

# Transport Connectivity, Medical Supplies, and People's Health Care Access

Evidence from Madagascar

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## Abstract

Health care access is a challenge in rural areas in Africa. On the demand side, rural people are often poor, and transport connectivity is typically bad in rural and remote areas. Because of limited transport connectivity, the quality of health care services provided is also often compromised. In Madagascar, the poor condition of the road network has long hampered the sustainability of the medical supply chain in rural areas. The paper shows that

people's demand for health care services is affected not only by local transport connectivity, but also availability of medical supplies at the health facility level, which is also determined by primary and secondary road network connectivity. This in turn further suppresses people's demand in rural areas. The results also indicate that it is important to ensure financial affordability among the poor, which is found to be one of the most crucial constraints.

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**Transport Connectivity, Medical Supplies, and People's Health Care Access:  
Evidence from Madagascar**

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## **I. Introduction**

Health care access is an important challenge in rural areas, particularly in developing countries. It is generally difficult for people who live in remote areas to access good-quality health services (e.g., Gamm et al. 2003; Institute of Medicine 2005; Bourke et al. 2012). Even in the United States, rural residents of Washington State were less likely to visit the emergency department than their urban counterparts (Lishner et al. 2000). According to Laditka et al. (2009), rural residents are more likely to be hospitalized for ambulatory care sensitive conditions in the United States. This could be prevented if people had better access to primary care, but because they do not, their condition tends to deteriorate.

Among others, transport connectivity is a particularly important constraint in rural areas. Rural dwellers' travel distance to health facilities is much longer than that of urban dwellers (Gamm et al. 2003). In Zambia, about 75 percent of urban residents, but only 30 percent of rural residents, live within 2 kilometers of the nearest health facility (Zambia Central Statistical Office 2012). Remoteness and unavailability of transport services increase costs further for rural residents, limiting them from accessing health care services (e.g., Klemick et al. 2009).

Limited transport connectivity not only reduces people's accessibility, but also compromises the quality of health care services provided. Bronstein et al. (1997) show that rural health services are cheaper but that fewer ancillary services are provided. Sufficient doctors and nurses may not be available in rural areas as well. This may be a more generic disadvantage of rural areas or remoteness. For whatever reason, doctors are less available in rural areas. In the United States, only 9 percent of physicians practice in rural areas where about 20 percent of the total population lives (Rosenblatt and Hart 2000). As a result, rural physicians often have to see more patients than urban doctors do, therefore, potentially compromising the level of services they provide. Medical supplies may also be compromised in rural and remote areas. How to ensure supply chain sustainability is an important research issue (e.g., Uysal and Tosun, 2014).

In particular in Africa, these constraints often tend to be severe. In the region, about 70 percent of the total rural population do not have access to any all-weather road (Roberts et al., 2006). In Liberia, about 40 percent of rural residents must spend more than 2 hours to walk to the nearest health facility (Kruk et al. 2010). Moreover, the road condition is generally poor in rural Africa. In Uganda, 79 percent of paved roads are in good condition, but 75 percent of unpaved roads are in poor condition. In Kenya, about 40 percent of tertiary roads are in bad condition (World Bank, 2016).

Demand-side constraints further aggravate rural people's health access already limited by the above-mentioned supply-side difficulties. In Africa, rural residents are generally much poorer than urban residents. Thus, holding everything else constant, the rural demand for health services is lower in rural areas. Jovanovic et al. (2003) show that subscription to health insurance is lower in rural areas. Because of the lack of proper insurance, rural residents are less likely to use emergency medical services (Fan et al., 2011). This is a particularly important concern in Africa where poverty is concentrated in rural areas. Many studies are supportive of the importance of health insurance to improve people's health care access in developing countries (see, e.g., Spaan et al., 2012). This means that financing is a critical issue for poor people.

This paper casts light on the nexus of transport connectivity, medical supply sustainability and people's health care service access. As discussed, these factors are interdependent on one another. To estimate the system of equations and solve the endogeneity problem, the paper relies on the three-stage least squares (3SLS) model (Zellner and Theil, 1962). One equation examines people's demand for health care services, and another represents the quality of the services determined by transport connectivity and other factors. The data come from Madagascar where rural transport connectivity is extremely limited, because of low road density as well as the poor condition of the rural road network. Detailed health facility databases are combined with spatial road condition data.

The following sections are organized as follows: Section II describes the data and methodologies. Section III presents the main estimation results and discusses policy implications. Then, Section IV concludes.

## II. Methodology and data

To examine people's demand for health care services, two particular impacts of transport connectivity are considered. On the demand side, health access is considered to be affected by the degree of transport impediment between health facilities and households. The less connected, the smaller number of patients. On the supply side, the quality of health care services offered is also dependent on transport connectivity. If a health facility is not well connected, medical supplies may not be sustained. Thus, people cannot expect quality services, which would in turn affect people's demand.

To assess both aspects simultaneously, the following system of equations is considered:

$$\frac{N}{POP} = T_1' \alpha_1 + X' \beta_1 + \gamma_1 M + \varepsilon_1 \quad (1)$$

$$M = T_2' \alpha_2 + X' \beta_2 + \varepsilon_2 \quad (2)$$

Note that our unit of observation is the health facility. In Madagascar, more than 3,000 health facilities, including hospitals and basic health centers (CSB), exist all over the country (**Figure 1**). The empirical analysis will only use data for about 900 facilities in eight regions (Alaotra-Mangoro, Analamanga, Bongolava, Itasy, Vakinankaratra, Amoron'i mania, Vatovavy Fitovinany, and Haute matsiatra), where detailed facility-level data are available.

**Figure 1. Health facility network in Madagascar**

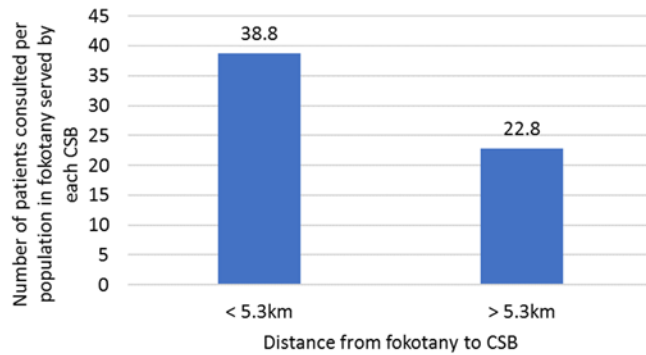


Source: Ministry of Health, Madagascar

The first equation aims at capturing the direct transport impacts on people's demand, for which the dependent variable is the share of patients out of the total local population.  $N$  is the number of patients who newly visited and were treated at each facility. To control for the size effect, this is divided by the total number of local population ( $POP$ ) in villages or *fokontany* covered by each facility.

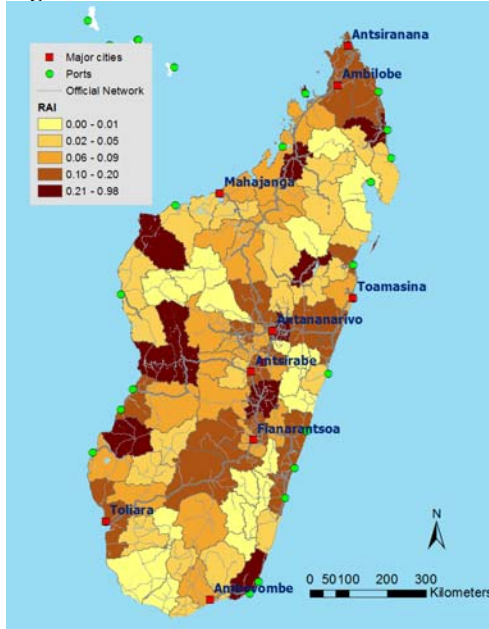
$T$  denotes a set of connectivity measurements. In Madagascar, many rural people are disconnected from the road network and health facilities: About half of *fokontany* where people live are more than 10 km away from the nearest basic health center. Even by simple statistics, it is clear that more people would likely visit health centers if they are closer to them (**Figure 2**). For Equation (1), local connectivity is measured by two variables: (i) weighted average distance between a *fokontany* and the nearest basic health center, and (ii) rural access index (RAI), which is available at the district level. The latter is a traditional transport indicator (**Figure 3**).

**Figure 2. People’s access and distance to health facilities**



Source: World Bank estimate.

**Figure 3. Rural Access Index**

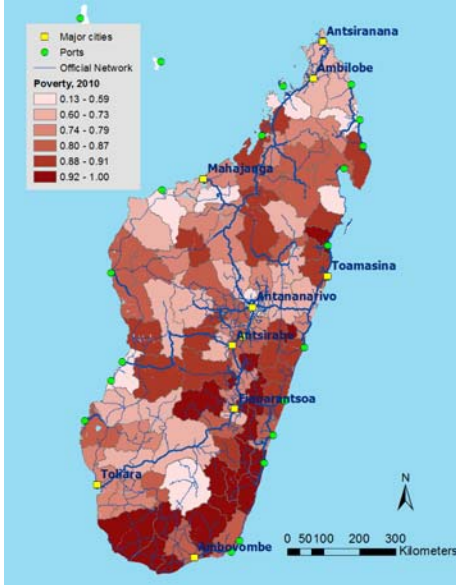


Source: World Bank estimate.

$X$  includes other explanatory variables that potentially affect the demand. As discussed above, the level of household affordability is a matter of particular concern. The district-level poverty data ( $POV$ ) are used to control for this. The latest available official poverty data are at the regional level. To increase granularity, the poverty equation is calibrated using the latest household survey in 2010, generating the district-level poverty rates (**Figure 4**). While it is not official, the estimates are broadly consistent with the general understanding of the geographic distribution of poverty in the country (**Figure 5**).

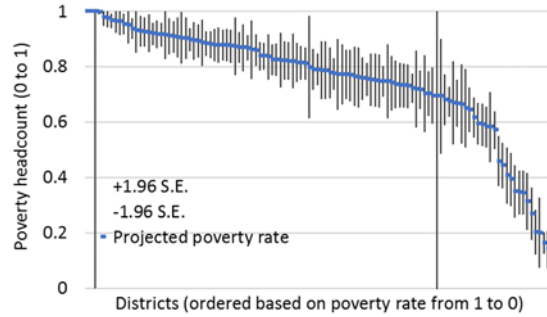


Figure 4. District-level poverty rate



Source: World Bank estimate.

Figure 5. Distribution of poverty estimates



Source: World Bank estimate.

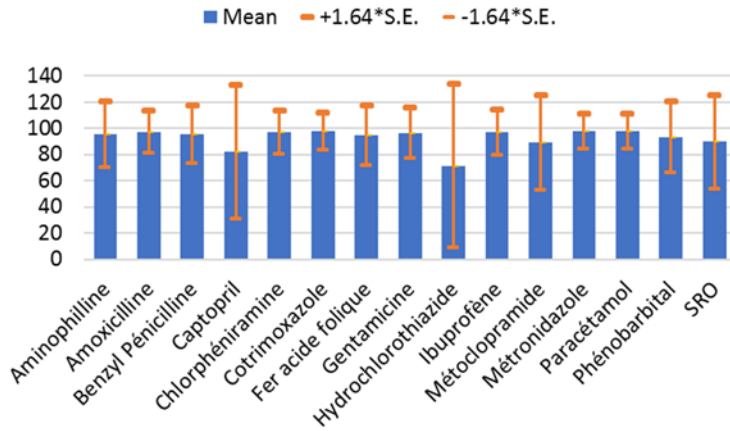
Finally, our main hypothesis in this paper is that the people's health care demand depends on the quality of health services, denoted by  $M$ . Of course, there are a number of aspects in this regard. For data availability and empirical tractability purposes, the following analysis uses the average availability of medical supplies at each health facility:

$$M = \frac{1}{15} \sum_j m_j \quad (3)$$

where  $m$  is the availability rate of medicine  $j$  at each facility. It is defined by the number of days when the stock is sufficient, divided by 365 days.

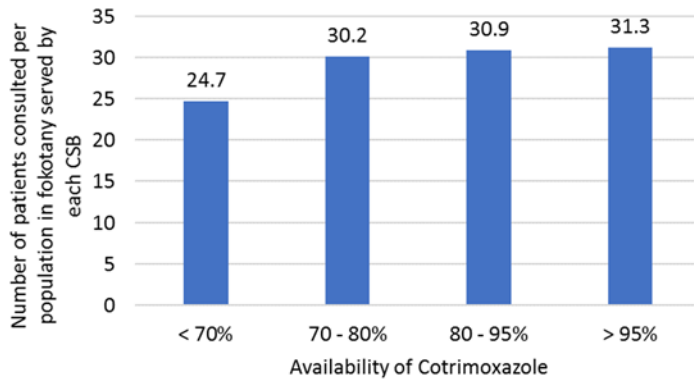
In Madagascar, detailed supply and stock data are available for 15 medicines. Because of unreliable transport connectivity, particularly in remote areas during the rainy season, availability of medical supplies varies significantly from one location to another (Figure 6). Even by simple statistics, it is clear that more people would likely more often visit health facilities (Figure 7). Needless to say, it is determined by not only medicine availability but also other factors. That is why we have other variables, such  $T$  and  $X$ , in Equation (1).

**Figure 6. Availability of medical supplies (%)**



Source: Ministry of Health, Madagascar.

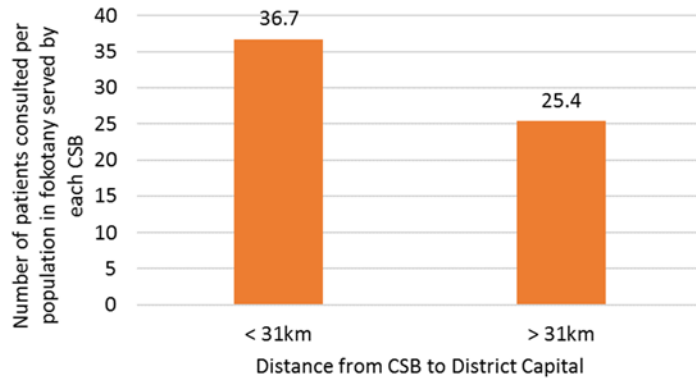
**Figure 7. People’s access to health care services and availability of medical supplies**



Source: World Bank estimate.

Importantly, the availability of medical supplies is crucially dependent on transport connectivity in rural Madagascar. About 25 percent of the health facilities are disconnected more than 5 km (approximately 1 hour walking distance) from the official road network. It is particularly challenging to sustain it in rural and remote areas, especially during the rainy season when rural roads are often flooded and impassable. There is broad negative correlation between people’s tendency to access health care services and remoteness of basic health centers (**Figure 8**). The latter is measured by distance from the district capital, which is an important part of the medical supply network in Madagascar.

**Figure 8. People’s access to health care services and remoteness of health centers**



Source: World Bank estimate.

Needless to say, there are other factors that potentially affect the availability or unavailability of medical supplies, as modeled in Equation (2). For  $T_2$ , two variables are used, which represent connectivity at the higher level of transport network than  $T_1$ : (i) distance from the road network and (ii) average travel time from each health center to the district capital. All the variables that are used in our empirical analysis are included in the summary statistics in **Table 1**.

To solve the endogeneity problem between the two equations and improve efficiency in estimation, the paper relies on the three-stage least squares (3SLS) model (Zellner and Theil, 1962). To instrument the endogenous variable  $M$ , three variables are used. First, the straight-line distance from each facility to Antananarivo, the capital city, is used. This is an artificial measurement, as often referred to as the “as-the-crow-flies” distance, and is unlikely to be directly related to people’s access to health care services. It should really depend on the actual road alignment and conditions on the ground. On the other hand, this is considered to be somewhat relevant to the availability of medical supplies because they are generally distributed from the center of the economy, Antananarivo.

Following Dinkelman (2011), geographic conditions are also used. Land gradient (denoted by  $SLOP$ ) and elevation ( $ELEV$ ) at each locality may affect the technical feasibility of developing road infrastructure, which is likely to impact the medicine availability. Of course, these geographic conditions may also possibly influence people’s accessibility to health

facilities, violating the validity of the instruments. This will ex post be examined by the conventional test of overidentifying restrictions.

**Table 1. Summary statistics**

Variable	Abb.	Obs	Mean	Std. Dev.	Min	Max
Number of new patients who visited each CSB in 2016	<i>N</i>	892	2378	2510	0	22563
Population in fokotany served by each (CSB)	<i>POP</i>	892	11220	15135	787	298597
Share of local people who visited CSB in 2016 (%)	<i>N/POP</i>	892	28.5	45.9	0.0	1039.8
Distance from fokotany to CSB (km)	<i>KM_FKT</i>	892	6.3	4.3	0.0	65.4
Rural Access index (%)	<i>RAI</i>	892	14.0	14.7	0.0	100.0
Poverty rate at the district level (%)	<i>POV</i>	892	76.6	16.4	16.3	97.6
Distance to the official road network (km)	<i>KM_RD</i>	892	3.3	5.6	0.0	45.5
Travel time from CSB to District capital (hours)	<i>TIME_DIST</i>	892	0.51	0.52	0.00	4.41
Medicine availability (% of days a year):						
Aminophilline	<i>m1</i>	892	93.9	17.9	0.0	100
Amoxicilline	<i>m2</i>	892	96.4	11.3	8.6	100
Benzyl Pénicilline	<i>m3</i>	892	94.3	15.2	0.0	100
Captopril	<i>m4</i>	892	77.9	33.3	0.0	100
Chlorphéniramine	<i>m5</i>	892	95.8	11.6	0.0	100
Cotrimoxazole	<i>m6</i>	892	96.9	10.2	0.0	100
Fer acide folique	<i>m7</i>	892	93.1	15.6	0.0	100
Gentamicine	<i>m8</i>	892	95.5	13.4	0.0	100
Hydrochlorothiazide	<i>m9</i>	892	64.0	39.8	0.0	100
Ibuprofène	<i>m10</i>	892	96.1	11.7	0.0	100
Métoclopramide	<i>m11</i>	892	86.1	24.1	0.0	100
Métronidazole	<i>m12</i>	892	97.2	9.1	0.0	100
Paracétamol	<i>m13</i>	892	97.1	9.3	0.0	100
Phénobarbital	<i>m14</i>	892	91.7	18.1	0.0	100
SRO	<i>m15</i>	892	87.9	23.5	0.0	100
Average availability of all medicines	<i>M</i>	892	90.9	11.2	13.3	100
Instrumental variables:						
Straight-line distance to Antananarivo (km)	<i>KM_TANA</i>	892	164.0	108.6	0.2	394.3
Slope at the location of each CSB (degree)	<i>SLOP</i>	892	1.45	1.41	0.02	11.22
Elevation at the location of each CSB (m)	<i>ELEV</i>	892	1034.7	485.2	0.0	2398.0

### III. Main estimation results

Although the results may be biased and inefficient, the ordinary least squares (OLS) regression is first performed: The results are shown in **Table 2**. The estimated coefficients are generally consistent to our prior expectation. Clearly, transport connectivity is likely to

matter to both people’s local accessibility to health facilities and availability of medical supplies. The coefficient of the medical supply availability in question is insignificant in both OLS and instrumental variable (IV) estimation. The coefficient is estimated at 0.007 and -2.333, respectively. Again, the results may be biased and the estimation efficiency can be improved by estimating the two equations together.

**Table 2. OLS and IV estimation results**

Dependent variable:	<i>N/POP</i>			<i>N/POP</i>			<i>M</i>	
	OLS			IV			OLS	
Estimation method:	Coef.	Std.Err.		Coef.	Std.Err.		Coef.	Std.Err.
KM_FKT	-1.184	(0.452)	***	-1.406	(0.691)	**		
RAI	-0.617	(0.230)	***	-0.440	(0.212)	**		
POV	-0.765	(0.278)	***	-0.783	(0.297)	**	-0.037	(0.019) **
M	0.007	(0.072)		-2.333	(2.577)			
KM_RD							-0.195	(0.130)
TIME_DIST							-1.757	(0.817) **
Constant	102.504	(26.476)	***	315.673	(252.608)		95.321	(1.399) ***
Obs.	892			892			892	
R-squared	0.063			...			0.026	
F statistic	2.39						4.78	
Wald chi2				9.03				

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

The 3SLS model is applied (Table 3). Two specifications are considered: with and without region-specific dummy variables. The results are broadly similar; however, our preferred model is the one without regional dummy variables, shown in the first column of the table. The Hansen-Sargan test statistic for overidentifying restrictions is estimated at 6.088, which is insignificant, suggesting the validity of our instruments. With regional dummy variables, the test statistic is 37.645, which is significant at the 1 percent level. In this specification, our instruments are found invalid.

Based on the result without regional dummies, the largest determinant in terms of elasticity is poverty, of which the coefficient is estimated at -0.696 with a standard error of 0.129. The implied elasticity is -1.87 with a standard error of 0.34, which means that if poverty is

reduced by 1 percent, the demand for health care service would increase by 1.87 percent (Figure 9). The availability of medical supplies also has a significant impact. The coefficient is 1.995, which can be translated into an elasticity of 0.42 with a standard error of 0.24.<sup>1</sup> Thus, if the availability of one particular medicine improves by 1 percent, the health care demand would increase by 0.24 percent.

An unexpected result is that rural accessibility has a negative coefficient. Rural accessibility is highly correlated with poverty as usual, and it seems that the poverty aspect dominates the possible impact of transport disconnectedness. Local transport connectivity (*KM\_FKT*) has a negative and significant coefficient, which is consistent with our prior expectation.

In the medicine supply equation, the results show that the availability of medicines, *M*, decreases with distance to the road network and connectivity to the district center, which is measured by travel time. Both are statistically significant, indicating that the primary and secondary road network connecting health facilities and district capitals is crucial to ensure the medical supply chain in Madagascar. Basic health centers should be better connected to the official road network and the nearest district centers where medical supplies are generally distributed. This impact would in turn affect people's demand for health care services. Recall that in the demand equation, the coefficient of *M* is significantly positive. Therefore, if a health facility is not well connected to the district center, its medical supplies are more likely to be insufficient, and as a result, people are less motivated to visit that health center.

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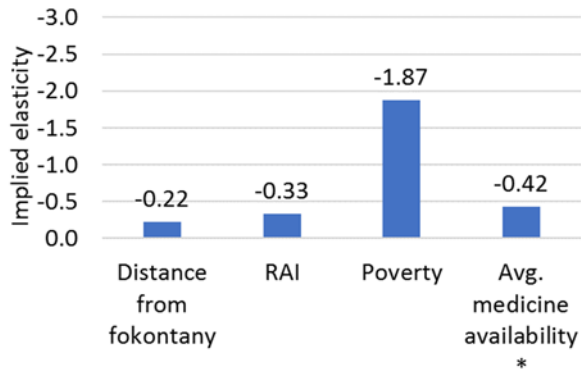
<sup>1</sup> It is divided by 15 since our dependent variable is the average of stock availability of 15 medicines.

**Table 3. Three-stage least squares estimation result**

	Without regional dummies		With regional dummies			
	Coef.	Std.Err.	Coef.	Std.Err.		
<i>N/POP</i> equation:						
KM_FKT	-1.002	(0.364)	***	-0.849	(0.361)	**
RAI	-0.676	(0.155)	***	-0.896	(0.153)	***
POV	-0.696	(0.129)	***	-0.626	(0.200)	***
M	1.995	(1.117)	*	2.411	(0.648)	***
Constant	-83.770	(102.575)		-110.666	(65.623)	*
<i>M</i> equation:						
KM_RD	-0.217	(0.063)	***	-0.139	(0.058)	**
TIME_DIST	-1.644	(0.678)	**	-1.499	(0.632)	**
POV	-0.037	(0.023)		-0.127	(0.028)	***
Constant	95.318	(1.767)	***	98.014	(1.819)	***
Obs.	892			892		
R-squared: <i>N/POP</i>	-0.169			-0.228		
<i>M</i>	0.026			0.126		
Overidentification statistic:	6.088			37.645		***

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

**Figure 9. Implied elasticity of people’s health care access**



Note: \* Divided by the number of medical supplies, *M*, for presentation purposes.

One might be concerned about the validity of our instruments, although it is confirmed by the traditional overidentification test as discussed above. Particularly, the two geographic variables (i.e., slope and elevation at each health facility) may also have some implication for people’s accessibility to health facilities: People might have more difficulty visiting a health facility in a mountainous area. To check this possibility, the 3SLS is performed with these

two variables included as explanatory variables in  $X$  (Table 4). It was found that they have little explanatory power in the equations. Thus, they are not considered to belong to the explanatory equations.

The estimation results are similar to the above: People's health care service demand declines with the distance between villages and health facilities as well as poverty prevalence. The availability of medical supplies also affects people's demand. To improve medicine availability, health facilities need to be connected to the road network and the district capital, which has an important role in the medical supply distribution system.

**Table 4. Three-stage least squares estimation results with two instrumental variables included**

	Without regional dummies			With regional dummies		
	Coef.	Std.Err.		Coef.	Std.Err.	
<i>N/POP</i> equation:						
KM_FKT	-1.010	(0.364)	***	-0.880	(0.360)	**
RAI	-0.671	(0.157)	***	-0.891	(0.154)	***
POV	-0.675	(0.132)	***	-0.702	(0.241)	***
AVG_M	2.015	(1.134)	*	1.719	(1.107)	
SLOP	-1.390	(1.238)		-1.021	(1.198)	
ELEV	0.0005	(0.0037)		0.018	(0.014)	
Constant	-85.697	(104.125)		-66.532	(125.669)	
<i>M</i> equation:						
KM_RD	-0.221	(0.064)	***	-0.169	(0.062)	***
TIME_DIST	-1.739	(0.700)	**	-1.693	(0.671)	**
POV	-0.043	(0.024)	*	-0.130	(0.028)	***
SLOP	0.234	(0.276)		0.089	(0.261)	
ELEV	-0.0006	(0.0008)		-0.011	(0.002)	***
Constant	96.057	(2.215)	***	112.046	(3.030)	***
Obs.	892			892		
R-squared: N/POP	-0.172			-0.071		
M	0.027			0.157		
Overidentification statistic:	4.286			5.993		

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



#### **IV. Conclusion**

Health care access is an important challenge in rural areas, particularly in developing countries. There are various reasons on both the demand and supply sides. On the demand side, rural people tend to be poorer than urban residents for whatever reason. In rural areas, transport connectivity is also more limited, which constrains people's demand for health care services but also compromises the quality of health care services provided. In Madagascar, the poor condition of the road network has long hampered the sustainability of the medical supply chain to rural and remote areas, where rural roads are often impassable during the rainy season. Without sufficient medical supplies, people's demand to visit health facilities would be suppressed.

The paper addresses this nexus of transport connectivity, medical supplies and people's health demand, by estimating a system of equations. The results indicate that transport connectivity is essential on both sides: While proximity to health facilities would increase the demand for health care services, the medical supply availability is also affected by transport connectivity, especially to the official road network and the nearest district center. The supply availability in turn influences people's demand for health care services. Therefore, the poor transport connectivity suppresses the demand further in rural areas.

Policy implications are straightforward: It is important to develop and maintain transport infrastructure to better connect all health facilities and sustain necessary medical supplies. The estimation results also highlight the importance of not only infrastructure but also institutional aspects. Poverty is one of the most significant factors affecting people's health demand. It is important to ensure financial affordability in the health sector, possibly providing targeted subsidies, expanding insurance mechanisms and/or implementing free health programs, especially in rural areas.

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