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Agricultural Production and Transport Connectivity

Evidence from Mozambique

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Abstract

Despite the richness of the existing literature, it remains a challenge to find rigorous evidence of the impacts of transport connectivity on agricultural production. The paper aims at contributing to the prolonged debate on the transport-agriculture nexus in Africa, by taking advantage of the unique circumstances in Mozambique where the government intensively invested in road infrastructure during a relatively short period of time in the 2010s. With the highly disaggregated location-specific fixed-effects and instrumental variable technique used to control for the endogeneity issue, the paper shows that the improved road connectivity increased agricultural production significantly. In particular, access to domestic markets is found to be important. It is also found that agricultural production exhibits decreasing returns to scale, heavily depending on land input.

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Agricultural Production and Transport Connectivity: Evidence from Mozambique

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I. INTRODUCTION

1. Among others, transport connectivity has long been considered an important constraint to agricultural growth in Africa. The literature commonly suggests that improved transport connectivity can reduce input prices and increase agricultural production (e.g., Khandker, Bakht and Koolwal, 2009; Donaldson, 2018; Dorosh, Wang, You and Schmidt, 2012). Better transport accessibility can also allow farmers to take advantage of advanced technologies. Irrigation and fertilizer are among the most important missing inputs (e.g., Gyimah-Brempong, 1987; Bravo-Ortega and Lederman, 2004; Xu et al., 2009).

2. Despite the seemingly rich literature, it remains a challenge to evidence the impacts of transport connectivity on agricultural production in a rigorous manner. One of the important empirical issues is endogeneity of transport infrastructure placement, which is often determined by a large number of political and socioeconomic factors. Since it is difficult, if not impossible, for researchers to observe all of them, it is important to control for endogeneity due to omitted variable bias. (e.g., Chandra and Thompson, 2000; Banerjee et al. 2012).

3. It is also noteworthy that transport accessibility is often not changed dramatically over time. This seems to be overlooked by the existing literature (e.g., Khandker, Bakht and Koolwal, 2009; Dercon et al. 2009), in which beneficiaries are often defined based on their proximity to improved roads in a binary manner. For instance, it is assumed that all households who live along or close to rehabilitated roads would benefit from improved connectivity. However, this may not be true for two reasons. First, roads constitute a network. Thus, there are always alternative routes. Second, a road section that is improved under a road program is often only a small stretch of the road network that people use to travel from one place to another. Therefore, the overall change in transport accessibility tends to be gradual for users. This is why it takes long time to measure the impacts of transport infrastructure (e.g., Khandker, Bakht and Koolwal, 2009; Mu and van de Walle, 2011) and why transport accessibility has not been improved for a long time despite spending a

significant amount of resources on road developments in developing countries (e.g., World Bank 2016).

4. The current paper attempts to tackle these challenges and estimate the impacts of improved road connectivity on agricultural production by taking advantage of the unique circumstances in Mozambique where transport connectivity was substantially improved during a relatively short period of time in the 2010s. For the same period detailed road network data are also available, which allow to assess intertemporal changes in various types of transport connectivity at a very granular level from the spatial point of view. Detailed nationwide household survey data are also available. By using highly disaggregated location-specific fixed effects as well as the instrumental variable (IV) technique, the paper attempts to minimize the risk of endogeneity and measurement error bias associated with transport connectivity variables.

5. By estimating the true impact of transport infrastructure, the paper ultimately aims at contributing to the prolonged discussion about Africa's low growth in the agriculture sector. In theory, the continent has great potential for agriculture. Together with agribusiness, it is estimated that agriculture currently generates US$31 billion or nearly half of the GDP of the region. This is projected to continue growing to US$1 trillion by 2030 (World Bank 2013). However, the potential has not been fully explored yet. For instance, the ratios of potential to actual agricultural outputs are estimated at 1.5 for cassava, 1.9 for rice, 2.7 for maize and 5 for wheat in West Africa. Particularly given its rapid urbanization and strong population growth, Africa needs to improve efficiency in agricultural production. From the agro-ecological point of view, Africa can feed itself if proper inputs, such as improved seeds and fertilizer, are used. Currently, the region imports US$15 billion of cereals, of which only 5 percent originated from the region (World Bank 2012).

6. The remaining sections are organized as follows: Section II provides an overall country context. Section III discusses the empirical methodology. Section IV describes our data.

Section V presents our main estimation results and discusses some policy implications. Section VI concludes.

II. Country Context

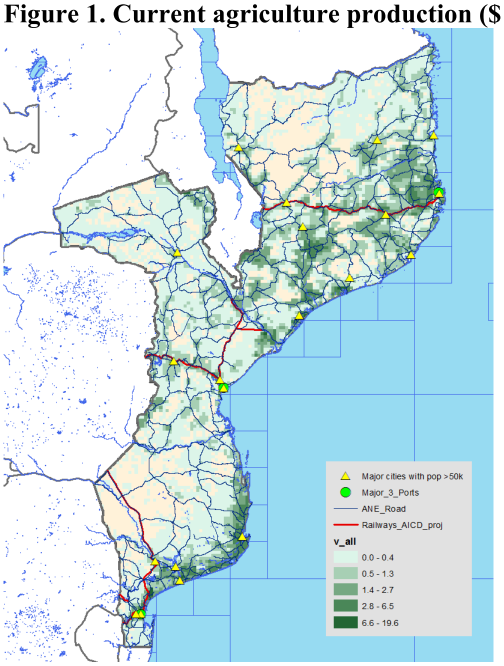
7. In Mozambique, poverty was reduced markedly in recent years but remains persistently high particularly in rural areas. Inequality has also been widening. In 2002/03, about 60 percent of Mozambicans were estimated to live below the poverty line. There was a slight drop to 58 percent by 2008/09, followed by a substantial drop to 48 percent by 2014/15. Still, there are about 12.3 million people living below the poverty line (World Bank 2020). There is also the growing literature on increasing inequality in Mozambique. Poverty is particularly high in the northern and central zones where private sector investments have been relatively modest. Among others, the increasing inequality may be attributed to the skewed distribution of benefits from the emerging non-subsistence sectors, such as mining (Gradin and Tarp, 2019) and the misallocation of public investment biased toward urban areas. Urban bias appears significant in the government's road spending (World Bank, 2019). As a result, the poor in remote rural areas tend to be left behind.

8. As in other African countries, agriculture remains an important sector in Mozambique; however, its productivity is low. It contributes to about one-fourth of GDP, employing about 80 percent of the national workforce (Ministry of Agriculture 2010). The country's economic growth has been robust until recently, with an average of 7 percent during the first half of the 2010s, mainly driven by the extractive and service sectors. But agricultural growth remains relatively weak and fluctuating. The vast majority of agricultural production is still subsistence farming. About 90 percent of land in use is used for small-scale subsistence farming (Ministry of Agriculture 2010).

9. From the agroclimatic point of view, Mozambique has significant untapped agricultural potential. The country currently produces about US$3 billion of crops, mainly in Nampula and Zambezia Provinces (**Figure 1**), but its agroclimatic potential is estimated at more than

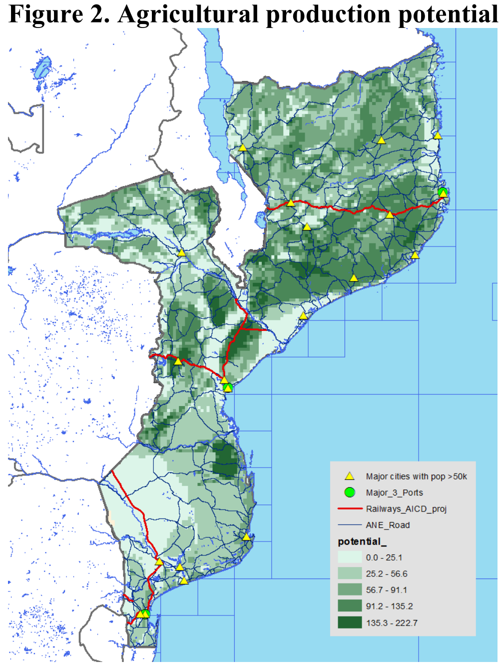
US$500 billion (**Figure 2**) according to IFPRI's Spatial Production Allocation Model (SPAM) (see You and Wood (2006)). The government's 10-year development plan aims at improving rural infrastructure, including road network and storage facilities, to double productivity by 2019. But there are still a number of constraints.

Figure 1. Current agriculture production ($ mil)



Source: IFPRI SPAM Update.

Figure 2. Agricultural production potential ($ mil)



Source: IFPRI SPAM Update.

10. In Mozambique, agricultural productivity growth has largely been stagnant in the last decade, especially in the southern provinces (Pauw et al. 2012). Although the farmers' market participation increased from 50 percent in 2008 to 64 percent in 2011, possibly because of high international commodity prices,[1] this is not associated with productivity growth but marginal increases in land input and other factors, such as availability of market information (Benfica et al. 2014).[2] More advanced inputs, such as fertilizer and improved seeds, need to be adopted. For instance, only 7 percent of smallholder farmers use fertilizer,

[1] There is a significant difference in farmers' market participation data. The government's Strategic Plan for Agricultural Development (PEDSA) 2010-19 indicates that only less than 10 percent of households participate in market transactions (Ministry of Agriculture, 2010).
[2] One of the problematic assumptions of their work is that several external variables that are used as instruments, such as use of animal traction and household ownership of a bike, seem to be very relevant to the dependent variables, crop productivity and market sales.

animal traction or small-scale irrigation in Mozambique (Mucavele, 2009). About 50,000 ha of land is currently irrigated, mainly in the central and southern provinces, which is only 1 percent of the country's arable land (Ministry of Agriculture, 2010).

11. The expansion of all-year road access to areas with high productive potential is identified as a key strategy to achieve an agricultural growth target of 7 percent per annum (Ministry of Agriculture 2010). Historically, Mozambique's north-south connectivity has been limited. Since the late 19th century, three east-west rail systems have been developed, all of which connect inland areas to major seaports of the Indian Ocean, such as Nacala in the north, Beira in the central and Maputo in the south. In 2006, the Government of Mozambique adopted the Road Sector Strategy 2007-14 and allocated significant public resources to developing the road network during the early 2010s (**Figure 3**), particularly focused on National Road 1 (N1), a main north-south corridor (**Figure 4**). As a result, the transport connectivity seems to have been significantly improved in recent years. The share of classified roads in good or fair condition was increased from 59 percent in 2006 to 70 percent in 2011 (National Roads Administration 2006; Ministry of Public Works and Housing 2015).

Figure 3. Road sector spending (MT mil)

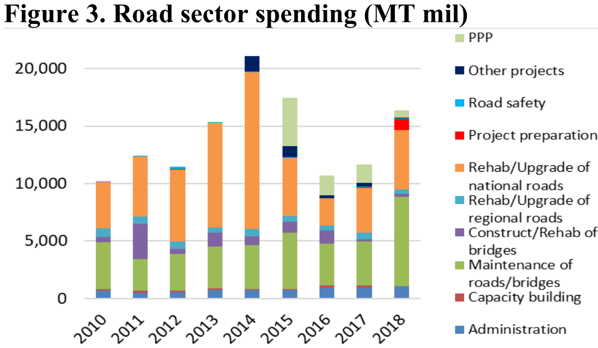
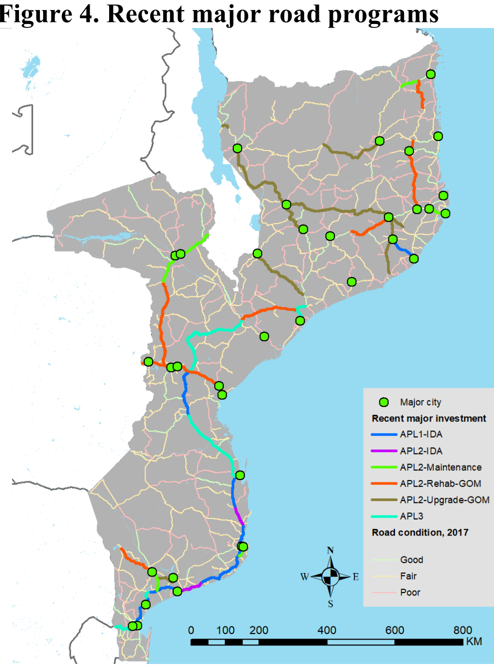


Figure 4. Recent major road programs



III. Empirical Model

12. To measure the impacts of transport connectivity and other factors, a conventional production function approach is adopted (see, for instance, Gyimah-Brempong (1987) and Bravo-Ortega and Lederman (2004) for literature reviews, and Dorosh et al. (2012)). Suppose that household *i* at location *j* produces a total value of crops, *v*, at time *t*, using various inputs *X*. Then, the following simple specification is considered:

$$\ln v_{ijt} = \beta_0 + \beta_{TR} \ln TR_{jt} + X'_{ijt}\beta_X + Z'_{ijt}\beta_Z + c_j + c_t + \varepsilon_{ijt} \qquad (1)$$

Transport connectivity at *i*'s location *j* is denoted by *TR*, which can affect agricultural productivity. Note that *TR* is time-variant. Our estimation exploits such a variation over time, apart from c_j, location-specific fixed effects. *Z* is a set of household characteristics to control for heterogeneity among households. c_t represents the time-specific fixed effects. ε is an idiosyncratic error.

13. For production inputs *X*, five inputs are considered: labor (*L*), land (*H*), fertilizer (*F*), pesticide (*P*), and employed labor (*N*). The logarithms are taken for all these variables.[3] In the literature, commonly considered production factors are labor, land, fertilizer and irrigation. Irrigation is not included here because its use is still minimal in Mozambique.[4] In general, fertilizer and other advanced inputs are critical to increase agricultural production, though the statistical significance varies across studies (Bravo-Ortega and Lederman, 2004). In Zambia, for instance, it is shown that timely availability of fertilizer could increase maize yields by 11 percent on average (Xu et al., 2009).

14. The literature also suggests that transport connectivity is an important determinant of agricultural productivity. Better market access can reduce input prices. Khandker, Bakht and

[3] A small positive number is added if the amount of input used is zero to avoid taking the logarithm of zero. For instance, fertilizer is not used in many observations of our sample.
[4] Even if the irrigation use is included, the estimation results turned out unchanged, while the irrigation variable is statistically insignificant.

Koolwal (2009) find that farm-gate fertilizer prices were lowered by rural road investment in Bangladesh. Better transport infrastructure can also provide more opportunities for farmers to engage in cash crop production and market transactions. Agricultural output prices increased by 2 percent and the volume of production was boosted by 22 percent (ditto).

15. Different types of connectivity may be required by different crops. For instance, access to domestic markets may be essential for farmers to not only sell their produce but also purchase necessary inputs and equipment. Access to a port may be more relevant to export crops, such as tobacco and cotton in the case of Mozambique.

16. The current paper examines three types of transport connectivity: First, the transport cost of taking one ton of goods to a major domestic market is computed by network analysis software based on the optimal route identified to minimize road user costs between pairs of locations (**Figure 5**).[5] Domestic markets are defined by the nearest city with more than 50,000 inhabitants. The road user costs are determined by road surface type and condition, which can be changed over time because of traffic and public road works.

17. Second, the transport cost to the nearest port is computed in the same manner. Three major ports are considered: Maputo, Beira and Nacala (**Figure 6**). Finally, the rural access index (RAI) is calculated for each location j (**Figure 7**). RAI, which is defined by the proportion of people who have access to an all-season road within an approximate walking distance of 2 km or a walking time of 25 minutes, is one of the global indicators in the transport sector, the Sustainable Development Goals (SDGs) Indicator 9.1.1.

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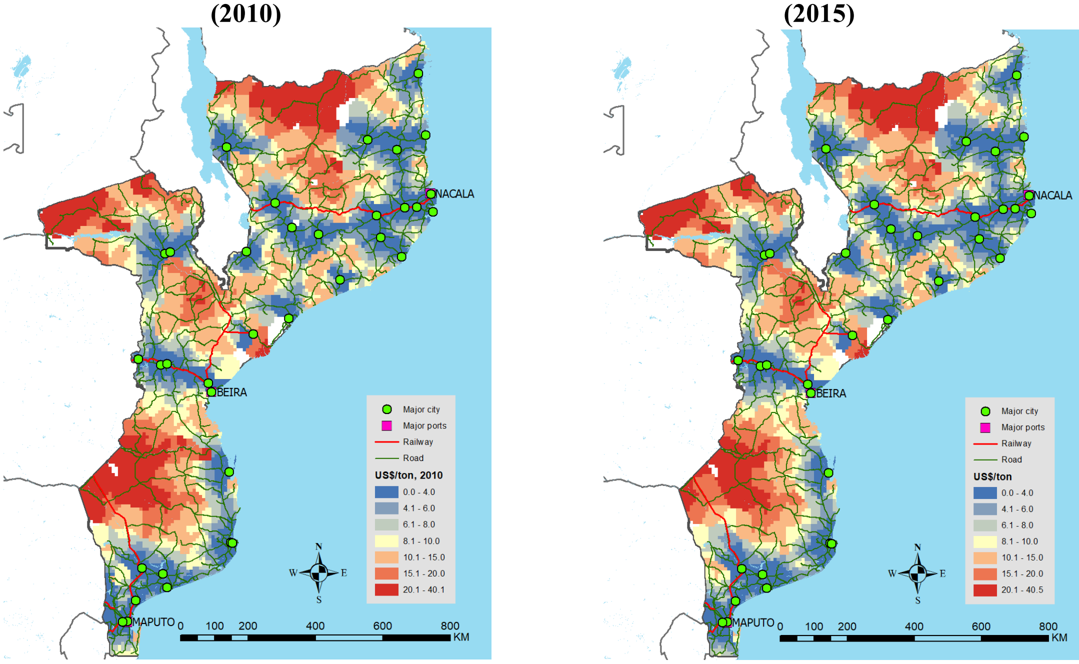
[5] Road user costs mainly comprise fuel costs, vehicle maintenance costs and time costs of drivers and passengers.

Figure 5. Transport costs to a large city with more than 50,000 population

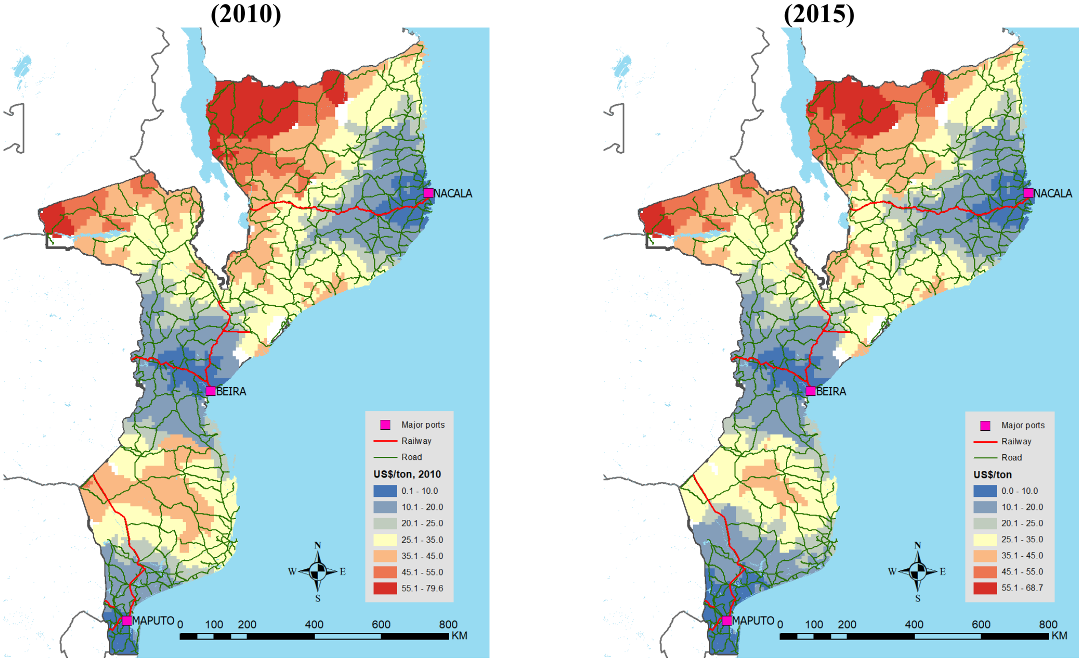
(2010) **(2015)**



Source: Authors' calculation based on data provided by National Roads Administration (ANE)

Figure 6. Transport costs to a major port

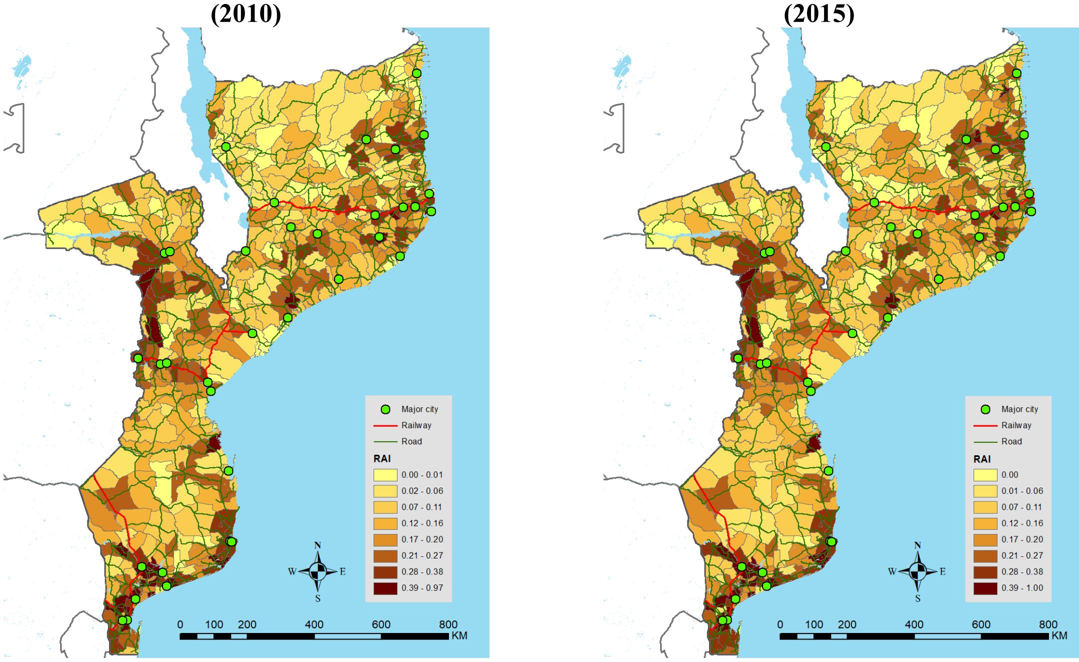
(2010) **(2015)**



Source: Authors' calculation based on data provided by National Roads Administration (ANE)

Figure 7. Rural Access Index by administrative post

(2010) **(2015)**



Source: Authors' calculation based on data provided by National Roads Administration (ANE)

18. One of the most important issues to estimate Equation (1) is endogeneity of transport connectivity. The government's infrastructure investment decision is affected by various tangible and intangible factors, therefore, potentially raising endogeneity due to omitted variable bias. For example, agricultural productivity is inherently high where agroclimatic potential already exists for meteorological and geological reasons. More and more people tend to live in such areas. Policy makers may invest more in public infrastructure where many people live. As a result, high road density can coexist with high agricultural productivity regardless of their actual impact. If this is the case, the ordinary least squares estimator is likely to be upward biased (e.g., Chandra and Thompson, 2000; Banerjee et al. 2012).

19. To mitigate this risk, the paper first takes advantage of the narrowly defined location-specific fixed effects (c_j) to control for unobservables. If panel data were available, their unobserved time-invariant characteristics could be removed. However, our data set is not a panel but composed of two rounds of cross-sectional data in 2012 and 2015. The farmers' locations are only identifiable at the *postos* level. *Postos* are the smallest administrative unit

in Mozambique. The country has 10 provinces, which are divided into 128 divisions. Each division has 1 to 7 *postos*. In most cases, there are 2 or 3 *postos* in each division. In total, Mozambique has 405 *postos*, in each of which on average about 53,000 people live. Thus, by using the *postos*-specific fixed effects, we can substantially control for location-specific unobservables, such as agroclimatic potential.

20. Note that our transport connectivity variables are time-variant. The underlying road condition data, based on which our transport variables are constructed, are available for 2010 and 2015. There is considerable variation in them (**Table 1**), presumably because of the government's intensive investments in the road network during the first half of the 2010s. In the *postos* where the sample data were collected, the transport cost to the nearest large city was increased by on average US$3.38, with a wide variation from a reduction of US$4 to an increase of US$42. The transport cost to a port declined by US$2.30 on average. Rural accessibility increased slightly by 0.9 percentage point, but the changes vary substantially, depending on location. The paper exploits these time variations to quantify the impact of transport connectivity.

Table 1. Changes in transport variables

	Difference over time			
	Mean	Std. Dev.	Min	Max
ΔTR_{CITY}	3.38	5.12	-4.41	42.24
ΔTR_{RAI}	0.009	0.077	-0.624	0.408
ΔTR_{PORT}	-2.30	5.99	-12.90	68.24

21. Second, the paper also takes advantage of the instrumental variable technique. Following the literature (e.g., Banerjee et al. 2012; Datta, 2012), two instrumental variables are constructed based on the history of transport infrastructure development in Mozambique. They are expected to allow to have some exogenous variation in the data. The first instrument is the straight-line distance from each *posto* to the existing rail lines. In the colonial era, many rail lines were developed based on political and military motivation in Africa (e.g., Amin, Willetts and Matheson, 1986). Their placement is often irrelevant to economic outcomes that are observed at present (Jedwab and Moradi, 2012). In the case of

Mozambique, some economic motives may have existed. The rail lines aimed to connect resource-rich inland areas, such as Northern Rhodesia (now Zambia) and Southern Rhodesia (now Zimbabwe), to the Indian Ocean. But the railway construction seems to have been less relevant to agricultural productivity in Mozambique. On the other hand, the established rail infrastructure has clearly been affecting the country's road transport development since then. Therefore, it is clearly relevant to our transport connectivity variables.

22. The second instrument is constructed using a historical map including eight landing sites that already existed in the 1860s (Kiepert 186?).[6] The logic behind it is the same as the above. The historic ports may have been "discovered" perhaps because of their topological conditions, and less likely to be related to agricultural productivity. But later, some of them were developed further to become the country's current major ports. Thus, the straight-line distance from each *posto* to the nearest historical landing site is likely to be related to the current transport connectivity, but less to agricultural productivity. Note that the validity of these instruments will ex post be tested empirically with actual data.

IV. DATA

23. The primary data come from the agricultural sample surveys in 2012 and 2015, each of which comprises about 6,500 households nationwide in Mozambique. Excluding the observations with missing data, the following analysis uses 11,000 observations. The data cover 43 food crops and vegetables. To aggregate different types of crops, the median values of local market prices from the surveys are used. In case local prices are not available, the regional average prices are employed from FAOSTAT (**Table 2**).

24. Summary statistics are shown in **Table 3**. An average farmer produces about US$5,000 of crops per annum. This is the total production value evaluated at market prices. Note that some of the crops produced may be self-consumed. The transportation costs of taking goods

[6] Delagoa Bay, Inhambane Port, Sofala Port, Luabo Port, Kalimane Port, Port Curro, Mozambique, and Ilha do Ibo Port.

to the nearest large city vary significantly from nearly zero to US$42 per ton, with an average of US$6.13. There are some inland areas in Manica, Niassa and Tete Provinces where transport costs exceed US$30 per ton. Those areas are clearly disconnected to domestic markets. Rural accessibility is on average 21 percent. The average cost of transporting goods to the nearest port is about US$23 per ton, with a wide variety from nearly zero to US$73.

25. The vast majority of households surveyed by the studies are small-scale farmers, owning less than 1.5 ha of land. The distribution of land areas is much skewed with a wide variation from 0.0001 ha to 57 ha. Fertilizer use is generally limited. The average land area is about 2 ha. Regarding the use of advanced agricultural inputs, about 5 percent of households use chemical or organic fertilizer in their production system. The average amount of fertilizer used is merely 13.3 kg. Similarly, there are only a few households that use pesticides. About 5.7 percent of households use pesticides with an average amount of 2.3 kg. In the sample data, there are some households relying on irrigation, which account for about 3 percent of the total sample. However, this variable turns out to be highly correlated with the use of fertilizer and pesticides and thus was omitted from our model.

Table 2. Crop prices

Crop	US$/ton	Crop	US$/ton
Maize	278	Tea	2806
Rice	370	Sugar cane	46
Sorghum	370	Sun flower	393
Millet	590	Sesame	926
Peanuts small	444	Cashew fruit	778
Peanuts large	574	Pumpkins	425
Common beans	926	Lettuce	671
Cowpea	463	Garlic	2501
Pigeon pea	370	Onions	568
Irish potato	357	Carrots	276
Cassava	185	Peas	534
Orange fleshed	185	Water melon	241
Non orange fleshed	215	Cucumber	600
Green beans	588	Chilies	862
Mung bean	926	Cabbage	216
Cotton	630	Tomatoes	484
Tobacco	2829		

Sources: Mozambique 2012 Agriculture Survey; FAOSTAT.

Table 3. Summary statistics

Variable	Abb.	Obs	Mean	Std. Dev.	Min	Max
Crop production value (US$)	*v*	10,993	5056	35083	0.16	1944825
Transport cost to a major city with population >50,000 (US$ per ton)	TR_{CITY}	10,993	6.13	5.75	0.01	42
Rural Access Index at postos level (0 to 1)	TR_{RAI}	10,993	0.21	0.17	0.00	0.98
Transport cost to the nearest port (US$ per ton)	TR_{PORT}	10,993	23.52	12.59	0.01	73
Number of household members working on crop production [1]	*L*	10,993	2.60	1.52	0	26.5
Land area cultivated (ha)	*H*	10,993	2.08	2.30	0	57
Fertilizer use (kg)	*F*	10,993	13.28	374.90	0	36700
Pesticide use (kg)	*P*	10,993	2.34	59.97	0	5000
Outside labor employed	*N*	10,993	0.11	1.03	0	40
Household head sex (male = 1)	*D_male*	10,993	0.74	0.44	0	1
Household head age	*Age*	10,993	44.68	15.64	13	99
Household head education attainment [2]	*Edu*	10,993	3.09	3.29	0	13
Household size	*Size*	10,993	5.34	2.93	1	56
Dummy for households receiving agriculture training	*D_training*	10,993	0.02	0.14	0	1
Dummy for household receiving agriculture extension services in last 12 months	*D_extension*	10,993	0.07	0.25	0	1
Dummy for animal traction use	*D_animal*	10,993	0.21	0.41	0	1
Number of household members engaged in employed activities	*Employed*	10,993	0.49	0.85	0	10
Number of household members engaged in self employment activities	*SelfEmp*	10,993	0.64	0.86	0	9
Local population within 50 km distance	*LocalPop*	10,993	82095	99989	3	989322
Year 2012		10,993	0	0	0	1
Year 2015		10,993	1	0	0	1
Instruments:						
Straight distance from the nearest historic port city (km)	*KM_port*	10,993	129.16	105.39	0.24	440.25
Straight distance from the rail line (km)	*KM_rail*	10,993	200.52	142.44	0.86	622.35

[1] A part-time worker counts for 0.5 of a full-time equivalent.

[2] Zero for no education, 1 to 12 for formal education grades, and 13 for more advanced education.

V. Estimation Results and Policy Implications

26. The OLS regression is performed with the location-specific fixed effects included (**Table 4**). The estimated coefficients are broadly consistent with prior expectation. The impact of transport connectivity, particularly access to domestic markets, is found to be important to stimulate agricultural production in Mozambique. The elasticity of transport costs to domestic markets is estimated at 0.094 in absolute terms. It is statistically significant, implying that a 10 percent reduction in transport costs would likely increase the value of agricultural production by about 0.9 percent. The estimated elasticity looks consistent with the literature suggesting elasticities in a range of 0.05 to 0.15 (see, for example, Khandker et al. (2009), Donaldson (2018) and Iimi et al. (2020)).

27. There is no conclusive evidence showing the impacts of port accessibility. The coefficient is negative at -0.013 but statistically insignificant. This is a different result from the literature that is often supportive of the importance of port access in African countries (e.g., Iimi et al., 2019). This may be attributed to the fact that Mozambique has a long coastline and three major regional ports. Thus, people have relatively good access to one of them regardless of where they live. It may also be because agricultural exports still account for a small portion of the total agricultural production in the country.

28. Rural accessibility also has an insignificant coefficient. This may be able to be interpreted to mean that rural accessibility, which mainly captures people’s proximity to the road network, is necessary but not sufficient to promote agricultural growth. Recall that the rural access index is defined by the proportion of people who have access to an all-season road within a distance of no more than 2 km from their home. Even though people are granted such access, those roads may not necessarily be connected well to their final destinations, such as markets.

29. When all three connectivity variables are included, the accessibility to domestic markets is found to be most important. The coefficient is -0.112, which remains statistically

significant, while the other two variables are insignificant. Policy implications are straightforward: Among others, improving transport connectivity to domestic markets is critical to promote agricultural growth in Mozambique. To increase the market accessibility, it is important to rehabilitate and maintain the road network connecting rural areas to large cities. Not only primary but also secondary and tertiary roads need to be improved.

30. Apart from transport connectivity, the estimated equation indicates that the current agricultural production system exhibits decreasing returns to scale. In the first column model, the sum of the coefficients of the five agricultural inputs, i.e., L, H, F, P and N, is estimated at 0.91 with a standard error of 0.037. The hypothesis that the degree of homogeneity is greater than or equal to one can be rejected. The chi-square statistic is 5.77.

31. The highest elasticity is associated with land used, which is estimated at about 0.55, regardless of which specification is used. This reflects the fact that Mozambique's agriculture is still focused on extensification, not intensification. For labor, the elasticity of labor input is relatively low, implying that labor productivity is low. Perhaps, labor is too abundant in rural areas. A 10 percent increase of labor input would result in a 1.6 percent increase in production. Extension services seem to have an important role to play in increasing agricultural production. The coefficient is always found to be significantly positive. On the other hand, the impact of agricultural training is unclear in our estimation. The coefficient is positive but not significant.

Table 4. OLS regression with location-specific fixed-effects

	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.
ln TR_{CITY}	-0.094	(0.028) ***					-0.112	(0.032) ***
ln TR_{RAI}			-0.011	(0.058)			-0.009	(0.058)
ln TR_{PORT}					-0.013	(0.039)	0.135	(0.121)
ln *L*	0.163	(0.029) ***	0.164	(0.030) ***	0.163	(0.029) ***	0.163	(0.030) ***
ln *H*	0.550	(0.020) ***	0.554	(0.020) ***	0.551	(0.020) ***	0.553	(0.020) ***
ln *F*	0.079	(0.009) ***	0.079	(0.009) ***	0.079	(0.009) ***	0.079	(0.009) ***
ln *P*	0.052	(0.011) ***	0.052	(0.012) ***	0.051	(0.011) ***	0.052	(0.012) ***
ln *N*	0.067	(0.018) ***	0.066	(0.019) ***	0.066	(0.018) ***	0.066	(0.018) ***
D_male	0.087	(0.038) **	0.076	(0.039) *	0.086	(0.038) **	0.077	(0.039) **
ln *Age*	0.292	(0.045) ***	0.272	(0.046) ***	0.290	(0.045) ***	0.274	(0.046) ***
ln *Edu*	0.025	(0.006) ***	0.025	(0.006) ***	0.024	(0.006) ***	0.025	(0.006) ***
ln *Size*	0.046	(0.032)	0.047	(0.033)	0.047	(0.032)	0.047	(0.033)
D_training	0.086	(0.113)	0.103	(0.115)	0.085	(0.113)	0.102	(0.115)
D_extension	0.346	(0.068) ***	0.348	(0.069) ***	0.348	(0.068) ***	0.346	(0.069) ***
D_animal	0.165	(0.053) ***	0.167	(0.054) ***	0.166	(0.053) ***	0.168	(0.054) ***
ln *Employed*	-0.014	(0.007) **	-0.016	(0.007) **	-0.014	(0.007) **	-0.016	(0.007) **
ln *SelfEmp*	0.029	(0.007) ***	0.030	(0.007) ***	0.029	(0.007) ***	0.030	(0.007) ***
ln *LocalPop*	-4.153	(2.854)	-3.765	(3.092)	-3.421	(2.864)	-3.921	(3.191)
t	-0.281	(0.300)	-0.419	(0.322)	-0.432	(0.298)	-0.293	(0.329)
constant	21.324	(10.56) **	20.219	(11.45) *	18.938	(10.63) *	19.933	(11.95) *
Obs.	10993		10474		10993		10474	
R-squared	0.3299		0.3295		0.3292		0.3304	
F-statistics	15.31		15.55		15.24		15.56	
No. of postos dummies	333		333		333		333	

Note: The dependent variable is the total value of crop production of each household. Robust standard errors are shown in parentheses. *, ** and *** indicate the statistical significance at the 10, 5 and 1 percent level, respectively.

32. Although the location-specific fixed-effect model can control for a large part of unobservables, there may still be concern about endogeneity associated with infrastructure placement and thus our transport variables. The above approach can reduce various sources of endogeneity bias but cannot eliminate the endogeneity bias in theory. To address this issue, the instrumental variable (IV) approach is used. As discussed in the previous section, the transport connectivity variables are instrumented by the two straight-line variables to the nearest rail line and port: *KM_rail* and *KM_port*. Since these variables are specific to location *j* (i.e., *postos*), the IV regression is performed without the *postos* fixed effects.

33. The IV regression shows that agricultural production increases with the accessibility to domestic markets. The coefficient of TR_{CITY} is found to be significantly negative at -0.067, consistent with the above result, though slightly smaller in absolute terms (**Table 5**). In addition, the specification with RAI supports the significant impact of rural accessibility as well. The coefficient is estimated at 0.185. Thus, rural access may also be important to promote agricultural growth in Mozambique. The coefficient of TR_{PORT} remains insignificant, implying that port access is not so important to stimulate agricultural production, possibly because of the currently modest presence of export crops in the country's total agricultural production. Especially, the agricultural sample survey data that are used in the current analysis are focused on relatively small farmers.

34. Our IV approach is found to be largely valid from the statistical point of view. For the first two column models, the exogeneity hypothesis can be rejected according to the conventional Hausman technique. The test statistics are estimated at 3.20 and 23.1, respectively. The first stage F statistics are fairly large, indicating that the instruments are relevant to the transport cost variables, such as TR_{CITY} and TR_{RAI}. Finally, the Sargan's test of over identifying restrictions cannot be rejected. The test statistics are estimated at 2.25 and 2.57, respectively Thus, the instruments are not correlated to with the error term and properly excluded from the equation. For the last column model, the exogeneity test cannot be rejected. Thus, the estimation result may not be efficient, though consistent. Still, the result is the same: Port access does not have a significant impact on agricultural production.

35. For other coefficients than transport connectivity, the overall result has not changed much, though there are some differences in the magnitudes of the coefficients. Land remains an important determinant of production. The impacts of fertilizer and pesticides are found productive. While agricultural training may not be effective, extension services are found to help agricultural production, indicating the importance of complementarities among different types of public services, including not only hard infrastructure, such as road connectivity, but also soft issues, such as technical knowledge transfers.

Table 5. IV regression results

	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.
ln TR_{CITY}	-0.067	(0.037) *				
ln TR_{RAI}			0.185	(0.057) ***		
ln TR_{PORT}					-0.047	(0.031)
ln *L*	0.172	(0.030) ***	0.163	(0.031) ***	0.161	(0.029) ***
ln *H*	0.614	(0.020) ***	0.634	(0.022) ***	0.608	(0.019) ***
ln *F*	0.069	(0.008) ***	0.072	(0.009) ***	0.069	(0.008) ***
ln *P*	0.059	(0.011) ***	0.054	(0.012) ***	0.057	(0.011) ***
ln *N*	0.058	(0.018) ***	0.067	(0.020) ***	0.061	(0.018) ***
D_male	0.191	(0.039) ***	0.200	(0.041) ***	0.181	(0.039) ***
ln *Age*	0.158	(0.048) ***	0.113	(0.050) **	0.176	(0.046) ***
ln *Edu*	0.020	(0.006) ***	0.020	(0.006) ***	0.022	(0.006) ***
ln *Size*	0.010	(0.033)	0.003	(0.034)	0.015	(0.033)
D_training	0.067	(0.118)	0.102	(0.120)	0.079	(0.117)
D_extension	0.353	(0.069) ***	0.363	(0.071) ***	0.346	(0.069) ***
D_animal	-0.415	(0.040) ***	-0.478	(0.048) ***	-0.398	(0.039) ***
ln *Employed*	-0.040	(0.007) ***	-0.043	(0.007) ***	-0.038	(0.007) ***
ln *SelfEmp*	0.034	(0.007) ***	0.035	(0.007) ***	0.036	(0.007) ***
ln *LocalPop*	0.025	(0.011) **	0.018	(0.011)	0.017	(0.010) *
t	-0.670	(0.043) ***	-0.760	(0.034) ***	-0.732	(0.033) ***
constant	5.744	(0.22) ***	6.339	(0.28) ***	5.873	(0.25) ***
Obs.	10993		10474		10993	
R-squared	0.2109		0.1975		0.2126	
Wald chi2	2789.0		2590.6		2800.2	
Exogeneity test chi2 stat.	3.200 *		23.106 ***		1.223	
First stage F-stat.	503.85 ***		558.84 ***		1210.07 ***	
Sargan overidentifying restrictions chi2	2.251		2.573		3.102 *	

Note: The dependent variable is the total value of crop production of each household. Robust standard errors are shown in parentheses. *, ** and *** indicate the statistical significance at the 10, 5 and 1 percent level, respectively.

VI. Conclusion

36. Africa has great potential for agriculture. However, the potential has not been fully explored yet. It is important to accelerate agricultural growth further. Africa can feed itself from the agro-ecological point of view. Mozambique currently produces about US$3 billion

of crops, but its agroclimatic potential is estimated at more than US$500 billion from a purely theoretical point of view.

37. A number of constraints exist to exploit such untapped potential. The paper reexamined a simple agricultural production function with micro data from Mozambique. It is found that transport connectivity to domestic markets is the most important to promote agricultural production. The elasticity is estimated at 0.07 to 0.11 in absolute terms, depending on the specification. It is important to improve and maintain the quality of the road network to provide good access to domestic markets to farmers. Of particular note, the vast majority of the poor still live in rural and remote areas in Mozambique.

38. Not only road infrastructure but also other complementary policies are important to boost agricultural productivity. Currently, land is the most dominant production input with an estimated elasticity of about 0.5 to 0.6, reflecting the traditional production system in Mozambique, which is largely subsistence farming. However, fertilizer and pesticides are found to be productive, reconfirming the importance to modernize and commercialize agricultural production with more advanced inputs used. In addition, providing extension services is also an important element to increase agricultural production.

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