level price index P_{it}. This Appendix discusses the procedure to adapt their methodology to the specificities of our data.

Step 1

First, we need to account for the fact that many products are not consistently identifiable across time due to the lack of a product category as identifier or to the fact that more than one product for the same firm in the same year have identical product code and unit measure. The solution we propose consists in treating non perfectly identifiable products as the elements of an aggregate product category that will be used alongside perfectly identifiable individual product categories. More precisely, all products with missing product code will be grouped in an aggregate product category (denoted with *nim* 'non identifiable missing') and all products with non-missing product code but still non identifiable (because they have the same values for both product code and unit measure within a firm-year pair) will be grouped in aggregate product categories depending on the non missing product code (*onih* 'other non identifiable with product code h'). In order to aggregate the information contained in product-level observations we proceed as follows:

Step 1A

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

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

where the superscripts d and x stand respectively for domestic and export market, and s^{ν}_{hit} is the share of the ν market in the total sales of product h by firm i at time t. We also perform some intuitive imputation in case some activity is reported but not all the required information is available. The approach we follow for inputing the data is 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 when we have 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 the minority of cases) the shares s^{ν}_{hit} cannot be computed. We correct for this by replacing the missing observation of 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 different years.

Step 1B

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. We create a database where products are actually product-aggregates but will be treated as individual products from now on.

Step 2

Second, we focus on product-level observations with perfectly identifiable products [8,174 product-level observations for 1984 firms]. We replicate Step 1A and we append the database created in Step1.

Then, we apply a Tornqvist formula to get the variation in firm-level prices. Notice that the dynamic structure of the Tornqvist formula requires that each product h is perfectly identifiable across time.

$$\Delta log(P_{it}) = \sum_{h} \frac{s_{hit} + s_{hi(t-1)}}{2} \times \left[log(P_{hit}) - log(P_{hi(t-1)})\right] \qquad \text{(A-2)}$$

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, select as a base year the one where the number of active firms is at its maximum, i.e. the end of the time span (2009), we set $P_{i,2009} = 1$, and we proceed recursively (backward) to retrieve the firm-level prices:

$$log(P_{i(t-1)}) = log(P_{it}) - \Delta log(P_{it}) \ \forall t \leq 2009 \qquad \text{(A-3)}$$

We first apply (A-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. 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 (A-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 which is between two time intervals where it is potentially possible to apply the recursive formula (A-3). This would cause the breaking 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.

We follow again the approach proposed by Eslava et al. (2004) to address these issues.

B Addressing potential endogeneity of tariff reforms

[In progress]