THE IMPACT OF INFRASTRUCTURE AND ACCESS TO MARKETS ON LAND VALUES IN RWANDA

Zain Nanji

Undergraduate Honors Thesis

Economics – Spring 2019

University of California, Berkeley

Advisor: Marco Gonzalez-Navarro*

Abstract

The Land Tenure Regularization program initiated by the Rwandan government in 2009 has provided a unique research opportunity to study the Rwandan economy through land values. This paper employs a fixed effects model to measure the impact of infrastructure development and access to markets on land values in Rwanda. The results demonstrate that these factors, measured using the distance of land parcels to national roads and Kigali, are crucial determinants of land values. These findings are highly significant and robust, and suggest that policymakers should prioritize infrastructure investment as a tool of economic growth.

* I would like to sincerely thank my thesis advisor, Professor Marco Gonzalez-Navarro, for his continued guidance and mentorship throughout this process. I would also like to express my deepest gratitude to my family for their endless support and belief in me.

1 Introduction

At 416 people per square kilometer, Rwanda has the highest population density among all African countries. Naturally, high population density poses serious land pressures, necessitating the need for strong land tenure laws. This, however, was not the case for Rwanda. Population pressures and conflict over land is believed to be one of the key issues that led up to the Rwandan genocide. Following the end of the conflict, the return of refugees combined with the rapid and violent transfer of land during the genocide severely strained Rwanda's informal system of land tenure. Under this structure, most land had been temporarily acquired, as opposed to permanent ownership, through practices such as leasing, government allocation, and informal occupation. In order to prevent the outbreak of another civil conflict, Rwanda initiated land reforms beginning in 2004.[1]

In 2009, the Rwandan government established the Land Tenure Regularization (LTR) program with the aim of registering and administering all land ownership in Rwanda. One of the key aspects of this initiative was the efforts to digitize and create a centralized database of all land transactions in Rwanda. This has had numerous benefits for the people of Rwanda, such as more efficient facilitation of land transfers, greater housing security, and even increased female empowerment, as demonstrated by Ali et al (2014) and Daley et al (2010). Moreover, this also provides researchers with a unique and unprecedented way of studying the Rwandan economy, especially for an African country, where such data is generally not available.

After a quarter century of stagnant growth from 1975-2000, sub-Saharan Africa has experienced rapid economic growth since 2000, averaging over 5% per annum, according to the World Bank. Over this period, Rwanda became one of the fastest growing African nations, averaging over 7% growth annually. Overall economic growth around the continent has been

[1] "Land Reform in Rwanda." Centre for Public Impact. December 21, 2017.

accompanied by solid infrastructural developments, rapid population growth, the rise of metropolitan cities, expansion of major markets, and tremendous growth in property values.

Using the data on land transactions in Rwanda, this paper seeks to understand how infrastructure and access to markets impact land values, an important indicator of economic performance. The distance of a particular parcel of land to a national road is used as a measure of infrastructure, and distance to Kigali is used as a proxy for access to markets. With a population of over one million people, Kigali is by far Rwanda's largest and most developed city. In comparison, no other city in the country has a population over 100,000. Kigali is the economic and cultural hub of Rwanda. As a result, proximity to Kigali indicates access to the largest and most important market in the country.

The rest of the paper will be organized as follows. Section 2 provides a discussion of existing literature related to the question at hand. Sections 3 and 4 explore the data and methodology used in this study in greater detail. Section 5 presents the results and implications of my analysis. Section 6 concludes and considers policy implications. An Appendix is also included to display figures of maps and regression tables for the various robustness checks.

2 Literature Review

Infrastructure development and market accessibility have long been recognized as key determinants of land value, and subsequently economic growth. In their paper, Coffman and Gregson (1998) look at how the development of railroads in the American Midwest during the 1840's and 1850's impacted land values, focusing their study in Knox County, Illinois. The authors determined that proximity to Galesburg—the main market in Knox County—was a key component of land values in the area, as the costs of transportation increased with distance from Galesburg, as expected. However, with the development of railroads in the region, the price of a plot of land increases for every given distance to Galesburg. In other words, many farms that were previously too far from Galesburg, that is their transportation costs were too high, could now become profitable. Thus, the railroad integrated more of the surrounding areas into the local economy. The authors calculated a lower bound estimate of $270,000 in aggregate capital gains in the 1850's due to the development of the railroad system in Knox County, or 9% of the land's value. Furthermore, capital gains varied by townships, and those that experienced the largest appreciations in land value were closer to the railroad, as well as had more sections through which the railroad traversed. For example, Salem reaped capital gains of 27.6%, the highest returns of the 19 townships in Knox County. Salem also had the lowest average distance to the railroad (0.68 miles) and the highest number of cross-sections (12). In contrast, the value of land in Victoria only appreciated by 1.4%, the lowest of any township. Victoria also happened to be furthest from the railroad on average (5.45 miles) and did not have any cross-sections. Lastly, benefits were not just realized through lower transportation costs and capital gains, but also through the increased volume of business that ensued following the development of railroads.

The development of infrastructure and access to markets have significant impacts on land values in the developing world too. In response to the rapid urbanization in Accra, Ghana in the 1970's and the challenges that accompanied it, Asabere (1981) argues that understanding the determinants of land values would better inform policymakers in developing strategies to address issues such as increasing traffic congestion and pollution. He develops a hedonic pricing model that takes into account a series of variables related to accessibility, location, cultural factors, time of the sale, and size of the land. Accessibility features include proximity to the Accra Central Market, class-A roads, and the sea. The Accra Central Market is the main economic hub of the city; the literature refers to this as the central business district, or CBD. Location is indicated by several dummy variables for whether the lot of land is located in a commercial zone, industrial zone, or a residential zone, which is categorized as high, middle, and low class. Cultural factors include whether or not the land was sold by a chief, and whether it was located in a predominantly homogeneous ethnic area or a more mixed heterogeneous one. Asabere finds that the closer a lot of land was to the CBD and major roads, the higher its value was, while the opposite was true for distance to the ocean, by virtue of being further from the city's economic center. Additionally, land values in commercial areas were higher, as they are located directly in the markets. High-end residential areas attracted high values, while the opposite effect was found for low-class areas, which is expected. Based on these findings, Asabere suggests a few policies to address certain urban challenges. He recommends more access roads be built, especially in poorer areas, to both reduce traffic and bring up low income residents. He also argues that decentralizing economic activities away from the CBD would reduce the rate of migration to Accra, thereby reducing congestion and supporting the development of other parts of Ghana.

In another paper, Jacoby (2000) examines the effect of rural roads and access to markets on rural development in Nepal, focusing particularly on redistributive effects. Building roads in rural areas is important for development as it provides relatively cheap access to markets in which farmers can not only sell their agricultural goods, but also purchase more advanced inputs for production and a wider variety of consumer goods. Better roads also provide rural residents with better access to schools and health facilities. Moreover, Jacoby finds that when travel time to a central market increases by 10%, the value of land decreases by 2.2%. Thus, road development essentially brings residents closer to larger markets. While he points out many positive effects of rural roads, however, Jacoby also finds that rural wages slightly decrease as travel time to markets decreases, although this relation is not statistically significant. Since his main goal is to understand whether building rural roads can redistribute wealth, he argues that such a policy is not effective at reducing inequality, as it benefits landowners through appreciated land values but does little for wage workers. Nonetheless, developing rural roads and infrastructure in general can bring many other advantages, as this study points out.

Most research looking at the impact of accessibility on land values—including some of the above papers—tend to use monocentric models, in which there is only one major market or economic hub that is taken into account when considering the value of a plot of land. However, Heikkila et al (1989) attempt to develop a polycentric model, in which the price of a plot of land depends more on how accessible it is to multiple sub-centers, or nodes. They look at properties in Los Angeles, a large, widely-spread city, to which such a model is well suited. They find that proximity to the Pacific Ocean and Santa Monica was a key determinant of land values, and highly statistically significant. Moreover, the estimate of the coefficient on distance to Los Angeles' CBD was insignificant. This would suggest that other nodes are becoming increasingly important. The authors list a few reasons to explain these findings. Firstly, in a large metropolitan city such as Los Angeles, there are multiple economic centers that provide job opportunities. As proximity to the workplace tends to be a key factor in an individual or a family's decision on where to live, areas with job growth naturally attract more residents. Secondly, individuals also consider other factors when choosing where to live, such as leisure opportunities. This would therefore explain the growth in the values of land around the Pacific Ocean and Santa Monica, as they provide access to many different activities beyond work.

Thus, by exploring the effects of infrastructure development and access to markets on land values in Rwanda, my paper seeks to expand on the existing literature and test the external validity of these findings in a previously unexplored country. Additionally, these studies on various determinants of land values point to factors I should look to control for to ensure my results are robust and in fact due to infrastructure and market access. By understanding the nature of this relationship, I hope this paper can contribute to driving policy changes regarding urban and rural development in order to foster greater economic, and more equitable, growth.

3 Data

3.1 Data on Land Transactions

The data on land transactions comes from a centralized database compiled by the Rwandan government in relation to the LTR initiative. The earliest transactions recorded are from 2014. While this initiative continues today, I only use data up to 2017. Each entry contains various details about the parcel of land that was transacted, including its location, price, and area. Location is specified by each of the five administrative levels discussed in the Introduction in Section 1, starting at the province level and going all the way down to the village. Prices are expressed in the national currency, the Rwandan franc.

Over the three-year period from 2014-2017, more than one million land transactions have been recorded. However, many observations are missing key details. Thus, the sample was determined by filtering out the transactions without prices or areas listed. After doing so, around twenty thousand observations remained. While this may cause some concern for selection bias, I verified that the sample was representative of the data. It contained transactions from all four provinces (not including Kigali City) and 11 of the 13 districts in the complete dataset. Over 250 cells are also included, thereby making me confident that the sample was indeed representative.[2] Figures 1 and 2 display district and cell maps of Rwanda respectively.

3.2 Data on Distance

The data on distance of specific cells to national roads and Kigali—the two key independent variables in this analysis—were gathered and extracted using ArcGIS. The geospatial layers were available in the archives of ArcGIS Online. I was then able to determine the distances of each cell to the nearest national road and Kigali. The distances are expressed in miles. A map of the national roads in Rwanda can be found in Figure 3.

[2] Rwanda is divided into 4 Provinces (not including Kigali City), 30 Districts, 416 Sectors, 2,148 Cells, and 14,837 Villages.

3.3 Data on Other Characteristics

The data on other characteristics come mostly from the same database as the land transactions data. Among the key details of each transaction, there are three particular dummy variables that describe the landscape of each parcel of land, specifically its wetland status: 1) whether it is a wetland, 2) whether it is partly a wetland, and 3) whether it previously was a wetland. These characteristics may indicate the level of rainfall each parcel of land receives, and more generally, a certain region receives. As land with greater rainfall tends to be more productive agriculturally, it is important to control for these factors. I also collected data on elevation. As with the distance data, I used ArcGIS to determine the average elevation in each cell. Figure 4 presents a topographical map of Rwanda.

4 Methodology

To analyze the effect of distance to national roads and access to markets on land values in Rwanda, I used the following regression model:

$$\ln(Price_{ict}) = \alpha_0 + \beta\ln(X_{ict}) + \delta\ln(area_{ict}) + \theta V_{ict} + \gamma_d + \sigma_t + \varepsilon_{ict}$$

In this model, $Price_{ict}$ is the outcome variable of interest. X_{ict} represents the two key independent variables: 1) the distance of a cell to a national road, and 2) the distance of a cell to Kigali. $area_{ict}$ refers to the area of the piece of land. V_{ict} is a set of controls for various land characteristics. These controls include wetland status and elevation. Each observation has a subscript of ict, which signifies land parcel i in cell c at time t. γ_d represents fixed effects at the district level, and σ_t is the year fixed effects. Lastly, ε_{ict} is the error term.

Before I ran my analysis, I winsorized my data. Winsorization is the process of replacing extreme values in the tail with those of the 1st percentile in the left tail and the 99th percentile in the right tail, to address the presence of outliers in the data. In this dataset in particular, certain land prices, especially in the left tail, appeared to be very skewed. Before winsorization, several observations had a price of one Rwandan franc, and more had extremely discounted prices. While these may have been the actual prices of the transactions, they are not accurate reflections of land values. Overall, however, winsorization did not change my estimates, although it does replace extreme values with more representative prices.

I chose to use fixed effects for both the district and year levels because it allows me to control for omitted variables. While each transaction in the regression is observed at the cell level, the fixed effects are used at the district level because the high number of cells in the dataset demonstrated too much variability. Consequently, the β coefficient was calculated as zero, which is an unreliable and inaccurate estimate. Furthermore, controlling by district is logical due to its administrative function. Districts are responsible for economic development and coordinating the delivery of public services. On the other hand, sectors, the next smallest administrative unit after cells, simply deliver those public services. Thus, districts actually do make policy decisions regarding the region under their jurisdiction.[3] As such, I use standard errors clustered at the district level because it is likely that the regression errors will have some sort of correlation within each cluster or district, but will be uncorrelated across clusters. Year fixed effects control for differences that occur from one year to the next, such as changes in inflation and rainfall.

I also chose to use a log-log regression specification. By doing so, I can measure how price changes with distance. Essentially, this allows me to determine the elasticity of price with respect to distances to infrastructure and markets. Moreover, since land values will vary quite heavily by transaction, measuring changes in percentage terms allows for comparison between districts on a relative scale.

[3] For more information regarding Rwanda's political structure, see the Rwandan Decentralization Strategic Framework (RDSF), which has been made publicly available online by the Rwandan government.

5 Empirical Results and Discussion

My findings are presented as six sets of regressions in Tables 1-6. Tables 1 and 2 show the effects of my key independent variables—distance to national roads and distance to Kigali—on land values. Tables 3-6 display the results from robustness checks. Each table contains four regressions. Columns 1 and 2 use OLS specifications, while Columns 3 and 4 use district and year fixed effects. Additionally, Columns 2 and 4 include controls for different land characteristics, while Columns 1 and 3 do not.

5.1 Land Values and Distance to National Roads

The regression results for the impact of a cell's distance to national roads on land values can be found in Table 1. From Column 1, I find that a 10% increase in the distance of a cell to a national road decreases land value by 0.47%, while the estimate for Column 2 is 0.44%. In Columns 3 and 4, I find that a 10% increase in the distance of a cell to a national road is associated with a 0.39% and 0.38% drop in land value, respectively. All results were statistically significant at the 1% level, demonstrating the importance of infrastructure development to land values.

Although these coefficients are statistically significant, they are relatively small compared to the findings made by Jacoby (2000), who estimated a 2.2% decrease in land value for a 10% increase in travel time, as discussed in Section 2. This discrepancy can be explained the notion of diminishing marginal returns. My estimates are calculated for Rwanda as a whole, regardless of whether the land transacted is urban or rural. Jacoby, however, studies rural Nepal, which is likely not as developed as Rwanda as a whole, especially considering this paper was released in 2000. Thus, returns to infrastructure will be higher in less developed areas, as initial returns to capital are higher than later returns. In the context of Rwanda and sub-Saharan Africa as a whole, where infrastructure is still fairly undeveloped relative to other developing regions in the world, constructing roads could generate massive returns to investment. Furthermore,

Table 1: Regressions of Land Values on Distance to National Roads

	Land Value			
	(1)	(2)	(3)	(4)
Distance to a National Road	-0.0470***	-0.0443***	-0.0389***	-0.0384***
	(0.00507)	(0.00508)	(0.00473)	(0.00473)
Area	0.207***	0.202***	0.232***	0.235***
	(0.00751)	(0.00757)	(0.00751)	(0.00762)
Controls				
Wetland		0.0549		0.478**
		(0.222)		(0.218)
Partial Wetland		-0.360***		-0.172*
		(0.102)		(0.105)
Previously Wetland		0.325***		0.298***
		(0.0754)		(0.0833)
Elevation		-0.315***		-0.301***
		(0.0579)		(0.0826)
Constant	12.40***	14.78***	12.83***	14.99***
	(0.0520)	(0.438)	(0.0488)	(0.589)
District Fixed Effects	No	No	Yes	Yes
Year Fixed Effects	No	No	Yes	Yes
Observations	19,287	19,287	19,287	19,287
R-squared	0.048	0.051	0.185	0.187

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

these returns would likely be even higher in rural areas. Differentiating returns on urban compared to rural infrastructure development could be a productive direction for future research. This could be carried about, for example, by looking at more regional level infrastructure, such as district roads.

5.1.1 Robustness Checks

I used two robustness checks to verify whether my findings were indeed sound. The first independent variable I use is a dummy variable for whether the cell is less than one mile away from a national road. Using OLS, I find that parcels of land within one mile of a national road are on average 11.3% more valuable than those further than one mile, as demonstrated in Column 1. Adding controls in Column 2, the estimate drops to 10.1%. Adding fixed effects to the model reduces the coefficients slightly. From Column 3, I find that parcels of land within one mile of a national road have on average 7.8% higher values. With controls, that premium decreases slightly to 7.5% All these results are statistically significant at the 1% level. The regression results can be found in Table 3 in the Appendix.

The second robustness check is similar to the first one above, except I am now comparing parcels of lands within two miles of a national road to those further out. From Column 1, I find that parcels of land within two miles of a national road are on average 10.1% more valuable. Adding controls, the estimate decreases to a 9.1% premium on average over parcels of land further than two miles away from a national road. As shown in Column 3, I find that parcels of land within two miles of a national road are on average 6.3% more expensive than those further out. Adding controls to the model, the estimate decreases slightly to 5.9%. Again, all these findings are statistically significant at the 1% level. The regression results can be found in Table 4 in the Appendix. Thus, these two tests demonstrate the relation between proximity to national roads and land value is highly robust.

An interesting point to note is that combining the two tests above indirectly provides a third check for my findings. For each regression specification, the estimates on the coefficients from the first robustness check are higher than those in the second one. Implicitly, this means that the average premium of land between one and two miles from a national road is less than that of land within one mile of a national road. As such, the second robustness check has lower coefficient estimates. This not only supports the idea that proximity to infrastructure is a crucial determinant of land values, but also suggests that prices are quite sensitive to access to infrastructure.

5.2 Land Values and Distance to Kigali

The regression results for the effect of a cell's distance to Kigali are presented in Table 2. Using a simple OLS specification in Column 1 yields a coefficient of -0.053, meaning that a 10% increase in the distance of a parcel of land to Kigali leads to a 0.53% drop in land value. Adding controls, as shown in Column 2, I find an estimate of a 0.66% decrease in land value. From Column 3, I find that a 10% increase in the distance to Kigali reduces value on average by 0.76%. Adding controls in Column 4, I find a 0.81% decrease in land value. As with distance to national roads, all these findings are also statistically significant at the 1% level, demonstrating that market access is a significant determinant of land value.

5.2.1 Robustness Checks

Again, I used two tests to verify the robustness of my results. The first check looks at how land values compare between those within 20 miles of Kigali and those further out. The OLS model suggests that land within 20 miles of Kigali is 10.9% more valuable, and with controls, 14.7% more valuable than those more than 20 miles away, as shown in Columns 1 and 2. The fixed effect models provides more moderate estimates. In Column 3, I find that parcels of land within 20 miles of Kigali are on average 9.3% more expensive. Adding controls in Column 4, the estimate increases to 10.2%. Nonetheless, all these results are statistically significant at the 1% level. The regression results can be found in Table 5 in the Appendix.

Similarly, the second robustness check uses a dummy of whether the parcel of land is within 40 miles of Kigali. The OLS estimates tell us that land within 40 miles of Kigali is 4.2% more valuable, and with controls, 5.2% more so. Using fixed effects, I find that land within 40 miles of Kigali is 14.9% more expensive than those further out. Adding controls increases that

Table 2: Regressions of Land Values on Distance to Kigali

	Land Value			
	(1)	(2)	(3)	(4)
Distance to Kigali	-0.0536***	-0.0663***	-0.0760***	-0.0811***
	(0.00990)	(0.0105)	(0.0109)	(0.0110)
Area	0.200***	0.204***	0.235***	0.236***
	(0.00773)	(0.00775)	(0.00776)	(0.00784)
Controls				
Wetland		-0.111		0.358
		(0.136)		(0.218)
Partial Wetland		-0.354***		-0.166
		(0.101)		(0.103)
Previously Wetland		0.428***		0.423***
		(0.0743)		(0.0826)
Elevation		0.285***		0.0802
		(0.0638)		(0.0839)
Constant	12.57***	10.46***	12.87***	12.29***
	(0.0666)	(0.472)	(0.0524)	(0.599)
District Fixed Effects	No	No	Yes	Yes
Year Fixed Effects	No	No	Yes	Yes
Observations	18,025	18,025	18,025	18,025
R-squared	0.045	0.048	0.176	0.177

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

estimate to 15.2%. Again, all these findings are statistically significant at the 1% level. The regression results can be found in Table 6 in the Appendix. Thus, both checks find that land value is robust in its relation to proximity to Kigali.

As with the first set of robustness checks for distance to national roads, these two tests can be considered together to determine more implicit and complex features about the relation between land values in Rwanda and their distance to Kigali. While the OLS coefficients for the first robustness check are higher than that of the second one, the estimates from the fixed effects model are lower, which may be somewhat surprising. There are multiple ways in which this finding can be interpreted. One possible explanation is that high road quality can offset the issue of being located further from Kigali, as strong infrastructure can better integrate surrounding areas into the economy. Another possibility is that a more polycentric model, as suggested by Heikkila et al (1989) and discussed in Section 2 above, is more relevant to Rwanda. While I argue above that Rwandan cities other than Kigali are likely too small to attract significant economic interest, and that the small area size of the entire country itself makes its economic activities more likely to be centered in Kigali, recent efforts at political decentralization may also affect economic centralization. This may be an interesting avenue for future research. Nonetheless, proximity to Kigali, Rwanda's most important market, is still a crucial determinant of land value.

5.3 Other Explanatory Variables

While the main independent variables of interest in this study are distance to national roads and distance to Kigali, other explanatory variables in my analysis also have significant effects on land value, and thereby merit some discussion. The first obvious one is area. All regressions suggest that a 10% increase in the size of a parcel of land increases land values by 2-2.4%. This relation is intuitive and unsurprisingly, highly significant.

The next interesting variables are those pertaining to whether the parcel of land observed has some sort of wetland status. The results are quite mixed, however. From the regressions using proximity to national roads as the independent variable, I find that on average, wetlands are about 48% more valuable, and previous wetlands 30% more so, statistically significant at the 5% and 1% levels, respectively. However, partial wetlands are about 18% less valuable, significant at the 10% level. From the regressions using proximity to Kigali as the independent variable, I find wetlands to be about 36% more valuable, although these coefficients are no longer significant. On the other hand, previous wetlands are now more valuable than before, 42% more to be precise. This finding is still significant at the 1% level. Lastly, partial wetlands are about 17% less valuable, which although is a similar estimate to the other regression, is no longer significant. Given Rwanda's reliance on agriculture, I would have expected wetlands and partial wetlands to be more expensive, while previous wetlands to be less valuable, as they may suggest soil exhaustion or aridity due to the change in wetland status.[4] However, less than 1% of land transactions in the dataset are assigned any one of these statuses, so the lack of observations contributes to the inconclusiveness of these results. I strongly believe that further research should be devoted understanding how factors relevant to agriculture—such as topography and climate shocks—affect land values in Rwanda.

The last variable of interest is elevation. Rwanda is known for its mountainous terrain and even referred to as the "Land of a Thousand Hills." This alone would suggest that elevation would have a noticeable effect on land values in Rwanda. The regressions using proximity to national roads suggest that a 10% increase in elevation decrease the value of land by 3%. On the other hand, the other regressions, which use proximity to Kigali, find no effect of elevation on land values. This is perhaps somewhat of a surprising result, given that farming tends to be less productive at high elevations. A more carefully constructed elevation variable, such as one that considers ideal elevation levels for agriculture or crop suitability to different elevations, may be more effective at determining its impact on land values. As such, I strongly recommend greater research in this direction.

[4] According to the Food and Agricultural Organization (FAO), a subsidiary of the World Bank, agriculture employs over 70% of the working age population, and over 70% of the land in Rwanda is devoted to agriculture.

6 Conclusion

This paper has studied the impact of infrastructure development and access to markets on land values in Rwanda. The results demonstrate that proximity to national roads and the capital city of Kigali are crucial determinants of land value. These findings are robust, highly statistically significant, and in line with existing literature. Moreover, adding controls for wetland status and elevation suggests that these factors may also be important components of land value, especially given the high share of agriculture in both employment and land use.

The findings of this paper also has several policy implications. Both proximity to infrastructure and markets are strongly correlated to land prices, but only one can be changed. Therefore, constructing and maintaining roads should be prioritized by both policymakers and international institutions. Moreover, new and better roads make transportation more accessible and efficient, and in doing so, facilitate access to markets by cutting down costs and traveling times, thereby better integrating previously disconnected regions. Better infrastructure and access to markets would also increase the volume of business, further supporting economic growth. This suggests a large multiplier effect for such investments.

The large impacts on Rwandan land values also have positive implications for the rest of Africa. As Rwanda is one of the more developed countries in sub-Saharan Africa, these effects could be even larger for less developed nations based on the notion of diminishing marginal returns. One point of concern, however, is that Rwanda is much smaller than other countries in terms of both area and population. Thus, while a monocentric model in which Kigali is the main market might work for Rwanda, it will be more difficult to implement such a model for larger countries. This would suggest that larger countries should look to develop multiple centers of large economic activity, rather than only one key market. The difference between the current and required levels of infrastructure in Africa is currently billions of dollars, so domestic and international institutions should work together to help bridge that gap.

References

Ali, Daniel Ayalew, Klaus Deininger, and Markus Goldstein. “Environmental and Gender Impacts of Land Tenure Regularization in Africa: Pilot Evidence from Rwanda.” *Journal of Development Economics* 110 (2014): 262-275.

Asabere, Paul Kwadwo. “The Determinants of Land Values in an African City: The Case of Accra, Ghana.” *Land Economics* 57, no. 3 (1981): 385-397.

Chaponda, Taz and Duncan Lishman. “Africa’s Prospects for Infrastructure Development and Regional Integration: Transport Sector.” In *Infrastructure in Africa: Lessons for Future Development.* Mthuli Ncube and Charles Leyeka Lufumpa, eds. Bristol University Press, Policy Press, 2017.

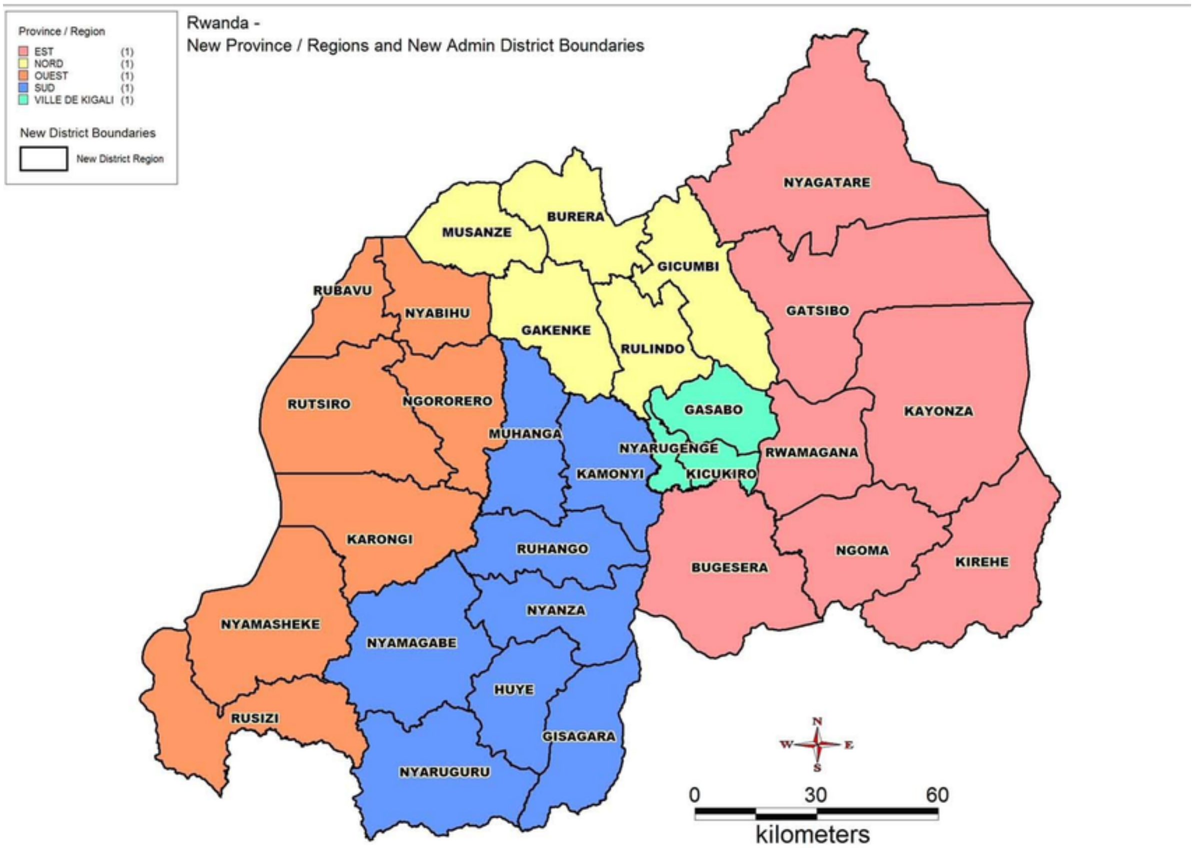
Daley, Elizabeth, Rachel Dore-Weeks, and Claudine Umuhoza. “Ahead of The Game: Land Tenure Reform in Rwanda and the Process of Securing Women's Land Rights.” *Journal of Eastern African Studies* 4, no. 1 (2010): 131-152.

Heikkila, Eric, Peter Gordon, Jae Ik Kim, Richard B. Peiser, Harry W. Richardson, and David Dale-Johnson. “What Happened to the CBD-Distance Gradient?: Land Values in a Policentric City.” *Environment and Planning A* 21, no. 2 (1989): 221-232.

Jacoby, Hanan G. “Access to Markets and the Benefits of Rural Roads.” *The Economic Journal* 110, no. 465 (2000): 713-737.

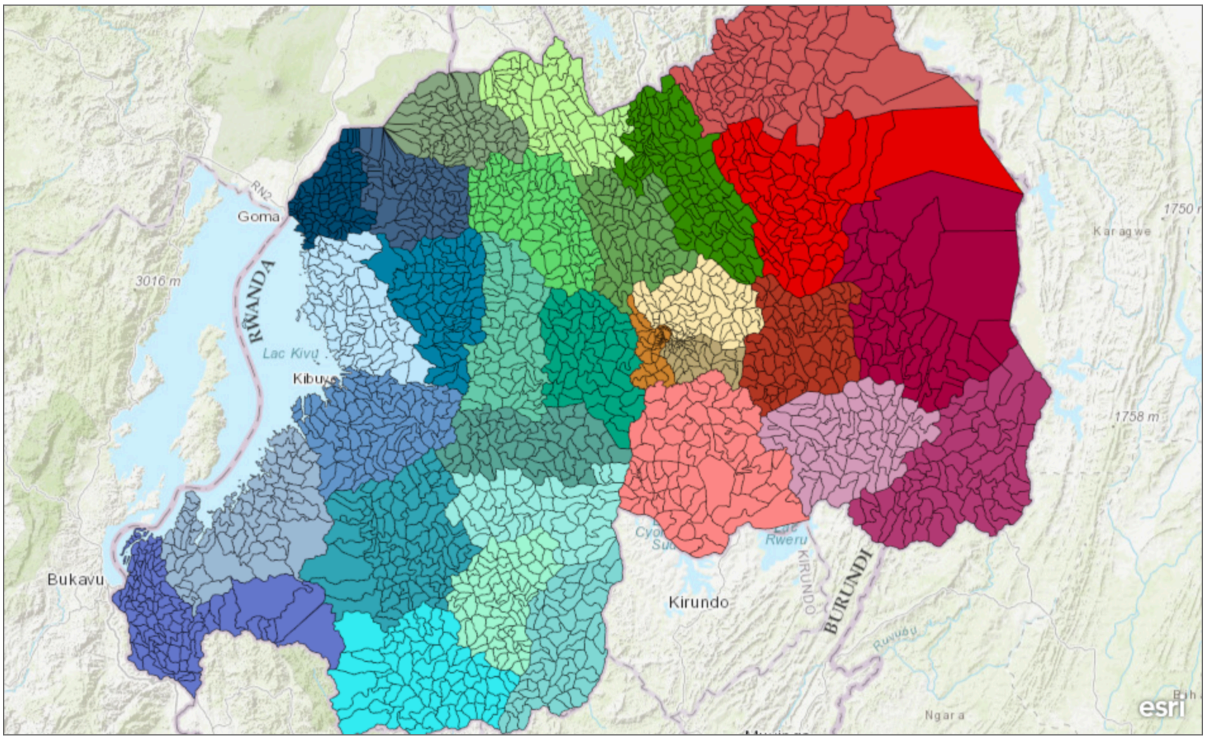
Appendix

Figure 1: Map of Rwandan Provinces and Districts



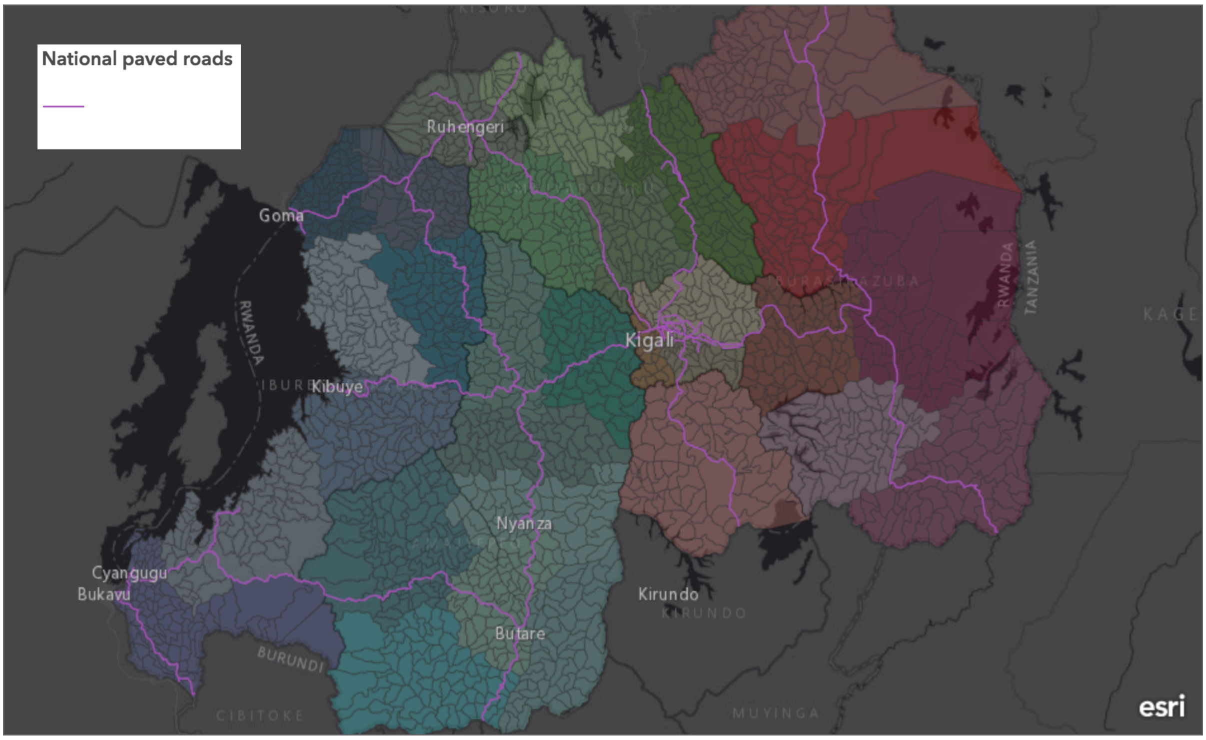
Source: Kalisa, Ina, Sabine Musange, David Collins, Uzaib Saya, and Theresa Kanda. "The Development of Community-Based Health Insurance in Rwanda - Experiences and Lessons." University of Rwanda College of Medicine and Health Sciences (2015).

Figure 2: Map of Rwandan Cells



Source: ArcGIS Online

Figure 3: Map of Rwandan National Roads



Source: ArcGIS Online

Figure 4: Map of Rwandan Topography

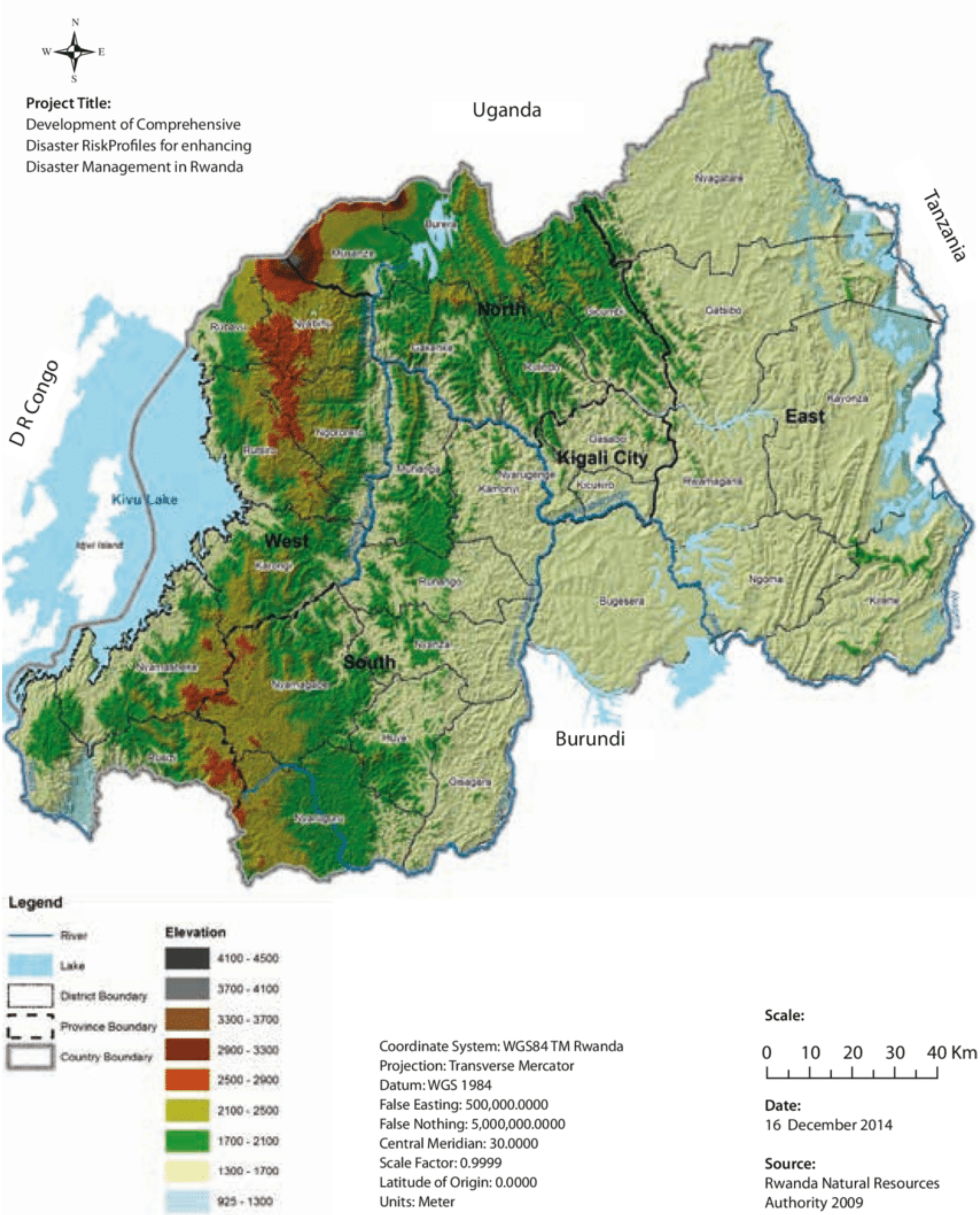


Table 1: Regressions of Land Values on Distance to National Roads

	Land Value			
	(1)	(2)	(3)	(4)
Distance to a National Road	-0.0470***	-0.0443***	-0.0389***	-0.0384***
	(0.00507)	(0.00508)	(0.00473)	(0.00473)
Area	0.207***	0.202***	0.232***	0.235***
	(0.00751)	(0.00757)	(0.00751)	(0.00762)
Controls				
Wetland		0.0549		0.478**
		(0.222)		(0.218)
Partial Wetland		-0.360***		-0.172*
		(0.102)		(0.105)
Previously Wetland		0.325***		0.298***
		(0.0754)		(0.0833)
Elevation		-0.315***		-0.301***
		(0.0579)		(0.0826)
Constant	12.40***	14.78***	12.83***	14.99***
	(0.0520)	(0.438)	(0.0488)	(0.589)
District Fixed Effects	No	No	Yes	Yes
Year Fixed Effects	No	No	Yes	Yes
Observations	19,287	19,287	19,287	19,287
R-squared	0.048	0.051	0.185	0.187

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2: Regressions of Land Values on Distance to Kigali

	Land Value			
	(1)	(2)	(3)	(4)
Distance to Kigali	-0.0536***	-0.0663***	-0.0760***	-0.0811***
	(0.00990)	(0.0105)	(0.0109)	(0.0110)
Area	0.200***	0.204***	0.235***	0.236***
	(0.00773)	(0.00775)	(0.00776)	(0.00784)
Controls				
Wetland		-0.111		0.358
		(0.136)		(0.218)
Partial Wetland		-0.354***		-0.166
		(0.101)		(0.103)
Previously Wetland		0.428***		0.423***
		(0.0743)		(0.0826)
Elevation		0.285***		0.0802
		(0.0638)		(0.0839)
Constant	12.57***	10.46***	12.87***	12.29***
	(0.0666)	(0.472)	(0.0524)	(0.599)
District Fixed Effects	No	No	Yes	Yes
Year Fixed Effects	No	No	Yes	Yes
Observations	18,025	18,025	18,025	18,025
R-squared	0.045	0.048	0.176	0.177

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Robustness Check with Distance to National Roads < 1 Mile

	Land Value			
	(1)	(2)	(3)	(4)
Distance to National Road < 1 Mile	0.113***	0.101***	0.0780***	0.0745***
	(0.0166)	(0.0167)	(0.0158)	(0.0158)
Area	0.207***	0.202***	0.232***	0.235***
	(0.00751)	(0.00757)	(0.00750)	(0.00762)
Controls				
Wetland		0.0441		0.481**
		(0.235)		(0.226)
Partial Wetland		-0.369***		-0.180*
		(0.102)		(0.104)
Previously Wetland		0.321***		0.289***
		(0.0755)		(0.0833)
Elevation		-0.318***		-0.299***
		(0.0584)		(0.0830)
Constant	12.35***	14.75***	12.78***	14.92***
	(0.0523)	(0.443)	(0.0486)	(0.592)
District Fixed Effects	No	No	Yes	Yes
Year Fixed Effects	No	No	Yes	Yes
Observations	19,287	19,287	19,287	19,287
R-squared	0.046	0.049	0.184	0.185

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Robustness Check with Distance to National Roads < 2 Miles

	Land Value			
	(1)	(2)	(3)	(4)
Distance to National Road < 2 Miles	0.101***	0.0911***	0.0630***	0.0586***
	(0.0150)	(0.0151)	(0.0142)	(0.0143)
Area	0.208***	0.203***	0.232***	0.235***
	(0.00751)	(0.00757)	(0.00751)	(0.00762)
Controls				
Wetland		0.0633		0.492**
		(0.236)		(0.226)
Partial Wetland		-0.369***		-0.178*
		(0.103)		(0.105)
Previously Wetland		0.318***		0.287***
		(0.0754)		(0.0832)
Elevation		-0.323***		-0.295***
		(0.0581)		(0.0828)
Constant	12.33***	14.77***	12.78***	14.89***
	(0.0527)	(0.441)	(0.0486)	(0.591)
District Fixed Effects	No	No	Yes	Yes
Year Fixed Effects	No	No	Yes	Yes
Observations	19,287	19,287	19,287	19,287
R-squared	0.046	0.049	0.183	0.185

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Robustness Check with Distance to Kigali < 20 Miles

	Land Value			
	(1)	(2)	(3)	(4)
Distance to Kigali < 20 Miles	0.109***	0.147***	0.0926***	0.102***
	(0.0214)	(0.0235)	(0.0229)	(0.0233)
Area	0.201***	0.205***	0.236***	0.237***
	(0.00774)	(0.00775)	(0.00776)	(0.00784)
Controls				
Wetland		-0.130		0.372*
		(0.136)		(0.216)
Partial Wetland		-0.351***		-0.169
		(0.102)		(0.104)
Previously Wetland		0.418***		0.386***
		(0.0740)		(0.0814)
Elevation		0.325***		0.0904
		(0.0665)		(0.0855)
Constant	12.36***	9.901***	12.67***	12.00***
	(0.0535)	(0.504)	(0.0558)	(0.616)
District Fixed Effects	No	No	Yes	Yes
Year Fixed Effects	No	No	Yes	Yes
Observations	18,025	18,025	18,025	18,025
R-squared	0.045	0.048	0.174	0.175

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Robustness Check with Distance to Kigali < 40 Miles

	Land Value			
	(1)	(2)	(3)	(4)
Distance to Kigali < 40 Miles	0.0423**	0.0524***	0.149***	0.152***
	(0.0171)	(0.0174)	(0.0178)	(0.0179)
Area	0.203***	0.206***	0.235***	0.236***
	(0.00772)	(0.00775)	(0.00776)	(0.00784)
Controls				
Wetland		-0.121		0.357
		(0.132)		(0.217)
Partial Wetland		-0.358***		-0.159
		(0.101)		(0.101)
Previously Wetland		0.410***		0.403***
		(0.0732)		(0.0818)
Elevation		0.206***		0.0441
		(0.0618)		(0.0838)
Constant	12.34***	10.78***	12.62***	12.29***
	(0.0535)	(0.470)	(0.0529)	(0.599)
District Fixed Effects	No	No	Yes	Yes
Year Fixed Effects	No	No	Yes	Yes
Observations	18,025	18,025	18,025	18,025
R-squared	0.044	0.046	0.177	0.178

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1