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Output- and Performance-Based Road Contracts and Agricultural Production

Evidence from Zambia

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Abstract

Rural access is among the most important infrastructure elements to stimulate economic growth in rural and remote areas. The sustainability of feeder road maintenance is a challenge in many developing countries. Many feeder roads are unpaved and need to be maintained frequently, but they are often neglected under budget pressure. Output- and performance-based road contracts are an instrument to ensure the sustainability of road maintenance. Contractors are required not only to improve roads, but also to maintain them. Using micro data from household surveys in Zambia, the paper examines the impacts of output- and performance-based road contracts on agricultural production. It shows that the contracts have a significant impact on crop production, especially maize and groundnuts, two major crops grown in the study area. The paper also finds that the measured impacts are associated with actual road maintenance works, regardless of contractual methods. Any road work can improve people's connectivity, even if it is not an output- and performance-based road contracts. The impact of the contracts is catalytic: more road works were implemented on contract roads than non-contract roads, holding everything else constant. This is an important contribution to the sustainability of road maintenance. Finally, road improvement works are found to facilitate farmers' market participation, but the impact seems weak. There may be other constraints. Transport service costs are found to have a negative impact on farmers' market sales. Thus, although roads are improved, transport services may be not available or too expensive, which still hamper farmers' market participation.

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Output- and Performance-Based Road Contracts and Agricultural Production: Evidence from Zambia

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I. Introduction

Rural access is among the most important infrastructure elements to stimulate economic growth in rural and remote areas. According to the Rural Access Index developed by Roberts et al. (2006), in Africa only 34 percent of the rural populations have access to an all-season road within an approximate 2-km walking distance. Many farmers and local businesses are still not well connected to the road network and do not have good access to markets. Rural access is particularly important from the poverty reduction point of view. The majority of the rural populations are living below the poverty lines, simply engaging in subsistence farming with few advanced inputs used. Rural access is also critical for people's access to social facilities, such as schools and hospitals.

The literature is generally supportive of the impacts of rural accessibility. In the short term, transport costs and travel time can be reduced by improved road conditions (e.g., Lokshin and Yemtsov 2005; Danida 2010). Over the longer term, agricultural productivity would likely be increased (Khandker et al. 2009; Bell and Van Dillen, 2012), and firms would become more profitable with more jobs created (Mu and van de Walle, 2011). Poverty could then be alleviated (Dercon et al., 2008; Khandker and Koolwal, 2011).

Road financing is a matter of particular concern in many developing countries. Despite the fact that there are significant unmet needs for road infrastructure, available resources are limited. In Africa, it is estimated that about US$12.7 billion would be needed to rehabilitate, upgrade and maintain the road network to meet minimum connectivity standards (AICD, 2009). Maintenance of rural roads, of which the traffic level is low at less than 200 vehicles per day, tends to be neglected under fiscal pressure. On the other hand, many rural roads in Africa are gravel or earth roads, which require frequent maintenance. The current shortfall in road maintenance spending is estimated to cost Africa US$1.9 billion a year (World Bank, 2010).

Performance-based contracting is a useful instrument to ensure sustainability of road maintenance. The literature has long been discussing an incentive problem in transport projects: About 90 percent of transport projects experienced significant cost overruns (Flyvbjerg et al., 2002). Africa's road projects were delayed by 10 months on average (Alexeeva et al., 2008). And each year of delay would likely cost on average US$4.6 million for a US$100 million transport infrastructure project (Flyvbjerg et al., 2004). In theory, output- and performance-based road contracts (OPRC) can tighten contractors' incentives to avoid cost overruns, while delivering outputs as agreed.[1] Under the OPRC framework, contractors are responsible for initial rehabilitation works and following maintenance works for an agreed period of time. Their performance is normally not measured by used inputs, such as bitumen and concrete, but by certain performance criteria, such as surface degradation and road user comfort.

Despite the fact that OPRC are being used widely, there is little evidence showing their effectiveness. On the cost implication side of OPRC, Lancelot (2010) shows that performance-based contracts were 20-35 percent cheaper than traditionally procured projects in Brazil. In Europe, it is found that the cost of public-private partnerships, which is relevant to but more advanced than OPRC, is 24 percent higher in the road sector. This is possible because of the risk premium of anticipated cost overruns (Blanc-Brude et al., 2009).

To the best of our knowledge, the current paper is one of the first attempts to examine the impacts of OPRC on the user side. Using data from a rural road project in Zambia, it will examine the possible impacts of OPRC on agricultural production. The following sections are organized as follows: Section II provides an overview of the road sector in Zambia. Section III develops our empirical strategy, and Section IV describes our data. Section V presents main results and discusses policy implications. And Section VI concludes.

[1] Theoretically, Bajari and Tadelis (2001) show that the incentive mechanism can be strengthened to improve the performance of contractors, while minimizing public procurement costs.

II. Recent developments of the Zambian road sector

Over the last decade, Zambia has been experiencing steady growth with an average growth of 7.7 percent. The mining sector, such as copper, is traditionally strong in the country, although it may be affected by the recent contraction of the commodity market. Agriculture is another important sector, employing about 65 percent of the total labor force and generating about 10-15 percent of GDP (LCMS 2010). Agricultural productivity remains low despite some emerging large-scale commercial production. The Zambian agriculture sector is dominated by smallholder farming based on a few hectares of land per household, with few advanced inputs and little machinery (e.g., Fink and Masiye, 2015; Sipangule and Lay, 2015).

From an agro-ecological point of view, Zambia has significant potential of agricultural production. The country currently produces about US$1.9 billion in crops (**Figure 1**). Purely from an agro-ecological point of view, the country is estimated to have US$291 billion in agricultural production potential, when evaluated at regional crop prices (**Figure 2**). Clearly, this has not been exploited yet. Importantly, Zambia imports more than US$200 million of crops and food products every year (c.f., fuel imports of US$1 billion and copper exports of US$6 billion). Agriculture can be an export, not import, industry if a variety of constraints are removed in the sector.

Figure 1. Current crop production value ($ million)

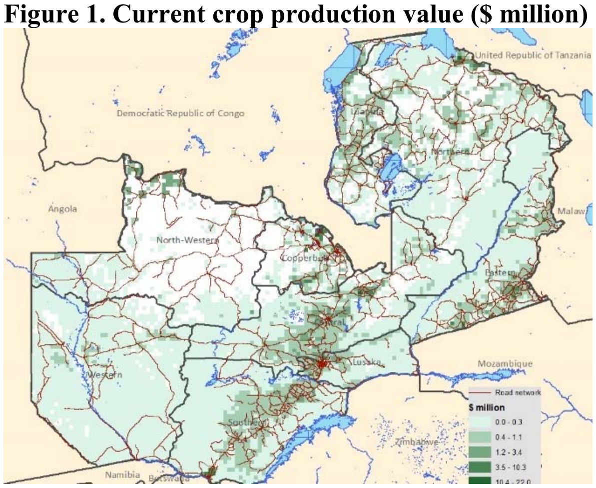
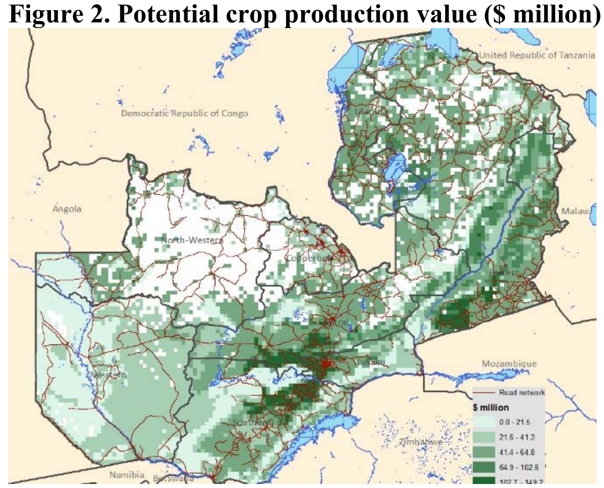


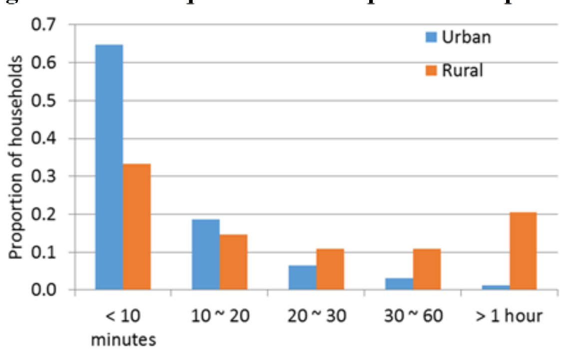
Figure 2. Potential crop production value ($ million)



Source: IFPRI SPAM 2000.

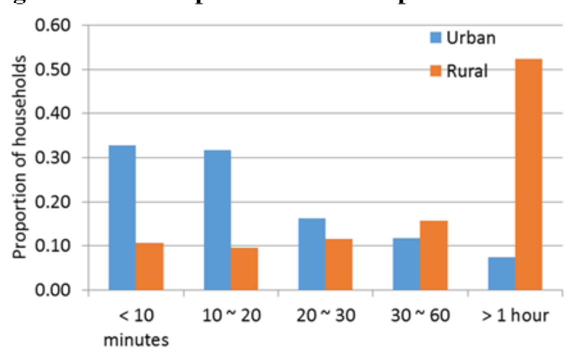
Among others, an important constraint is rural accessibility. According the Living Conditions Monitoring Survey, rural people do not have good access to markets, social facilities or public transportation services. In rural areas, only about half of the population lives within 20-minute distance of the nearest public transportation (**Figure 3**). The average distance is estimated at 6.1 km in rural areas, which is unfavorably compared to 0.7 km in urban areas. Similarly, many rural farmers lack access to markets. It takes more than one hour to go to the nearest input market (e.g., fertilizer and improved seeds) in the majority of rural areas in Zambia (**Figure 4**). The average distance to market is estimated at 20.9 km and 3.4 km in rural and urban areas, respectively.

Figure 3. Time required to access public transport



Source: Living Conditions Monitoring Survey (2010)

Figure 4. Time required to access input market



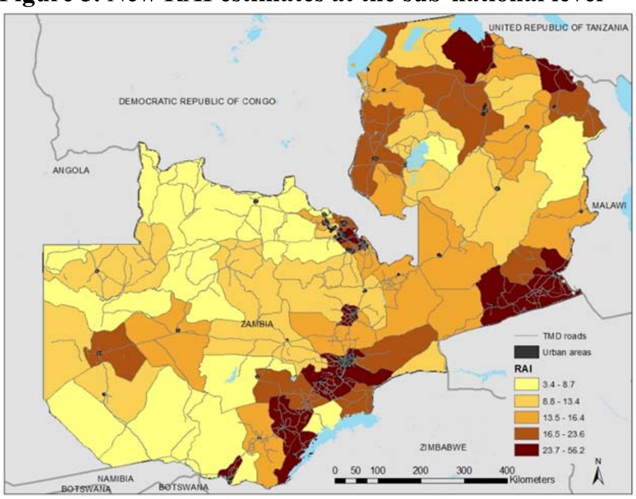
Source: Living Conditions Monitoring Survey (2010)

According to the recently updated rural access index (RAI), it is estimated that only 17 percent of the rural population lives within 2km of a road in good condition. About 7 million people are still left unconnected to the road network (**Figure 5**).[2] The previous RAI, estimated by Roberts et al. (2006), was 64 percent, which was predicted by calibrating a statistical model based on data from other countries. It seems to have been upward biased given the country's low population density in rural areas and the poor condition of the rural road network, as shown below. The new estimate, which uses detailed population and road data, is considered more accurate and consistent.

[2] Zambia is among the most urbanized countries in Africa. The total population in Zambia is about 15.7 million, of which about 40 percent of the total population live in urban areas, which are excluded from the RAI calculation. See World Bank (2016) for more details.

Zambia has a road network comprised of 40,454 km of classified roads, called Core Road Network (CRN), of which about half are Trunk, Main and District (TMD) roads, and another half are urban and primary feeder roads. This translates into a low road density of 5.4 km per 100 km^2 of land, which is unfavorably compared to its neighboring countries (e.g., 9.8 km in Tanzania, 14 km in Malawi, and 28.4 km in Kenya). About 10,100 km of trunk, main and district roads are paved and well maintained, however, the majority of feeder roads are generally in poor condition, crucially undermining the connectivity of the rural population. Both low population density and poor, limited road network are attributed to the country's low rural accessibility.

Figure 5. New RAI estimates at the sub-national level

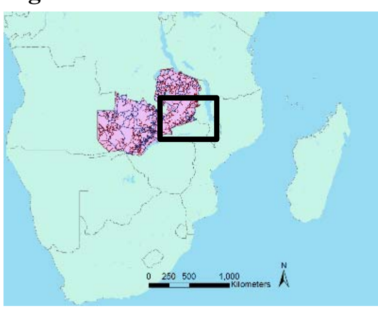


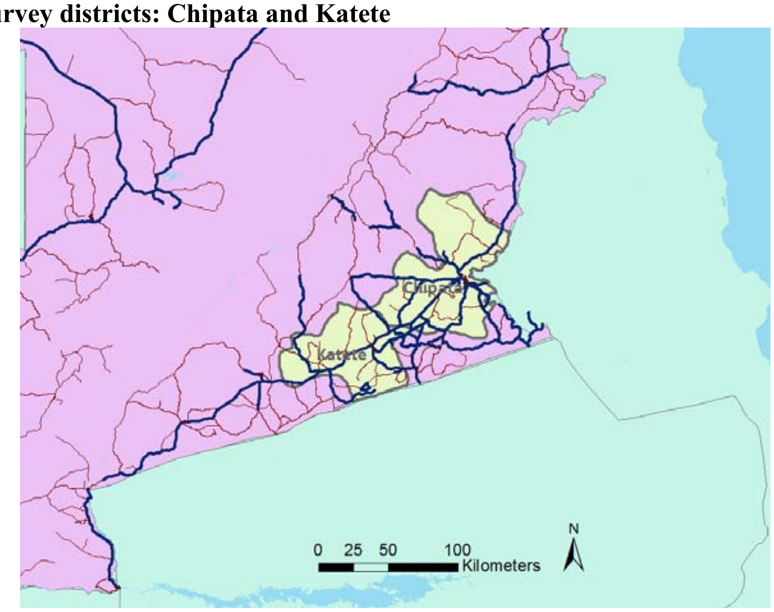
Source: World Bank (2016).

To improve transport connectivity and support agricultural growth, the Government of Zambia has made significant efforts to improve the main road network and extend feeder roads with the assistance of the international community. For instance, the Danish International Development Agency, DANIDA, supported the Small Scale Community Access (SSCA) component under its Road Sector Programme Support (RSPS) in 2002-2007. The program aimed at spot improvements on non-core roads to improve community access in rural areas, focused on six districts along the Lusaka-Mongu corridor.

In 2006-2014 the World Bank also supported the Agricultural Development Support Project (ADSP) to improve smallholder farmers' access to agricultural inputs and output markets in 5 districts: Choma, Chipata, Katete, Chongwe and Lundazi. The ADSP rehabilitated and maintained a total of 1,131 kilometers of feeder roads at a cost of US$27 million. Under the project, the OPRC scheme was adopted for the first time in Zambia. The following analysis relies on household surveys carried out in two districts: Chipata and Katete before and after the project (**Figure 6**).[3] These two districts adjoin each other in Eastern Province, bordering Malawi and Mozambique. This region is generally fertile and has relatively high rural accessibility at about 30 percent (see the above figures).

Figure 6. ADSP and household survey districts: Chipata and Katete





[3] The household surveys were actually carried out in three districts, including Choma District. However, the Choma data cannot be matched unambiguously with project implementation data because of missing identification data. In addition, many sampled households could not be covered by the follow-up survey, due to the changes in the designation of Standard Enumeration Areas (SEAs) after the 2010 National Population census. In Choma District, only 52 percent of the Treatment sample and 74 percent of the Control sample could be revisited under the follow-up survey (RDA, 2013).

III. Empirical strategy

The current analysis relies on two household surveys carried out in Chipata and Katete before and after the ADSP. The project areas were selected based on local agricultural potential. Eastern Province is among the most important agricultural areas in Zambia, producing cotton, soybean, groundnuts and tobacco as well as maize. Chipata and Katete produce more than 20 percent of the nation's total groundnuts. Based on agricultural productivity, about 200 km of feeder roads were selected in each of the districts (**Table 1**). These account for about 24 percent of total feeder roads in Chipata, and 38 percent in Katete. Before the project, almost all feeder roads were in poor condition in these two districts.

Under the project, 5-year OPRCs were made from March 2009 to March 2014. The awarded contractors were required to rehabilitate selected road links in the first year and maintain them by spot improvements as well as emergency works in the following 4 years. In the five years, a total of 385 km of roads were improved with gravel surface, box culverts and stone patching. Note that the OPRCs were targeted at a specific set of roads, but they did not prevent other road works elsewhere in the districts. Regardless of the OPRCs, the local governments actually implemented some other traditional road improvement and maintenance works wherever needed.

Table 1. Selected project roads under ADSP in Chipata and Katete

	Chipata Road works (km)			Katete Road works (km)	
Link name	Planned	Actual	Link name	Planned	Actual
D128	23.4	23.4	RD410	4.2	4.2
RD595-R280	11.0	11.0	RD411	38.1	38.1
R348-RD596	27.7	26.7	RD412	18.8	18.8
RD116	48.4	48.4	U20	23.2	23.2
RD117	19.9	19.9	U22	1.5	4.5
R266	13.3	13.3	RD687	19.9	18.0
RD694	34.2	30.5	RD592-1	6.0	6.0
RD697	16.6	16.6	RD592-2	12.1	12.1
			R300	11.2	11.2
			R306	15.3	15.1
			U29	17.8	17.8
			R291-R292	26.6	26.6
Total	194.6	189.9		194.6	195.5

Source: RDA (2014).

To assess the impacts of road works under OPRC on agricultural production, the following agricultural production function is considered:

$$\begin{aligned} \ln V_{it} &= \sum_j \ln\left(p_j q_{ijt}\right) \\ &= \beta_0 + \beta_1 OPRC_{it} + \beta_2 t + \beta_3 OPRC_{it} \cdot t + \beta_4 \ln POT_{it} + \sum_k \beta_k \ln x_{ikt} + \sum_m \beta_m z_{imt} + u_{it} \end{aligned} \tag{1}$$

where V is the total value of crops produced by household i at time t. The analysis only takes into account 7 major crops that are grown in the survey area: j={*maize, cotton, cassava, vegetable, soybean, tobacco, groundnuts*}. The vast majority of farmers in the area grow maize, and the second most popular crop is groundnuts. Some farmers also produce other crops, such as cotton. To aggregate different types of crops, regional producer prices (p_j) are used from FAOSTAT.[4]

[4] Average producer prices are used from three countries: Kenya, Rwanda and South Africa, where comprehensive data are available. The prices of maize, cotton, cassava, tobacco, vegetable, soybean and groundnuts are assumed to be $0.22 per kg, $1.34, $0.25, $2.66, $0.16, $0.47 and $0.97, respectively.

Our identification strategy is based on the difference-in-differences (DID) method with other covariates taken into account. *OPRC* is a dummy variable for the adoption of OPRC. There are two periods of time: before (t=0) and after (t=1) the project. The impact of OPRC is expected to be captured by β_3 in the equation. An advantage of the DID estimator is that it allows to control unobserved heterogeneity between the treatment and control groups and mitigate the self-selection bias, as long as they are time-invariant. However, as often discussed, it is a strong assumption that no time-variant factor affects the outcome indicators. To mitigate this risk, time-variant household characteristics are included on the right-hand side of the regression equation (e.g., Jalan and Ravallion 1998).

Following the agricultural economics literature (e.g., see Gyimah-Brempong (1987) and Bravo-Ortega and Lederman (2004)), six inputs are considered for x_k: $k = \{L, H, S, F, P, TR\}$, where L and H denote labor and land, respectively. Three advanced inputs are included: improved seeds (S), fertilizer (F), and pesticides (P). TR is the amount of spending on transportation services to take outputs to market.

Agricultural production must depend on underlying agro-climatic conditions. *POT* is an estimate of potential crop production based on agro-ecological and soil conditions. It is defined by $\sum_j p_j H_{ijt} Y_j$ where H_{ijt} is household i's land area used for production of crop j at time t. Y_j is a yield estimate (kg/ha) of crop j at this location under the rainfed high inputs assumption. This comes from a global spatial data set, Global Agro-Ecological Zones (GAEZ).

Other observable household characteristics, such as access to utility services and household assets, are also included in z_m, and u is an error term.

One empirical challenge is that many input variables are likely to be zero, when analyzing data from developing countries. As will be seen below, only half of the farmers actually use fertilizer (both basal and surface dressing included) in Zambia. About 15 percent and less than 10 percent use pesticides and transport services, respectively. The market participation rate is only 35 percent in our sample data.

One traditional approach to deal with this problem is to add a small positive number to avoid taking the logarithm of zeros. However, this may cause significant bias in estimation results (Battese, 1997). To remove that bias, the following analysis uses the Battese's specification, which introduces dummy variables, *D*, for the incidence of zero inputs:

$$\begin{aligned}\ln V_{it} &= \beta_0 + \beta_1 OPRC_{it} + \beta_2 t + \beta_3 OPRC_{it} \cdot t + \beta_4 \ln POT_{it} \\ &\quad + \sum_k \beta_k \ln x^*_{ikt} + \sum_k \gamma_k D_{ikt} + \sum_m \beta_m z_{imt} + u_{it}\end{aligned} \tag{2}$$

where

$$D_{ikt} = \begin{cases} 1 & \text{if } x_{ikt} = 0 \\ 0 & \text{if } x_{ikt} > 0 \end{cases} \text{ and } x^*_{ikt} = \max(x_{ikt}, D_{ikt}) \tag{3}$$

Another empirical challenge is endogeneity: By construction, *OPRC* is endogenously determined because the OPRC scheme was applied to places where agricultural potential is presumably high. Thus, regardless of the actual road works, agricultural production may be greater along the OPRC roads. This is a general endogeneity problem of infrastructure placement. Some areas are more productive than others because of better infrastructure, but at the same time, governments often invest more where productivity is inherently high no matter for what reason.

To address this issue, the instrumental variable technique is used. Three instrumental variables are constructed: *ELEV*, *SLOP* and *KMT4.* The first two variables represent geographic conditions of each road location: *ELEV* is the level of elevation in meters, and *SLOP* is the slope angle of the terrain. These are likely to be relevant to the necessity of road works (but less relevant to agricultural production), because the main challenge in rural areas of Eastern Province is accessibility during the rainy season. Many rural roads tend to be inundated and inaccessible because of the poor condition of roads. Thus, *ELEV* and SLOP are expected to explain potential needs for road works to a certain extent. The data come from a global spatial data set, the Shuttle Radar Topography Mission (SRTM), which provides 90m resolution elevation data of the world. Under the ADSP, about 340 pipe culverts and 20 box culverts were installed. Still, five clusters of emergency works were carried out to repair washed away embankments in 2010, 2012 and 2013 (RDA 2014).

In addition, remoteness from a main trunk road, which is T4 in Eastern Province, is also considered important to predict project areas. On one hand, roads are generally supposed to form an integrated network. Since the primary road network has already been well maintained in Zambia, feeder roads close to it are more likely to be improved as well. On the other hand, the project aimed at providing transport connectivity to remote areas. If this is the case, more remote areas would receive more road works. To capture this effect, the straight-line distance from each project site to T4 is calculated (denoted by *KMT4*). Note that as discussed above, agricultural potential is also an important instrument to determine the OPRC roads. Our model has already included *POT* as an independent variable. The validity of the instruments will be ex post examined by conventional tests, such as exogeneity and overidentifying restriction tests.

An important policy question is why the OPRC intervention could increase agricultural production. It is obvious that nothing would happen unless significant road improvement works are actually carried out, even though a performance-based contract is made. When the follow-up survey was carried out, some rehabilitation works do not seem to have been completed.[5] Then, no impact would have materialized even though roads were under the OPRC.

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[5] Although the RDA status reports show that all the rehabilitation works were completed when the follow-up survey was carried out, the perception of road users was sometimes different. Some respondents along the treatment roads indicated that roads were still under rehabilitation, for example, D128 in Chipata District and U29 in Katete District (RDA, 2031).

On the other hand, agricultural production could be increased by any road improvement work, even though it is implemented under the traditional input-based contracts. For instance, RD585 and D60 in Katete were selected as paired roads in the control group but improved outside of the ADSP OPRC. Based on the users' perspective, in total, about 62 percent of the roads received significant rehabilitation works in both treatment and control groups (RDA 2013).

To examine this impact, the following equation is considered:

$$\begin{aligned} \ln V_{it} &= \beta_0 + \beta_1 WORK_{it} + \beta_2 t + \beta_3 WORK_{it} \cdot t + \beta_4 \ln POT_{it} \\ &\quad + \sum_k \beta_k \ln x^*_{ikt} + \sum_k \gamma_k D_{ikt} + \sum_m \beta_m z_{imt} + u_{it} \end{aligned} \tag{4}$$

where *WORK* is equal to one if actual road work is carried out. To deal with the endogeneity issue, the same instruments are used. In addition, *OPRC* is also included as another instrument. It is believed that the existence of OPRCs could affect the likelihood of receiving road improvement and maintenance works, because the contractors were obliged to keep the roads in good condition.

IV. DATA

Micro data were collected though two household surveys carried out before the project in 2009 and after the project in August to November 2012. The follow-up data were collected before the full completion of the OPRCs, which started in March 2009 and ended in March 2014. Thus, the impacts measured by the surveys are presumably associated with the initial rehabilitation works in the first year of the contracts. However, some emergency and maintenance works were also implemented in not only treatment but also control areas before the follow-up survey. Hence, the measured impacts may also reflect these effects.

The OPRC roads were not selected randomly but chosen based on existing agricultural potential. For each of the OPRC roads, a comparable road was selected in the same and adjoining districts, based on socioeconomic characteristics, proximity to social facilities, such as schools and health clinics, as well as access to the main trunk road (**Figure 7**). For each road (both treatment and control), at least 20 households were surveyed in each of the standard enumeration areas (SEAs) that the road passes. In total, the baseline survey covers about 650 households in Chipata (**Table 2**) and about 780 households in Katete (**Table 3**).

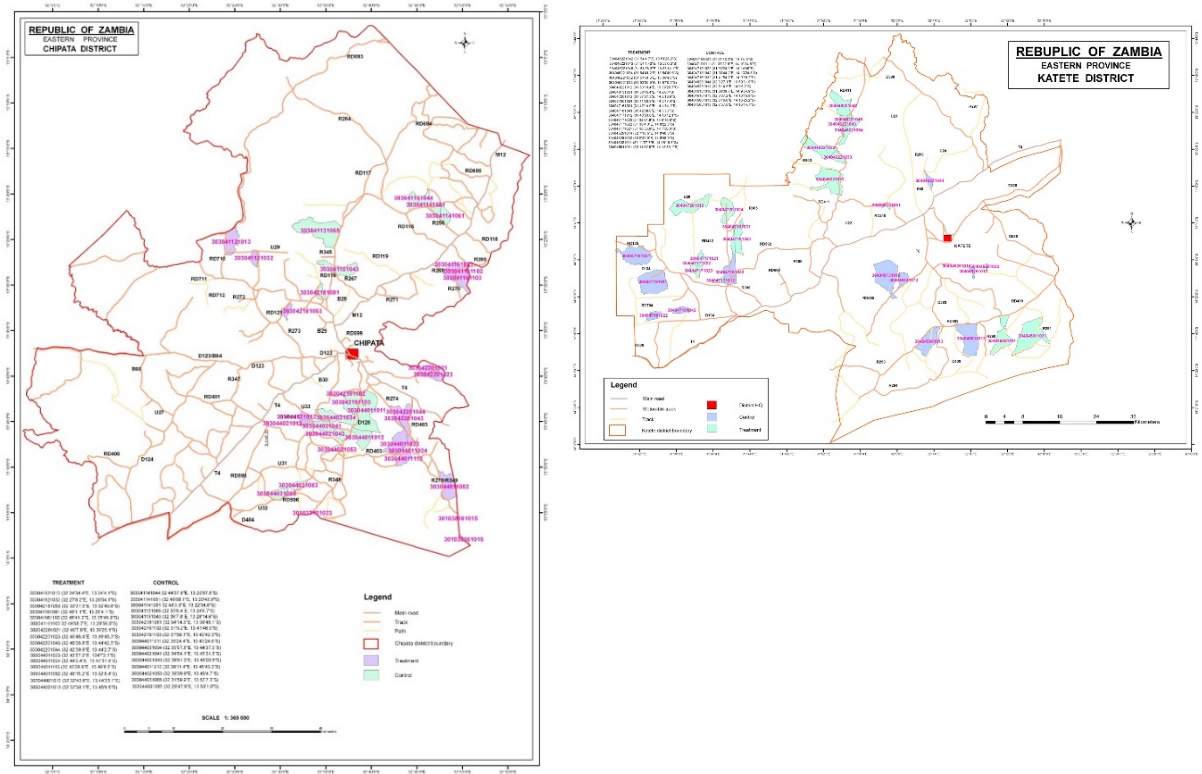
Table 2. Sample size for Chipata

	Treatment	Obs.		Control	Obs.	
Road pair		t=0	t=1		t=0	t=1
A1	R128 up to RD596	120	119	RD403	120	120
A2	R128 first part	39	39	D131	40	40
A3	R348-RD596			U33		
A4	R348-RD596	40	40	U33	20	20
A5	RD116/B28/R267	40	40	RD709, RD710	40	40
A6	RD116/B28/R267	20	20	D12-R273, RD121	20	24
A7	R266-RD166	60	60	R269, RD268, RD270-RD118	60	58
B1	RD596	20	20	D130 in Chadiza	20	20
	Total	339	338		320	322

Table 3. Sample size for Katete

	Treatment	Obs.		Control	Obs.	
Road pair		t=0	t=1		t=0	t=1
A1	U29	20	20	RD585	40	41
A2	R291	40	39	D583-RD409	40	0
A3	RD410	20	19	D60-R296	20	20
A4	R306	40	40	RD703-R308	40	39
A5	U20-RD412	40	60	RD704, RD705, RD135	40	40
B1	RD411-R303, RD687	140	119	RD582 in Petauke	12	11
B2	U20-RD412	80	100	RD582 in Petauke	60	62
B4	RD412	40	39	RD413 in Petauke	41	42
B6	U29	41	43	R286 in Chadiza	39	35
	Total	461	479		332	290

Figure 7. SEAs along treatment and control roads in Chipata and Katete



As expected, the OPRC and control households are broadly comparable according to their basic characteristics. There is no statistical difference in demographics, such as household size and age of household head (**Table 4**). Living conditions are also broadly similar, however, availability of certain infrastructure services, such as water supply, is slightly different. But the differences are numerically very small. To ensure statistical comparability between the two groups, a conventional matching technique is used: Only 2 observations are found outside the common support, and thus, excluded from the following empirical analysis.

Table 4. Comparison of household characteristics between treatment and control group

	OPRC=0	*OPRC*=1	Difference		
	Mean	Mean	Mean	Std.Err.	
HH size	5.24	5.42	0.18	0.13	
Male HH head	0.80	0.79	-0.01	0.02	
HH head age	42.64	41.57	-1.06	0.85	
HH head educational attainment	4.23	4.33	0.11	0.19	
Concrete floor of the house	0.11	0.11	0.00	0.02	
Borehole use as a main source of water supply	0.650	0.586	-0.064	0.024	***
Tap water as a main source of water supply	0.008	0.021	0.013	0.006	**
Toilet use (pit latrine, ventilated, or flush)	0.481	0.447	-0.034	0.024	
Electricity or gas use as a main source of lighting	0.065	0.050	-0.015	0.011	
HH assets:					
Solar panels	0.062	0.080	0.018	0.013	
Vehicle	0.002	0.006	0.004	0.003	
Motorcycle	0.024	0.023	-0.001	0.008	
Bicycle	0.618	0.635	0.018	0.024	
Mobile phone	0.256	0.275	0.019	0.022	

The summary statistics are shown in **Table 5**. The average value of crop production is US$801 or about ZKW4,000 per household. Recall that in Zambia about 78 percent of the rural population lives below the national poverty line.[6] In Chipata and Katete District, the poverty rates are estimated at 72.6 percent and 82.9 percent, respectively (World Bank 2015). The agro-climatic potential exceeds US$4,300, which is five times more than currently produced. The currently dominant production system is clearly subsistence farming, with little fertilizer and few pesticides. Average land cultivated is about 1.6 ha. Only about one-third of the households participated in market transactions.

[6] In Zambia, the income distribution is highly skewed. According to the Government of Zambia, the threshold of poverty is defined by the nation's 2010 food basket to meet minimal nutritional requirements, which is ZKW96,366 per household (6 household members). This is significantly higher than many households' incomes. ZIPAR (2013), analyzing the income distribution in the country, indicates that the threshold of household income for the lower income group is ZKW510 in 2012. This group is estimated to account for about 24 percent of the total population.

Table 5. Summary statistics

Variable	Abb.	Obs	Mean	Std. Dev.	Min	Max
Total value of 7 crops produced (maize, cotton, cassava, tobacco, vegetable, soybean, groundnuts)	*V*	2,049	801	2,306	9	80,359
Total value of 7 crops sold	*SALE*	749	749	1,212	11	19,408
Dummy variable for roads under OPRC	*OPRC*	2,049	0.563	0.496	0	1
Dummy variable for roads where actual work was implemented	*WORK*	1,895	0.563	0.496	0	1
Dummy variable for the period after the project	*t*	2,049	0.474	0.499	0	1
Total value of 7 crops that could potentially be produced given agro-climatic conditions	*POT*	2,046	4,354	17,919	173	776,212
Number of 16 household members aged 16 or older who do not have wage job	*L*	2,030	2.984	1.723	1	17
Total land used (ha)	*H*	2,046	1.632	4.304	0.063	162.279
Total seeds used (kg)	*S*	2,038	37.194	35.829	0.500	411.600
Total fertilizer used, including both basal and top dressing (kg)	*F*	1,071	279.94	431.20	1	6000
Total spending on pesticides (ZKW)	*P*	330	110,488	100,232	5,000	1,500,000
Total spending on transport services to bring produce to market (ZKW)	*TR*	172	39,214	75,080	2	440,000
Size of household	*SIZE*	2,049	6.025	2.667	1	19
Dummy variable for male household head	*MALE*	2,049	0.785	0.411	0	1
Age of household head	*AGE*	2,049	43.829	15.240	1	94
Years of education attained by household head	*EDU*	2,049	4.507	3.836	0	71
Dummy variable for concrete	*CONC*	2,049	0.136	0.343	0	1
Dummy variable for	*TOIL*	2,049	0.516	0.500	0	1
Dummy variable for household possessing motorcycle	*MOTO*	2,049	0.019	0.137	0	1
Dummy variable for household possessing bike	*BIKE*	2,049	0.679	0.467	0	1
Dummy variable for Chipata District	*CHIPATA*	2,049	0.502	0.500	0	1
Slope angle of terrain (degree)	*SLOP*	2,049	2.779	3.585	0.220	22.733
Elevation (meter)	*ELEV*	2,049	1,049	115	823	1,437
Distance to a main trunk road, T4 (km)	*KMT4*	2,049	15.282	8.624	1.297	36.111

V. MAIN RESULTS

The instrumental variable (IV) regression is performed to estimate Equation (2). First of all, the IV approach is found to be appropriate with our data. The exogeneity test statistics are estimated at 30.51 and 50.98 with the Battese specification and the small-positive number specification (**Table 6**). Both are well above the conventional significance value. Thus, it is confirmed that the selection of OPRC roads is not exogenous. On the other hand, the overidentifying restriction tests indicate that our selected instruments are valid. The estimated test statistics are well below the critical value: The hypothesis that the instruments are not correlated with *V* cannot be rejected.

Second, from the empirical specification point of view, the Battese model fits the data better than the conventional small-positive number model. According to the Wald statistics, the overall goodness of fit is much greater at 845.3 in the Battese model. In addition, the hypothesis that all coefficients of d(*S*), d(*F*), d(*P*) and d(*TR*) are zero can be rejected easily with a test statistic of 22.41. Therefore, the Battese specification can be accepted. As discussed above, the small-positive-number model generated the possibly underestimated impacts of production factors that have a number of zero observations. See Battese (1998) for more discussion.

For the impact of OPRC, it is found that the impact is statistically significant. The coefficient of *OPRC**t* is positive at 4.57 under the Battese specification. The marginal effect is estimated at 1.30. Thus, it can be concluded that the OPRC increases agricultural production. The estimation result also indicates that everything else assumed constant, total agricultural production declined significantly between 2009 and 2012. The coefficient of *t* is estimated at -2.59, which is also significant. This may have been attributed to the relatively poor rainfall in 2012.

Regarding other variables in the estimated production function, land (*H*), seeds (*S*) and fertilizer (*F*) are found productive. The coefficients of ln*H*, ln*S* and ln*F* are all significantly positive. Particularly, the result indicates that the elasticity of land is particularly high: This must reflect the current production system in Zambia, which is highly land-intensive. On the other hand, labor (*L*) does not seem to be an important production factor. The coefficient is still positive but not significant, possibly indicating the fact that labor is abundant. There is little use of pesticides and transportation services for market sales. These impacts are not significant.

Overall, the estimated production function exhibits constant returns to scale: The sum of the coefficients of the six production factors is estimated at 1.081 with a standard error of 0.155. The null hypothesis of constant return cannot be rejected.

Table 6. Instrumental variable estimation: OPRC effect

	Battese's specification			Small-positive-number model		
	Coef.	Std.Err.		Coef.	Std.Err.	
*OPRC*t*	4.574	(2.777)	*	6.902	(3.248)	**
OPRC	-1.595	(1.356)		-2.323	(1.573)	
t	-2.590	(1.536)	*	-3.953	(1.776)	**
ln *POT*	0.014	(0.042)		-0.552	(0.217)	**
ln *L*	0.021	(0.082)		0.022	(0.114)	
ln *H*	0.418	(0.084)	***	1.058	(0.275)	***
ln *S*	0.334	(0.090)	***	0.009	(0.037)	
ln *F*	0.180	(0.065)	***	0.020	(0.006)	***
ln *P*	0.119	(0.096)		0.051	(0.013)	***
ln *TR*	0.009	(0.031)		-0.004	(0.013)	
d (*S*)	1.657	(0.437)	***			
d (*F*)	0.540	(0.310)	*			
d (*P*)	0.402	(1.058)				
d (*TR*)	0.164	(0.308)				
ln *SIZE*	0.050	(0.083)		0.124	(0.111)	
d (*MALE*)	0.033	(0.082)		0.056	(0.115)	
ln *AGE*	0.145	(0.103)		0.210	(0.142)	
ln *EDU*	0.070	(0.037)	*	0.008	(0.006)	
CONC	0.047	(0.101)		0.175	(0.138)	
TOIL	0.167	(0.081)	**	0.279	(0.106)	***
MOTO	0.436	(0.219)	**	0.636	(0.309)	**
BIKE	0.043	(0.075)		0.051	(0.105)	
CHIPATA	0.276	(0.133)	**	0.336	(0.170)	**
Constant	3.068	(1.264)	**	10.544	(1.662)	***
Obs	2049			2049		
R-squared	-0.456			-2.127		
Wald chi2	845.43			338.76		
Exogeneity test:						
C statistic (chi2)	30.541 ***			50.977 ***		
Overidentifying restriction:						
Hansen's J statistic (chi2)	2.098			0.490		
Marginal effect of *OPRC*	1.301	(0.790)	*	1.964	(0.924)	**

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

One might be concerned about the magnitude of the estimated marginal effect of OPRC. One possible reason is that the estimated coefficient may include the effect of agro-climatic potential. Recall that the OPRC roads were selected based on agricultural potential. In addition, the underlying crop production patterns may have changed significantly during the project implementation period.

To investigate this, the simple average DID estimator is considered. Note that our data are cross-sectional at two periods of time, not panel data. The double difference statistics need to be adjusted with the weight, *w*, given by kernel matching (Heckman, Ichimura and Todd, 1997):

$$\alpha = \frac{1}{n_1}\sum_i \left\{ q_{i1} \middle| OPRC = 1 - \sum_j w(i,j) q_{j1} \middle| OPRC = 0 \right\} - \frac{1}{n_0}\sum_i \left\{ q_{i0} \middle| OPRC = 1 - \sum_j w(i,j) q_{j0} \middle| OPRC = 0 \right\}$$

While maize production in the sample area increased between 2009 and 2012, other crops, including groundnuts, which is another important crop produced in the survey area, were harvested much less (**Table 7**). This is consistent with the national agriculture statistics: Zambia experienced a significant drop in agriculture production in 2012/2013. Particularly, cotton production in 2012/13 decreased by nearly 50 percent because of unfavorable market prices in the Southern African region. In our data, no cotton production was recorded in the follow-up survey.

Together with these drastic changes in production patterns, the significant increase in maize production is likely to explain the measured large impact of OPRC on the total production value. Maize production in the OPRC areas increased from 1,385 kg to 2,208 kg, which is more than 50 percent growth. Although production in the control group also increased, the net impact is significant at 209 kg per household. The net impact on groundnuts production is also significant at 40 kg per household, a more than 10 percent increase.

Table 7. Simple average DID estimator

	Before		After		Double difference		
	Treatment	Control	Treatment	Control	Coef.	Std.Err.	
Production (kg)							
Maize	1,385	1,049	2,208	1,511	361	209	*
Cotton	1,905	1,215					
Cassava	850	1,025	325	500			
Tobacco	885	468					
Vegetable	700	499	447	1,038	-793	1,085	
Soybean	285	384	397	571	-76	192	
Groundnuts	366	452	296	271	111	40	***

*, ** and *** indicate the statistical significance at the 10, 5 and 1 percent, respectively.

To answer the question of why OPRC has a positive impact on agriculture production, Equation (4) is estimated using the same set of independent variables as above. This also addresses a likely question of whether this is because of OPRC or road maintenance works in general regardless of contractual arrangements. The results are broadly unchanged: The selected instruments are valid, and the impact of *WORK* is positive and significant (**Table 8**). This is the main reason for the observed OPRC impact. Not surprisingly, the statistical significance of *WORK* is much higher than that of *OPRC*. Holding everything else constant, crop production was increased where road improvement works were actually implemented regardless of contractual arrangements. This is obvious: Without actual works, people's connectivity would not be improved. The marginal effect is estimated at 0.95. Notably, however, this does not mean that OPRC has no effect on connectivity. It has an important indirect impact (see further discussion below).

Technically, the measured impact can be associated with all kinds of works implemented, such as rehabilitation, gravel roads, emergency works, installation of culverts and road signs. Given the timeline of the project implementation and follow-up survey, it is likely to be the impact of initial rehabilitation works under OPRC. But other possibilities cannot be excluded.[7]

[7] To answer this question, more detailed and frequent data would be needed on both project implementation and farmers' behavior (i.e., household surveys).

One difference from the previous estimation result is that the production function with *WORK* exhibits increasing returns to scale. The degree of returns to scale is estimated at 1.236 with a standard error of 0.122. However, the production system, again, looks highly land-intensive: The coefficient of land, *H*, is the largest at 0.55 among production factors. Labor is positive and weakly significant, but its elasticity is much smaller than land.

Table 8. Instrumental variable estimation: Actual work effect

	Battese's specification			Small-positive-number model		
	Coef.	Std.Err.		Coef.	Std.Err.	
*WORK*t*	3.424	(1.306)	***	4.147	(1.470)	***
WORK	-1.183	(0.685)	*	-1.211	(0.764)	
t	-1.916	(0.717)	***	-2.336	(0.783)	***
ln *POT*	0.028	(0.026)		-0.497	(0.179)	***
ln *L*	0.131	(0.070)	*	0.160	(0.085)	*
ln *H*	0.551	(0.076)	***	1.054	(0.197)	***
ln *S*	0.268	(0.086)	***	0.037	(0.037)	
ln *F*	0.136	(0.043)	***	0.010	(0.006)	*
ln *P*	0.192	(0.089)	**	0.043	(0.008)	***
ln *TR*	-0.041	(0.031)		0.019	(0.006)	***
d (*S*)	1.409	(0.454)	***			
d (*F*)	0.500	(0.254)	**			
d (*P*)	1.340	(0.982)				
d (*TR*)	-0.610	(0.274)	**			
ln *SIZE*	-0.018	(0.066)		0.043	(0.079)	
d (*MALE*)	0.001	(0.067)		0.022	(0.078)	
ln *AGE*	0.069	(0.068)		0.139	(0.086)	*
ln *EDU*	0.104	(0.036)	***	0.010	(0.005)	**
CONC	0.114	(0.089)		0.275	(0.106)	***
TOIL	0.013	(0.065)		0.083	(0.075)	
MOTO	0.188	(0.228)		0.300	(0.269)	
BIKE	0.084	(0.064)		0.125	(0.074)	*
CHIPATA	0.518	(0.126)	***	0.640	(0.147)	***
Constant	3.104	(1.195)	***	9.775	(1.618)	***
Obs	1891			1891		
R-squared	-0.456			-0.408		
Wald chi2	1142.21			639.14		
Exogeneity test:						
C statistic (chi2)	33.342	***		44.399	***	
Overidentifying restriction:						
Hansen's J statistic (chi2)	1.328			5.603	*	
Marginal effect of *WORK*	0.949	(0.362)	***	1.149	(0.407)	***

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

The first stage regression can provide more insight into the relationship among the OPRC, actual road works and the resultant agricultural production growth. From the IV estimation with OPRC, it is found that the coefficient of *SLOP* is negative and significant (**Table 9**). This can be interpreted to mean that more road improvement and maintenance works are needed where the slope of the terrain is less steep, and therefore, more drainage capacity is needed. The coefficient of *KMT4* is also found to be significant. It is consistent to the view that the project was focused on remote and isolated areas.

The second column model of the table shows that the use of OPRC contributed to more frequent road works. Recall that regardless of the project, local governments and communities can implement some other road maintenance or emergency works, whenever needed. But since the government has already been committed to the 5-year maintenance under the OPRC, the treatment roads were more likely to receive necessary road works in a timely manner. The coefficient of *OPRC* is significantly positive at 0.18, meaning that the OPRC roads have an 18 percentage point higher probability of receiving road works than other non-OPRC roads. There seems to be a systematic difference in share of households with actual work between OPRC and non-OPRC areas (**Figure 8**). As discussed above, this is the most important indirect effect of OPRCs.

This result is consistent with another model to test the placebo effect. No significant impact of OPRC is found when the data are limited to cases where no road improvement works were carried out. The sub-sample size is 828, and the estimated coefficient of *OPRC***t* is -14.28 with a standard error of 14.72 (**Table 10**). Thus, the OPRC can have an impact only if actual work is implemented. This is considered as the same effect as the placebo effect.

Table 9. First stage regression results for *OPRC* and *WORK* selection

Dependent var.	*OPRC* Coef.	Std.Err.		*WORK* Coef.	Std.Err.	
OPRC				0.180	(0.021)	***
ln *SLOP*	-0.030	(0.013)	**	-0.010	(0.011)	
ln *ELEV*	0.263	(0.164)	*	0.753	(0.119)	***
ln *KMT4*	0.240	(0.020)	***	0.243	(0.020)	***
t	0.031	(0.026)		0.029	(0.022)	
ln *POT*	0.021	(0.017)		0.006	(0.010)	
ln *L*	-0.017	(0.027)		0.018	(0.023)	
ln *H*	-0.016	(0.030)		-0.011	(0.020)	
ln *S*	-0.018	(0.021)		0.014	(0.017)	
ln *F*	0.021	(0.015)		-0.005	(0.015)	
ln *P*	0.043	(0.033)		-0.052	(0.030)	*
ln *TR*	-0.029	(0.011)	***	0.021	(0.010)	**
d (*S*)	-0.195	(0.160)		0.340	(0.121)	***
d (*F*)	-0.014	(0.075)		-0.046	(0.075)	
d (*P*)	0.413	(0.376)		-0.591	(0.341)	*
d (*TR*)	-0.167	(0.089)	*	0.098	(0.077)	
ln *SIZE*	0.023	(0.028)		-0.049	(0.023)	**
d (*MALE*)	-0.030	(0.029)		0.012	(0.025)	
ln *AGE*	-0.026	(0.034)		-0.012	(0.025)	
ln *EDU*	0.003	(0.013)		0.020	(0.012)	*
CONC	0.020	(0.033)		-0.051	(0.028)	*
TOIL	-0.054	(0.023)	**	-0.040	(0.021)	*
MOTO	0.052	(0.090)		-0.119	(0.048)	**
BIKE	0.088	(0.025)	***	-0.008	(0.023)	
CHIPATA	-0.128	(0.032)	***	-0.548	(0.027)	***
Constant	-2.162	(1.255)	*	-4.578	(0.947)	***
Obs	2049			1891		
R-squared	0.1145			0.357		
F-statistic	15.9			77.62		

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

Figure 8. Share of households affected by actual road works

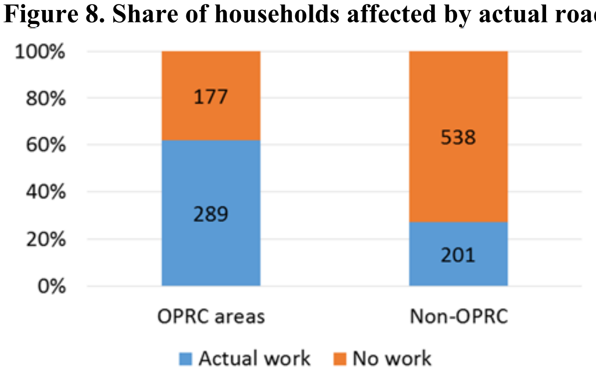


Table 10. Instrumental variable estimation with limited samples where no actual works took place

	Battese's specification			Small-positive-number model		
	Coef.	Std.Err.		Coef.	Std.Err.	
*OPRC*t*	-14.283	(14.719)		-19.312	(17.122)	
OPRC	7.306	(7.479)		10.176	(8.852)	
t	6.157	(6.450)		8.214	(7.515)	
ln *POT*	0.044	(0.093)		-1.251	(0.913)	
ln *L*	0.502	(0.535)		0.714	(0.650)	
ln *H*	0.324	(0.298)		2.103	(1.389)	
ln *S*	0.566	(0.317)	*	-0.131	(0.271)	
ln *F*	-0.176	(0.382)		-0.043	(0.059)	
ln *P*	0.640	(0.756)		-0.006	(0.032)	
ln *TR*	-0.109	(0.185)		0.101	(0.073)	
d (*S*)	6.477	(3.608)	*			
d (*F*)	-0.409	(1.253)				
d (*P*)	7.378	(8.963)				
d (*TR*)	-2.607	(2.710)				
ln *SIZE*	-0.345	(0.502)		-0.529	(0.693)	
d (*MALE*)	0.156	(0.392)		0.120	(0.460)	
ln *AGE*	-0.215	(0.442)		-0.277	(0.594)	
ln *EDU*	-0.007	(0.206)		-0.002	(0.033)	
CONC	0.607	(0.704)		0.715	(0.682)	
TOIL	-0.260	(0.511)		-0.310	(0.605)	
MOTO	-0.724	(1.165)		-1.044	(1.580)	
BIKE	0.233	(0.320)		0.352	(0.446)	
CHIPATA	-0.168	(0.465)		-0.398	(0.616)	
Constant	-2.523	(7.780)		14.447	(7.231)	***
Obs	828			2049		
R-squared	-10.247			-19.669		
Wald chi2	46.76			17.72		
Exogeneity test:						
C statistic (chi2)	20.394	***		31.318	***	
Overidentifying restriction:						
Hansen's J statistic (chi2)	0.108			0.245		

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

Finally, the impact of OPRC on market sales is examined: The total value of crops sold in the market is regressed on the same independent and instrumental variables as above. No significant impact of OPRC is found. The coefficient of *OPRC*t* is not significant.

On the other hand, the impact of actual road improvement is found to be positive, but the observed impact seems to be relatively weak: The marginal impact is 0.273, and it is only significant at the 10 percent level. All the indications are that although OPRCs or road improvements in general are conducive to increasing crop production, people still may not benefit from possible market opportunities. Their market participation is limited. This is generally consistent with a view that transport services may not be available or too expensive, even though roads are improved. The coefficient of transport spending, of which the available data are limited to less than 90 households at each round of the surveys, is negative and significant, meaning that high transport service prices are constraining farmers' market sales.

In addition, feeder roads should form one road network, but there are still many roads that are in poor condition in the study area. Finally, other complementary facilities and services, such as warehouses and processing mills, may also be needed to facilitate people's market participation.

Table 11. Instrumental variable estimation of total crop sales

	Battese's specification			Battese's specification		
	Coef.	Std.Err.		Coef.	Std.Err.	
*OPRC**t*	-2.545	(1.834)				
OPRC	1.895	(0.647)	***			
*WORK**t*				2.087	(1.111)	*
WORK				0.100	(0.474)	
t	0.465	(1.019)		-2.000	(0.606)	***
ln *POT*	0.254	(0.118)	**	0.292	(0.124)	**
ln *L*	0.190	(0.226)		0.204	(0.201)	
ln *H*	0.823	(0.310)	***	0.868	(0.322)	***
ln *S*	-0.734	(0.629)		-0.901	(0.619)	
ln *F*	0.129	(0.072)	*	0.136	(0.068)	**
ln *P*	0.222	(0.188)		0.332	(0.182)	*
ln *TR*	-0.027	(0.045)		-0.092	(0.039)	**
d (*S*)	-54.199	(60.434)		-55.077	(58.760)	
d (*F*)	0.994	(0.408)	**	1.092	(0.392)	***
d (*P*)	2.080	(2.089)		2.852	(2.001)	
d (*TR*)	-0.834	(0.406)	**	-1.172	(0.336)	***
ln SIZE	0.092	(0.142)		0.222	(0.131)	*
d (*MALE*)	-0.237	(0.333)		-0.230	(0.313)	
ln *AGE*	0.126	(0.162)		0.259	(0.162)	*

ln *EDU*	0.036	(0.080)	0.092	(0.073)	
CONC	0.190	(0.136)	0.284	(0.131)	**
TOIL	0.120	(0.112)	-0.011	(0.114)	
MOTO	0.215	(0.389)	0.374	(0.388)	
BIKE	0.193	(0.252)	0.269	(0.236)	
CHIPATA	-0.028	(0.213)	0.453	(0.273)	*
Constant	2.107	(1.784)	1.676	(1.680)	
Obs	753		697		
R-squared	-1.995		-2.012		
Wald chi2	373.99		388.95		
Exogeneity test:					
C statistic (chi2)	19.888	***	15.052	***	
Overidentifying restriction:					
Hansen's J statistic (chi2)	0.000		0.016		
Marginal effect	-0.419	(0.302)	0.273	(0.145)	*

The dependent variable is the log of total crop sales, *SALE*. Robust standard errors are shown in parentheses. *, ** and *** indicate the statistical significance at the 10, 5 and 1 percent, respectively.

VI. Conclusion

Rural access is among the most important infrastructure elements to stimulate economic growth in rural and remote areas. Many rural farmers and local businesses are still likely faced with a crucial constraint to have access to input and output markets. The literature is generally supportive of the importance of feeder road connectivity in rural areas. Without the feeder road network maintained in good condition, it is difficult to improve agricultural productivity and encourage farmers to particulate in market transactions.

One of the most important challenges lies in maintenance of feeder roads. It is often neglected under budget pressure given limited available resources. Particularly, unpaved feeder roads require more frequent maintenance. Output- and performance-based road contracting (OPRC) is considered as an important policy instrument to ensure sustainability of road maintenance after the road rehabilitation. It normally requires contractors to not only improve roads but also maintain them through routine and emergency works.

Using the instrumental variable technique, the paper examined the impact of the recent OPRC experience in Chipata and Katete Districts, Zambia. By comparing the two areas: one area along the feeder roads under the OPRCs, and another area where socio-economic characteristics are broadly similar and there are comparable feeder roads but there are no OPRCs, it is found that the OPRC has a significant impact on agricultural production. This is mainly attributed to the positive impact on production of maize and groundnuts, two major crops grown in the study region.

Most of the measured OPRC impacts are associated with actual road improvement works regardless of contractual arrangements. This is obvious: Without actual works, people's connectivity would not be improved. On the other hand, any road work can improve people's connectivity if it is not OPRC. The most important effect of the OPRCs is that the OPRC can increase the probability of receiving necessary road works whenever needed. The government has already been committed to the 5-year maintenance under the OPRCs, and the contractors are explicitly obliged to maintain those roads to meet the agreed performance criteria. Regardless of OPRCs, the government will carry out road improvement and maintenance works, whenever necessary, and it actually did. However, road works on non-OPRC roads seem to be more vulnerable to budget pressure. Without OPRCs, the probability of receiving road works is 18 percentage points lower than OPRC roads.

Road improvement works can also contribute to facilitating farmers' market participation. The impact of actual road improvement is found to be positive and significant, though relatively weak. People's market participation is generally limited because of a number of constraints. Of particular note, the impact of transport service costs is found negative on farmers' market sales. It is consistent with the view that transport services may not be available or too expensive, even though roads are improved.

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