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Rail Transport and Firm Productivity

Evidence from Tanzania

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Abstract

Railway transport generally has the advantage for large-volume, long-haul freight operations. Africa possesses significant railway assets. However, many rail lines are currently not operational because of the lack of maintenance. The paper recasts light on the impact of rail transportation on firm productivity, using micro data collected in Tanzania. To avoid the endogeneity problem, the instrumental variable technique is used to estimate the impact of rail transport. The paper shows that the overall impact of rail use on firm costs is significant despite that the rail unit rates are set lower when the shipping distance is longer. Rail transport is a cost-effective option for firms. However, the study finds that firms' inventory is costly. This is a disadvantage of using rail transport. Rail operations are unreliable, adding more inventory costs to firms. The implied elasticity of demand for transport services is estimated at –1.01 to –0.52, relatively high in absolute terms. This indicates the rail users' sensitivity to prices as well as severity of modal competition against truck transportation. The study also finds that firm location matters to the decision to use rail services. Proximity to rail infrastructure is important for firms to take advantage of rail benefits.

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RAIL TRANSPORT AND FIRM PRODUCTIVITY: EVIDENCE FROM TANZANIA

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JEL classification: H54; H41; D24; C21.

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I. INTRODUCTION

In theory, railway transport generally has the advantage for large-volume long-haul freight operations. Because of the significant amount of fixed costs required, railway transport exhibits large economies of scale. It is a common view that 1 million net tons a year are needed to justify economic viability of railways (World Bank 2010). With an average haulage of more than 500 km, railways can achieve good financial performance (e.g., World Bank 2013). There is also an increasing recognition that railways are an important factor to foster sustainable green transportation. Theoretically, railways can be more than 50 percent greener than road transportation (Kopp et al., 2013). In the world, the rail sector accounts for 3.6 percent of total transport emissions, while it transports over 8 percent of the world's passengers and goods (IEA and UIC, 2015).

Railway carries 6.3 percent of the global passenger transport demand and 9 percent of the total freight demand (**Table 1**). For passenger movements, road transport is a dominant mode in many countries, except for some countries, such as China, India, Japan and the Russian Federation, where railway accounts for about 15-30 percent of the total passenger transport (**Figure 1**). In Africa, railway passenger transport is minimal.

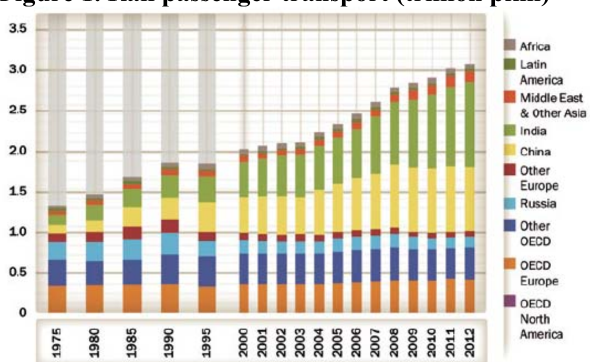
On the other hand, railway has a more vital role to play in freight transportation. With navigation excluded, rail carries the same amount of freight as road does. In non-OECD countries, the demand for rail freight transport has been increasing in recent years, while developed countries have been experiencing more stable rail freight activities (**Figure 2**). The rail dependency varies across countries: While rail freight accounts for more than 30 percent in India and the United States, the modal share of rail freight in Japan is less than 1 percent. In the Russian Federation, the share exceeds 85 percent.

Table 1. Global transport modal share (%), 2012

	Passenger (passenger-km)	Freight (ton-km)	Total (Transport unit)
Road	82.7	8.8	31.3
Aviation	10.6	0.7	3.7
Navigation	0.3	81.5	56.8
Rail	6.3	9.0	8.2

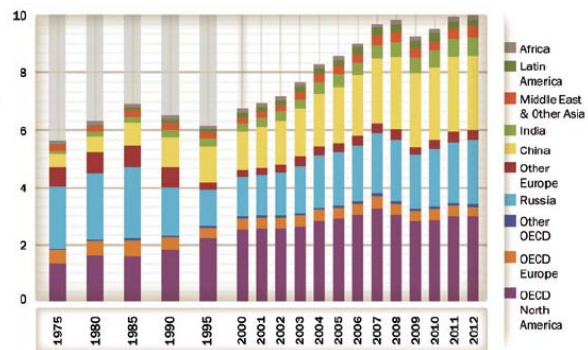
Source: IEA and UIC (2015)

Figure 1. Rail passenger transport (trillion pkm)



Source: IEA and UIC (2015)

Figure 2. Rail freight transport (trillion tkm)



Source: IEA and UIC (2015)

Africa possesses important railway assets. At the end of 2008, there were 52 railways operating in 33 countries in the region. The total rail network size is about 70,000 km, out of which 55,000 km are under operations. Historically, Africa's rail traffic has heavily been concentrated on a few lines connected to major mines and agricultural production areas. The rest carry less than 300,000 tons a year. Rail freight tariffs, which range from US$0.03 to US$0.06 per ton-km, are competitive against road user costs (**Table 2**), but the quality of services has been deteriorating because of lack of maintenance of rail infrastructure. Most of the rail lines in Africa are more than 100 years old and need to be rehabilitated (see Gwilliam (2011) for detailed discussion).

Table 2. Road user costs and average rail tariff (US$/ton-km)

Country/Region	Company	(a) Road	(b) Rail	(a)/(b)
Senegal-Mali	Transrail	7.9	5.3	1.49
Côte d'Ivoire-Burkina / Mali	Sitarail	7.9	5.5	1.44
Cameroon–Chad	Camrail	11.2	6.3	1.78
Mozambique	CCFB/CFM	10.0	5.5	1.82
Tanzania-Great Lakes	TRL	13.5	4.3	3.14

Source: World Bank (2013)

Despite the long-neglected maintenance, some countries have been increasing efforts toward reviving railway assets in recent years. Ethiopian Railways Corporation embarked upon a phased program for the construction of 5,000 km of rail lines to connect Addis Ababa to the country's main gateway port, Djibouti, as well as other major cities. In Kenya and Uganda, new standard gauge rail construction was started to connect Mombasa to Nairobi in 2014. Tanzania is rehabilitating the Central Corridor connecting inland cities, such as Kigoma and Mwanza, and neighboring countries, such as Burundi and Rwanda, to the Port of Dar es Salaam ("Big Results Now" program). These long-distance rail services could dramatically reduce transport and trade costs in inland areas and landlocked countries in the region. In Africa, there are 16 landlocked countries.

The current paper aims at estimating the impact of rail transportation on firm productivity with micro data collected in Tanzania. The literature suggests that with better transport infrastructure, regardless of mode, firms can improve their productivity. Firm inventory can be decreased by highway investment in the United States (Shirley and Winston, 2004). International trade reduces with transport costs (Limão and Venables, 2001). Because of those effects, firms prefer to be located along major highways (e.g., Holl, 2004). Several empirical challenges exist in estimating the impacts of large-scale infrastructure investment, including endogeneity, self-selection and contamination: While inherently productive firms may choose to be located where particular transport infrastructure exists, policy makers may invest more (or less) depending on where those firms are located. Therefore, the possible impacts of transport infrastructure may or may not be attributed to the investment itself. To avoid this problem, the current paper uses the instrumental variable technique and the three-stage least squares (3SLS) estimator.

The remaining sections are organized as follows: Section II provides an overview of recent developments in transport infrastructure in Tanzania. Section III develops our empirical model and presents data. Section IV presents main estimation results, and Section V discusses policy implications. Then Section VI concludes.

II. Recent Developments in Transport Infrastructure

Tanzania has about 3,557 km of rail lines, which are operated by two rail companies: Tanzania Railways Limited (TRL) and Tanzania Zambia Railway Authority (TAZARA). The TRL lines were constructed during the colonial era in the early 20th century. The construction of the Central Railway was started in 1905, to Kigoma, a port town situated on Lake Tanganyika, which was reached in 1914 (e.g., Amin, Willetts and Matheson, 1986). The current TRL was established as a parastatal company jointly owned by Reli Assets Holding Company (RAHCO) on behalf of the Government of Tanzania (49 percent) and an Indian private operator RITES (51 percent) in 2007. However, the anticipated increase in performance under RITES management did not materialize.[1] Since the completion of renegotiations in 2011, the company has fully been owned by the government.

The TRL network is based on a 1,000-mm narrow-gauge standard and extends more than 2,500 km, connecting Dar es Salaam and large inland cities, such as Mwanza, Kigoma and Arusha. These inland areas are more than 1,000 km away from the coast. Historically, rail transport has been playing an important role to provide affordable access to the global market to Tanzania, which is a large country with a land area of more than 900,000 km^2.

TAZARA is another major rail line connecting Dar es Salaam to Mbeya and New Mposhi in Zambia. Unlike the TRL, which is primarily a national network with the ends of lines located at Dar es Salaam and Tanga on the Indican Ocean, Mwanza on Lake Victoria and Kigoma on Lake Tanganyika, TAZARA is a binational rail network, extending 1,860 km, with 975 km in Tanzania and 885 km in Zambia (**Table 3**). TAZARA is a statutory body established under TAZARA Act No.4 of 1995 (Repealed Act No.23 of 1975) and jointly owned by the two governments, Tanzania and Zambia, on a 50:50 basis. Other neighboring countries, such as Malawi and Southern Democratic Republic of Congo, which are practically landlocked in the

[1] Based on the TRL website and TRL (2014). TRL performance review: JTSR 2014.

region, are also benefiting from the TAZARA lines. The network is based on the Cape Gauge with a width of 1,067 mm, a different standard from TRL. It is relatively new compared to the TRL lines. However, the rail infrastructure has already been in poor condition because of lack of proper maintenance. Recently, the two governments have agreed to take up responsibility of funding infrastructure maintenance, locomotives and wagons.[2]

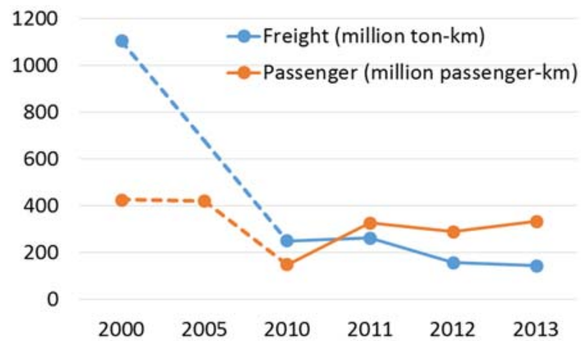
Given the deterioration of the service quality as well as the improvement of road infrastructure along the regional corridors, the current freight volume hauled by the TRL represents only 13 percent of the peak demand in the early 2000s (**Figure 3**). Similarly, the traffic on TAZARA is only about 15 percent of its peak demand during the early 1990s (**Figure 4**). Despite the deteriorated service quality, some businesses and shippers are still using rail transport, mainly because of low relative costs to road transport. Rail tariffs have increased in U.S. dollar terms in recent years but are still lower than truck road user costs in Tanzania (**Figure 5**).

Table 3. Tanzania: Rail networks (km)

TRL	2,582	TAZARA	1,860
Central Line	1,254	Tanzania	975
Tanga Line	437	Zambia	885
Link Line	188		
Mwanza Line	378		
Mpanda Line	210		
Singida Line	115		

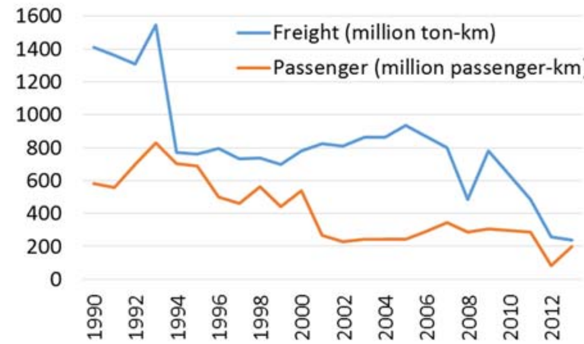
[2] Tanzania Zambia Railway Authority. (2014). TAZARA performance review: JTSR 2014.

Figure 3. TRL rail traffic



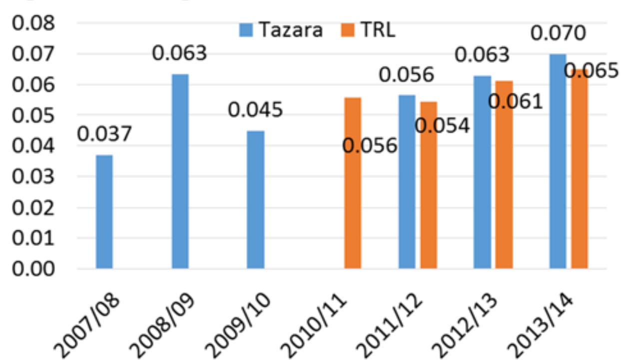
Source: TRL (2014).

Figure 4. TAZARA rail traffic



Source: TAZARA (2014).

Figure 5. Average rail tariffs (US$/ton-km)



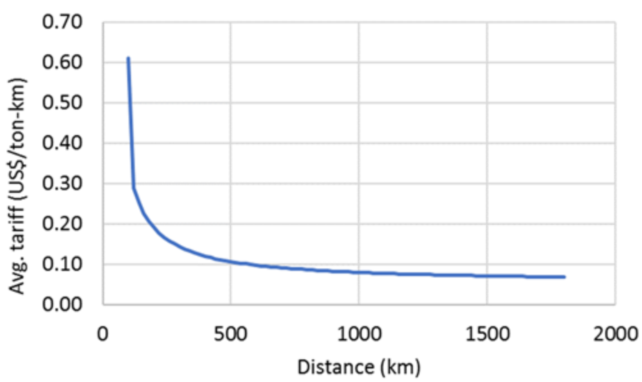
Sources: TRL (2014) and TAZARA (2014)

The advantage of using rail freight is mainly attributed to the fact that unit rail tariffs are often set lower when the shipping distance is longer. For instance, the TRL tariff for general goods is TSh1.5 million per large wagon for the first 100 km, which translates into about 61 U.S. cents per ton-km (**Figure 6**).[3] But when the shipping distance is greater than 500 km, the tariff is TSh2.6 million per wagon, which is equivalent to about 11 U.S. cents per ton-km. The unit rate is even lower when the distance exceeds 1,000 km, i.e., TSh3.9 million per wagon or 8 U.S. cents per ton-km.

[3] Average loaded weight per wagon is assumed to be 36.5 tons.

Such a pricing strategy is rational because loading and unloading goods from rail wagons incur significant fixed costs, especially when transported goods are uncontainerized bulk cargo. Waiting times that are required for each train to have sufficient wagons to carry may also add additional economic costs to shippers. Because of these fixed costs, short-haul rail shipping tends to be relatively expensive, and long-haul bulk shippers are more induced to use rail transportation. Although no detailed data are available, most rail cargo are large volumes, such as minerals, cement, agricultural products and fertilizer.[4] According to the port statistics, at the Port of Dar es Salaam, wheat accounted for about 40 percent of total imports, followed by fertilizer, cement and rice (**Figure 7**). Similarly, wheat and fertilizer are among major commodities exported through the Port of Dar es Salaam.

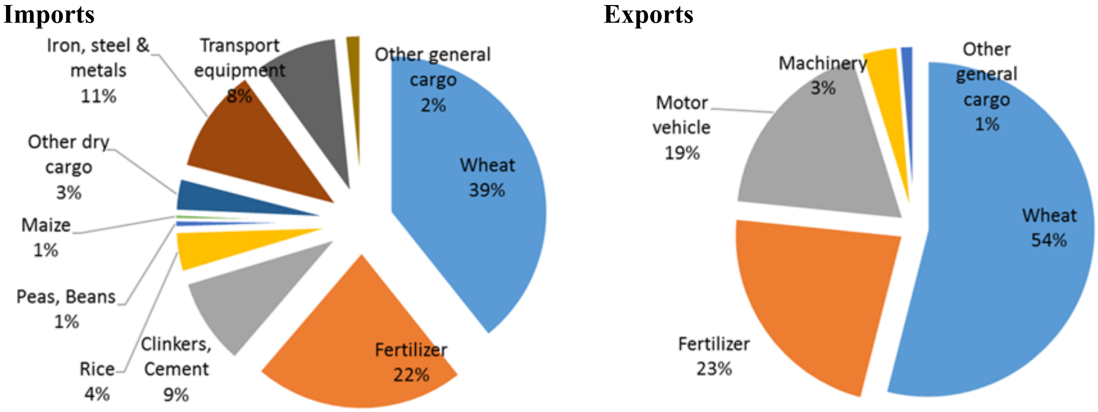
Figure 6. TRL average tariff by distance



Source: Ministry of Transport, Tanzania (2011).

[4] This is consistent with our survey data. See the following sections.

Figure 7. General cargo handled at Dar es Salaam Port



Source: Ministry of Transport, Tanzania (2011).

Meanwhile, Tanzania has a well-developed road network composed of over 86,000 km of roads. The government spends approximately US$310 million for road development and maintenance every year. Regional and trunk roads managed by a national road agency, Tanzania National Roads Agency (TANROADS), are generally well-maintained. About 12,000 km are paved, of which half or 55 percent are maintained in good or fair condition. But most rural roads remain unpaved, and nearly 90 percent are in poor or very poor condition.

Road user costs for heavy trucks are estimated at US$0.05 to US$0.12 per ton-km in Tanzania, depending on road surface and condition. This is generally higher than rail tariffs especially for long-haul shipments. Of particular note, actual truck transport service prices may be even higher than road user costs, because the trucking industry is often considered less competitive in Africa. Teravaninthorn and Raballand (2009) show that Africa's average transport prices of 6 to 11 U.S. cents are relatively high compared to other regions. This is because of the poor quality of the road network and the lack of competition in the trucking industry. In East Arica (e.g., between Nairobi and Mombasa), the profit margins are estimated to reach 60 percent.[5]

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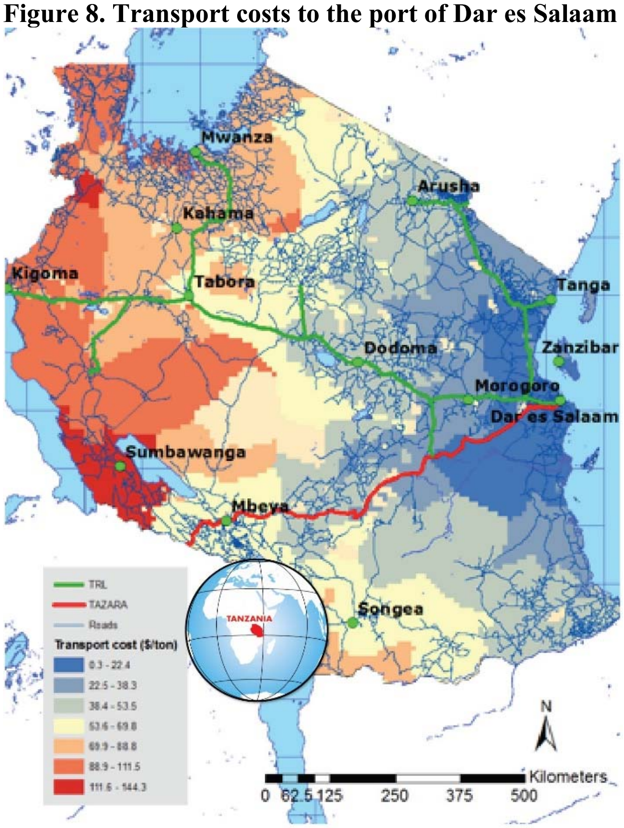
[5] Our data do not cover the entire trucking industry.

Although the vast majority of freights are moved by road transport, some firms and shippers are still using railways, possibly depending on their locations. In Tanzania, transport connectivity is highly heterogeneous. For instance, transport costs from Mwanza and Kigoma to the Port of Dar es Salaam are estimated at about US$91 and US$95 per ton, respectively (**Figure 8**).[6] Because of its low tariff rate, rail transport has cost advantage particularly for long-haul shipment from and to the hinterland of Northern and Western Tanzania.

Figure 8. Transport costs to the port of Dar es Salaam



Source: Authors' estimation

Since Tanzania is an importing country, port accessibility is critical to any business. Although the country's manufacturing sector is still thin, some light manufacturing industries have been emerging, such as agribusiness and textile. The share of manufactured exports

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[6] These are estimated by the network analysis with engineering road and rail transport costs assumed. The road transport costs are assumed to vary depending on road surface and condition, from 5 to 12 U.S. cents per ton-km. Average rail tariffs are 6.5 U.S. cents per ton-km for TRL and 7 U.S. cents per ton-km, respectively.

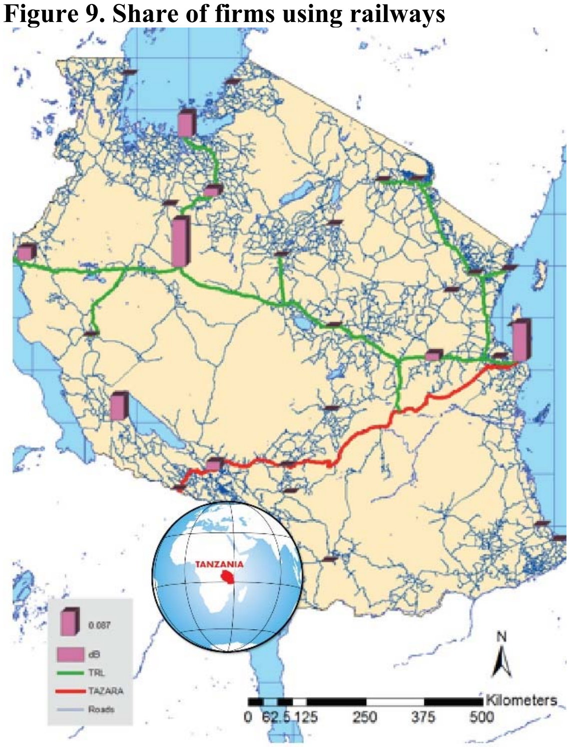
increased from 10 percent in 2005 to 20 percent in 2010, as the government has been making efforts toward creating many industrial parks, such as Special Economic Zones and Export Processing Zones (Ministry of Industry and Trade, 2012). Naturally, rail transport has an important role to connect firms to the port.

Our collected firm data show the mixed impacts of railways.[7] As discussed above, rail transport is generally cheaper than road user costs but much less reliable than truck transportation. As a result, rail users can economize on transportation costs but may have to bear more costs on inventory. In theory, the economic order quantity model or (*S*,*s*) model suggests that a firm determines its inventory level, depending on the size of total demand, ordering and transportation costs, and opportunity costs of inventory (e.g., Arrow et al., 1951). Low rail tariffs allow firms to reduce their inventory, but unreliability in rail operations may add more inventory, therefore, increasing firms' total costs.

Clearly, in hinterland areas, firms are still more likely to use railways (**Figure 9**). Except for Dar es Salaam, current rail users are located in the areas far from Dar es Salaam (**Figure 10**). However, these firms seem to tend to hold more inventory (**Figure 11**). There is weak correlation between the probability of rail use and the average inventory level (**Figure 12**). Note that this may or may not be attributable to the unreliability of railways, yet. Transport costs paid by firms are highly heterogeneous. Transport costs appear low even in some inland areas, such as Kigoma and Mwanza (**Figure 13**). They are potential beneficiaries from TRL lines. On the other hand, the average transport cost in Mbeya, which is located along another rail line, TAZARA, is high.

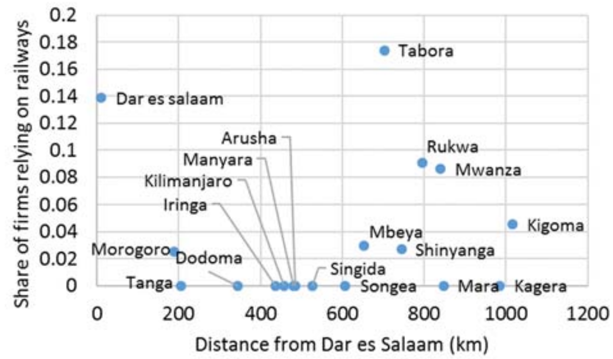
[7] See the following sections for detailed discussion.

Figure 9. Share of firms using railways



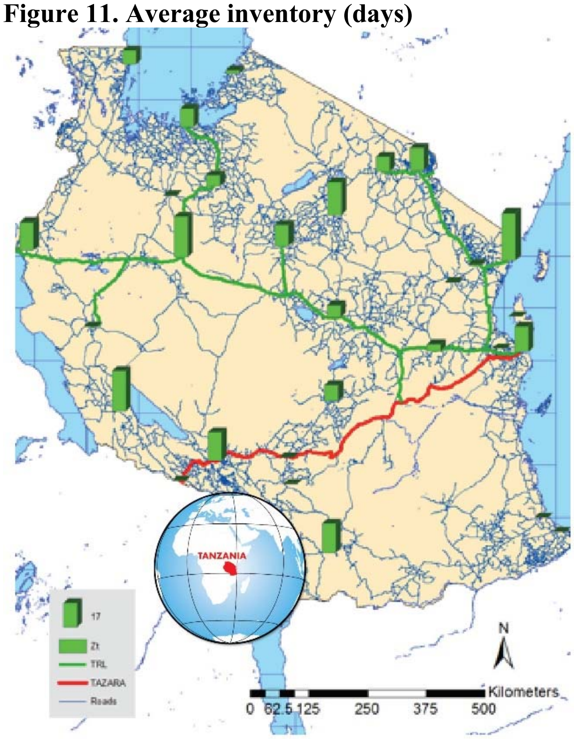
Source: Authors' survey data.

Figure 10. Rail use and distance from Dar es Salaam



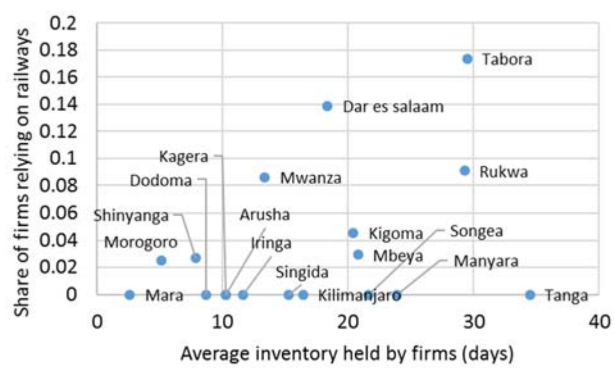
Source: Authors' survey data.

Figure 11. Average inventory (days)



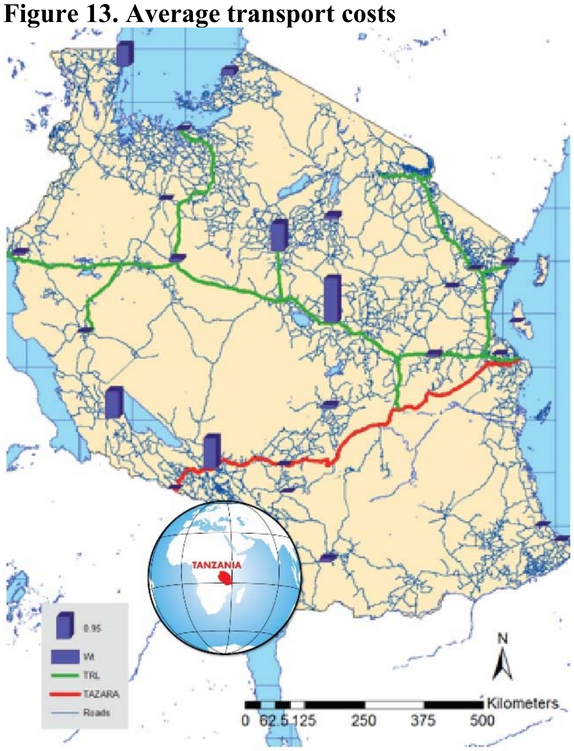
Source: Authors' survey data.

Figure 12. Rail use and average inventory



Source: Authors' survey data.

Figure 13. Average transport costs



Source: Authors' survey data.

All these findings suggest that it is of particular importance to control for firm-specific heterogeneity: Firms in different sectors are different, requiring different types of transportation. This will be taken into account in our following empirical modeling. Formally, two-sample *t*-tests are performed (**Table 4**). Rail users and road users look highly different: In our sample data, rail users are light manufacturers and agribusinesses. There are also road users in these industries. About half of the surveyed firms belong to the light manufacturing sector, and about 30 percent to the agribusiness industry. There is little difference between rail and road users. However, foreign ownership is higher among rail users: The average foreign share is 20.2 percent among rail users (c.f., 6.1 percent among road users). This is consistent with the fact that road users are more focused on local markets: The share of firms responding that their main markets are local (within their localities) is 85 percent among road users, while 32 percent of the rail users indicated their local orientation.

Rail users are more focused on global and/or national markets.[8] In our sample, rail users are also found to be relatively larger: The average operating costs are significantly greater at TSh539 million. Their transport cost shares are also greater: Rail users seem more transport-intensive. As indicated above, rail users tend to hold more inventory, though the *t*-test statistic is not statistically significant.

Table 4. Two-sample t test statistic tests between road and rail users

	Road users		Rail beneficiaries		Difference		
	Mean	Std. Err.	Mean	Std. Err.	Coef.	Std. Err.	
Sector dummy variables:							
Light manufacturers	0.460	(0.028)	0.529	(0.125)	-0.069	(0.124)	
Agribusinesses	0.323	(0.026)	0.294	(0.114)	0.029	(0.117)	
Foreign share (%)	6.152	(1.288)	20.294	(9.220)	-14.142	(6.023)	**
Market orientation dummy:							
Global market	0.131	(0.019)	0.294	(0.114)	-0.163	(0.086)	*
National market	0.482	(0.028)	0.882	(0.081)	-0.401	(0.123)	***
Local market	0.857	(0.019)	0.529	(0.125)	0.327	(0.090)	***
Total cost (TSh billion)	0.247	(0.018)	0.539	(0.101)	-0.292	(0.084)	***
Share of transport costs (%)	13.025	(0.851)	17.015	(6.623)	-3.990	(4.020)	
Inventory (days)	21.405	(1.749)	25.000	(4.899)	3.595	(7.149)	

III. Empirical Model

To assess the possible impact of rail transport on firm productivity, the traditional cost function is considered as a basis of empirical modeling. As discussed above, this approach has particular advantage for controlling potential heterogeneity across firms. Our sample data cover significantly different firms, as will be discussed below:

$$C = f(W, Y, X, RAIL, Z) \tag{1}$$

[8] While local market orientation is referred to mean that firms' main product lines are targeted at their local areas, national market orientation indicates that firms are active in several locations in the country. Global market oriented firms involve significant amounts of international transactions.

where C is the firm's total cost. W and Y represent input prices and output, respectively. Each firm is assumed to minimize the operating cost by selecting the levels of various inputs, including infrastructure services, such as electricity and transportation. Firms' productivity (or cost) is also dependent on other firm-specific characteristics, X. *RAIL* is a dummy variable which is set to one if a firm uses rail transportation, and zero otherwise. The impact of rail transport, which is the main interest of the paper, is expected to be captured by this.

Z is the level of inventory. Inventory is financially costly to firms, and it also limits their operational flexibility. Too much inventory prevents firms from investing elsewhere. In the literature, annual inventory costs are estimated at between 7 and 16 percent of the value of inventory (Brown, 2011). The more inventory, the more costs.

A simple Cobb-Douglas cost function is first assumed:

$$\ln C = \beta_0 + \beta_Y \ln Y + \sum_i \beta_{W_i} \ln W_i + \sum_k \beta_{X_k} \ln X_k + \beta_{RAIL} RAIL + \beta_S \ln Z + \varepsilon \qquad (2)$$

C denotes the amount of total operating cost, Y is an output proxy, and W_i is ith input price. Seven inputs are considered: labor (L), electricity (E), fuel (F), water (W), transport (T), communications (C), and the rest of costs (M). Conceptually, the last can be referred to as capital or equipment. The prices of these production factors are denoted by W_i. For W_L, it is defined by the average wage of each firm. For other factor prices, such as W_E, W_F, W_W, W_T, W_C, they are calculated by the firm's spending on each infrastructure service divided by the replacement cost of the firm's assets (e.g., machinery, buildings, and land).[9] Finally, W_M is defined by the rest of the operating costs (such as annual depreciation and rental fees) divided by the asset replacement costs. As usual, the function is assumed to be homogeneous of degree one in factor prices. That is:

[9] Our survey did not ask input quantities because the questionnaire already involved a significant number of detailed questions. However, the share of input spending in the total operating costs or total assets can be used as a good proxy.

$$\sum_i \beta_{W_i} = 1 \tag{3}$$

Output is measured by total sales in Tanzanian shillings. There is no other common measurement to quantify firm outputs in different industries. To control for heterogeneity across firms, other characteristics are included in *X*, such as age of firm and industry-specific fixed-effects. The level of inventory, *S*, is measured by the number of days measured by days of production or sales.

To estimate Equation (2), the conventional instrumental variable (IV) regression is used because the equation includes several explanatory variables that are likely endogenous. Although all variables are potentially endogenous, the paper is focused on three transport-related variables: *RAIL*, *Z* and W_T. The use of rail transportation, which is a variable of main interest of this paper, is self-selected possibly based on firm-specific unobservables. The order quantity model also suggests that the level of inventory is endogenous, depending on transportation costs and other factors. The transport input price, W_T, is often treated as exogenous in the empirical literature where cost functions are examined, because this is theoretically exogenous if factor markets are competitive. However, this is ex ante unknown to the econometrician. The conventional Hausman exogeneity test will be applied to examine the actual exogeneity.

In addition to the Cobb-Douglas specification, the translog model is also examined to check robustness of the estimation results. Following the literature (e.g., Nerlove, 1963; Christensen and Greene, 1976), the translog cost function is considered:

$$\begin{aligned}\ln C = \beta_0 + \beta_Y \ln Y + \frac{1}{2}\beta_{YY} \ln Y \ln Y + \sum_i \beta_{W_i} \ln W_i + \frac{1}{2}\sum_i \sum_j \beta_{W_i W_j} \ln W_i \ln W_j \\ + \sum_i \beta_{YW_i} \ln Y \ln W_i + \sum_k \beta_{X_k} \ln X_k + \beta_{RAIL} RAIL + \beta_S \ln S + \varepsilon\end{aligned} \tag{4}$$

To have a well-behaved cost function, the following symmetry and homogeneity restrictions are imposed:

$$\beta_{W_iW_j} = \beta_{W_jW_i}, \sum_i \beta_{W_i} = 1, \sum_i \sum_j \beta_{W_iW_j} = 0, \sum_i \beta_{YW_i} = 0 \tag{5}$$

In addition, by Shephard's lemma, the following factor share equations can be derived from Equation (4):

$$S_i = \frac{\partial \ln C}{\partial \ln W_i} = \beta_{W_i} + \sum_j \beta_{W_iW_j} \ln W_j + \beta_{YW_i} \ln Y \tag{6}$$

where S_i is the cost share of input i.

The cost function (4) is estimated simultaneously with six factor share equations (6).[10] By estimating a system of equations, efficiency in estimation can be improved without wasting the degree of freedom (Christensen and Greene, 1976). However, the conventional seemingly unrelated regression (SUR) is likely to be biased for the same reason as above. To avoid the potential endogeneity bias, the three-stage least squares (3SLS) regression (Zellner and Theil 1962) is applied.

Using spatial data and techniques, four instrumental variables (IVs) are constructed: (i) straight line distance from each firm to TRL line (KM_{TRL}), (ii) straight line distance from each firm to TAZARA line (KM_{TAZARA}), (iii) the slope angle of the terrain where a firm is located (*SLOP*), and (iv) the level of elevation in meters (*ELEV*). The first two variables are expected to represent geographic proximity to rail transportation services and relevant to the firm's modal choice, though less directly relevant to firms' economic performance. The idea is similar to Chandra and Thompson (2000), which examines the impact of the U.S. interstate highways on earnings of firms. Banerjee et al. (2012) also apply the same method to the case

[10] One of the factor equations should be dropped to avoid the singularity problem.

of Chinese railways, calculating the distance from counties to straight lines connecting historic cities and ports. Note that technically speaking, the two rail lines in Tanzania, TRL and TAZARA, are not connected to each other, because they operate based on different systems of rail gauges (i.e., Narrow Gauge for TRL and Cape Gauge for TAZARA). Therefore, proximity to TRL line does not necessarily mean proximity to TAZARA.

The last two instruments represent geographic conditions at each firm location: *ELEV* is the level of elevation in meters, and *SLOP* is the slope angle of the terrain where a firm exists. These are likely relevant to transport connectivity because rail infrastructure is normally aligned to relatively flat terrain. However, these are less likely to affect firm productivity. The data are extracted from a global spatial data set, the Shuttle Radar Topography Mission (SRTM), which provides 90m resolution elevation data of the world. The validity of the instruments will be tested with the actual data.

IV. DATA

To collect firm-level data covering a wide range of locations, an enterprise survey was carried out in February to May 2016. The survey aimed at about 500 firms focused on light manufacturers in major urban areas of 18 regions (see **Figures 9, 11 and 13** above).[11] The identification of firms to be included in the survey was started with the customer databases provided by the two rail companies. As discussed above, only a small number of firms are currently directly using railway services for shipping their freights, because of the diminished rail operations and the poor quality of the services.[12] The rest were randomly selected in each major urban area. The subsample size was determined in proportion to the size of each city.

[11] Arusha, Dar es Salaam, Dodoma, Iringa, Bukoba, Kigoma, Moshi, Babati, Musoma, Mbeya, Morogoro, Mwanza, Sumbawanga, Shinyanga, Singida, Songea, Tabora, and Tanga.

[12] From the empirical point of view, the current sample frame may not be ideal because it is significantly unbalanced. It is not easy to identify clear rail transport users. Still, there is economic potential to (re)develop rail transportation in large countries, such as Tanzania. Thus, the current study was designed as a potential baseline for further surveys. As the government is investing in rail (and lake) transport infrastructure, the follow-up surveys are expected to show more visible impacts of improved rail transport.

Some of the firms randomly selected turned out to be direct and indirect beneficiaries from rail services. Both are defined as rail users in the following analysis. Some are directly using rail services for their transport purposes. Others have transactions with freight forwarders and clearing agents that are using rail transportation. The questionnaire was designed to ask all these possibilities. Many rail users rely on railway for exporting or importing a large quantity of commodities and goods. Some small firms rely on rail freight forwarders for shipping their inputs and outputs domestically.

The summary statistics are shown in **Table 5**. The following analysis uses a subsample comprising 343 firms with outliers and observations with missing values excluded.[13] In this subsample, only 5 percent of firms surveyed are currently using rail transportation. Proximity to the rail network varies from nearly zero km to over 900 km. This is of course likely to affect the firms' decision of rail use. The sample data indicate that Tanzanian firms hold an inventory of about 17.3 days of production or sales.

Firms differ in size as well as nature. About 46 percent of the sample firms are light manufacturers producing textiles and apparel, followed by agro-businesses (about 32 percent). The average size of firms is TSh2.1 billion in terms of annual sales. The variation is significant, from TSh1.5 million to TSh900 billion in terms of total annual sales. Similarly, the total operating costs range from TSh1.5 million to TSh100 billion. The sample covers both new and old firms. While some were established more than 90 years ago, others were created just one year ago. Labor costs account for on average 28 percent of total costs, followed by 13 percent for transportation costs. This is much higher than other infrastructure expenditure.

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[13] 22 observations were removed because some data items are missing. 77 observations were omitted because their total cost C and/or transport unit price W_T are considered as outliers based on the letter-value display analysis, which identifies extreme values in the tails of the distribution.

Table 5. Summary statistics for firm cost function estimation

Variable	Abb.	Obs.	Mean	Std. Dev.	Min	Max
Dummy variable for rail freight users	*RAIL*	345	0.05	0.22	0.00	1.00
Number of inventory measured by days of production	Z	345	17.26	26.20	0.10	100.00
Total operating cost (TSh billion)	C	345	0.26	0.34	0.00	1.68
Transport cost	W_T	345	0.14	0.23	0.00	1.07
Wage (average per employee) (TSh million)	W_L	345	2.43	2.97	0.00	21.79
Energy cost	W_E	345	0.15	0.53	0.00	6.33
Fuel cost	W_F	345	0.07	0.20	0.00	1.65
Water cost	W_W	345	0.02	0.07	0.00	0.77
Communication cost	W_C	345	0.04	0.30	0.00	5.00
Other input cost	W_M	345	1.30	6.48	0.00	111.70
Total annual sales (TSh billion)	Y	345	2.15	10.74	0.00	100.00
Age of firm	*AGE*	345	12.36	11.93	1.00	97.00
Education level attained by firm manager interviewed (0: No education; 1: Primary; 2: Secondary; 3: Vocational; 4: Bachelor degrees; 5: Above)	*EDU*	345	3.29	1.37	0.00	5.00
Dummy variable for firms focused on global markets	*GLBL*	345	0.14	0.35	0.00	1.00
Foreign ownership share (%)	*FORN*	345	6.85	24.37	0.00	100.00
Sector-specific dummy variables:						
Agriculture		345	0.32	0.47	0.00	1.00
Forestry and wood products		345	0.10	0.29	0.00	1.00
Light manufacturing		345	0.46	0.50	0.00	1.00
Mining		345	0.03	0.18	0.00	1.00
Area-specific dummy variables:						
Arusha		345	0.03	0.18	0.00	1.00
Dar es salaam		345	0.22	0.42	0.00	1.00
Dodoma		345	0.03	0.17	0.00	1.00
Iringa		345	0.05	0.22	0.00	1.00
Kagera		345	0.02	0.14	0.00	1.00
Kigoma		345	0.04	0.20	0.00	1.00
Kilimanjaro		345	0.04	0.20	0.00	1.00
Manyara		345	0.03	0.17	0.00	1.00
Mara		345	0.03	0.18	0.00	1.00
Mbeya		345	0.07	0.25	0.00	1.00
Morogoro		345	0.10	0.29	0.00	1.00
Mwanza		345	0.11	0.31	0.00	1.00
Rukwa		345	0.02	0.13	0.00	1.00
Shinyanga		345	0.08	0.27	0.00	1.00
Singida		345	0.01	0.09	0.00	1.00
Songea		345	0.04	0.20	0.00	1.00
Tabora		345	0.06	0.24	0.00	1.00
Tanga		345	0.02	0.13	0.00	1.00
Straight line distance to TRL	KM_{TRL}	343	74.43	123.70	0.01	428.77
Straight line distance to TAZARA	KM_{TAZARA}	343	310.84	289.45	0.14	903.61
Elevation of the location where each firm exists	*ELEV*	343	877.84	570.11	10.00	1862.00

Slope of the terrain where each firm exists	*SLOP*	343	0.88	0.67	0.06	4.40
Factor share: Labor	S_L	345	0.28	0.22	0.00	0.98
Energy	S_E	345	0.06	0.11	0.00	0.87
Fuel	S_F	345	0.04	0.09	0.00	0.97
Water	S_W	345	0.01	0.02	0.00	0.12
Transport	S_T	345	0.13	0.16	0.00	0.92
Communications	S_C	345	0.01	0.04	0.00	0.50

Source: Authors' survey data.

IV. Main Estimation Results

First of all, the ordinary least squares regression is performed: The result is shown in **Table 6**. The result is potentially biased because of the possible endogeneity problem of infrastructure placement. To deal with this problem, the IV regression model is estimated. Three variables are instrumented: *RAIL*, ln*Z* and lnW_T. The results are broadly similar and consistent with prior expectation, although some variables have the different statistical significance and magnitude. The Hausman exogeneity test statistic is estimated at 4.88, of which the *p*-value is 0.18. Although the test statistic is below the conventional critical value, these three variables may or may not be exogenous. According to the overidentifying restriction test, the selected instruments are considered to be valid.

The use of rail, *RAIL*, is considered highly endogenous, while the inventory and transport input price variables can be treated as exogenous. Two more IV models are estimated under different endogeneity assumptions (**Table 7**). When W_T is excluded from the endogenous variables, the exogeneity test statistic is estimated at 3.55, which is still below the critical value. However, the exogeneity test can be rejected when only *RAIL* is instrumented. The test statistic is above the 10 percent critical value according to the chi squared distribution with a degree of freedom of one. Therefore, it is likely that *RAIL* is endogenous and the other two variables are exogenous.

The coefficients of *RAIL* are consistently negative and significant. In the IV regression model, the coefficient is estimated at -5.16 with a standard error of 2.65. It can be concluded that firms can reduce their operating costs when rail transport is used. This should be interpreted as an overall impact of rail use despite the fact that the rail unit rates are set lower when the shipping distance is longer, because of loading and unloading costs and waiting times. The distance effect is empirically controlled by a set of regional dummy variables. Still, the rail use has a significant cost saving effect.

The inventory impact is also found to be significant: The coefficient is 0.078, which is significant. Firm costs are increased when more inventory is held. The cost impact of transport prices remains inconclusive.

Other coefficients are largely consistent with economic theory. Given the log linear cost function specification, the own price elasticity of demand for each input is calculated by the factor share minus one. By Shepard's lemma, the elasticity is given by each coefficient (**Table 8**). The demand for labor, electricity and transport inputs seems to be highly elastic. Firms are expected to use more transport services when the market prices are lower. The elasticity is estimated at -1.014, which is relatively large in absolute terms but consistent to the existing literature. For example, the price elasticity of automobile fuel demand ranges from -0.03 to -0.4 in the short run and -0.6 to -1.1 in the long run (Chamon et al. 2008; Hughes et al. 2008). The high price elasticity possibly indicates the rail users' sensitivity to prices. The modal competition against truck transportation is also becoming increasingly severe. Therefore, firms would likely prefer to use other modes even if rail tariff rates are slightly increased. This is consistent with the historic downturn of rail use observed in Tanzania.

The first-stage regression suggests that distance to rail lines matters. The coefficients of the distance measurements to the rail lines, TRL and TAZARA, are significantly negative (**Table 9**). Firms that are located far from the rail lines are less likely to use the rail freight services. This is an expected result. The geographic condition also explains the firms' rail use to a certain extent. Firms are less likely to use rail services at hilly locations. The coefficient of

SLOP is negative and significant. This may be related to the historical fact that the railways are placed on relatively flat terrain. Therefore, when the slope of the terrain where a firm exists is steep, it is more difficult to utilize rail operations.

Table 6. Cobb-Douglas Cost Function: OLS and IV regression

	OLS			IV		
	Coef.	Std. Err.		Coef.	Std. Err.	
RAIL	-1.072	(0.546)	**	-5.451	(3.186)	*
lnZ	0.035	(0.039)		0.049	(0.210)	
$\ln W_T - \ln W_M$	0.030	(0.045)		-0.357	(0.361)	
$\ln W_L - \ln W_M$	0.138	(0.039)	***	0.117	(0.049)	**
$\ln W_E - \ln W_M$	-0.074	(0.058)		-0.105	(0.087)	
$\ln W_F - \ln W_M$	0.282	(0.044)	***	0.441	(0.164)	***
$\ln W_W - \ln W_M$	0.322	(0.065)	***	0.409	(0.086)	***
$\ln W_C - \ln W_M$	0.180	(0.069)	***	0.298	(0.108)	***
lnY	0.431	(0.061)	***	0.479	(0.086)	***
lnAGE	0.243	(0.104)	**	0.525	(0.210)	**
EDU	0.282	(0.066)	***	0.230	(0.085)	***
GLBL	0.364	(0.299)		0.445	(0.380)	
FORN	-0.005	(0.004)		-0.003	(0.005)	
Constant	11.366	(1.161)	***	11.068	(1.375)	***
Obs.	345			343		
R squared	0.7355			0.6107		
F stat.	32.64					
Wald chi				945.43		
No. of dummy variables:						
Industry	4			4		
Region	16			16		
Exogeneity test:						
Chi2 (3) stat.				4.882		
Overidentifying restriction test:						
Chi2 (1) stat.				0.387		

The dependent variable is $\ln C$-$\ln W_M$. Robust standard errors are shown in parentheses. *, ** and *** indicate the statistical significance at 10, 5 and 1 percent, respectively. For the IV regression, three variables are instrumented: *RAIL*, $\ln Z$ and $\ln W_T$.

Table 7. IV regression under different endogeneity assumptions

Endogenous var.:	*RAIL* and *Z*			*RAIL*		
	Coef.	Std. Err.		Coef.	Std. Err.	
RAIL	-4.686	(2.822)	*	-5.168	(2.658)	**
lnZ	0.021	(0.183)		0.078	(0.048)	*
$\ln W_T - \ln W_M$	-0.011	(0.058)		-0.014	(0.059)	
$\ln W_L - \ln W_M$	0.115	(0.045)	**	0.109	(0.038)	***
$\ln W_E - \ln W_M$	-0.134	(0.073)	*	-0.127	(0.067)	*
$\ln W_F - \ln W_M$	0.288	(0.046)	***	0.287	(0.047)	***
$\ln W_W - \ln W_M$	0.395	(0.079)	***	0.397	(0.080)	***
$\ln W_C - \ln W_M$	0.214	(0.072)	***	0.222	(0.069)	***
lnY	0.447	(0.077)	***	0.458	(0.070)	***
lnAGE	0.471	(0.187)	**	0.493	(0.186)	***
EDU	0.248	(0.075)	***	0.258	(0.070)	***
GLBL	0.493	(0.343)		0.511	(0.355)	
FORN	-0.003	(0.004)		-0.003	(0.004)	
Constant	11.570	(1.220)	***	11.457	(1.207)	***
Obs.	343			343		
R squared	0.6753			0.6597		
Wald chi	1139.03			1130.06		
No. of dummy variables:						
Industry	4			4		
Region	16			16		
Exogeneity test:						
Chi2 stat.	3.557			3.537	*	
Overidentifying restriction test:						
Chi2 stat.	1.526			1.529		

The dependent variable is $\ln C$-$\ln W_M$. Robust standard errors are shown in parentheses. *, ** and *** indicate the statistical significance at 10, 5 and 1 percent, respectively.

Table 8. Implied Own Price Elasticity of Demand for Input: OLS and IV

	OLS			IV		
	Elasticity	Std. Err.		Elasticity	Std. Err.	
Labor	-0.862	(0.039)	***	-0.891	(0.038)	***
Electricity	-1.074	(0.058)	***	-1.127	(0.067)	***
Fuel	-0.718	(0.044)	***	-0.713	(0.047)	***
Water	-0.678	(0.065)	***	-0.603	(0.080)	***
Transport	-0.970	(0.045)	***	-1.014	(0.059)	***
Communications	-0.820	(0.069)	***	-0.778	(0.069)	***

Robust standard errors are shown in parentheses. *, ** and *** indicate the statistical significance at 10, 5 and 1 percent, respectively.

Table 9. First Stage Regression Result

	IV Coef.	Std. Err.	
KM_{TRL}	-0.0011	(0.0004)	***
KM_{TAZARA}	-0.0004	(0.0002)	*
lnELEV	0.028	(0.018)	
lnSLOP	-0.067	(0.027)	**
lnZ	0.008	(0.005)	*
$\ln W_T - \ln W_M$	-0.009	(0.007)	
$\ln W_L - \ln W_M$	-0.008	(0.004)	*
$\ln W_E - \ln W_M$	-0.011	(0.006)	**
$\ln W_F - \ln W_M$	0.001	(0.006)	
$\ln W_W - \ln W_M$	0.021	(0.007)	***
$\ln W_C - \ln W_M$	0.006	(0.007)	
lnY	0.008	(0.009)	
lnAGE	0.057	(0.018)	***
EDU	-0.010	(0.009)	
GLBL	0.023	(0.045)	
FORN	0.001	(0.001)	
Constant	-0.131	(0.166)	
Obs.	343		
R squared	0.2602		
F-stat	0.750		
No. of dummy variables:			
Industry	4		
Region	16		

The dependent variable is *RAIL*. Robust standard errors are shown in parentheses. *, ** and *** indicate the statistical significance at 10, 5 and 1 percent, respectively.

One might be concerned about robustness of the results showing the benefits from rail use. A different functional form is considered: The translog cost function is assumed. To avoid the endogeneity of firms' rail use, the three-stage least squares (3SLS) regression is used. As discussed, if it was exogenous, the SUR model would be consistent and efficient. The Hausman test statistic is estimated at 92.54, rejecting the exogeneity hypothesis. The estimated coefficients are consistent with the above estimates (**Table 10**). The use of rail freight transportation has the advantage to save firm costs. The coefficient of *RAIL* is estimated at -0.94, which is statistically significant. Therefore, rail transport is clearly cost-effective for firm production.

Using the Allen's partial elasticities of substitution between inputs *i* and *j* (e.g., Uzawa, 1962; Berndt and Wood, 1975), the implied own price elasticity of demand for factor *i* is computed:

$$\eta_{ii} = (\beta_{W_iW_i} + S_iS_i - S_i)/S_i \tag{7}$$

The estimated elasticities are relatively moderate than the above (**Table 11**). The elasticity associated with transport inputs is estimated at -0.52. Not only labor but also water and communications are found to be price-elastic under this specification.

Table 10. Three Stage Least Squares Regression Result

	Coef.	Std. Err.			Coef.	Std. Err.	
β_{RAIL}	-0.7691	(0.4651)	*	β_{WfWw}	-0.0036	(0.0021)	**
β_{Z}	0.0534	(0.0210)	**	β_{WfWt}	-0.0030	(0.0023)	
β_{Y}	2.3370	(0.2945)	***	β_{WfWc}	0.0019	(0.0022)	
β_{YY}	-0.0822	(0.0156)	***	β_{WfWm}	-0.0088	(0.0025)	***
β_{Wl}	0.0978	(0.0831)		β_{WwWw}	0.0135	(0.0036)	***
β_{We}	0.1531	(0.0635)	**	β_{WwWt}	0.0051	(0.0027)	*
β_{Wf}	0.2572	(0.0530)	***	β_{WwWc}	0.0076	(0.0026)	***
β_{Ww}	0.0691	(0.0594)		β_{WwWm}	-0.0038	(0.0029)	
β_{Wt}	0.3189	(0.0879)	***	β_{WtWt}	0.0444	(0.0045)	***
β_{Wc}	0.1823	(0.0668)	***	β_{WtWc}	0.0014	(0.0028)	
β_{WlWl}	0.0268	(0.0018)	***	β_{WtWm}	-0.0281	(0.0044)	***
β_{WlWe}	-0.0055	(0.0017)	***	β_{WcWc}	0.0092	(0.0038)	**
β_{WlWf}	-0.0051	(0.0013)	***	β_{WcWm}	0.0017	(0.0034)	
β_{WlWw}	-0.0031	(0.0015)	**	βY_{Wl}	-0.0211	(0.0042)	***
β_{WlWt}	-0.0116	(0.0022)	***	βY_{We}	0.0024	(0.0032)	
β_{WlWc}	-0.0101	(0.0017)	***	βY_{Wf}	-0.0013	(0.0026)	
β_{WlWm}	-0.0137	(0.0035)	***	βY_{Ww}	0.0050	(0.0029)	*
β_{WlWe}	0.0403	(0.0033)	***	βY_{Wt}	0.0033	(0.0044)	
β_{WeWf}	-0.0011	(0.0020)		βY_{Wc}	0.0023	(0.0034)	
β_{WeWw}	-0.0036	(0.0025)		β_{AGE}	0.2161	(0.0632)	***
β_{WeWt}	-0.0054	(0.0027)	**	β_{EDU}	0.1745	(0.0357)	***
β_{WeWc}	-0.0063	(0.0026)	**	β_{GRGL}	0.6518	(0.1448)	***
β_{WeWm}	-0.0102	(0.0032)	***	β_{FORN}	0.0015	(0.0019)	

β_{WfWf}	0.0326	(0.0025)	***	$\beta_{constant}$	-8.4402	(2.9614)	***
Obs.		343					
R squared		0.8846					
Wald chi		5652.25					
No. of dummy variables:							
Industry		4					
Region		16					

The dependent variable is $\ln C$-$\ln W_M$. Robust standard errors are shown in parentheses. *, ** and *** indicate the statistical significance at 10, 5 and 1 percent, respectively.

Table 11. Implied Own Price Elasticity of Demand for Input: Three Stage Least Squares

	3SLS Elasticity	Std. Err.	
Labor	-0.663	(0.014)	***
Electricity	-0.476	(0.053)	***
Fuel	-0.532	(0.046)	***
Water	-0.712	(0.063)	***
Transport	-0.520	(0.046)	***
Communications	-0.641	(0.158)	***

Robust standard errors are shown in parentheses. *, ** and *** indicate the statistical significance at 10, 5 and 1 percent, respectively.

V. DISCUSSION

Although the evidence consistently shows that freight rail is beneficial for firms to reduce their overall costs, it remains debatable where the benefits come from. To cast insight on this, two empirical models are considered. First, the inventory model is estimated (e.g., Shirley and Winston, 2004; Iimi et al., 2015). As discussed, economic theory suggests that the optimal level of firm inventory is dependent on the size of demand, ordering and transportation costs and opportunity costs of inventory. Thus, the level of inventory, Z, is regressed on transport costs and sales as well as other firm characteristics. The results are shown in **Table 12**. Freight rail has a clear negative impact on firm inventory. The estimated coefficients are significantly positive. Rail users hold more inventory. This can be interpreted to mean that rail transportation is less reliable, causing high inventory costs, although the same is true for truck transportation as well.

Table 12. Inventory Model Estimation

	OLS			IV		
	Coef.	Std. Err.		Coef.	Std. Err.	
RAIL	1.333	(0.546)	**	9.791	(3.339)	***
W_T	1.744	(1.601)		0.448	(2.355)	
$W_T * W_T$	-5.372	(4.009)		-4.015	(5.422)	
Y	0.003	(0.021)		-0.002	(0.022)	
Y*Y	0.000	(0.000)		0.000	(0.000)	
lnAGE	-0.171	(0.167)		-0.688	(0.284)	**
EDU	-0.157	(0.093)	*	-0.136	(0.119)	
GLBL	-0.216	(0.381)		-0.955	(0.562)	*
FORN	-0.002	(0.005)		-0.003	(0.005)	
Constant	1.479	(0.683)	**	2.028	(0.927)	**
Obs.	333			331		
R squared	0.2636			…		
F stat.	7.21					
Wald chi				152.96		
No. of dummy variables:						
Industry	4			4		
Region	16			16		
Exogeneity test:						
Chi2 (1) stat.				10.266	***	
Overidentifying restriction test:						
Chi2 (3) stat.				6.532	*	

The dependent variable is the volume of inventory, *Z*. Robust standard errors are shown in parentheses. *, ** and *** indicate the statistical significance at 10, 5 and 1 percent, respectively.

Second, the transport cost is regressed on rail use. The transport costs are divided by the distance to the Port of Dar es Salaam.[14] Freight rail is clearly cheaper than road transportation. The OLS model is considered consistent: The Hausman exogeneity test cannot be rejected in this case. The coefficient of *RAIL* is estimated at -0.019. Hence, the benefits from rail freight can largely be attributed to low prices. Although the overall impact of rail use on firm costs is still significant (as shown in **Tables 6 and 10**), one disadvantage may be unreliability: Unreliable transportation causes high inventory costs to firms.

[14] To measure the transport costs, the network analyst toolbox is used. Transport costs per km are estimated given each firm's location.

Table 13. Transport Cost Estimation

	OLS			IV		
	Coef.	Std. Err.		Coef.	Std. Err.	
RAIL	-0.019	(0.011)	*	-0.058	(0.060)	
lnY	0.000	(0.002)		0.000	(0.001)	
lnAGE	0.006	(0.004)		0.008	(0.005)	*
EDU	-0.002	(0.002)		-0.002	(0.002)	
GLBL	-0.014	(0.008)	*	-0.011	(0.009)	
FORN	0.000	(0.000)		0.000	(0.000)	
Constant	-2.748	(0.031)	***	-2.755	(0.029)	***
Obs.	331			331		
R squared	0.7558			0.7468		
F stat.	251.26					
Wald chi				6498.2		
No. of dummy variables:						
Industry	4			4		
Region	16			16		
Exogeneity test:						
Chi2 (1) stat.				0.446		
Overidentifying restriction test:						
Chi2 (3) stat.				12.806	***	

The dependent variable is the transport costs per km. Robust standard errors are shown in parentheses. *, ** and *** indicate the statistical significance at 10, 5 and 1 percent, respectively.

VI. Conclusion

In theory, rail transport has the advantage for large-volume long-haul freight operations. Because of the significant amount of fixed costs required, railway transport exhibits large economies of scale. It is a common view that 1 million net tons a year are needed to justify economic viability of railways. Africa possesses significant railway assets. However, many rail lines are currently not operational because of the lack of maintenance.

1. This paper recast light on the impact of rail transportation on firm productivity, using micro data collected in Tanzania. Only a small share of surveyed firms is currently using rail freight services to export or import goods through the Port of Dar es Salaam. To avoid the

endogeneity problem, the instrumental variable technique is used to estimate the cost function of firms.

The result shows that rail transport is a cost-effective option for firms. Transport costs are lower for rail users than other firms that rely on alternative modes, primarily truck transportation. However, rail operations are unreliable, therefore, imposing more inventory costs on firms. This is a main disadvantage of rail use. The overall impact of rail use on firm costs is still significant despite the fact that the rail unit rates are set lower when the shipping distance is longer because of loading and unloading costs and waiting times: The rail use can reduce firm operating costs. Controlling the endogeneity as well as firms' heterogeneity, the coefficient of rail use is always found to be negative and significant in the firm cost function.

The implied elasticity of demand for transport services is found to be relatively large in absolute terms. It is estimated at -1.01 to -0.52, depending on estimation models. The high price elasticity possibly indicates the rail users' sensitivity to prices as well as severity of modal competition against truck transportation: Firms might prefer to use other modes even if rail tariff rates are slightly increased. This is consistent with the historic downturn of rail use observed in Tanzania. Firm location matters to the decision to use rail services. Firms that are located close to rail lines are more likely to use rail services. Proximity to rail infrastructure is important to businesses.

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