Public Disclosure Authorized

RESHAPING URBANIZATION IN RWANDA

Economic and Spatial Trends and Proposals

Public Disclosure Authorized

Public Disclosure Authorized

Note 3: Urbanization, Job Creation, and Poverty Reduction in Rwanda

Public Disclosure Authorized

WORLD BANK GROUP

December 2017

Standard Disclaimer:

This volume is a product of the staff of the International Bank for Reconstruction and Development/ The World Bank. The findings, interpretations, and conclusions expressed in this paper do not necessarily reflect the views of the Executive Directors of The World Bank or the governments they represent. The World Bank does not guarantee the accuracy of the data included in this work. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgment on the part of The World Bank concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

Copyright Statement:

The material in this publication is copyrighted. Copying and/or transmitting portions or all of this work without permission may be a violation of applicable law. The International Bank for Reconstruction and Development/ The World Bank encourages dissemination of its work and will normally grant permission to reproduce portions of the work promptly.

For permission to photocopy or reprint any part of this work, please send a request with complete information to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, USA, telephone 978-750-8400, fax 978-750-4470, http://www.copyright.com/.

All other queries on rights and licenses, including subsidiary rights, should be addressed to the Office of the Publisher, The World Bank, 1818 H Street NW, Washington, DC 20433, USA, fax 202-522-2422, e-mail pubrights@worldbank.org.

Cover photo: By Dr Antoine R. Gasasira (Own work) [CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0)], via Wikimedia Commons

Table of Contents

Cover Note v
Abstract vi
1. Introduction 1
2. How can urbanization contribute to poverty reduction? 5
3. Trend of poverty and job creation 10
3.1. Poverty 10
3.2. Nonfarm job creation 14
4. Linkage among poverty, job creation, and urbanization 17
4.1. Urbanization has contributed to poverty reduction since 2002 17
4.2. Faster urbanizing areas created more nonfarm jobs between 2002 and 2012 22
4.3. Poverty rates among farm workers declined faster in areas where nonfarm workers became better-off 26
5. Conclusions 29
References 30
Appendices 32
Appendix A. Descriptive statistics of geographic sector characteristics 32
Appendix B. Provinces in Rwanda 33
Appendix C. Market accessibility index 33
Appendix D. Travel cost across geographic sectors 34
Appendix E. Hot spot analysis 35
Appendix F. Econometrics models 36
Appendix G. Population density snapshots 37
Appendix H. Regression tables 42

Box
Box 1. Analytical approach 18

Figures
Figure 1. Changes in poverty headcount ratio and the number of poor, 2001/02 to 2011/12 1
Figure 2. Employment share, 2001 to 2011 2
Figure 3. Composition of contributions to poverty reduction, 2001 to 2011 2
Figure 4. Urban areas in 2002 and 2015 3
Figure 5. Per capita GDP and urban population rate, 2002 and 2015 5
Figure 6. Conceptual framework on urbanization links to poverty reduction 6
Figure 7. Population density and distance to the city core in secondary cities 7
Figure 8. Built-up ratio and distance to the city core in secondary cities 8
Figure 9. Population density and living standards in African countries 9
Figure 10. Geographic distribution of the total population and the poor, 2012 11
Figure 11. Number of multidimensional poor, 2002 and 2012 12
Figure 12. Spatial distributions of MPI in 2002 and 2012 12
Figure 13. Clusters of geographic sectors with high MPI and low MPI in 2002 and 2012 13

Figure 14. Geographic Sector MPI and distance and travel cost to the city core in Greater Kigali 13
Figure 15. MPI and distance to the city core in the six secondary cities 14
Figure 16. Shares of population and nonfarm employment among Kigali, the six secondary cities, and other areas, 2012 15
Figure 17. Number and share of nonfarm employment in Greater Kigali and the six secondary cities, 2002 and 2012 15
Figure 18. Changes in nonfarm employment share between 2002 and 2012 16
Figure 19. MPI, population density, and built-up ratio, 2002 and 2012 17
Figure 20. Estimated linkage between increasing density and poverty reduction 19
Figure 21. Estimated linkage between increasing density and poverty reduction by baseline density 20
Figure 22. Estimated linkage between increasing density and poverty reduction by geography 21
Figure 23. Linkage between increasing density and poverty reduction by travel cost to Kigali and market accessibility 22
Figure 24. Share of nonfarm employment, MPI, population density, and built-up ratio, 2002 and 2012 23
Figure 25. Estimated linkage between increasing density and nonfarm job creation by baseline density 24
Figure 26. Estimated linkage between increasing density and nonfarm job creation by geography 25
Figure 27. Linkage between increasing density and nonfarm employment share by travel cost to Kigali and market accessibility 25
Figure 28. MPI among farmers and non-farmers, 2002 and 2012 27
Figure 29. Linkage with poverty reduction among farmers 28
Figure 30. Direct, indirect, and total effects for poverty reduction among farmers 28
Figure 31. Rural accessibility index and MPI in selected secondary cities 30
Figure A1. Histograms of key variables 32
Figure B1. Greater Kigali and Provinces in Rwanda 33
Figure C1. Market Accessibility Index, 2012 33
Figure D1. Travel costs to Kigali 35

Tables

Table 1. Indicators of Multidimensional Poverty Index 10
Table 2. Summary of estimated linkage between increasing density and poverty reduction 20
Table A1. Summary statistics 32
Table C1. List of sectors by MAI (only MAI greater than 30) 34
Table H1. MPI and population density, 2002 and 2012 42
Table H2. MPI and built-up ratio, 2002 and 2012 42
Table H3. Changes in MPI (moderate poverty) and population density, 2002 and 2012 43
Table H4. Changes in MPI (severe poverty) and population density, 2002 and 2012 43
Table H5. Regional heterogeneity in density effects for poverty reduction 43
Table H6. Changes in MPI (moderate poverty) and built-up ratio, 2002 and 2012/14 44
Table H7. Changes in MPI (severe poverty) and built-up ratio, 2002 and 2012/14 44
Table H8. Changes in share of nonfarm employment and density between 2002 and 2012 44
Table H9. Changes in share of wage employment and density between 2002 and 2012 45
Table H10. Regional heterogeneity in density effects for nonfarm (wage) employment share 45
Table H11. MPI among farmers 45
Table H12. MPI among farmers (outside Greater Kigali) 46
Table H13. Estimation results of spatial fixed-effects models 46

Cover Note

Reshaping Urbanization in Rwanda: Economic and Spatial Trends and Proposals is an Advisory Services and Analytics (ASA), jointly provided by the Poverty and Equity Global Practice and the Social, Urban, Rural and Resilience Global Practice at the World Bank. The objective of this report is to inform the Government's policies and strategies on urbanization as a driver of economic development, job creation, and poverty reduction, through the following four stand-alone but closely related notes.

- Note 1: Urbanization and the Evolution of Rwanda's Urban Landscape
- Note 2: Internal Migration in Rwanda
- Note 3: Urbanization, Job Creation, and Poverty Reduction in Rwanda
- Note 4: Profiling Secondary Cities in Rwanda—Dynamics and Opportunities

Note 1 examines Rwanda's urbanization process since 2002 by analyzing satellite images and various other sources. The changes in urban population and built-up areas are discussed together with the characteristics of the urban system and urban form and—in view of the key policy and legal framework guiding Rwanda's urbanization process—the spatial economy of cities and production and dimensions of density and connectivity. Note 2 analyzes internal migration patterns of Rwandan households, mainly based on the last two household surveys, and discusses the main drivers or reasons for migration. Note 3 explores whether and to what extent urbanization—in the sense of increased density and enhanced connectivity—has resulted in job creation and poverty reduction in Rwanda. Note 4 provides a detailed analysis of the core secondary cities of the country, discussing their expansion in terms of urban area and population, economic profiles and potential, access to services, and urban development plans.

Abstract

This Note analyzes whether and how the country's rising urbanization levels (measured primarily by population density) are associated with nonfarm job creation and poverty reduction. By focusing on Rwanda's 416 geographic sectors for the decade from 2002 and 2012, the analysis shows that, overall, a 10 percent increase in population density at the geographic sector level was associated with a 1.2 percent lower multidimensional poverty index and 1.4 point higher share of nonfarm employment. These linkages are estimated to be stronger in the areas with higher population density as of 2002, were closer to Kigali, and/or had better market access. Although increasing population density was profoundly associated with poverty reduction and job creation in secondary cities and areas within a five-kilometer radius, those linkages are less clear in areas beyond five kilometers from the city cores. The finding highlights the importance of extending economic opportunities to the poor living in the outer areas of secondary cities, which accounts for a third of the country's poor population. This Note also finds that fewer farmers are poor where fewer nonfarm workers are in poverty in the same areas or surrounding areas, and the latter points to spillover effects.

1. Introduction

Rwanda achieved a sizable poverty reduction between 2001/02 and 2011/12. The proportion of poor in the country decreased by more than 20 percent, irrespective of poverty being measured on a monetary or non-monetary basis. According to the World Bank (2015a), the headcount ratio of monetary poverty decreased from 59 percent in 2001 to 45 percent in 2011 (Figure 1).[1] The proportion of people in multidimensional poverty—which does not directly encompass consumption but instead considers a variety of factors such as education, health, and living standards—decreased in parallel, from 44 percent in 2002 to 34 percent in 2012. Despite the declining poverty rates, measured either by consumption or by multidimensional poverty, the number of poor did not change much; nevertheless, given its steady population growth (2.6 percent annual growth), the country has reduced poverty considerably.[2]

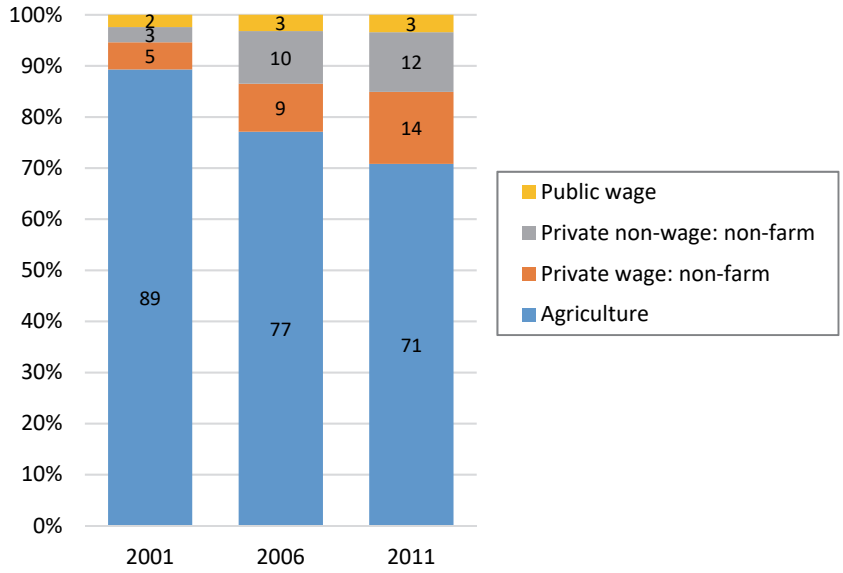
Figure 1. Changes in poverty headcount ratio and the number of poor, 2001/02 to 2011/12

Sources: Staff calculation based on 2002 and 2012 Census; World Bank (2015a) based on Integrated Household Living Conditions Survey (EICV3).

A recent report by the World Bank suggests that the increasing share of nonfarm employment in Rwanda has accounted for over a quarter of its poverty reduction. The share of nonfarm (private) employment increased from 8 percent in 2001 to 26 percent in 2011, while agriculture's share of employment decreased from 89 percent to 71 percent (Figure 2). A decomposition analysis of poverty changes between 2001 and 2011 (World Bank 2015a) indicates that alongside improvements in agricultural production and commercialization (respectively accounting for 20 percent and 12 percent of poverty reduction in Rwanda between 2001 and 2011), nonfarm jobs play a key role in poverty reduction (Figure 3).[3] Nonfarm self-employment and nonfarm wage employment contributed to 15 percent and 12 percent of poverty reduction during the decade, respectively.

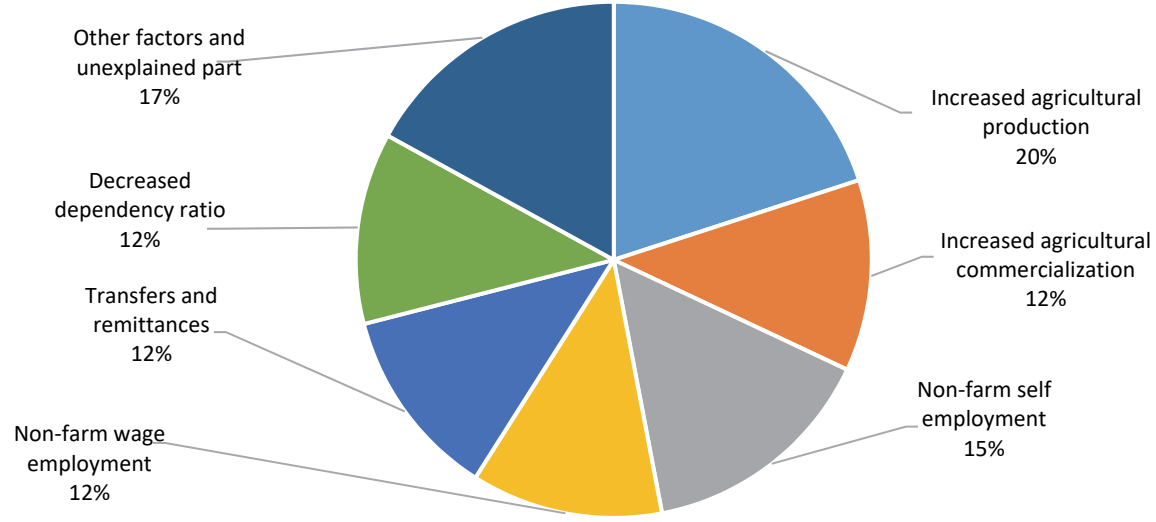
[1] Rwanda's national poverty line is set at RWF 118,000 per adult equivalent per year in 2011 prices.
[2] The number of consumption poor decreased very slightly from 4.8 million in 2001 to 4.7 million in 2011, whereas the number of multidimensional poor remained around 3.6 million during the period.
[3] Decomposing the poverty change into urban/rural difference is not technically straightforward because of the changes in urban definitions in EICV surveys.

Figure 2. Employment share, 2001 to 2011



Source: World Bank (2015b) based on EICV1, 2, and 3.

Figure 3. Composition of contributions to poverty reduction, 2001 to 2011



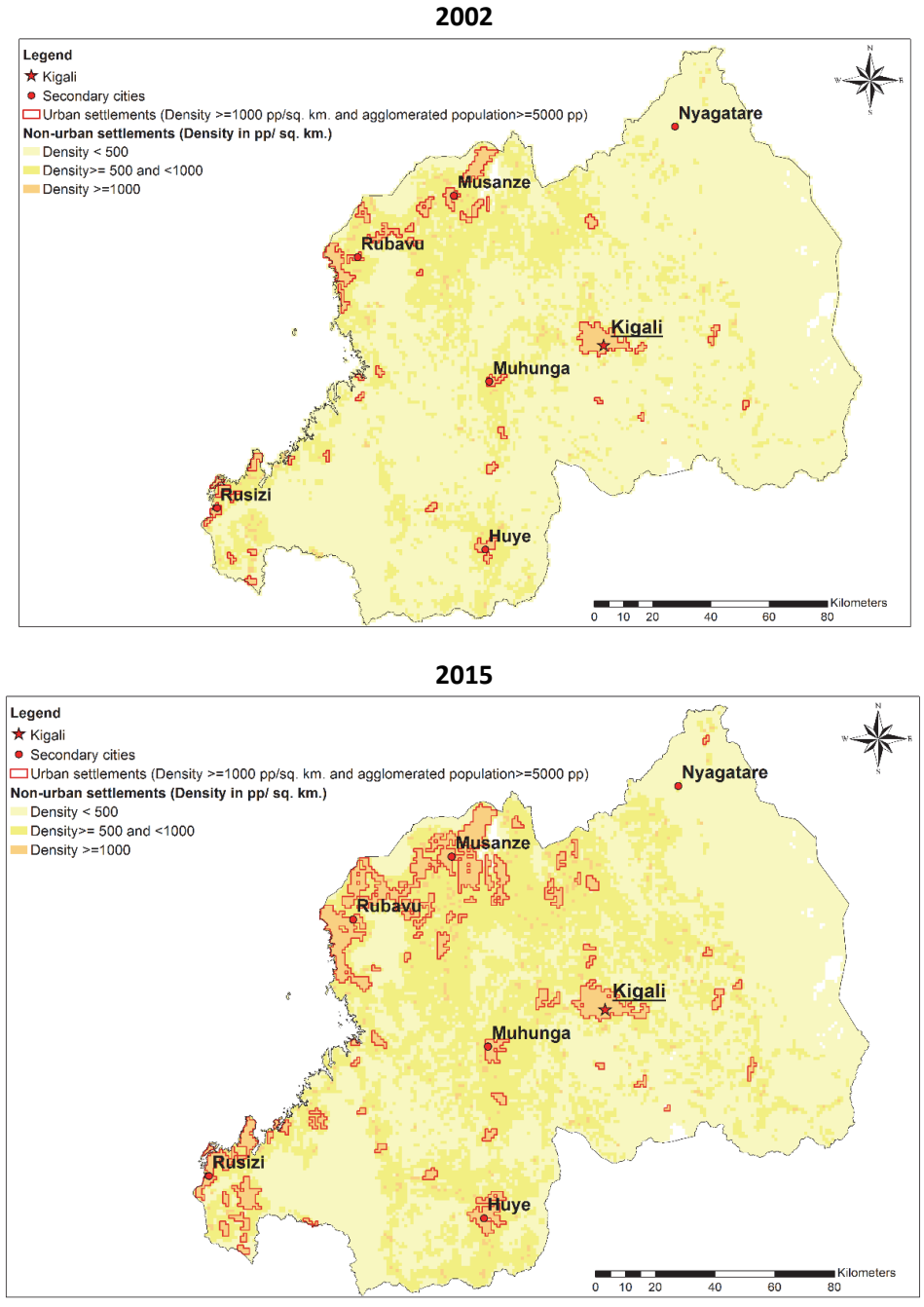
Source: World Bank (2015a) based on EICV1 and 3.

In tandem, Rwanda's urban population has more than doubled; however, it is not necessarily clear whether, and to what extent, such urbanization has facilitated poverty reduction. As reviewed in Note 1, urban areas are defined quite differently in the 2002 and 2012 Censuses, which makes it difficult to measure urban population growth over the decade. When an alternative urban definition is applied,[4] urban population in Rwanda increased profoundly from 1.5 million in 2002 to 3.5 million in 2015. The corresponding urban population rates are 15.8 percent and 26.5 percent, respectively. Urban growth has been prominent in Greater Kigali in the form of a low-density sprawl, while modest in secondary cities

[4] Under this definition, urban areas contain any village that accommodates 5,000 or more persons with a minimum density of 1,000 persons per km^2. See Note 1 for details.

except for the Rubavu-Musanze urban corridor (Figure 4). As examined in detail in Note 2, the recent urban population growth has been driven by a natural population increase rather than rural-to-urban migration.[5]

Figure 4. Urban areas in 2002 and 2015



Source: FY2016-17 Rwanda Economic Geography and Urbanization Study Note 1

[5] As Note 2 shows, however, rural-to-urban migration has been surging since 2011. For example, around 14 percent of Kigali residents as of 2014 migrated from rural areas during the last three years. Since this note focuses on the decade between two census years (2002-2012), this recent migration trend is not captured in the analysis.

Against the backdrop of Rwanda's urbanization and poverty reduction, this Note attempts to show to what extent, and how, urbanization has contributed to poverty reduction in Rwanda between 2002 and 2012, with a focus on job creation and the role of Kigali and secondary cities. The analytical approach in this Note is to focus on the country's 416 (geographic) sectors in 2002 and 2012, relating the changes in their population density to the share of nonfarm employment and multidimensional poverty index (MPI).[6] While Rwanda's household surveys (EICV) have a great advantage in its panel structure, the changes in their urban definitions make it difficult to relate urbanization to poverty reduction. The limited geographical representativeness of the surveys also hinders any nuanced spatial analysis. Therefore, the analysis in this Note focuses on the 416 geographic sectors, using 2002 and 2012 Census datasets. Although the census datasets do not include information about consumption, they still have enough information to calculate multidimensional poverty status for each person and, by aggregating those individual status, the MPI at each geographic sector. As a measure of the degree of urbanization, population density and the rate of built-up areas at the geographic sector level are used.

This Note presents the following key findings.

- **First and foremost, urbanization has contributed significantly to poverty reduction in Rwanda.** Urbanized areas tend to have a smaller proportion of residents in poverty. While this relationship has been observed both in 2002 and 2012, it is stronger in the latter. Moreover, changes in poverty rates between 2002 and 2012 are related to the urbanization process. The geographic sectors that increased population density and/or built-up ratio more than other geographic sectors tend to have greater reductions in poverty (in particular, severe poverty). This linkage between increasing population density and poverty reduction also depends on connectivity of geographic sectors, as measured by the distance to Kigali and market accessibility. The linkage between increasing density and poverty reduction is less clear in areas beyond 5 kilometers (km) from one of the secondary cities.

- **Second, increasing density is also related to a higher share of nonfarm employment.** The linkage between increasing population density and nonfarm job creation holds even after controlling for educational levels sector-wide. As with poverty, increasing density is less clearly associated with nonfarm job creation in areas beyond 5 km from one of the secondary cities.

- **Finally, it is found that farmers also benefited from the urbanization process**: Poverty reduction among non-farmers was associated with poverty reduction among farmers in the same geographic sectors. Furthermore, farmers were less likely to be poor when poverty rate of non-farmers not only in the same geographic sectors but also surrounding geographic sectors is lower.

This Note is structured as follows. Section 2 briefly discusses the conceptual framework on the linkage among urbanization, job creation, and poverty reduction, presenting three key questions to be explored in this note. Section 3 reviews recent trends of poverty and nonfarm jobs in Rwanda. Section 4 examines the three questions one by one, followed by a brief conclusion and policy implications in the last section.

[6] To avoid confusion with economic sectors, this note always refers to Rwanda's 416 sectors as geographic sectors.

2. How can urbanization contribute to poverty reduction?

In view of a positive relationship between urbanization and per capita gross domestic product (GDP) observed in countries around the world, Rwanda's per capita GDP is at a predictable level based on its urbanization rate in both 2002 and 2015. A clear trend emerges from a comparison of urbanization rate and the log of per capita GDP for countries in the world (Figure 5): the higher the urbanization rate, the higher the per capita GDP. Although Rwanda is among the countries with both the lowest urbanization rate and per capita GDP, the country is neither an outstanding underperformer (lower per capita GDP relative to urbanization rate) nor an outperformer (higher per capita GDP relative to urbanization rate).

Figure 5. Per capita GDP and urban population rate, 2002 and 2015

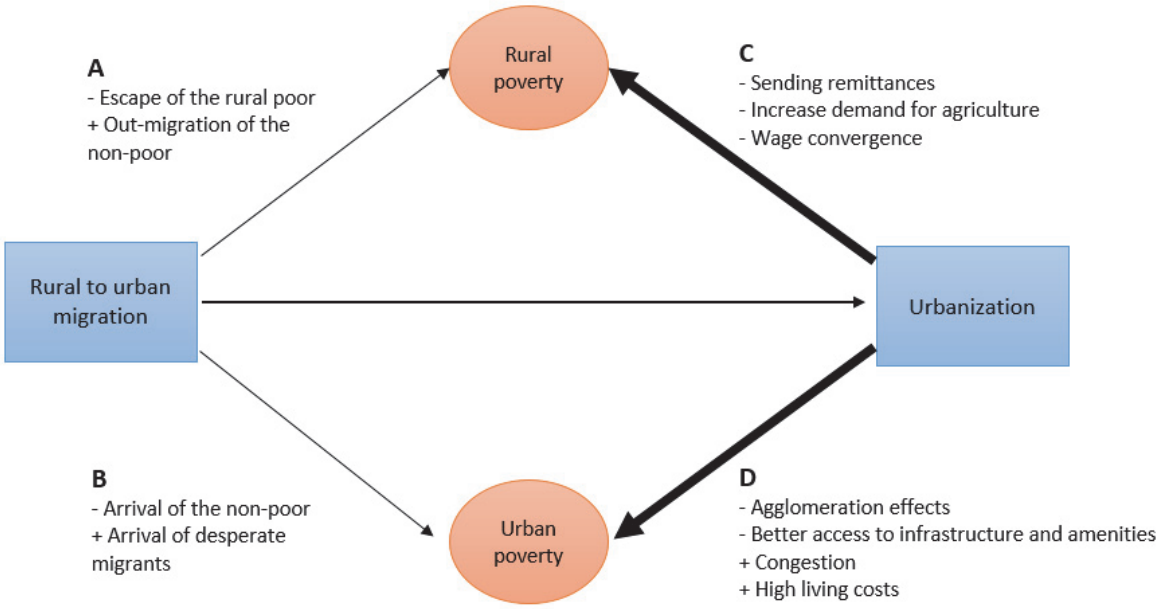
Source: Staff calculation based on World Development Indicators.
Note: Rwanda's urbanization rates are based on the definition of urban areas as any village that accommodates 5,000 or more persons with a minimum density of 1,000 persons per km^2.

In theory, urbanization potentially promotes poverty reduction in rural and urban areas.[7] Most directly, the rural poor can escape from poverty by migrating to urban areas where they can find more economic opportunities.[8] A related indirect effect of urban-rural migration is rural poverty reduction based on remittances sent by family members or relatives who migrated to cities (path C in Figure 6). Urbanization may also influence rural poverty indirectly by increasing the demand for local agricultural products or promoting a wage convergence between rural and urban areas, among other channels. With respect to urban poverty, urbanization potentially promotes economic growth and poverty reduction in urban areas by improving access to infrastructure, facilitating nonfarm job creation (structural transformation), and enhancing productivity through agglomeration effects (path *D* in Figure 6).[9] In fact, across Sub-Saharan

[7] See Christiaensen and Todo (2014) for more explanations.
[8] A positive linkage between migration and consumption is found in Bangladesh (Bryan, Chowdhury, and Mobarak 2014) and Tanzania (Beegle, de Weerdt, and Dercon 2011).
[9] A review of the empirical literature on agglomeration economies in various countries by Rosenthal and Strange (2004) suggests that the elasticity of income with respect to city population ranges from 3 percent to 8 percent, meaning that each doubling of city size increases productivity by 5 percent. A recent work for Colombia (Duranton,

Africa, half of the decline in poverty originated in urban areas and through the urbanization process (World Bank and IMF 2013).

Figure 6. Conceptual framework on urbanization links to poverty reduction



Note: Paths are not exclusive but only illustrative.

However, it is misleading to measure the effects of urbanization on poverty reduction based purely on migration and associated demographic changes. This Note aims to assess the linkage between urbanization and poverty reduction through the paths C and D in Figure 6. However, it is possible that rural-to-urban migration is dominated by individuals with better education levels and/or skills, who will become better-off regardless of their rural/urban residence. If their success in urban areas is simply due to their innate skills, rather than agglomeration effects or other benefits from urbanization, it is misleading to interpret their improved economic circumstance as due to urbanization. This Note will revisit this issue in the next section.

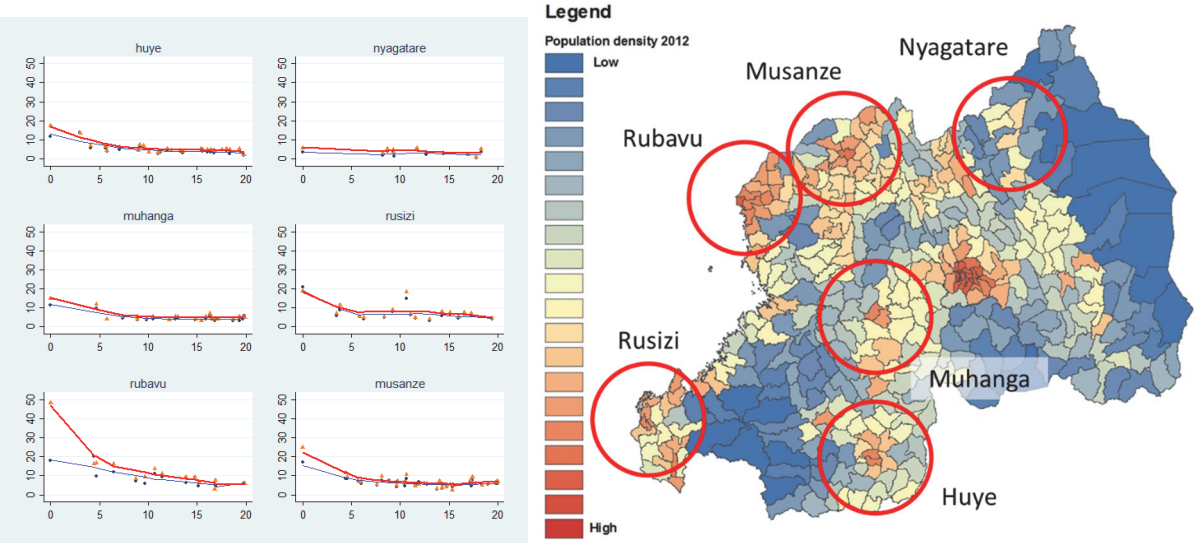
Some recent research emphasizes the role of secondary cities as an important driver of poverty reduction. While big cities function as the engines for economic growth, the absolute number of the rural poor who can migrate to those cities tends to be limited. Further, the lack of manufacturing and formal jobs in African cities makes economic survival difficult for those migrants, as reflected by higher unemployment (or underemployment) and urban-to-rural migration patterns that exist there. By contrast, the rural poor may find secondary cities more accessible, with more opportunities for nonfarm jobs and to diversify their economic activities. Recent research supports this in Tanzania (Christiaensen, de Weerdt, and Todo 2013) and India (Gibson, Datt, Murgai, and Ravallion 2017), though it is not obvious if this applies to a geographically small country like Rwanda.[10]

2016) estimates the elasticity of nominal wages with respect to population about 5 percent.

[10] Christiaensen, De Weerdt, and Todo (2013) analyze a panel of 3,300 individuals in rural Kagera, Tanzania from 1991 to 2010, finding that a majority of those who escaped from poverty diversified their economic activities in rural areas and/or moved to secondary cities, rather than big cities. Another study by Christiaensen and Todo (2014) analyzes household surveys of 51 low- and middle-income countries between 1980 and 2014. It finds that rural diversification

In this Note, the level of urbanization is measured primarily based on geographic sector-level population density, with built-up ratio as an alternative measure. As Note 1 explains, definitions of an urban area differ substantially between the 2002 and 2012 Censuses, making it challenging to compare the urbanization trend consistently. Thus, this Note uses geographic sector-level population density (the number of persons per square kilometer (km^2)) as an alternative proxy of the urbanization level. The geographic sector-level population in 2012 varied from 10,390 to 65,700. The size of sectors ranged from 1 km^2 to 642 km^2, the (unweighted) average being 58 km^2 (see Appendix A for descriptive statistics). The average density of the 416 geographic sectors increased from 725 persons per km^2 in 2002 to 878 persons per km^2 in 2012 (Appendix G illustrates increased density in the built-up areas over time).[11] Population density is relatively high in Kigali and in six secondary cities (Huye, Muhanga, Rubavu, Nyagatare, Rusizi, and Musanze) and their surrounding areas (Figure 7). Around the secondary cities, however, density tapers off about 10 km from the center, and density increased only slightly in those geographic sectors since 2002.[12] Similar patterns are observed when built-up ratio—the percentage of area covered by manmade surfaces (that is, built-up area), such as roofs, roads, and other infrastructure—is used as a measure of urbanization (Figure 8).

Figure 7. Population density and distance to the city core in secondary cities



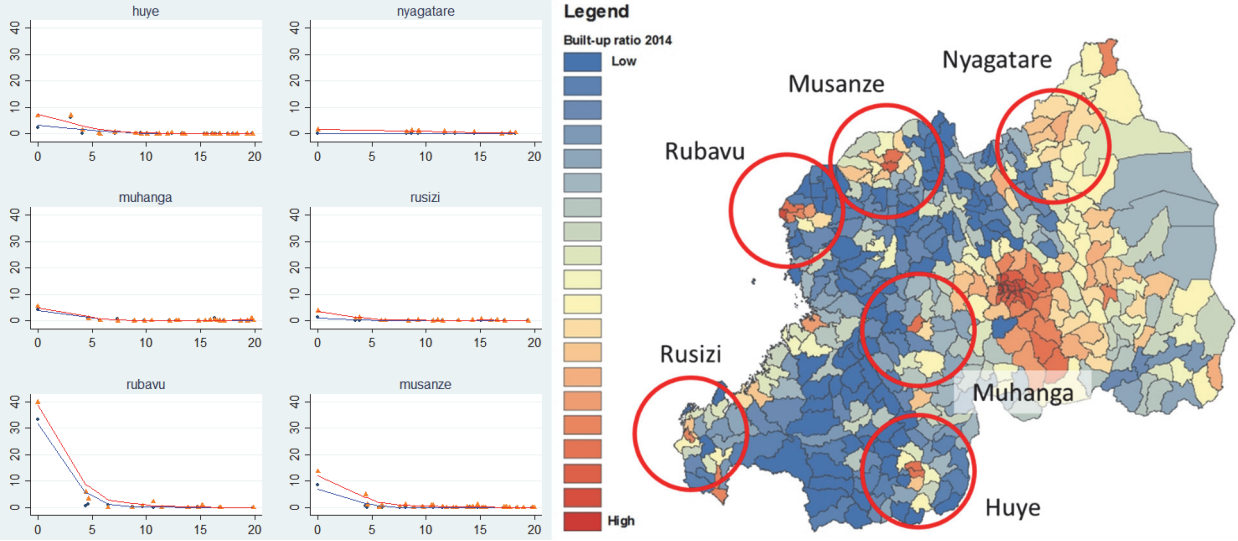
Source: Staff calculation based on 2002 and 2012 Census.
Note: On the left panel, the x-axis indicates distance from the center of the secondary city, and the y-axis indicates population density (hundred persons per km^2). Blue dots and red triangles indicate sectors in 2002 and 2012, respectively. Red lines and blue lines indicate smoothed trend lines in 2002 and 2012, respectively. On the right panel, a ring indicates a radius of 20 km from the center of the secondary city.

and secondary towns played an important role in poverty reduction.

[11] The average density at the sector levels (878 persons per km^2 in 2012), calculated by $\frac{1}{416}\sum_{i=1}^{416}(POPULATION_i/AREA_i)$ does not coincide with the officially-reported average density at the national level (415 in 2012) calculated by $(\sum_{i=1}^{416} POPULATION_i)/(\sum_{i=1}^{416} AREA_i)$.

[12] In this note, the distance between two sectors is calculated either as Euclidian distance between their centroids or as generalized travel costs (see Appendix D for the methodology).

Figure 8. Built-up ratio and distance to the city core in secondary cities



Source: Staff calculation based on 2002 and 2012 Census.
Note: On the left panel, the x-axis indicates distance from the center of the secondary city, and the y-axis indicates built-up ratio (%). Blue dots and red triangles indicate sectors in 2002 and 2012, respectively. Red lines and blue lines indicate smoothed trend lines in 2002 and 2012, respectively. On the right panel, a ring indicates a radius of 20 km from the center of the secondary city.

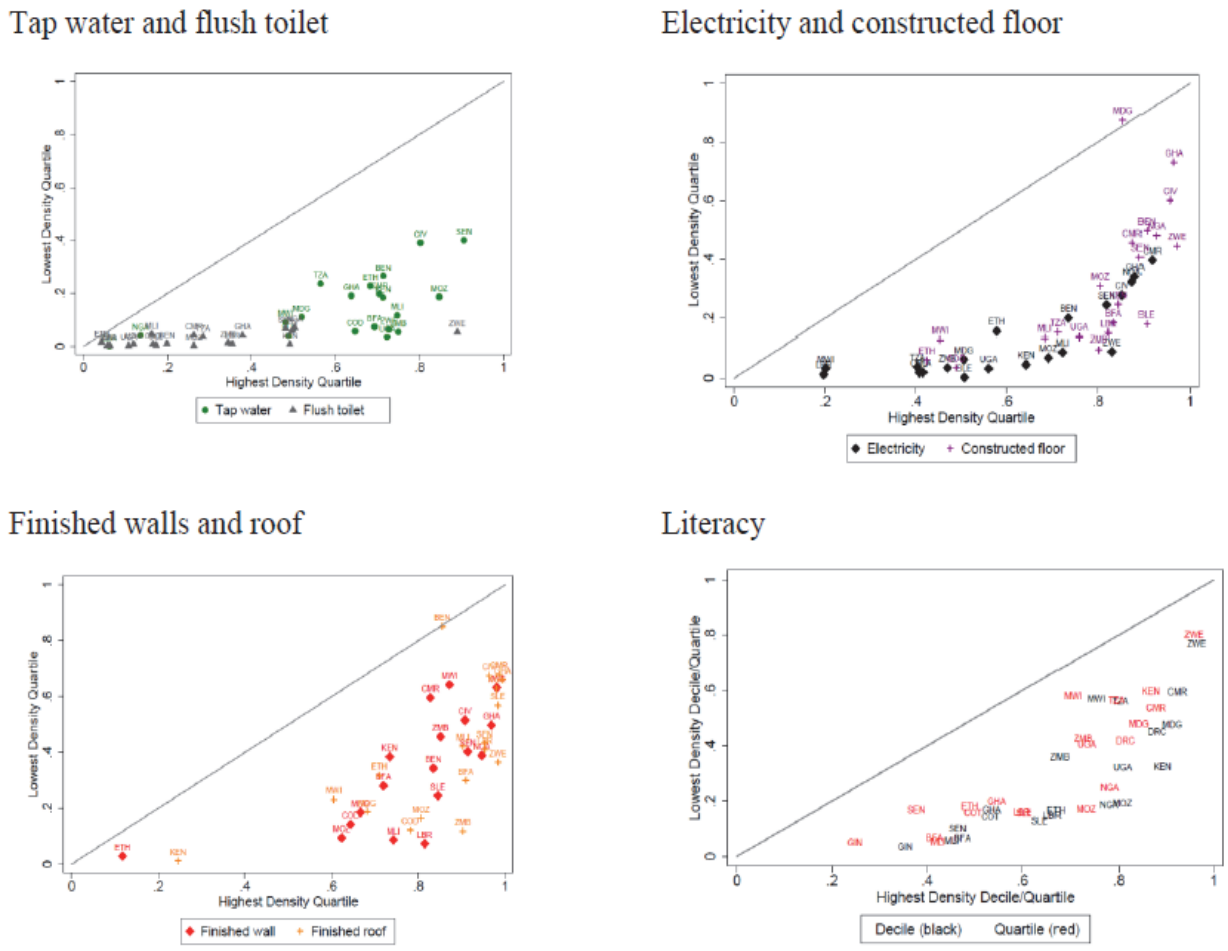
The positive correlation between density and living standards is widely observed in African countries. Based on recent Demographic and Health Surveys (DHS), Gollin et al. (2015) examines various living standard indicators, such as access to tap water and toilet, electricity and constructed floor, and finished walls and roof, as well as literacy. The study finds that higher population density is overall linked to better living standards (Figure 9).

This Note aims to shed light on the extent and the way urbanization has contributed to poverty reduction in Rwanda since 2002, by addressing the following three questions:

- **To what extent has urbanization contributed to poverty reduction in Rwanda?** The first step is to analyze whether more urbanized geographic sectors have lower poverty rates in a given year than relatively less urbanized geographic sectors. A negative correlation between population density and poverty in each year, however, does not guarantee a correlation in changes between 2002 and 2012. Thus, the second step is to conduct a comparative evaluation of geographic sectors over time, and to ask whether geographic sectors that saw population density or built-up ratio increasing more than other geographic sectors between 2002 and 2012 also had comparatively greater reductions in poverty.

- **Have rapidly urbanizing sectors created more nonfarm employment than other sectors between 2002 and 2012?** Since nonfarm employment plays a key role in poverty reduction, it is important to investigate how urbanization has contributed to increasing jobs. In addition to analyzing the nonfarm employment as a whole, this note looks at the increase in wage employment in relation to urbanization.

Figure 9. Population density and living standards in African countries



Source: Gollin, Kirchberger, and Lagakos 2015 (as cited in World Bank 2017).

- **Did farmers also benefit from urbanization?** As reviewed above, urbanization has the potential to reduce rural poverty directly and indirectly, e.g., through remittances, increasing demand of local products, or rural-urban wage convergence. To address this question, this Note explores whether a smaller proportion of farmers are poor in the more-rapidly urbanizing geographic sectors and their surrounding areas. As it is not possible to directly measure spillover effects of urbanization on poverty reduction, given the lack of consistent urban definitions, this Note examines the linkage in poverty changes between farmers and non-farmers.

3. Trend of poverty and job creation

3.1. Poverty

This Note employs the multidimensional poverty index (MPI) as the poverty indicator. MPI is calculated by following the internationally-standardized methodology of the Oxford Poverty and Human Development Initiative.[13, 14] Multidimensional poverty is identified based on a weighted average of nine indicators: years of schooling, child school attendance, child mortality, electricity, sanitation, drinking water, flooring, cooking fuel, and assets ownership (Table 1). Rwanda's MPI places equal weight (that is, one third) to education, health, and living standards, and then weights each component under these three categories. Households are identified as moderately poor if their calculated deprivation scores are greater than 33 percent. In particular, households that score greater than 50 percent are identified as severely poor. Then, the MPI at a geographic sector scale is calculated by multiplying the incidence of poverty *(H)* and the average intensity of the deprivation among the poor *(A)*:

$$MPI_j = H_j \times A_j$$

where H_j is the headcount ratio of poor individuals at the *j*-th geographic sector and *A* represents the average deprivation scores among the poor at the *j*-th geographic sector.

Table 1. Indicators of Multidimensional Poverty Index

Indicator	MPI International standard	Weights MPI International standard	MPI with modifications	Weights MPI with modifications
Years of Schooling	No household member has completed five years of schooling.	1/6	MPI International standard was used.	1/6
Child School Attendance	Any school-aged child is not attending school up to class 8.	1/6	MPI International standard was used.	1/6
Child Mortality	Any child of women aged between 15-49 years has died in the family.	1/6	Any child of women aged between 15-35 years has died in the family. The age group was modified in order to reduce the effect of the genocide against the Tutsi.	1/3
Nutrition	Any adult or child for whom there is nutritional information is malnourished.	1/6	This indicator was dropped; there is no such data in the Census.	-
Electricity	The household has no electricity.	1/18	MPI International standard was used.	1/18
Sanitation	The household's sanitation facility is not improved (according to MDG guidelines), or it is improved but shared with other households.	1/18	MPI International standard was used but information on pit latrines in the Census was not disaggregated, so it was not possible to identify the improved types.	1/18
Drinking Water	The household does not have access to improved drinking water (according to MDG guidelines) or safe drinking water is more than a 30-minute walk from home, roundtrip.	1/18	MPI International standard was used, but information about distance to water source is not available in the Census.	1/18
Flooring	The household has a dirt, sand or dung floor.	1/18	MPI International standard was used.	1/18
Cooking fuel	The household cooks with dung, wood or charcoal.	1/18	The household cooks with dung and wood. Charcoal was removed from the list.	1/18
Assets ownership	The household does not own more than one radio, TV, telephone, bike, motorbike or refrigerator and does not own a car or truck.	1/18	MPI International standard was used.	1/18

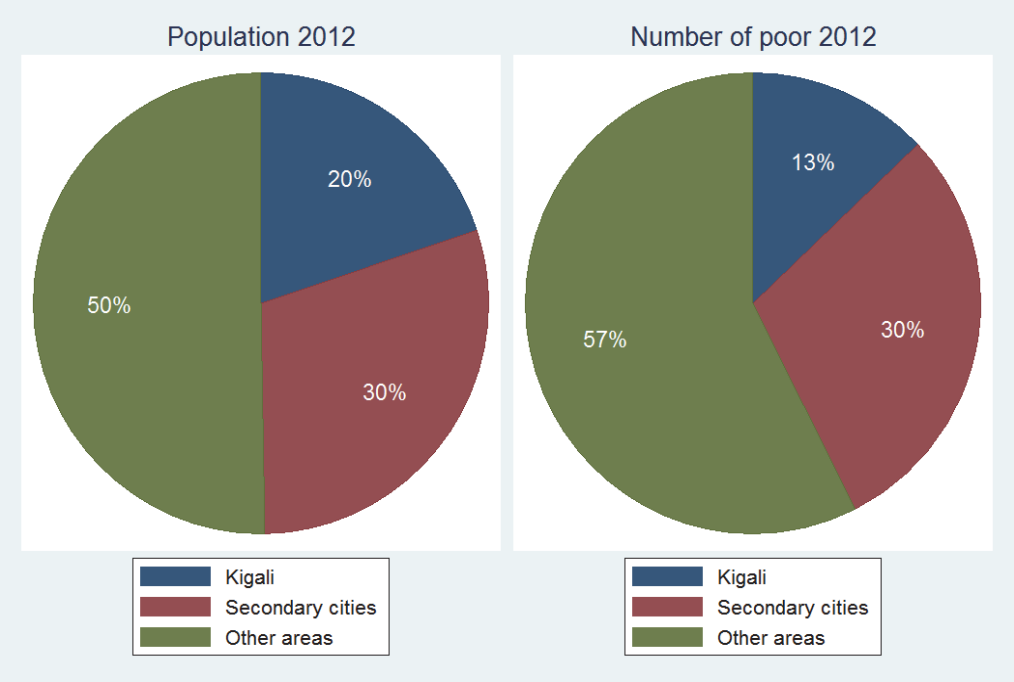
Source: NISR and MINICOFIN 2012.

[13] See NISR and MINICOFIN (2012) for details in Rwanda's case.

[14] In the rest of this note, 'poverty' always refers to multidimensional poverty unless otherwise mentioned.

A geographic pattern of poverty has persisted in Rwanda since 2002, with nearly half of the poor living within 20-30 km of the country's primary and secondary urban centers. In 2012, 13 percent of Rwanda's poor lived in areas within a 30 km range from the center of the City of Kigali (referred to here as Greater Kigali for purposes of analysis). Six secondary cities together accommodated 30 percent of the country's poor within 20 km (Figure 10). Poverty rates also decreased in each of the 5 km rings in Greater Kigali and secondary cities (Figure 11). It is a challenge to extend economic opportunities in secondary cities outward toward those surrounding areas. Yet, the geographic distribution presents a tremendous opportunity to harness urbanization to achieve poverty reduction in those areas with properly targeted policies.

Figure 10. Geographic distribution of the total population and the poor, 2012

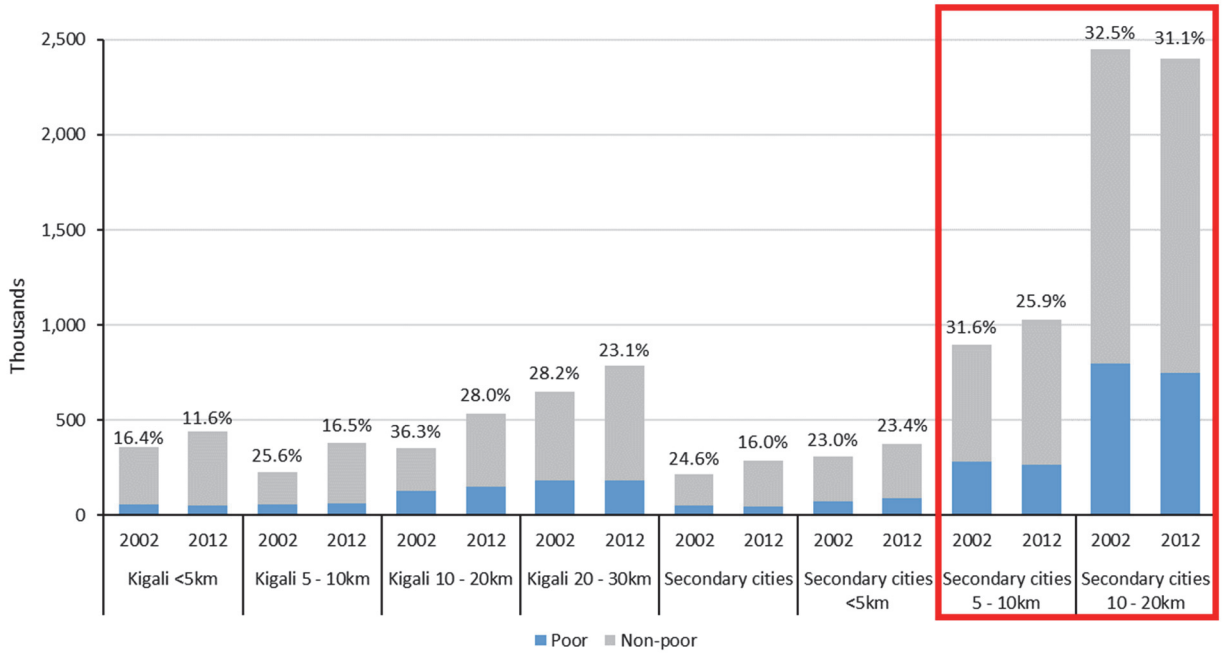


Source: Staff calculation based on 2002 and 2012 Census.
Note: Kigali includes geographic sectors within 30 km from the center of the City of Kigali; secondary cities include sectors within 20 km from the center of secondary cities (Huye, Muhanga, Musanze, Nyagatare, Rubavu, Rusizi), excluding the sectors within 30 km from Kigali.

Geographic sectors with lower MPI cluster around Kigali. Maps in Figure 12 show how geographic sectors with an MPI of less than 10 percent (colored in light blue or dark blue) dramatically increased between 2002 and 2012, as did their concentration around Kigali. The results of hot-spot analysis (Figure 13), which statistically identifies a cluster of sectors that have higher ("hot") or lower ("cold") MPI than other sectors, also shows that geographic sectors with lower MPI are clustered around Kigali. The overall spatial patterns of hot and cold spots remain unchanged between 2002 and 2012, though the comparison of Moran's I statistics indicate that the degree of spatial clustering has become stronger (see Appendix E for the methodology).[15] In other words, a geographic sector with high (or low) poverty rate tends to be located next to a geographic sector with high (or low) poverty rate. This suggests that sectors are increasingly spatially connected.

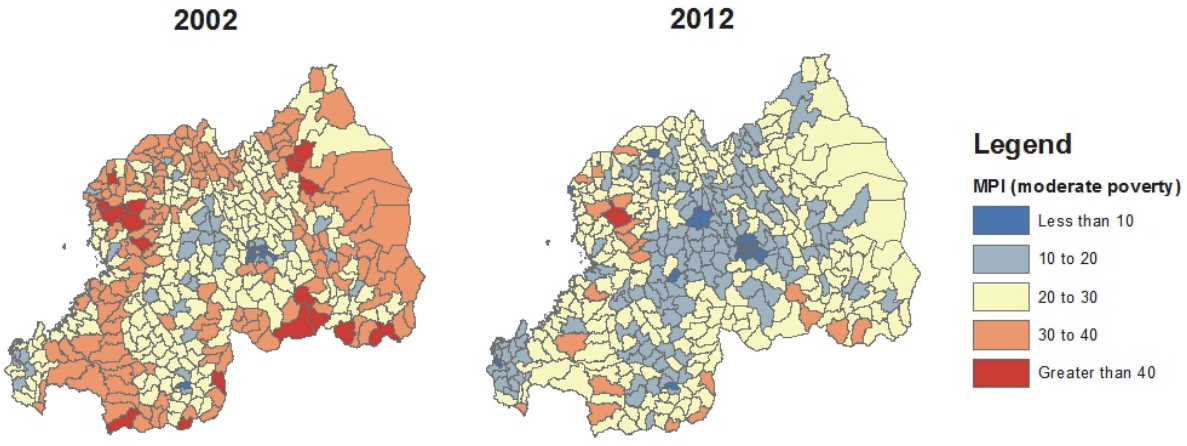
[15] Global Moran's I statistics increased from 0.159 in 2002 to 0.163 in 2012 (both are statistically significant at the 1 percent level).

Figure 11. Number of multidimensional poor, 2002 and 2012



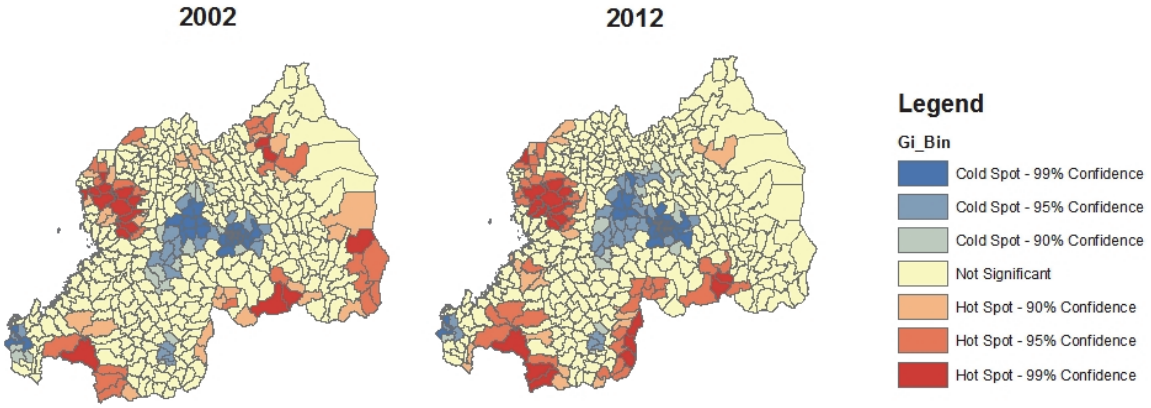
Source: Staff calculation based on 2002 and 2012 Census.
Note: Bar labels indicate poverty headcount ratios. The red rectangles highlight the areas where the number of poor and the rate of poverty remain high.
Note: Kigali includes geographic sectors within 30 km from the center of the City of Kigali; secondary cities include sectors within 20 km from the center of secondary cities (Huye, Muhanga, Musanze, Nyagatare, Rubavu, Rusizi), except for the geographic sectors within 30 km from Kigali.

Figure 12. Spatial distributions of MPI in 2002 and 2012



Source: Staff calculation based on 2002 and 2012 Census.

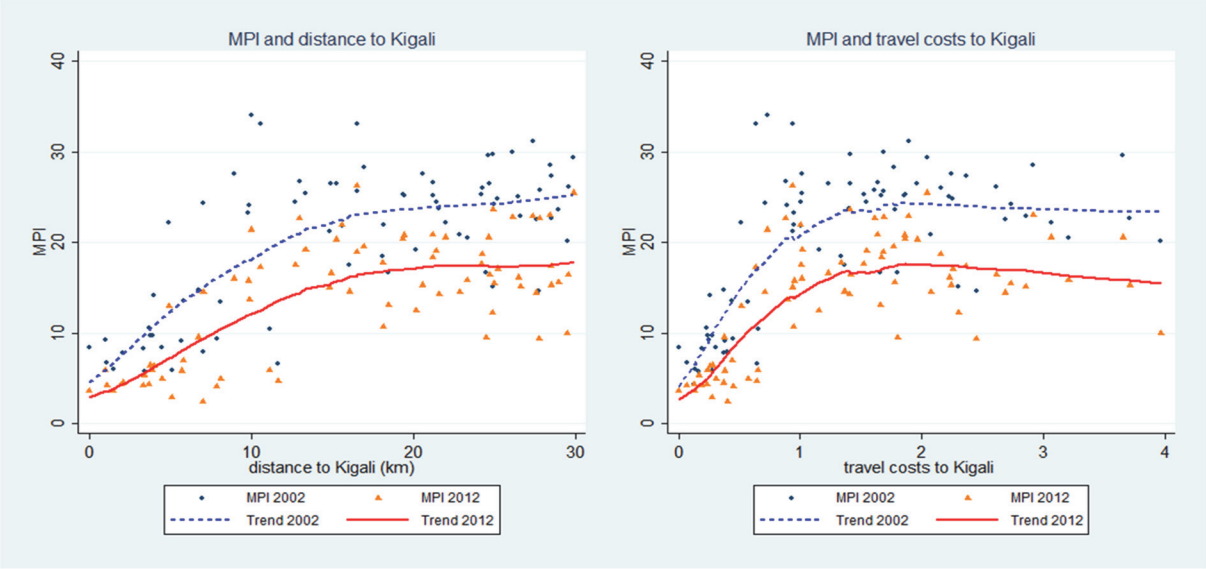
Figure 13. Clusters of geographic sectors with high MPI and low MPI in 2002 and 2012



Source: Staff calculation based on Census 2002 and 2012.
Note: Calculation based on Getis-Ord Gi* statistics (contiguity edges only). Areas in red indicate the clusters of geographic sectors with a higher MPI (that is, hot spots); areas in blue indicate the clusters of geographic sectors with a lower MPI (that is, cold spots).

In Greater Kigali and areas surrounding the six secondary cities, locations closer to the city core have lower MPIs. Among geographic sectors in Greater Kigali, those closer to the city core had a lower MPI in 2002 and 2012 (Figure 14).[16] The relationship between MPI and distance from the city's urban core becomes unclear beyond 15 km from Kigali (Figure 14, left panel) or at travel costs to Kigali greater than 1.5 (Figure 14, right panel). Similar relationships between the MPI and distance to the city core are observed in secondary cities, though they taper off quickly around 5 km from the core (Figure 15).

Figure 14. Geographic Sector MPI and distance and travel cost to the city core in Greater Kigali

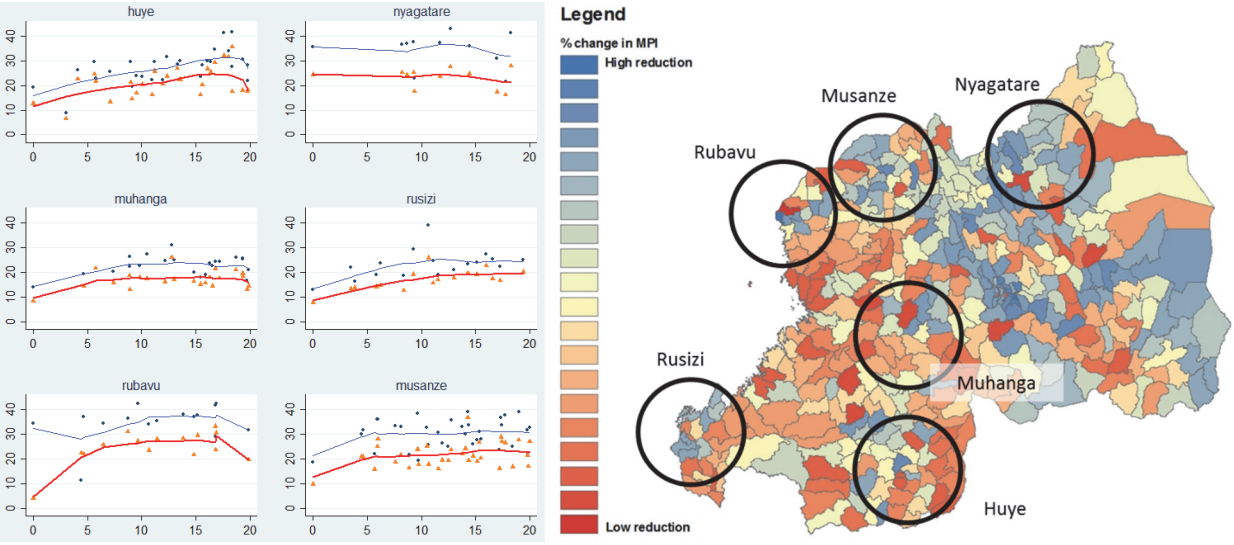


Source: Staff calculation based on 2002 and 2012 Census.

[16] See Appendix D for the methodology of calculating generalized travel costs among sectors.

Note: Only geographic sectors within 30km from Kigali are shown. Blue dots and orange triangles indicate sectors in 2002 and 2012, respectively. Blue and red lines indicate smoothed trend lines for 2002 and 2012, respectively. Travel costs are relative, in terms of sectoral travel costs from the core of Kigali city.

Figure 15. MPI and distance to the city core in the six secondary cities

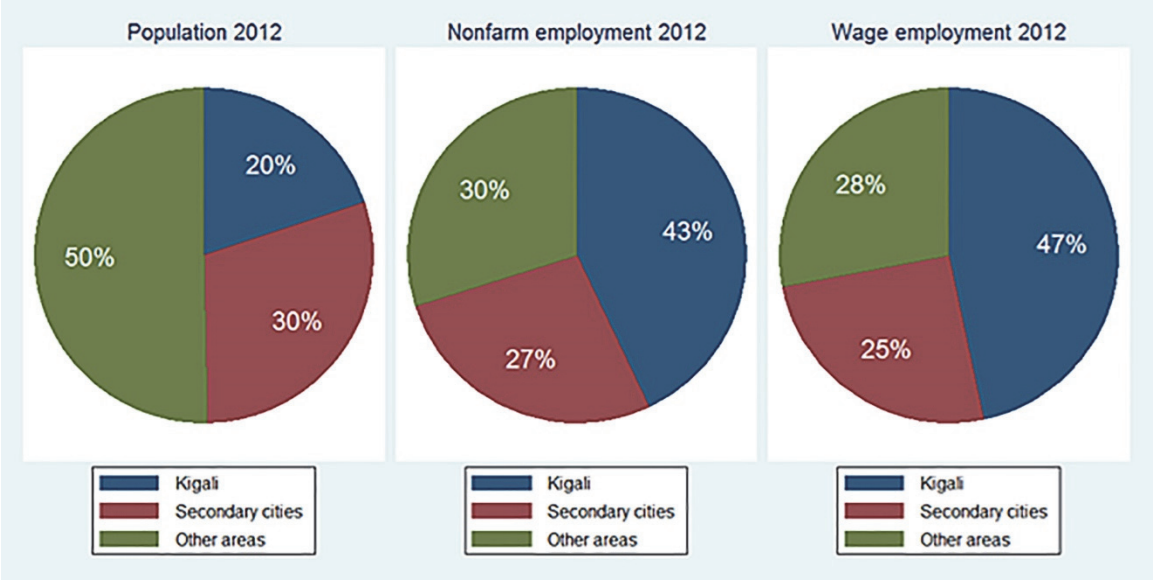


Source: Staff calculation based on 2002 and 2012 Census.
Legend: Left panel: (i) x-axis indicates distance from the center of the secondary city; (ii) y-axis indicates the MPI; (iii) Blue dots and red triangles indicate sectors in 2002 and 2012, respectively; (iv) Red lines and blue lines indicate smoothed trend lines in 2002 and 2012, respectively. Right panel: a ring indicates a radius of 20km from the center of the secondary city.

3.2. Nonfarm job creation

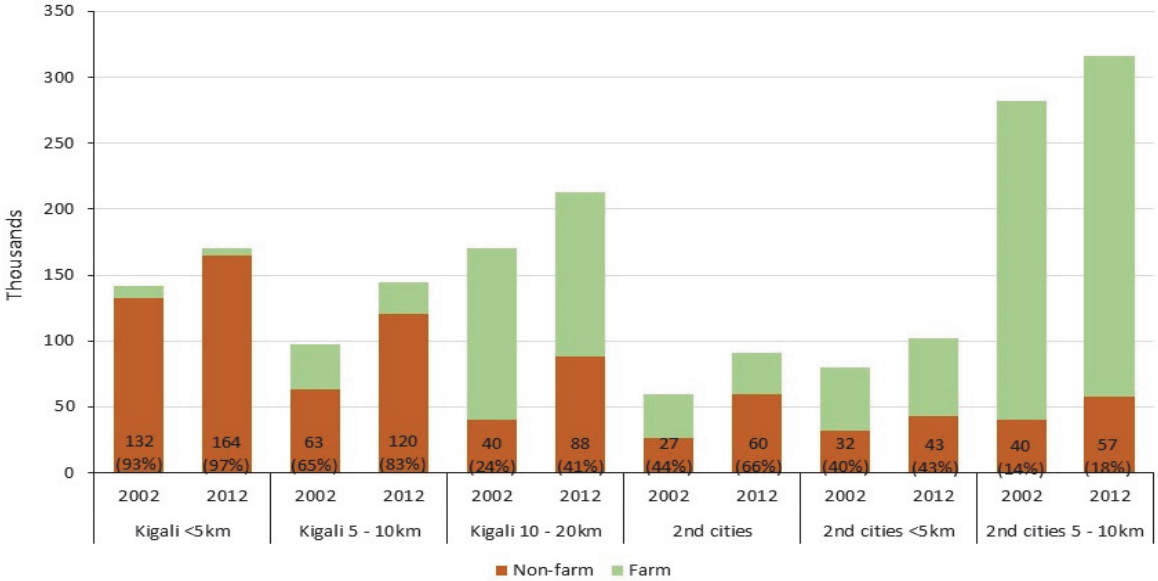
Greater Kigali holds a disproportionally large share of Rwanda's nonfarm employment. The share of nonfarm employment overall is very low in Rwanda, and the wage employment opportunities are particularly limited. In the decade from 2002 to 2012, however, the average share of nonfarm employment at the geographic sector level increased from 13 percent to 24 percent, and the average share of wage employment increased from 7 to 10 percent. Greater Kigali accounted for 20 percent of Rwanda's total population in 2012 and almost 43 percent of total nonfarm employment (Figure 16), the latter down slightly from 46 percent in 2002. The six secondary cities and sectors within 20 km together accounted for 27 percent of the country's nonfarm employment. At these secondary cities' urban core, nonfarm employment accounted for 66 percent, but fell with distance away the center, decreasing to 43 percent within 5 km from the city (Figure 17). Even in Greater Kigali, in 2012, the nonfarm employment share was 83 percent within the 5 to 10 km radius area, falling to 41 percent in its 10 to 20 km radius area.

Figure 16. Shares of population and nonfarm employment among Kigali, the six secondary cities, and other areas, 2012



Source: Staff calculation based on 2002 and 2012 Census.
Note: Kigali includes geographic sectors within 30 km from the center of the City of Kigali; secondary cities include sectors within 20 km from the center of secondary cities (Huye, Muhanga, Musanze, Nyagatare, Rubavu, Rusizi), except for the geographic sectors within 30 km from Kigali.

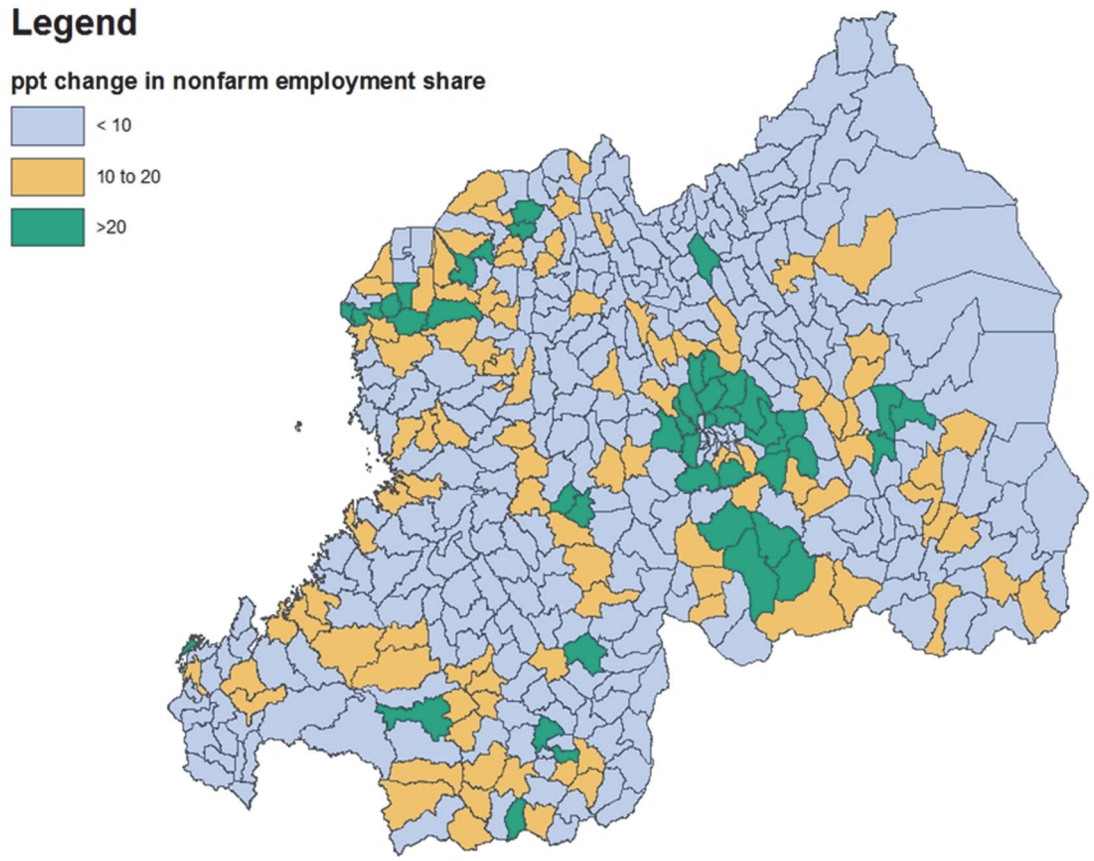
Figure 17. Number and share of nonfarm employment in Greater Kigali and the six secondary cities, 2002 and 2012



Source: Staff calculation based on 2002 and 2012 Census.
Note: Bar labels indicate the number and share of nonfarm employment.
Note: Kigali includes geographic sectors within 30 km from the center of the City of Kigali; secondary cities include sectors within 20 km from the center of secondary cities (Huye, Muhanga, Musanze, Nyagatare, Rubavu, Rusizi), except for the geographic sectors within 30 km from Kigali.

Strong growth in the share of nonfarm employment is observed in periphery areas of Kigali, the Rubavu-Musanze Urban Corridor, the Muhanga-Huye Corridor, and the Bugesera district. These areas experienced an increase in the nonfarm employment share by 20 percentage points or more since 2002 (Figure 18). As of 2012, nonfarm workers living in peripheral Kigali were mainly engaged in construction (27 percent), wholesale and retail (20 percent), transport (14 percent), and manufacturing (10 percent). Those in the geographic sectors in the Rubavu-Musanze Urban Corridor that experienced a rapid increase in nonfarm employment shared work in wholesale and retail (25 percent), construction (15 percent), transport (11 percent), and manufacturing (10 percent). While the share of transport among nonfarm jobs has increased in those areas, the overall job structure remained stable. By contrast, the geographic sectors in Bugesera experienced a dramatic change in job structure. In 2012, 27 percent of nonfarm workers were engaged in construction jobs, 11 percent of nonfarm workers worked in manufacturing, and 10 percent of nonfarm workers were involved in transport. These jobs previously accounted for a very small share in 2002.[17]

Figure 18. Changes in nonfarm employment share between 2002 and 2012



Source: Staff calculation based on 2002 and 2012 Census. Nonfarm share is calculated at the household head level.

[17] Note 4 examines jobs in secondary cities in details.

4. Linkage among poverty, job creation, and urbanization

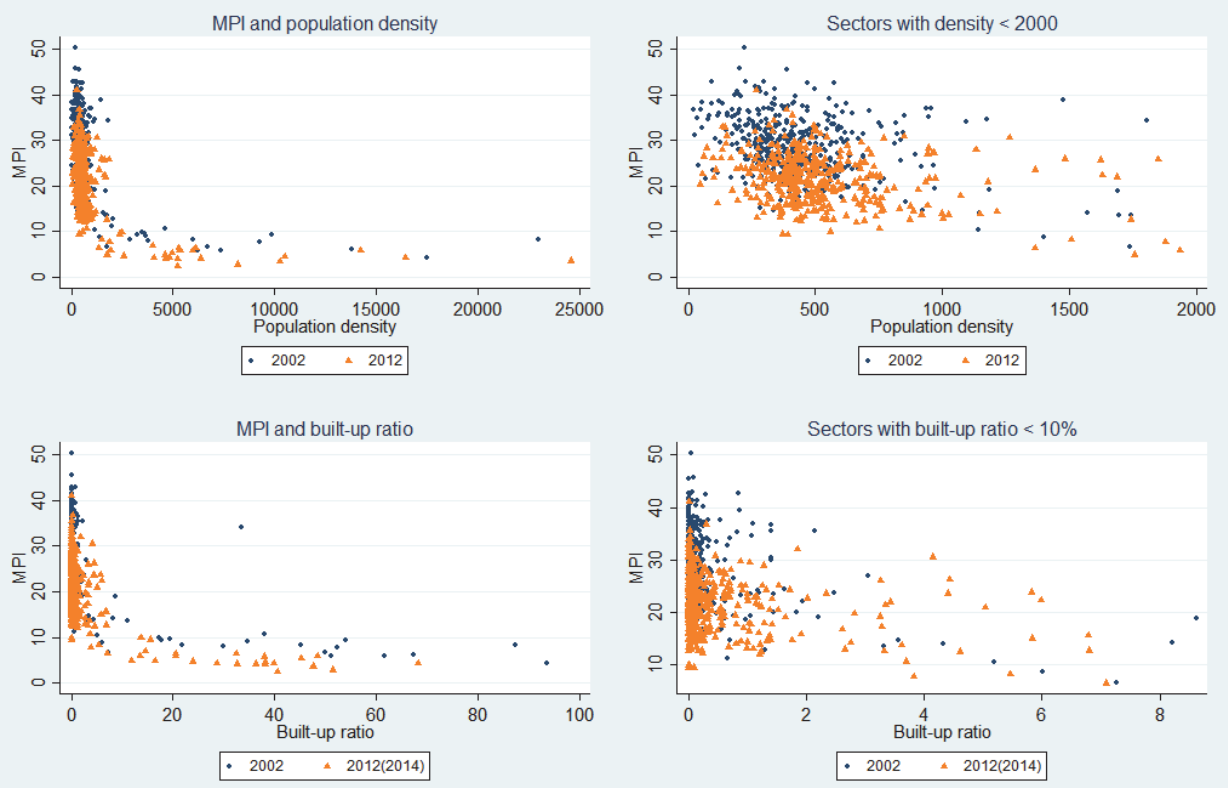
This section presents findings for each of the following key questions on the linkage between poverty reduction, job creation, and urbanization:

- To what extent has urbanization contributed to poverty reduction since 2002?
- To what extent has urbanization brought about nonfarm employment creation since 2002?
- Has urbanization benefited farmers?

4.1. Urbanization has contributed to poverty reduction since 2002

A static view of geographic sectors both in 2002 and 2012 demonstrates that the higher the population density or built-up ratio, the lower is the MPI. A plot of 416 geographic sectors by their MPI and population density (or built-up ratio) for 2002 and 2012 in Figure 19 clearly illustrates this linkage.

Figure 19. MPI, population density, and built-up ratio, 2002 and 2012



Source: Staff calculation based on 2002 and 2012 Census.

While a negative correlation is observed in each year, the poverty elasticity to population density is higher in 2012. According to the estimation results of the Ordinary Least Squares (OLS) regressions, a 10 percent higher density is associated with a 2.31 percent lower MPI in 2002 and 2.89 percent lower MPI in 2012

(Table H1 in Appendix H).[18] Overall similar findings are observed when built-up ratio is used as a measure of urbanization (Table H2 in Appendix H).

The negative relationship observed above between population density and the MPI is much stronger in the geographic sectors with particularly high density. The poverty elasticity to population density is more than triple for the geographic sectors with density ranked within the top 10 percent (in columns 4 and 8, Table H1 in Appendix H). For those very dense sectors, a 10 percent higher density is associated with a 3.29 percent lower MPI in 2002 and 4.75 percent lower MPI in 2012. Indeed, few geographic sectors have maintained poverty rates less than 20 percent without their density exceeding 1,000 persons per km^2.

The result of the analysis on the over-time changes in the MPI and density suggest their linkage in Rwanda. In order to assess the extent to which the changes in population density were associated with the changes in MPI at the geographic sector level between 2002 and 2012, a series of geographic-sector fixed-effects models were estimated (see Table H3 and H4 for the detailed results). This approach allows one to control for all the geographic-sector characteristics, either observed or unobserved, as long as they did not change over time (Box 1 discusses the empirical approach and Appendix F explains econometric models). According to the estimation results of the base specification, which also controls for observed demographic changes (e.g., share of working-age population, sex ratio, and education level at each age-cohort), a 10 percent increase in population density was associated with a 1.2 percent lower moderate-poverty MPI and a 1.6 percent lower severe-poverty MPI (Figure 20). Similar results were obtained when measured only for the households that did not migrate across districts between 2002 and 2012. When longitudinal changes in educational levels are also controlled for, the linkage between the changes in population density and MPI becomes weaker and less clear (but remain statistically significant). This points to the influence of residential sorting.

Box 1. Analytical approach

This Note aims to assess the linkage between urbanization, as measured by an increase in population density, and poverty reduction, both in urban and rural areas, as described in paths C and D in Figure 6. The main analytical approach in this note is a geographic-sector fixed-effects panel regression that relates the change in population density to the changes in poverty rates at the geographic sector level between 2002 and 2012. A methodological challenge is an endogeneity problem due to residential sorting, which might cause a bias in estimation. As Note 2 shows, rural residents with higher capacity, observed and unobserved, are more inclined to migrate to areas with higher population density. Relating changes in population density to changes in poverty without taking account of this residential sorting could lead to a misleading conclusion.

(Continued next page)

[18] In addition to adding district fixed effects, the mean slope of each geographic sector, which may be associated with its density and poverty levels, is controlled for, though it does not substantially change the estimation results (see Table H1). Regressing 2012 poverty rates on lagged population density variable (that is, log of population density as of 2002) results in lower coefficient estimates for the density variables, but they remain high. Finally, these estimates change only slightly when geographic sectors are weighted based on their populations (not reported).

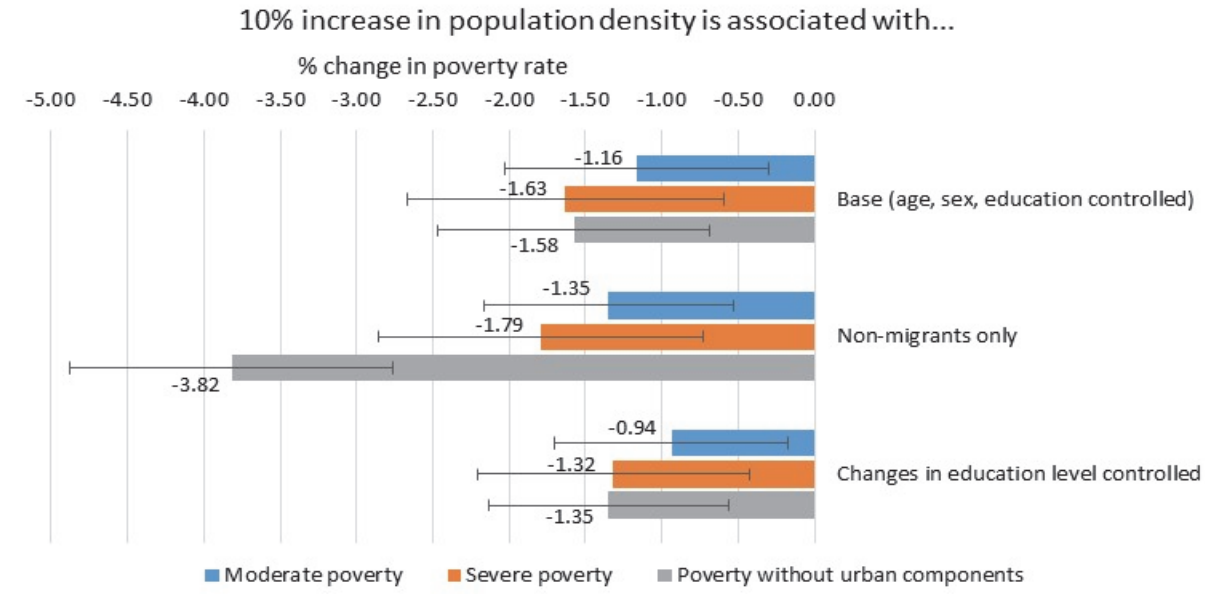
Box 1 (continued)

This note adds several observed factors that must be critically related to both migration patterns and welfare, such as the share of working-age population, sex ratio, and average education level at the geographic sector level. Since simply controlling for the education level could also negate improvement due to density bonus (Combes, Duranton, and Gobillon 2011), this note instead adds mean years of schooling for each of the five-year age male-cohort. Even after controlling for these observed demographic compositions, some other unobserved factors may critically influence migration intensity and poverty.[a]

As a robustness check, this Note estimates alternative models. It first deals with a concern that some components fed into the calculation of MPI may be too obviously tied to urbanization. To assess the sensitivity of the estimation results against such endogeneity, alternative MPI is constructed by removing those components (for example, floor, water, sanitation, and electricity) and used for another set of regression analysis. Second, the same sets of regressions are estimated using MPI calculated solely on households that remained in the same districts between the two Census periods. The presence of the association between an increase in density and a reduction in poverty among those non-migrants corroborate density benefits. Finally, to test the influence of residential sorting on estimation results, this Note additionally estimates the regressions by adding the changes in the average level of education.

a. For example, Young (2013) argues that gaps in consumption between urban and rural areas across 65 countries can be explained by efficient geographic sorting of individuals based on unobserved human capital and skills.

Figure 20. Estimated linkage between increasing density and poverty reduction



Source: Staff calculation based on 2002 and 2012 Census.
Note: Bars indicate the percentage change in MPI corresponding to a 10 percent increase in population density at the geographic sector level. MPI without urban components is calculated by excluding electricity, sanitation, drinking water, flooring, and cooking fuel. Error bars indicate 90 percent confidence intervals.

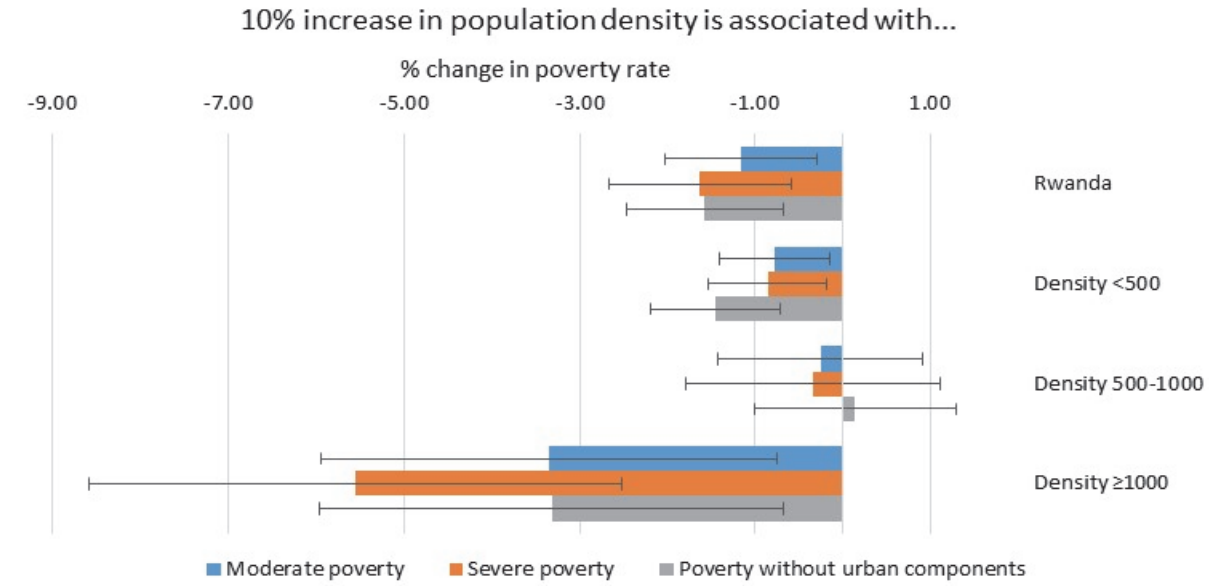
Table 2. Summary of estimated linkage between increasing density and poverty reduction

	Population density				Built-up ratio
		Baseline density			
	All	<500	500–1000	≥1000	All
	(1)	(2)	(3)	(4)	(5)
Moderate poverty					
(1) Base fixed-effects model	-1.50**	-0.14	-1.14	-6.96***	-0.29***
(2) Age, sex, & education controlled	-1.16**	-0.77**	-0.26	-3.35**	-0.07
(3) Only non-migrants	-1.35***	-1.13***	0.15	-3.31**	-0.06
(4) Changes in education level controlled	-0.94**	-0.76**	-0.33	-2.14	-0.06
Severe poverty					
(5) Base fixed-effects model	-2.33**	0.04	-1.82*	-11.71***	-0.53***
(6) Age, sex, & education controlled	-1.63**	-0.86**	-0.35	-5.56***	-0.24***
(7) Only non-migrants	-1.79**	-1.26***	0.14	-5.26***	-0.24***
(8) Changes in education level controlled	-1.32**	-0.77**	-0.48	-4.18***	-0.24***
Poverty without urban components					
(9) Base fixed-effects model	-2.18***	-0.89*	-1.01	-7.86***	-0.34***
(10) Age, sex, & education controlled	-1.58***	-1.45***	0.14	-3.32**	-0.10
(11) Only non-migrants	-3.82***	-4.30***	-0.77	-4.20**	0.03
(12) Changes in education level controlled	-1.35***	-1.45***	0.06	-2.04	-0.08

Note: Figures indicate the percentage changes in MPI corresponding to a 10 percent increase in population density (or built-up areas) at the geographic sector level. MPI is based on moderate poverty (rows 1 to 4); severe poverty (rows 5 to 8); and poverty without urban components (rows 9 to 12). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Importantly, the linkage between increasing density and poverty reduction depends on the baseline density (that is, density as of 2002). For the geographic sectors with a population density of greater than 1,000 in 2002, a 10 percent increase in population density leads to a 3.4 percent lower moderate poverty rate and a 5.6 percent lower severe poverty rate (Figure 21. See column 5, Table H3 and H4 for details). This result indicates that high-density areas are strongly associated with reductions in poverty.

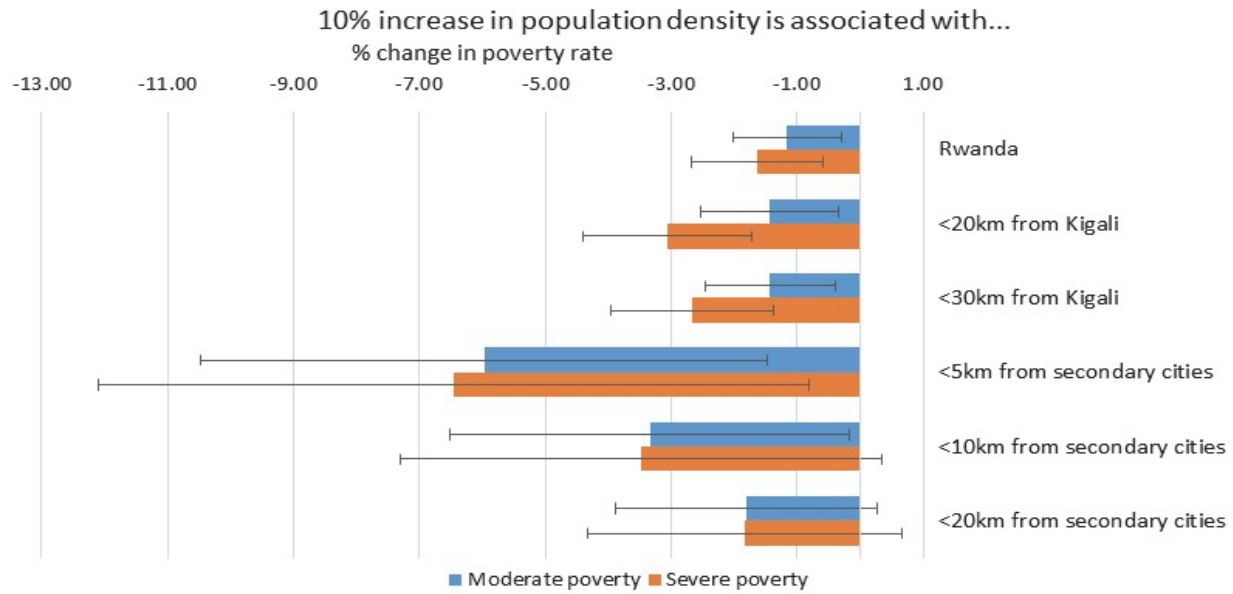
Figure 21. Estimated linkage between increasing density and poverty reduction by baseline density



Source: Staff calculation based on 2002 and 2012 Census.
Note: Bars indicate the percentage change in MPI corresponding to a 10 percent increase in population density at the geographic sector level. Error bars indicate 90 percent confidence intervals.

The analysis in this Note also suggests that the linkage between increasing density and poverty reduction is particularly strong in secondary cities and their surrounding areas within 5 km. The estimated density effects are not spatially uniform; increasing density is especially strongly related to MPI reduction in secondary cities and their surrounding areas (Figure 22. See Table H5 for details). A 10 percent increase in density is associated with a 6.0 percent lower moderate poverty rate and a 6.5 percent lower severe poverty rate in the geographic sectors within 5 km from one of the six secondary cities. However, this density benefit does not reach areas beyond the 5 km radius. Once geographic sectors within 10 km from one of the six secondary cities are included, the linkage between an increase in population density and poverty reduction become unclear (not statistically significant at the 10 percent level).[19]

Figure 22. Estimated linkage between increasing density and poverty reduction by geography

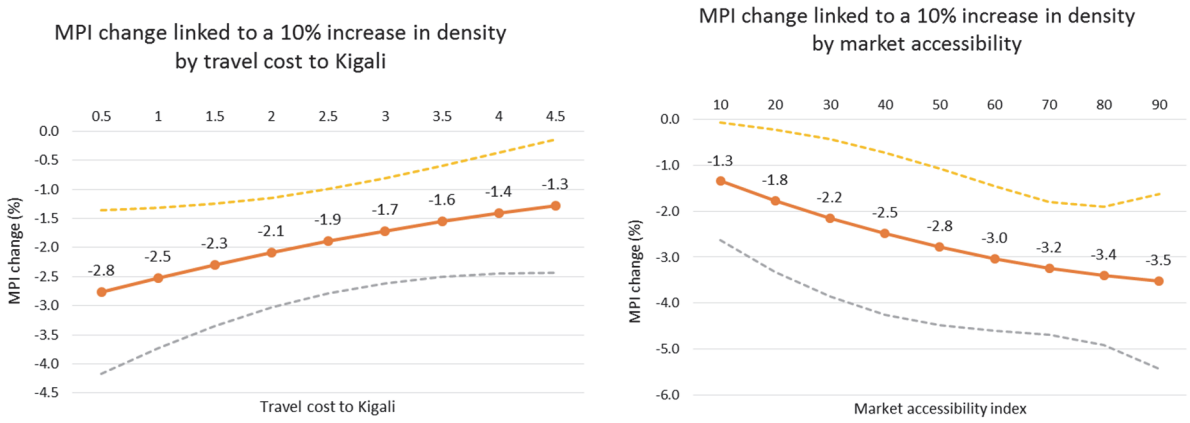


Source: Staff calculation based on 2002 and 2012 Census.
Note: Bars indicate the percentage change in MPI corresponding to a 10 percent increase in population density at the geographic sector level. Error bars indicate 90 percent confidence intervals.

Importantly, the linkage between increasing density and poverty reduction are also a function of the travel cost to Kigali and market accessibility. As illustrated in Figure 23, the estimated linkage between increasing density and poverty reduction becomes smaller as the travel cost to Kigali becomes higher. Sector-level market accessibility is measured as the market accessibility index (MAI) (see Appendix C for the methodology). The MAI of a geographic sector is calculated as the sum of population accessible from the sector within a certain range of travel time. Calculated in this way, the MAI indicates how well the geographic sector is connected with areas with large population base (that is, market size). As Figure 23 shows, a 10 percent increase in density was associated with a 1.8 percent lower MPI for the geographic sectors with MAI being 20, whereas the geographic sectors with the MAI being 70 would have the MPI reduced a lot more at about 3.2 percent. About 80 percent of the 416 geographic sectors have a MAI of less than 20 (see Figure C1 in Appendix C).

[19] Among the four provinces, Northern Province and Eastern Province has benefited from increasing density.

Figure 23. Linkage between increasing density and poverty reduction by travel cost to Kigali and market accessibility



Source: Staff calculation based on 2002 and 2012 Census.
Note: Y-axis indicates the expected percentage change in the Multidimensional Poverty Index (MPI) when population density increases by 10 percent. Dashed lines indicate 90 percent confidence intervals. The MPI is based on severe poverty.

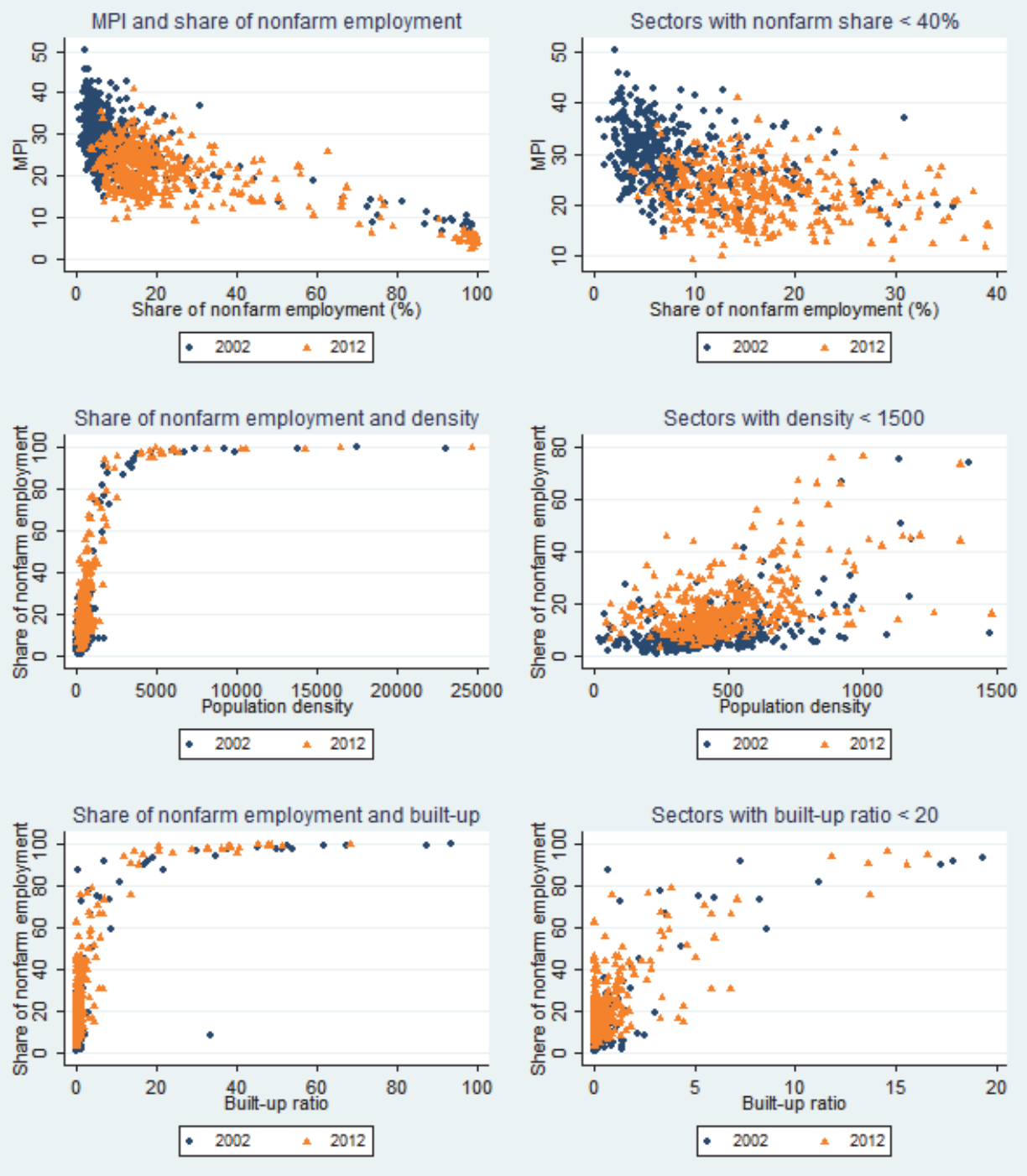
The results become less clear when the same sets of regression models were estimated using built-up ratio as an urbanization-level indicator. Column 5 in Table 2 (above) summarizes the results (see Table H6 and H7 for details). When MPI is measured based on severe poverty, the linkage between increasing built-up areas and poverty reduction is observed regardless of whether the model controls for changes in education levels or is estimated for only non-migrants. However, when MPI is measured based on moderate poverty or without urban components, the relationship between built-up ratio and poverty is not clear. This implies that infrastructure development might be driving the linkage between built-up ratio and reducing poverty.

A rapid increase in built-up areas and its association with severe poverty reduction in Eastern Province is unique, given its still relatively low population density. As discussed in Note 2, a lot of people have moved out of Kigali and settled in Eastern Province, where land is abundant and housing construction is less expensive. Although the rate of population growth has been high in Eastern Province, the overall population still remains relatively low. The high built-up ratio in Eastern Province (Figure 8), despite its relatively low population, reflects infrastructure development in the area. In addition to the Kigali-to-Eastern migration, this infrastructure development may have contributed to the reduction in severe poverty there.

4.2. Faster urbanizing areas created more nonfarm jobs between 2002 and 2012

The share of nonfarm employment is closely correlated with the MPI, population density, and built-up ratio at the geographic sector level in 2002 and 2012. Sector-level plots of MPI and share of nonfarm employment for both 2002 and 2012 show that geographic sectors with higher nonfarm employment shares tend to have a lower MPI in each year (Figure 24). In contrast to the seemingly linear relationship between nonfarm employment share and the MPI, the relationship between the share of nonfarm employment and population density (and built-up ratio) is far from linear. While nonfarm employment share remains very low in low-density geographic sectors, such as those with a population density of less than 500 persons per km^2, the share of nonfarm employment rises in tandem with population density for the other relatively dense geographic sectors (e.g., those with a population density ranging from 500 to 1,500). Nonfarm employment share reaches 80 percent or more among a few of high-density geographic sectors (e.g., those with a population density of greater than 1,500).

Figure 24. Share of nonfarm employment, MPI, population density, and built-up ratio, 2002 and 2012

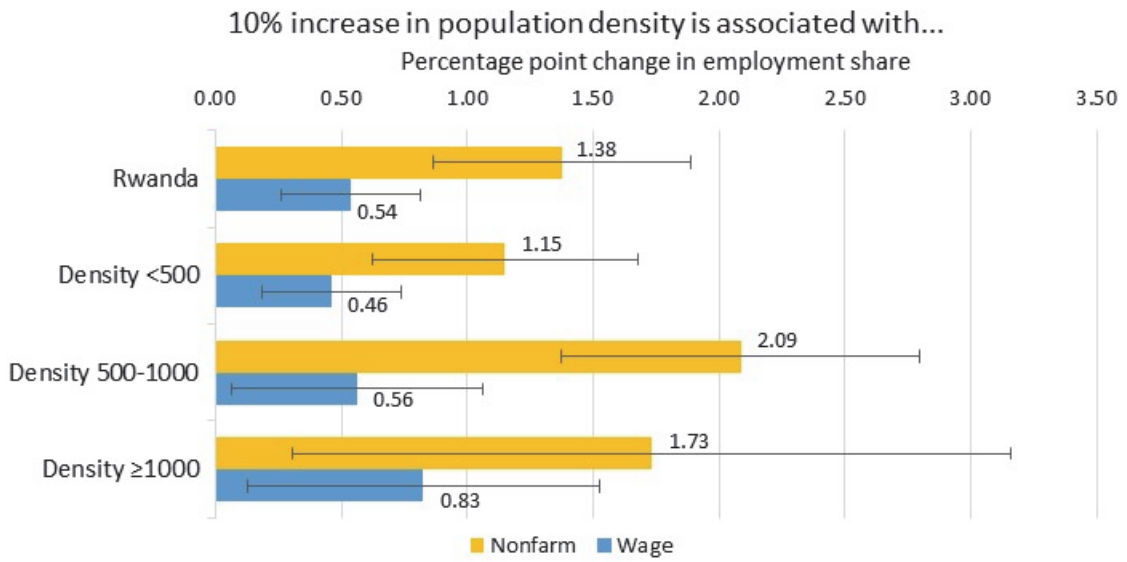


Source: Staff calculation based on 2002 and 2012 Census.

Panel regression analysis hints at a positive linkage between changes in population density and the share of nonfarm employment, even after controlling for changes in educational levels. When geographic sector-level time invariant characteristics, observed and unobserved, are controlled for, a 10 percent change in population density is linked to a 1.4 point higher share of nonfarm employment (Figure

25. See Table H8 for details). Moreover, geographic sectors with higher density at the baseline benefit more: a 10 percent increase in population density was associated with a 1.2 point higher share for geographic sectors with a density of less than 500; a 2.1 point higher share for sectors with a density of between 500 and 1,000; and 1.7 points for the geographic sectors with a density of greater than 1,000.

Figure 25. Estimated linkage between increasing density and nonfarm job creation by baseline density

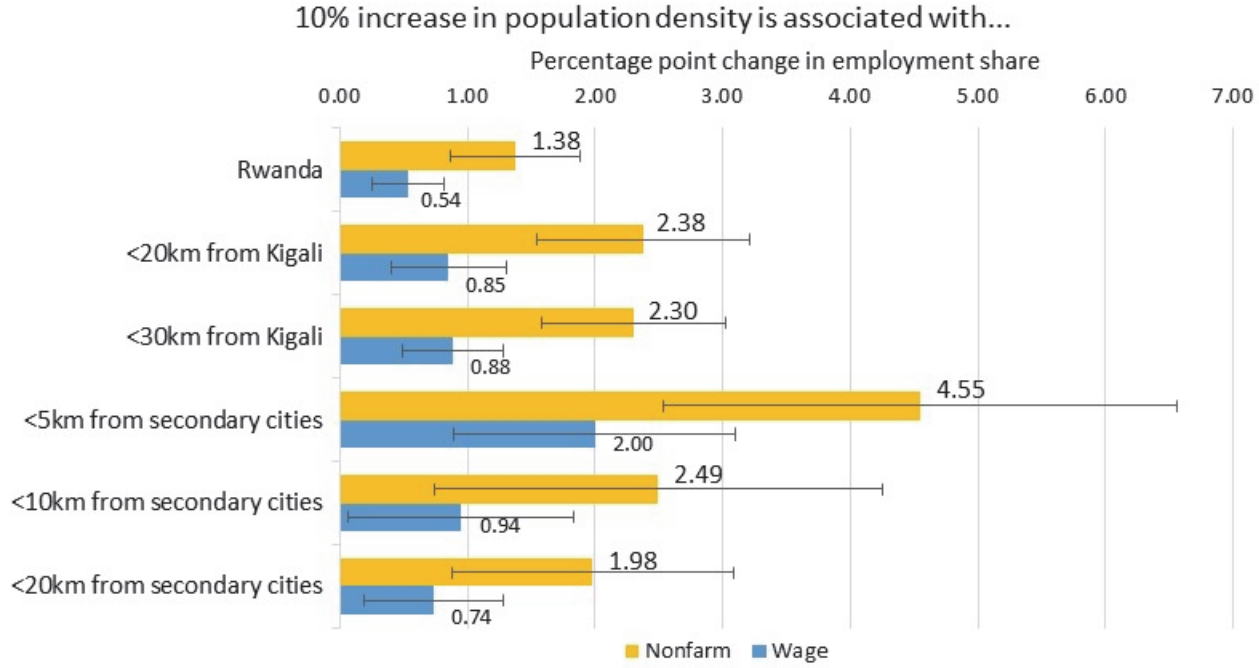


Source: Staff calculation based on 2002 and 2012 Census.
Note: Bars indicate the percentage point change in share of nonfarm and wage jobs corresponding to a 10 percent increase in population density at the geographic sector level. Error bars indicate 90 percent confidence intervals.

The linkage between increasing density and nonfarm job creation are particularly strong in Greater Kigali and the areas surrounding one of the six secondary cities. Figure 26 summarizes the regional variations in estimated density effects for nonfarm employment share. A 10 percent increase in density is associated with a 2.4 percentage point higher nonfarm employment share within 20 km from Kigali and a 4.6 percentage point higher share in the areas within 5 km from secondary cities. In contrast, increasing density is less clearly related to nonfarm job creation in the areas beyond 10 km from secondary cities, indicating that those areas may not be fully integrated into the economy of the secondary cities and that simply increasing population (density) does not automatically lead to job creation.

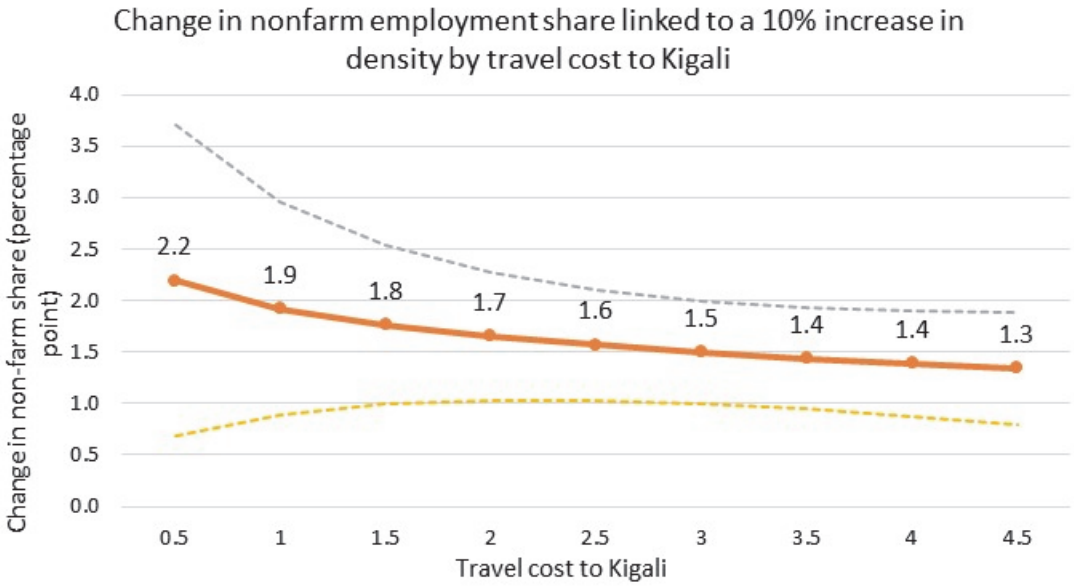
The finding of the prominent density effect in Kigali is consistent with the recent analysis of the trend of nonfarm job creation in Rwanda. As analyzed in the World Bank (2016a), about 30,000 nonfarm jobs were created annually in Rwanda between 2011 and 2014. One-third of those jobs were located in Kigali. Larger new firms, particularly in the formal sector, have tended to locate in Kigali rather than in the countryside, and existing firms in Kigali have been growing and adding jobs. In more general terms, increasing density leads to nonfarm job creations in geographic sectors closer to Kigali and connected to larger populations (that is, better market accessibility) (Figure 27).

Figure 26. Estimated linkage between increasing density and nonfarm job creation by geography



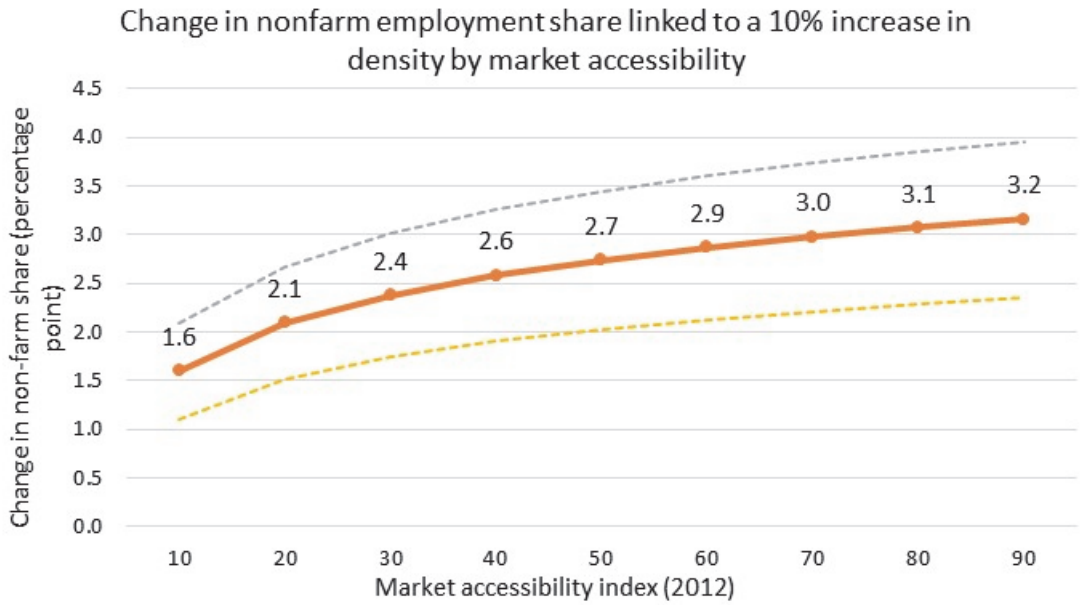
Source: Staff calculation based on 2002 and 2012 Census.
Note: Bars indicate the percentage change in share of nonfarm jobs corresponding to a 10 percent increase in population density at the geographic sector level. Error bars indicate 90 percent confidence intervals.

Figure 27. Linkage between increasing density and nonfarm employment share by travel cost to Kigali and market accessibility



(Continued next page)

Figure 27 (continued)



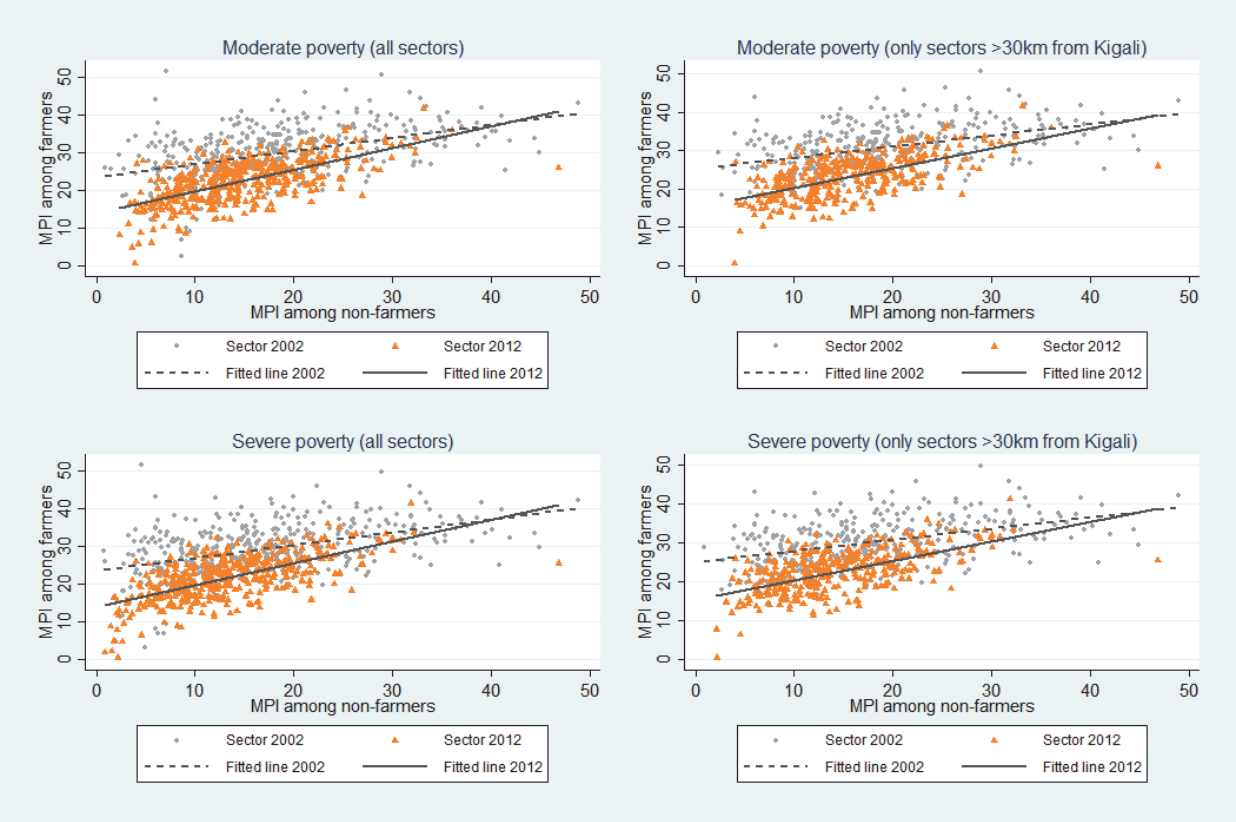
Source: Staff calculation based on 2002 and 2012 Census.
Note: Y-axis indicates the expected percentage point increase in nonfarm employment share when population density increases by 10 percent. Dashed lines indicate 95 percent confidence intervals.

4.3. Poverty rates among farm workers declined faster in areas where nonfarm workers became better-off

To examine poverty among those who are engaged in on-farm jobs and nonfarm jobs, geographic sector-level MPI were calculated separately for each and found that **the linkage between poverty among farmers and poverty among non-farmers had become stronger.** This is illustrated by the fact that while poverty rates among farmers did not reflect poverty rates among non-farmers in 2002, this had changed by 2012, with the former are now more aligned with the latter (the lower the MPI among non-farmers, the lower the MPI among farmers). The plots of geographic sectors over the MPI for farmers (y-axis) and the MPI for non-farmers (x-axis) on the upper-left panel in Figure 28 show that the trend line is flat in 2002 (the estimated slope is 0.308). In other words, poverty rates among farmers used to be high, irrespective of the well-being of non-farmers in the same areas. However, this situation has changed as demonstrated by the steeper slope in 2012 on the chart (the estimated slope is 0.625), corresponding to the increase in the number of sectors with lower MPIs for farmers and non-farmers. This analysis implies that farmers are less likely to be poor in the areas where non-farmers are less poor.[20] Focusing on the sectors outside Greater Kigali reveals a similar trend (the right panels in Figure 28).

[20] When MPI is calculated based on severe poverty among farmers, the estimated slopes are 0.327 in 2002 and 0.663 in 2012, respectively.

Figure 28. MPI among farmers and non-farmers, 2002 and 2012



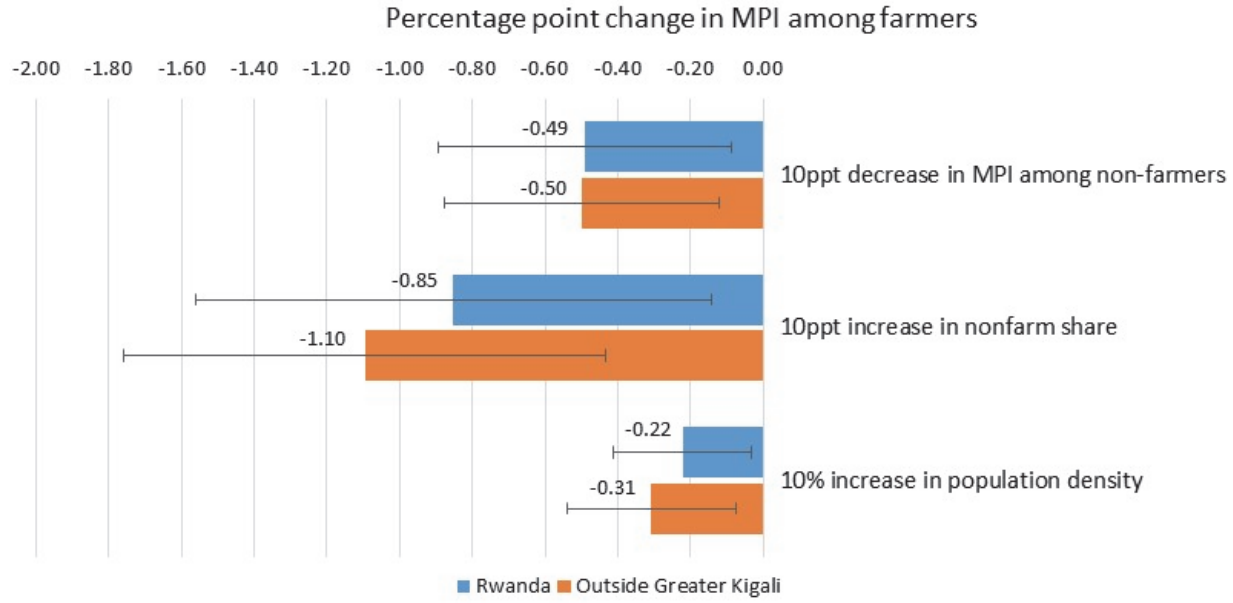
Source: Staff calculation based on 2002 and 2012 Census.
Note: Trend lines are based on locally weighted scatterplot smoothing.

Poverty rates among farmers are associated with poverty rates among non-farmers in the same geographic sectors, share of nonfarm employment, and population density (among others). According to the estimation results of panel regressions, a 10 percentage point decrease in the MPI among non-farmers is associated with a 0.49 percentage point lower MPI among farmers within the same geographic sectors (Figure 29 and column 1, Table H11). It also finds that geographic sectors with an increasing nonfarm share experienced poverty reduction among farmers. Finally, increasing density is related to a lower MPI only outside Greater Kigali: a 10 percent increase in density is translated into a 0.32 percentage point lower MPI among farmers (column 5, Table H12). These results imply a linkage between urbanization and rural poverty reduction (Figure 6).

Moreover, poverty rates among farmers are influenced not only by the poverty rate among non-farmers within the same geographic sectors but also in surrounding sectors. To measure such spatial spillover effects, several spatial econometrics models are estimated (see Appendix F for details). Column 1 in Table H13 in Appendix H summarizes the estimation result of a Spatial Durbin Model (SDM), which estimates both spatial spillover (that is, poverty reduction influenced by surrounding sectors) and spatial autocorrelations (that is, unobserved errors that are spatially correlated). In its formula, the effect of the decrease in the MPI among non-farmers to the MPI among farmers is transmitted through (a) direct effects from the former to the latter in the same geographic sector and (b) indirect effects through influencing the MPI of surrounding geographic sectors. The sum of those direct and indirect effects equals the total effect. The result indicates that a 10 percentage point decrease in MPI among non-farmers was associated

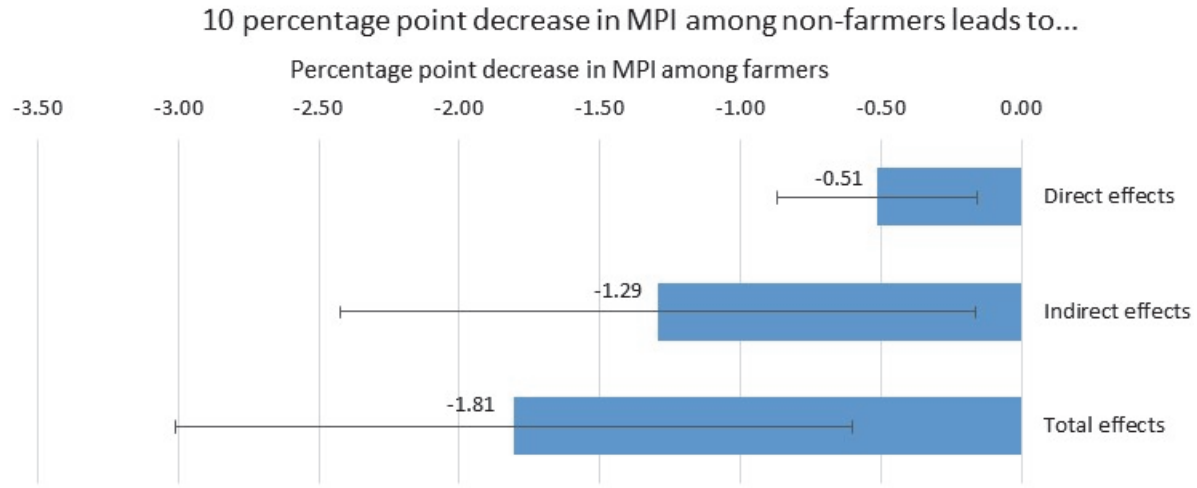
with MPI reduction among farmers by 0.51 percentage points through direct effects and 1.29 points through indirect effects. The resulting total effect is a reduction of 1.81 points (Figure 30).

Figure 29. Linkage with poverty reduction among farmers



Source: Staff calculation based on 2002 and 2012 Census.
Note: Bars indicate the percentage point change in MPI (moderate poverty) among farmers corresponding to 1) a 10 percent point decrease in MPI among non-farmers; 2) a 10 percent point increase in nonfarm share; and 3) a 10 percent increase in population density at the geographic sector level. Error bars indicate 90 percent confidence intervals.

Figure 30. Direct, indirect, and total effects for poverty reduction among farmers



Source: Staff calculation based on 2002 and 2012 Census.
Note: Bars indicate the estimated farmer-non-farmer poverty linkage as the percentage point change in MPI (moderate poverty) among farmers corresponding to a 10 percent decrease in MPI among non-farmers at the geographic sector level. Error bars indicate 90 percent confidence intervals.

5. Conclusions

The key findings of this Note are summarized as follows. First, it confirms that urbanized areas (as characterized by higher nonfarm employment, population density, and built-up ratio) tend to have a smaller proportion of residents in poverty. While this relationship is observed both in 2002 and 2012, it is stronger in the latter. Second, changes in poverty rates between 2002 and 2012 are also related to the urbanization process. The geographic sectors that have increased population density and/or built-up ratio relative to other sectors also tend to have relatively less poverty (in particular, severe poverty). This linkage between increasing population density and poverty reduction also depends on the initial density size (increasing density is not translated to lower poverty unless the areas are already dense to some extent), travel cost to Kigali (the closer to Kigali, the more sectors benefit from increasing density), and market accessibility (the better the market accessibility is, the larger the density benefits are). Third, increasing density is also related to a higher share of nonfarm employment. This density effect holds even after controlling for educational levels. Similar to the linkage between increasing density and poverty reduction, the positive correlation between density increase and nonfarm job creation also depends on the initial density, travel cost to Kigali, and market accessibility. Finally, it is found that farmers also benefited from the urbanization process: poverty reduction among farmers and non-farmers has happened hand in hand.

The analyses in this Note, overall, suggest that, with regard to the linkage between urbanization and poverty reduction, secondary cities have shown similar performance to Greater Kigali. However, the size of the secondary cities and their adjacent areas are still small and may not be functionally integrated into the economic system. The linkage between increasing density and poverty reduction and job creation is less clear in areas beyond 5 km from the core of one of the secondary cities. Nevertheless, given that a third of Rwanda's poor live within 20 km from one of the six secondary cities, promoting urbanization in those areas has significant potential as a driver of poverty reduction.

It should be remembered that the results in the econometric analysis in this Note does not guarantee the causal effect of urbanization for poverty reduction. Identifying such effect by isolating residential sorting based on unobserved human capital and skills from benefits from urbanization (such as agglomeration economies) requires another empirical strategy, which was not feasible for this study.

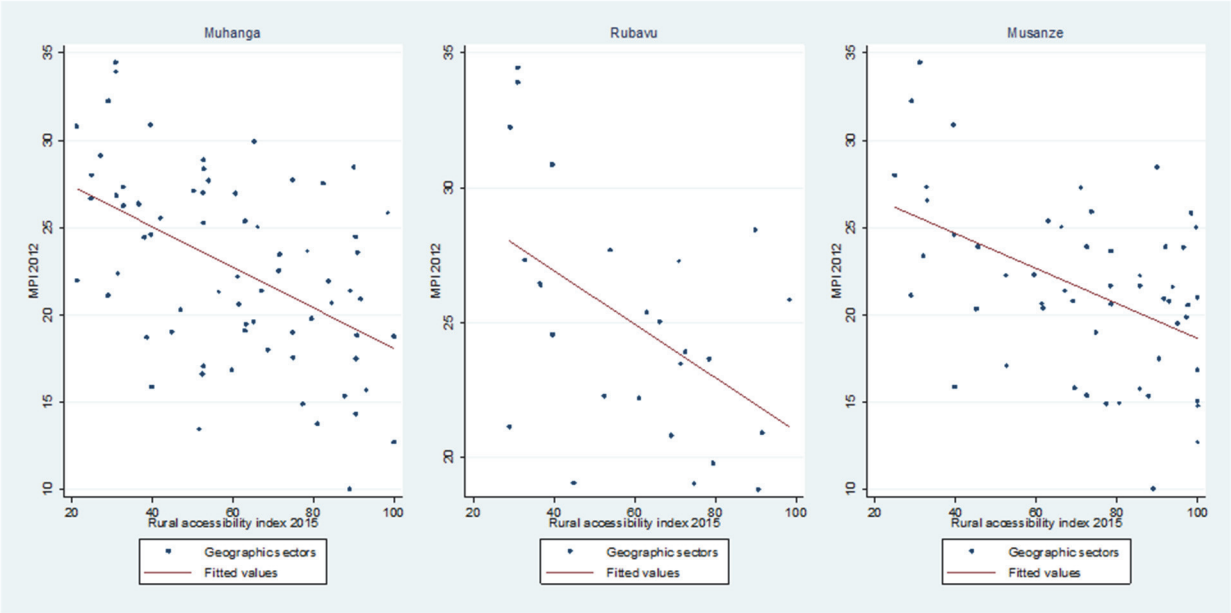
With the caution above in mind, the findings on the linkage between urbanization, poverty reduction, and job creation raise several areas for policy attention:

- **High density development, coupled with increased connectivity, is critical.** Population density is strongly correlated to poverty reduction and nonfarm job creation in Rwanda. Counterexamples are Southern Province where low-density urbanization has seen little improvement on either front. However, increasing density alone (and accelerating urbanization by definition) is insufficient for nonfarm job creation. It has to be accompanied with enhanced connectivity in terms of transport time and cost and access to markets.

- **Areas surrounding Kigali and secondary cities need to be better integrated.** Performance measured in terms of poverty reduction and job creation decline sharply in the areas 5−20 km away from secondary cities, as compared to that of city cores. Opportunities for leveraging the benefit of urbanization lie in these peri-urban areas, which in turn should be better connected to the city cores both physically and economically. In Rwanda, according to the analysis of rural accessibility index, about 8.2 million people, or about 72 percent of the total population, live in rural areas, of which about 4.3 million people are still unconnected to road networks in good

condition.[21] Areas with low rural accessibility also suffer from high poverty rates (Figure 31). The investment priority is those areas where agricultural production exists but the road condition remains poor. Rural access seems to be closely related to agricultural production. Although Rwanda's agricultural potential is considerable, there is unmet demand for access in the productive south-east of the country (i.e. the Southeast).

Figure 31. Rural accessibility index and MPI in selected secondary cities



Source: Staff calculation based on 2012 Census and based on WorldPop and road condition data from Rwanda RTDA.

References

Anselin, L. 1988. *Spatial Econometrics: Methods and Models*. Boston: Kluwer Academic Publishers.

Anselin, L., and H. Kelejian. 1997. "Testing for Spatial Error Autocorrelation in the Presence of Endogenous Regresors." *International Regional Science Review* 20 (1): 153–182.

Beegle, K., J. de Weerdt, and S. Dercon. 2011. "Migration and Economic Mobility in Tanzania: Evidence from a Tracking Survey." *The Review of Economics and Statistics* 93 (3): 1010-1033.

Belotti, F., G. Hughes, and A. P. Mortari. 2016. "Spatial Panel Data Modules using Stata." *CEIS Tor Vergata Research Paper Series* 14(5): 373.

Bryan, G., S. Chowdhury, and A.M. Mobarak. 2014. "Underinvestment in a Profitable Technology: The Case of Seasonal Migration in Bangladesh." *Econometrica* 82 (5): 1671-1748.

Christiaensen, L., and Y. Todo. 2014. "Poverty Reduction during the Rural-Urban Transformation: The Role of Missing Middle." *World Development* 63: 43–58.

[21] The rural accessibility index is one of the traditional global indicators in the transport sector. It measures the share of rural population who has access to an all-season road within an approximate two km walking distance. See World Bank (2016b) for details.

Christiaensen, L., J. De Weerdt, and Y. Todo. 2013. "Urbanization and Poverty Reduction: The Role of Rural Diversification and Secondary Towns." *Agricultural Economics* 44: 435-447.

Combes, P-P., G. Duranton, and L. Gobillon. 2011. "The Identification of Agglomeration Economies." *Journal of Economic Geography*, 11: 253-266.

Drukker, D. M., H. Peng, I. R. Prucha, and R. Raciborski. 2013. "Creating and Managing Spatial-Weighing Matrices with the SPMAT Command." *The Stata Journal* 13 (2): 242–286.

Duranton, G. 2016. Agglomeration Effects in Colombia. *Journal of Regional Science* 56 (2): 210–238.

Elhorst, J. P. 2010. "Applied Spatial Econometrics: Raising the Bar." *Spatial Economic Analysis,* 5 (1): 9–28.

Gibson, J., G. Datt, R. Murgai, and M. Ravallion. 2017. "For India's Rural Poor, Growing Towns Matter more than Growing Cities." *World Bank Policy Research Working Paper* 7994.

Gollin, D., Kirchberger, M., and Lagakos, D. 2015. *Living Standards across Space: Evidence from Sub-Saharan Africa*. Working Paper. World Bank, Washington, DC.

LeSage, J., and R. Pace. 2009. *Introduction to Spatial Econometrics.* Boca Raton, FL: CRC Press.

NISR (National Institute of Statistics of Rwanda) and MINICOFIN (Ministry of Finance and Economic Planning). 2012. *Fourth Rwanda Population and Housing Census. Thematic Report: Measurement and Mapping of Non-Monetary Poverty*. Kigali, NSIR.

NISR (National Institute of Statistics of Rwanda) and MINICOFIN (Ministry of Finance and Economic Planning). Various years. Integrated Household Living Conditions Survey (EICV). Kigali, NSIR.

Rosenthal, S. S., and Strange, W. 2004. Evidence on the Nature and Sources of Agglomeration Economies. In *Handbook of Regional and Urban Economics*, vol. 4, ed by V. Henderson and J. F. Thisse. Amsterdam: North-Holland. 2119–71.

Rwanda Transport Development Agency (RTDA). 2015. Road Condition Report 2014/15 and Feeder Roads Policy and Strategy. Kigali, RTDA.

University of Southampton. Various years. WorldPop database. http://www.worldpop.org.uk/data/.

World Bank and IMF (International Monetary Fund). 2013. *Global Monitoring Report 2013: Rural-urban Dynamics and the Millennium Development Goals.* Washington, DC: World Bank and International Monetary Fund.

World Bank. 2017. *Africa's Cities: Opening Doors to the World*. Washington, DC: World Bank.

World Bank. 2016a. *Rwanda: Firm Growth and Job Creation Study.* Washington, DC: World Bank.

World Bank. 2016b. *Measuring Rural Access: Using New Technologies.* Washington, DC: World Bank.

World Bank. 2015a. *Rwanda Poverty Assessment.* Washington, DC: World Bank.

World Bank. 2015b. *Rwanda: Employment and Job Study.* Washington, DC: World Bank.

Young, A. 2013. "Inequality, the Urban-Rural Gap, and Migration." *The Quarterly Journal of Economics* 128(4): 1727–85.

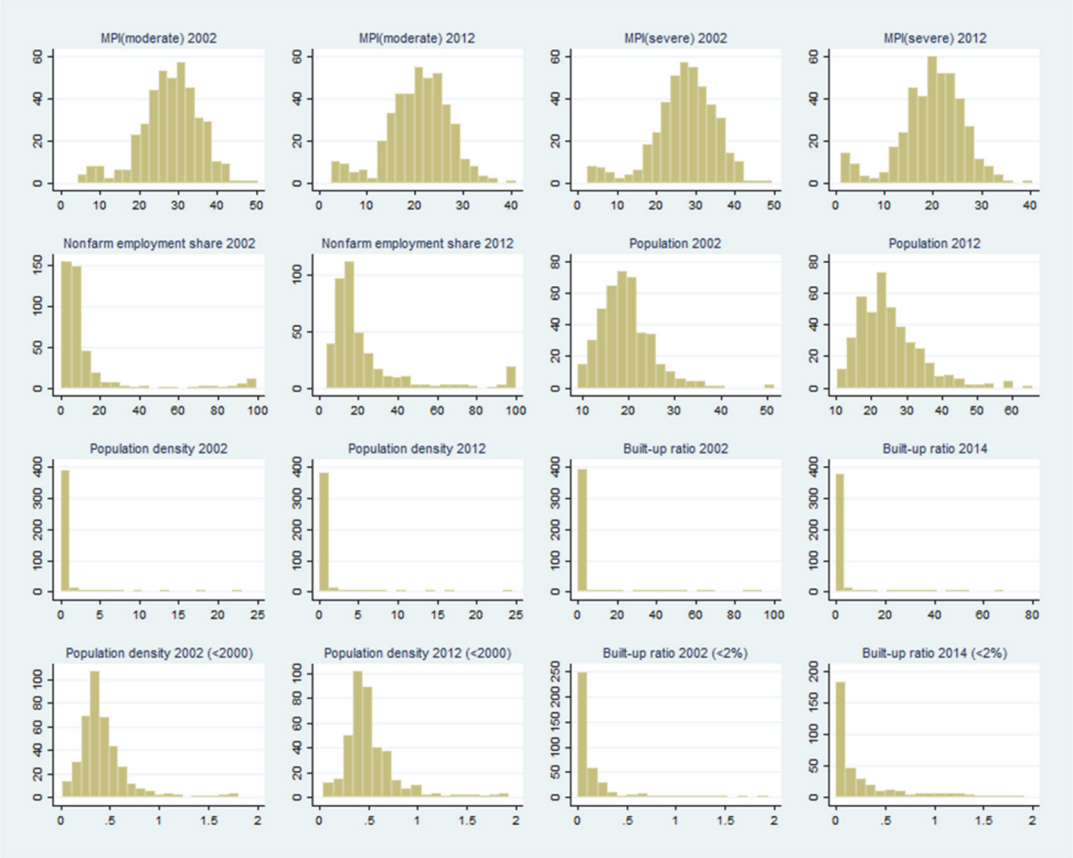
Appendices

Appendix A. Descriptive statistics of geographic sector characteristics

Table A1. Summary statistics

		2002			2012/14		
	count	mean	min	max	mean	min	max
MPI: moderate poverty	416	27.96	4.37	50.20	20.72	2.50	41.05
MPI: severe poverty	416	27.19	2.52	49.35	19.82	0.94	40.60
MPI among farmers (moderate poverty)	416	29.66	2.47	51.39	22.30	0.72	41.75
MPI among farmers (severe poverty)	416	29.11	3.09	51.39	21.56	0.50	41.48
MPI without urban components (moderate poverty)	416	27.49	4.21	49.35	20.37	2.50	40.75
MPI without urban components (severe poverty)	416	26.29	3.79	49.24	18.70	1.63	40.05
Share of nonfarm employment (%)	416	13.24	0.54	99.65	23.98	3.60	100.0
Share of wage employment (%)	416	7.08	0.26	66.28	10.22	1.24	53.73
Population	416	19,540	9,071	51,461	25,279	10,390	65,700
Population density (per km^2)	416	725.4	20.91	23025	877.6	45.00	24,603
Built-up ratio (%)	416	2.181	0.000	93.59	2.410	0.000	68.28
Area (km^2)	416				58.26	1.019	642.0
Market accessibility index (2012)	416				14.78	0.000	100.0

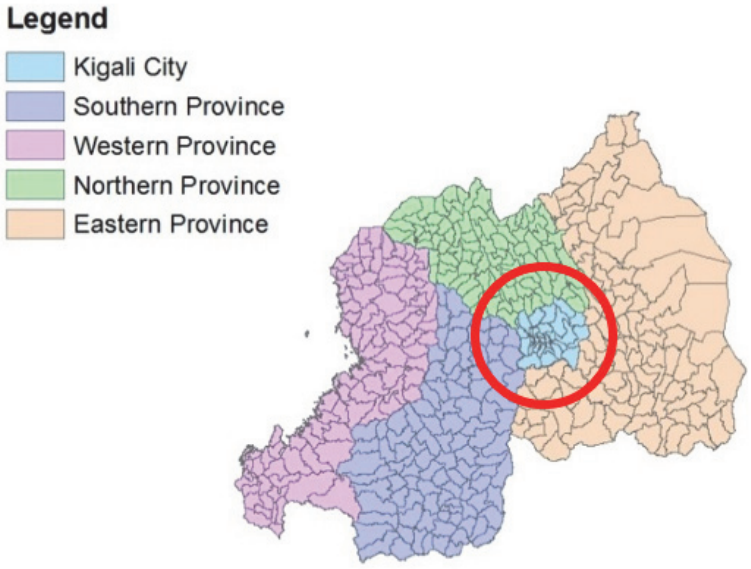
Figure A1. Histograms of key variables



Note: Y-axis indicates the number of geographic sectors.

Appendix B. Provinces in Rwanda

Figure B1. Greater Kigali and Provinces in Rwanda

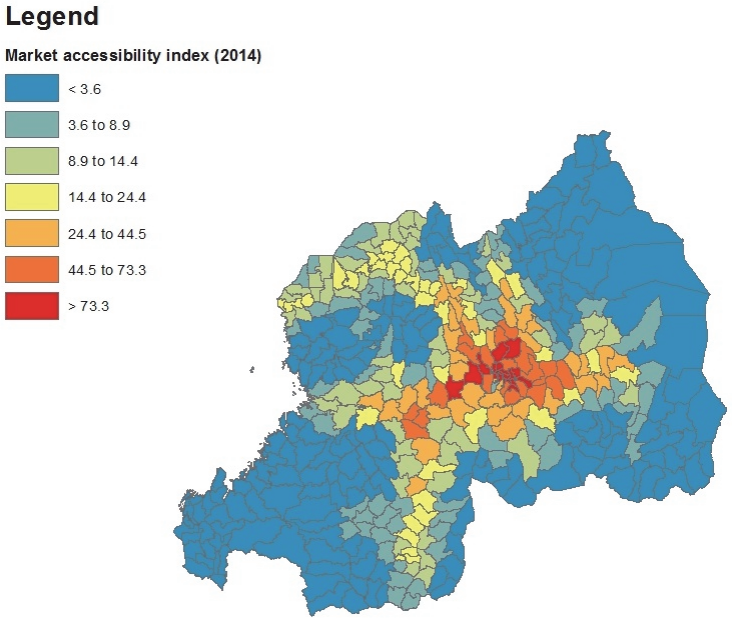


Note: The red circle indicates 30km from the center of the City of Kigali.

Appendix C. Market accessibility index

The market accessibility index is constructed as the population-weighted travel time to a town of at least 50,000 people, and as such, proxies the proximity to larger urban markets. It is noted that cities outside Rwanda are not considered, which significantly undermines the market accessibility of some cities near the national borders (for example, Rubavu, facing Goma across Rwanda-Democratic Republic of Congo border).

Figure C1. Market Accessibility Index, 2012



(Continued next page)

Figure C1 (continued)

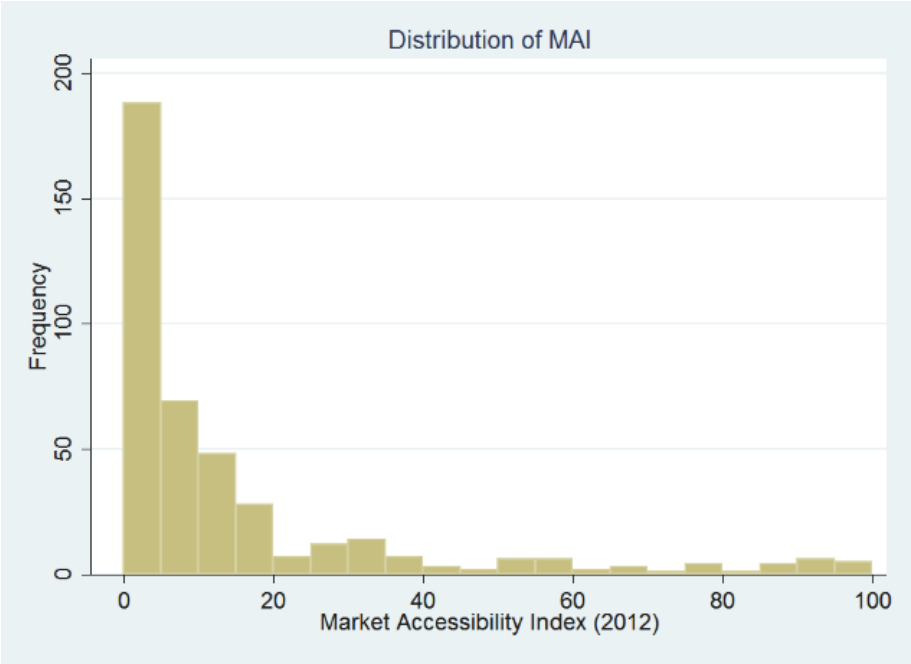


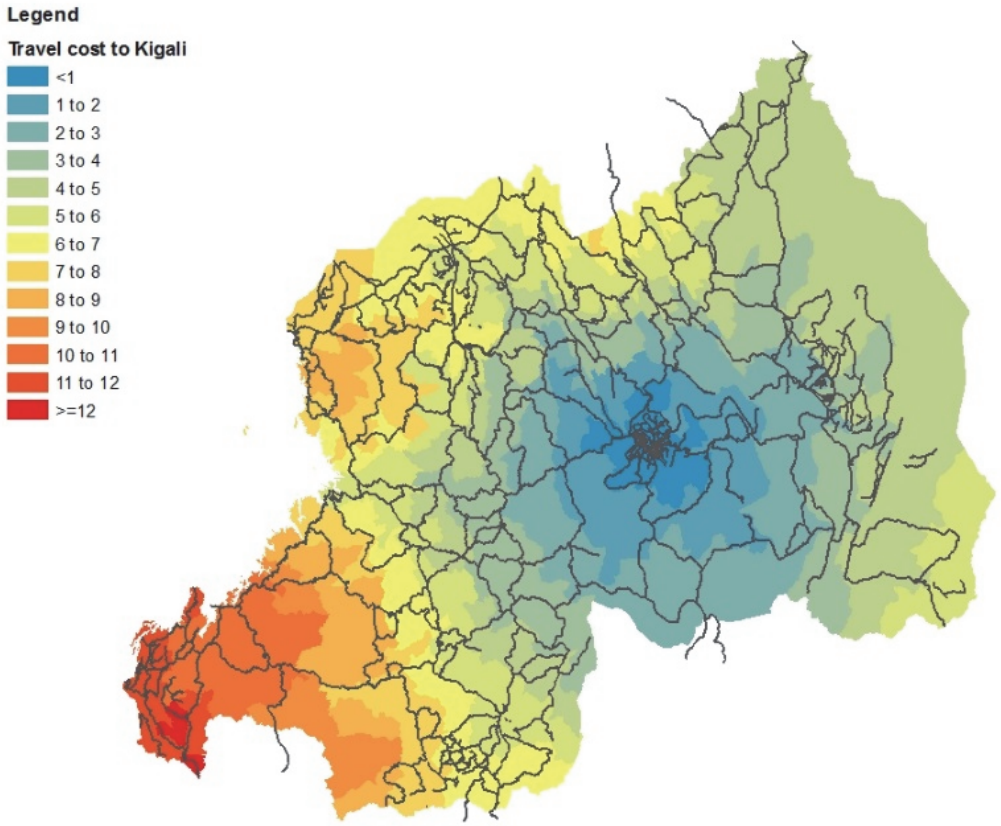
Table C1. List of sectors by MAI (only MAI greater than 30)

MAI	Sectors
30 - 50	Byimana, Rusiga, Muhanga, Ntarama, Nyakabanda, Nyamiyaga, Nyakariro, Nyarubaka, Rugalika, Nyamata, Rutunga, Cyeza, Musha, Bushoki, Mutete, Mageragere, Munyiginya, Mwulire, Ruhango, Kigarama, Kigabiro, Rukoma, Nyarusange, Ngamba, Murambi, Muhondo
50 - 75	Kinyinya, Kanombe, Gahanga, Rusororo, Nyamabuye, Ndera, Jali, Muyumbu, Masaka, Masoro, Kigali, Gahengeri, Musambira, Ntarabana, Shyogwe, Shyorongi, Mumbogo, Gatenga
>=75	Muhima, Gitega, Gatsata, Kicukiro, Niboye, Kimihurura, Nyarugunga, Nyarugenge, Kimisagara, Remera, Kanyinya, Gisoze, Kacyiru, Kimironko, Gikondo, Kagarama, Runda, Gacurabwenge, Nduba, Jabana

Appendix D. Travel cost across geographic sectors

Generalized travel cost is calculated for each pair of the 416 sectors in Rwanda by considering the following factors: Euclidian distance, slope of the cells, existing road networks, and type of roads. The calculated generalized travel cost has no unit and thus indicate only travel costs in relative terms. The map below illustrates travel costs from the core of the City of Kigali.

Figure D1. Travel costs to Kigali



Appendix E. Hot spot analysis

Hot spot analysis of poverty in this Note is conducted using ArcGIS. The ESRI website explains this well:[22]

> The Hot Spot Analysis tool calculates the Getis-Ord Gi* statistic for each feature in a dataset. The resultant Z score tells you where features with either high or low values cluster spatially. This tool works by looking at each feature within the context of neighboring features. A feature with a high value is interesting, but may not be a statistically significant hot spot. To be a statistically significant hot spot, a feature will have a high value and be surrounded by other features with high values as well. The local sum for a feature and its neighbors is compared proportionally to the sum of all features; when the local sum is much different than the expected local sum, and that difference is too large to be the result of random chance, a statistically significant Z score results.

Mathematically, the Getis-Ord Gi* statistic is expressed as follows:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}x_j - \bar{X}\sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{\left[n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}}$$

where x_j is the attribute value for feature j (that is, poverty headcount ratio in each sector), $w_{i,j}$ is the spatial weight between feature i and j, n is equal to the total number of features (that is, 416 sectors), and

[22] http://resources.esri.com/help/9.3/arcgisengine/java/gp_toolref/spatial_statistics_tools/how_hot_spot_analysis_colon_getis_ord_gi_star_spatial_statistics_works.htm

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n}$$
$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\bar{X})^2}$$

Appendix F. Econometrics models

Non-spatial fixed-effects model

The non-spatial fixed-effects model used in this Note is

$$y_{it} = \beta X_{it} + \alpha_i + u_{it} + \delta_{t=2002} T_{t=2002}$$

where Y_{it} indicates a dependent variable (for example, MPI, share of nonfarm employment, and so on) of sector i at year t (2002 or 2012); X_{it} indicates an independent variable (for example, population density); α_i is an unknown intercept for each sector; u_{it} is an error term; and Tt is a binary time regressor. β, a parameter to be estimated, indicates the extent to which one unit change in x is associated with a change in y between 2002 and 2012.

Although X can include only time-variant sector characteristics, it is possible to examine the heterogeneity in, for example, the estimated density effect for poverty reduction as follows:

$$\text{Log(MPI)}_{it} = \beta_1 \text{Log(density)}_{it} + \beta_2 [\text{Log(density)}_{it} \times \text{KIGALI}_i] + \alpha_i + u_{it} + \delta_{t=2002} T_{t=2002}$$

where KIGALI is a binary indicator about whether sector i is located within Greater Kigali (KIGALI=1) or not (KIGALI=0). The density effect is estimated as β_1 for sectors outside Greater Kigali and $\beta_1 + \beta_2$ for sectors within Greater Kigali.

Spatial fixed-effects model

The spatial fixed-effects model used mainly in this study is the SDM, which is written as follows:

$$y_t = \rho W y_t + X_t \beta + \text{W} Z_t \theta + \alpha + u_t$$

where W is a spatial weights matrix, which in this Note indicates the inverse of distance between each pair of two sectors. Z includes independent variables that are spatially weighted (that is, population of density in this note).[23] Total effects of changing population density that takes into account the feedback process of spillover effects, are calculated following Belotti, Hughes, and Mortari (2016).

Following LeSage and Pace (2009) and Elhorst (2010), this Note first estimates the SDM since the SDM is a general form of Spatial Autoregressive Model (SAR) and Spatial Error Model (SEM). In case $\theta = 0$, SDM is reduced to the following SAR:

$$y_t = \rho W y_t + X_t \beta + \alpha + u_t$$

And if $\rho = 0$ but errors are still spatially autocorrelated, then the SEM below is the right model.

$$y_t = X_t \beta + \alpha + v_t$$
$$v_t = \lambda M v_t + \varepsilon_t$$

Since the SAR and the SEM are nested under the SDM, it is possible to perform a Lagrange Multiplier (LM) test (Anselin 1988; Anselin and Kelejian 1997) for the presence of spatial dependence and spatial autocorrelation.

[23] This note uses *spmat* (Drukker et al. 2013) command in Stata for the construction of the spatial weights and *xsmle* (Belotti, Hughes, and Mortari 2016) command for the estimation of spatial fixed-effects models.

Appendix G. Population density snapshots[24]

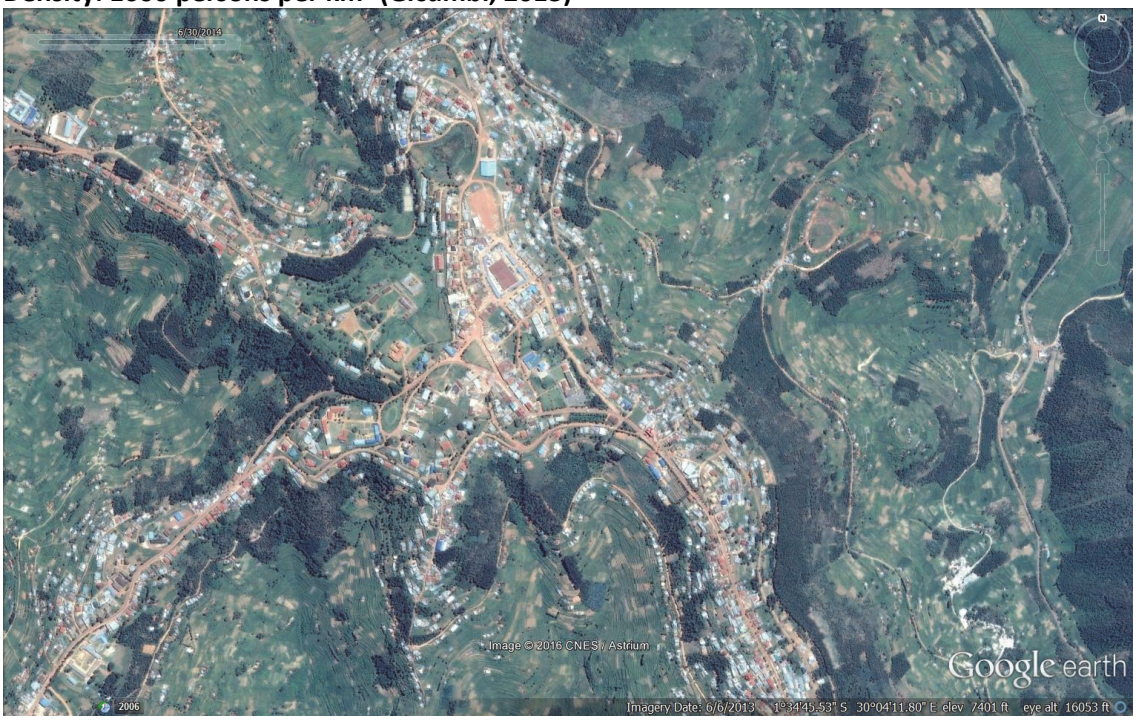
Density: 500 persons per km^2 (Nyagatare, 2011)

S

Nyagatare, 2006

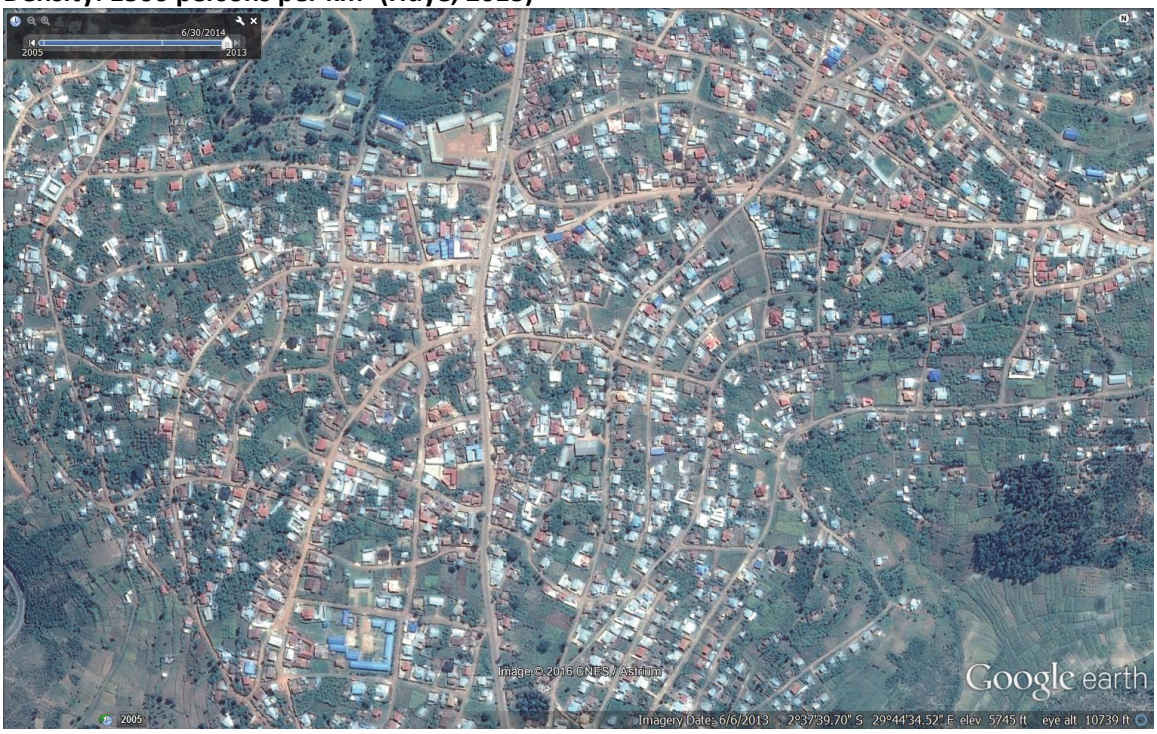
[24] Satellite images are retrieved from GoogleEarth.

Density: 1000 persons per km^2 (Gicumbi, 2013)



Gicumbi, 2006

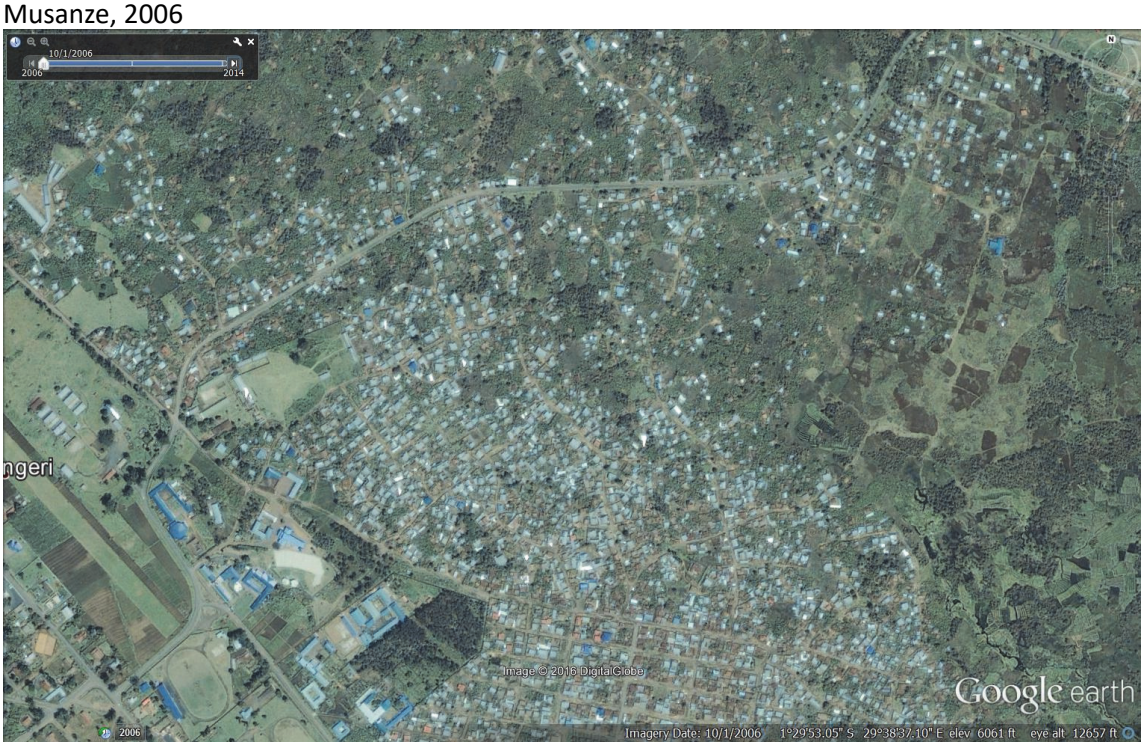
Density: 1500 persons per km^2 (Huye, 2013)



Huye, 2006

Density: 2500 persons per km^2 (Musanze, 2014)

Musanze, 2006



Density: 5000 persons per km^2 (Giseyni, 2010)

Giseyni, 2003

Appendix H. Regression **tables**

Table H1. MPI and population density, 2002 and 2012

	Log of MPI (moderate poverty) 2002			
	(1)	(2)	(3)	(4)
Log(Density 2002)	-0.236***	-0.231***	-0.090***	-0.329***
	(0.019)	(0.019)	(0.022)	(0.100)
Mean slope		0.012***	0.008**	0.039*
		(0.004)	(0.003)	(0.021)
District FE	Yes	Yes	Yes	Yes
Sub-sample	No	No	B90	T10
R squared	0.662	0.671	0.357	0.841
Obs.	416	416	374	41

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Constant terms are not shown. MPI is based on moderate poverty.

	Log of MPI (moderate poverty) 2012						
	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Log(Density 2012)	-0.296***	-0.289***	-0.113***	-0.475***			
	(0.024)	(0.024)	(0.028)	(0.148)			
Mean slope		0.010**	0.008*	0.027	0.013***	0.009**	0.027
		(0.004)	(0.004)	(0.023)	(0.004)	(0.004)	(0.027)
Log(Density 2002)					-0.263***	-0.103***	-0.359***
					(0.021)	(0.025)	(0.124)
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sub-sample	No	No	B90	T10	No	B90	T10
R squared	0.693	0.697	0.401	0.796	0.698	0.404	0.799
Obs.	416	416	374	41	416	374	41

Table H2. MPI and built-up ratio, 2002 and 2012

	Log of MPI (moderate poverty) 2002			
	(1)	(2)	(3)	(4)
Log(Built-up ratio 2002)	-0.098***	-0.292***	-0.315***	-0.296***
	(0.019)	(0.020)	(0.077)	(0.058)
Mean slope		0.007**	0.007**	0.021
		(0.003)	(0.003)	(0.022)
District FE	Yes	Yes	Yes	Yes
Sub-sample	No	No	B90	T10
R squared	0.704	0.707	0.343	0.870
Obs.	416	416	374	41

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Constant terms are not shown. MPI is based on moderate poverty.

	Log of MPI (moderate poverty) 2012						
	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Log(Built-up ratio 2014)	-0.350***	-0.347***	-0.127***	-0.550***			
	(0.022)	(0.022)	(0.044)	(0.078)			
Mean slope		0.003	0.006	-0.016	0.006*	0.006*	0.019
		(0.004)	(0.004)	(0.023)	(0.004)	(0.003)	(0.027)
Log(Built-up ratio 2002)					-0.380***	-0.394***	-0.264***
					(0.021)	(0.081)	(0.073)
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sub-sample	No	No	B90	T10	No	B90	T10
R squared	0.738	0.738	0.374	0.860	0.777	0.426	0.846
Obs.	416	416	374	42	416	374	41

Table H3. Changes in MPI (moderate poverty) and population density, 2002 and 2012

	Log(MPI: moderate poverty)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log(density)	-0.314***	-0.244***	-0.150**	-0.116***	-0.335**	-0.331**	-0.214
	(0.027)	(0.031)	(0.071)	(0.052)	(0.158)	(0.146)	(0.141)
× [Density<500]					0.258*	0.219	0.139
					(0.150)	(0.138)	(0.132)
× [Density 500-1000]					0.309**	0.346**	0.181
					(0.153)	(0.147)	(0.133)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District FE	No	Yes	No	No	No	No	No
Sector FE	No	No	Yes	Yes	Yes	Yes	Yes
Age, sex & education controlled	No	No	No	Yes	Yes	Yes	Yes
MPI measured only for non-migrants	No	No	No	No	No	Yes	No
Changes in education levels controlled	No	No	No	No	No	Yes	Yes
R squared (overall)	0.538	0.712	0.460	0.765	0.613	0.509	0.731
Obs.	832	832	832	832	832	832	832

Note: Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Constant terms are not shown.

Table H4. Changes in MPI (severe poverty) and population density, 2002 and 2012

	Log(MPI: severe poverty)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log(density)	-0.435***	-0.343***	-0.233**	-0.163**	-0.556***	-0.526***	-0.418***
	(0.038)	(0.042)	(0.096)	(0.063)	(0.184)	(0.193)	(0.160)
× [Density<500]					0.470***	0.400**	0.341**
					(0.175)	(0.181)	(0.151)
× [Density 500-1000]					0.521***	0.540***	0.370**
					(0.185)	(0.193)	(0.156)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District FE	No	Yes	No	No	No	No	No
Sector FE	No	No	Yes	Yes	Yes	Yes	Yes
Age, sex & education controlled	No	No	No	Yes	Yes	Yes	Yes
MPI measured only for non-migrants	No	No	No	No	No	Yes	No
Changes in education levels controlled	No	No	No	No	No	Yes	Yes
R squared (overall)	0.565	0.733	0.511	0.828	0.678	0.621	0.760
Obs.	832	832	832	832	832	832	832

Note: Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Constant terms are not shown.

Table H5. Regional heterogeneity in density effects for poverty reduction

	Log(MPI: moderate poverty)		Log(MPI: severe poverty)	
	Inside	Outside	Inside	Outside
<20km from Kigali	-1.45**	-1.07*	-3.06***	-1.17
<30km from Kigali	-1.43**	-1.07*	-2.67***	-1.27*
<5km from secondary cities	-5.98**	-0.84**	-6.46*	-1.30***
<10km from secondary cities	-3.34*	-0.87**	-3.48	-1.38***
<20km from secondary cities	-1.81	-1.03**	-1.82	-1.59***
Southern Province	-0.55	-1.21**	-0.56	-1.71***
Western Province	-1.03	-1.18***	-1.76	-1.62***
Northern Province	-1.68**	-1.10**	-0.84	-1.73**
Eastern Province	-1.10***	-1.22*	-1.35***	-1.90**

Note: Figures as estimated marginal effects of a 10 percent increase in population density. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

.

Table H6. Changes in MPI (moderate poverty) and built-up ratio, 2002 and 2012/14

	Log(MPI: moderate poverty)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Built-up ratio	-0.041***	-0.035***	-0.029***	-0.007	-0.007	-0.006	-0.006
	(0.004)	(0.003)	(0.008)	(0.006)	(0.006)	(0.005)	(0.005)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District FE	No	Yes	No	No	No	No	No
Sector FE	No	No	Yes	Yes	Yes	Yes	Yes
Age, sex & education controlled	No	No	No	No	Yes	Yes	Yes
MPI measured only for non-migrants	No	No	No	No	No	Yes	No
Changes in education levels controlled	No	No	No	No	No	No	Yes
R squared (overall)	0.479	0.656	0.457	0.743	0.743	0.708	0.869
Obs.	810	810	810	810	810	810	810

Note: Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Constant terms are not shown. The 11 geographic sectors with a decreasing built-up area between 2002 and 2012 in Kigali City are not included for the analysis.

Table H7. Changes in MPI (severe poverty) and built-up ratio, 2002 and 2012/14

	Log(MPI: severe poverty)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Built-up ratio	-0.062***	-0.054***	-0.053***	-0.024***	-0.024***	-0.024***	-0.024***
	(0.005)	(0.004)	(0.011)	(0.007)	(0.007)	(0.007)	(0.006)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District FE	No	Yes	No	No	No	No	No
Sector FE	No	No	Yes	Yes	Yes	Yes	Yes
Age, sex & education controlled	No	No	No	No	Yes	Yes	Yes
MPI measured only for non-migrants	No	No	No	No	No	Yes	No
Changes in education levels controlled	No	No	No	No	No	No	Yes
R squared (overall)	0.565	0.706	0.560	0.809	0.809	0.785	0.890
Obs.	810	810	810	810	810	810	810

Note: Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Constant terms are not shown. The 11 geographic sectors with a decreasing built-up area between 2002 and 2012 in Kigali City are not included for the analysis.

Table H8. Changes in share of nonfarm employment and density between 2002 and 2012

	Nonfarm employment share					
	(1)	(2)	(3)	(4)	(5)	(6)
Log(density)	20.25***	15.37***	16.06***	14.44***	18.19**	15.37*
	(1.494)	(1.652)	(3.474)	(3.250)	(9.109)	(8.425)
× [Density<500]					-6.131	-3.610
					(9.385)	(8.851)
× [Density 500-1000]					3.686	6.989
					(9.520)	(9.008)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
District FE	No	Yes	No	No	No	No
Sector FE	No	No	Yes	Yes	Yes	Yes
Age, sex & education controlled	No	No	No	Yes	Yes	Yes
Changes in education levels controlled	No	No	No	No	No	Yes
R squared (overall)	0.621	0.790	0.617	0.699	0.363	0.252
Obs.	832	832	832	832	832	832

Note: Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Constant terms are not shown.

Table H9. Changes in share of wage employment and density between 2002 and 2012

	Wage employment share					
	(1)	(2)	(3)	(4)	(5)	(6)
Log(density)	9.697***	7.236***	5.470***	5.638***	8.661*	7.326*
	(0.800)	(0.858)	(1.725)	(1.776)	(4.473)	(4.400)
× [Density<500]					-3.855	-2.423
					(4.523)	(4.479)
× [Density 500-1000]					-2.752	-0.978
					(5.026)	(5.056)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
District FE	No	Yes	No	No	No	No
Sector FE	No	No	Yes	Yes	Yes	Yes
Age, sex & education controlled	No	No	No	Yes	Yes	Yes
Changes in education levels controlled	No	No	No	No	No	Yes
R squared (overall)	0.564	0.752	0.550	0.539	0.706	0.617
Obs.	832	832	832	832	832	832

Note: Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Constant terms are not shown.

Table H10. Regional heterogeneity in density effects for nonfarm (wage) employment share

	Nonfarm share		Wage share	
	Inside	Outside	Inside	Outside
<20km from Kigali	24.95***	11.04***	8.94***	4.57**
<30km from Kigali	24.14***	11.08***	9.27***	4.38**
<5km from secondary cities	47.72***	12.18***	21.00***	4.59***
<10km from secondary cities	26.17**	12.84***	9.91*	5.06***
<20km from secondary cities	20.77***	13.14***	7.74**	5.20***
Southern Province	11.53**	14.66***	4.67*	5.71***
Western Province	28.14***	13.05***	9.73**	5.22***
Northern Province	24.23***	13.24***	15.55***	4.42**
Eastern Province	6.41***	22.08***	2.31*	8.80***

Note: Figures as estimated marginal effects of a 10 percent increase in population density. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table H11. MPI among farmers

	MPI among farmers (moderate poverty)					
	(1)	(2)	(3)	(4)	(5)	(6)
MPI among non-farmers	0.049**	-0.149				
	(0.023)	(0.152)				
× [Nonfarm<4]		0.169				
		(0.155)				
× [Nonfarm 4-20]		0.225				
		(0.155)				
Share of nonfarm employment			-0.085**	-0.233***		
			(0.040)	(0.058)		
× [Density<500]				0.190***		
				(0.058)		
× [Density 500-1000]				0.218***		
				(0.058)		
Log(density)					-2.326	-3.539
					(1.487)	(4.945)
× [Density<500]						0.872
						(4.796)
× [Density 500-1000]						4.654
						(4.757)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Age, sex & education controlled	Yes	Yes	Yes	Yes	Yes	Yes
R squared (overall)	0.530	0.525	0.513	0.402	0.525	0.128
Obs.	832	832	832	832	832	832

Note: Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Constant terms are not shown.

Table H12. MPI among farmers (outside Greater Kigali)

	MPI among farmers (moderate poverty)					
	(1)	(2)	(3)	(4)	(5)	(6)
MPI among non-farmers	0.050**	-0.005				
	(0.025)	(0.126)				
× [Nonfarm<4]		0.023				
		(0.129)				
× [Nonfarm 4-20]		0.075				
		(0.130)				
Share of nonfarm employment			-0.110**	-0.207***		
			(0.043)	(0.058)		
× [Density<500]				0.127**		
				(0.063)		
× [Density 500-1000]				0.199***		
				(0.062)		
Log(density)					-3.218***	-15.10***
					(1.217)	(5.645)
× [Density<500]						11.79**
						(5.697)
× [Density 500-1000]						16.27***
						(5.757)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Age, sex & education controlled	Yes	Yes	Yes	Yes	Yes	Yes
R squared (overall)	0.557	0.539	0.496	0.440	0.496	0.036
Obs.	678	678	678	678	678	678

Note: Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Constant terms are not shown.

Table H13. Estimation results of spatial fixed-effects models

	MPI among farmers (moderate)			MPI among farmers (severe)		
	SDM	SAR	SEM	SDM	SAR	SEM
	(1)	(2)	(3)	(4)	(5)	(6)
MPI among non-farmers	0.048**	0.045**	0.039*	0.054**	0.049**	0.045**
	(0.022)	(0.023)	(0.022)	(0.017)	(0.022)	(0.022)
MPI among non-farmers (W)	0.185*			0.177		
	(0.112)			(0.111)		
rho	0.299*	0.296		0.212	0.287	
	(0.181)	(0.187)		(0.199)	(0.189)	
lambda			0.406***			0.322**
			(0.134)			(0.146)
Direct effect	0.051**	0.045**		0.056***	0.050**	
	(0.022)	(0.023)		(0.022)	(0.022)	
Indirect effect	0.129*	0.008		0.115*	0.008	
	(0.071)	(0.007)		(0.069)	(0.007)	
Total effect	0.181**	0.053**		0.171**	0.058**	
	(0.076)	(0.026)		(0.073)	(0.026)	
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Age, sex & education controlled	Yes	Yes	Yes	Yes	Yes	Yes
AIC	3679	3694	3678	3734	3747	3733
R squared (overall)	0.484	0.517	0.595	0.547	0.547	0.622
Obs.	832	832	832	832	832	832

Note: Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Constant terms are not shown.
SDM: Spatial Durbin Model. SAR: Spatial Autoregressive Model. SEM: Spatial Error Model. See Appendix F for details.

WORLD BANK GROUP