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Rural-Urban disparities in missed opportunities for vaccination in sub-Saharan Africa: A Multi-country Decomposition Analyses

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Rural-Urban disparities in missed opportunities for vaccination in sub-Saharan Africa: A Multi-country Decomposition Analyses

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ABSTRACT

Background: In this study, we aimed to explore the rural-urban disparities in the magnitude and determinants of missed opportunities for vaccination (MOV) in sub-Saharan Africa.

Methods: This was a cross-sectional study using nationally representative household surveys conducted between 2007 and 2017 in 35 countries across sub-Saharan Africa. The risk difference in MOV between rural or urban dwellers were calculated. Logistic regression method was used to investigate the urban-rural disparities in multivariable analyses. Then Blinder-Oaxaca method was used to decompose differences in MOV between rural and urban dwellers.

Results: The median number of children aged 12 to 23 months was 2113 (Min: 370, Max: 5896). There was wide variation in the the magnitude of MOV among children in rural and urban areas across the 35 countries. The magnitude of MOV in rural areas varied from 18.0% (95% CI 14.7 to 21.4) in the Gambia to 85.2% (81.2 to 88.9) in Gabon. Out of the 35 countries included in this analysis, pro-rural inequality was observed in 16 countries (i.e. MOV is prevalent among children living in rural areas) and pro-urban inequality in five countries (i.e. MOV is prevalent among children living in urban areas). The contributions of the compositional 'explained' and structural 'unexplained' components varied across the countries. However, household wealth index was the most frequently identified factor.

Conclusions: Variation exists in the level of missed opportunities for vaccination between rural and urban areas, with widespread pro-rural inequalities across Africa. Although several factors account for these rural-urban disparities in various countries, household wealth was the most common.

INTRODUCTION

Immunization is one of the most effective public health interventions for preventing common childhood infectious diseases (1). According to estimates from the Global Burden of Disease study in 2017, under-five mortality has significantly reduced between 1970 and 2016 from 16.4 million to 5.0 million respectively (2). This global decline in child mortality is partly attributed to childhood immunization (3). To sustain this, childhood immunization has remained an important global health agenda (4). However, global immunization coverage has stagnated in recent years (5). In 2008, coverage with third dose of diptheria-tetanus-pertussis containing vaccine (DTP3 coverage) was estimated to be 83% (5). This coverage level only increased marginally by 3% in 2015, and remained at same level in 2016 (5). Consequently, an estimated 19.5 million children, which represents about one-fifth of the annual global birth cohort, remain unvaccinated or undervaccinated (6).

In an effort to breach this gap, the World Health Organization (WHO) has reinvigorated efforts to reduce missed opportunities for vaccination (MOV) (7). MOV is defined by the WHO as “any contact with health services by a child (or adult) who is eligible for vaccination (unvaccinated, partially vaccinated or not up-to-date, and free of contraindications to vaccination), which does not result in the individual receiving all the vaccine doses for which he or she is eligible” (8). MOV assessments are conducted in health facilities across Africa and other continents in order to help local stakeholders to plan appropriate interventions (8).

Several social determinants of health that contribute to inequalities in Africa, also affect access to immunization services (9-13). However, there is a dearth of evidence on how underlying inequalities, particularly, rural – urban disparities, affects MOV. Inequality results in disproportionate access to vaccines, therefore impeding progress towards univeral access. Identifying the disparities where they exists will serve as useful information for policy-makers at regional and national level when planning programmes to address MOV and improve immunization coverage. In addition, understanding the factors that influence rural-urban disparities in MOV can foster consideration for context-specific interventions for addressing MOV.

In this study we determined the burden of MOV among children aged 12 – 23 months in rural and urban areas and described the factors associated with rural-urban disparity. The findings from this study advanced current knowledge by exploring the relationship between place of residence and missed opportunities for vaccination in sub-Saharan Africa.

RESULTS

Survey and Sample Characteristics

The surveys were conducted between 2007 and 2017. The median (min,max) number of children aged 12 to 23 months was 2113 (370, 5893) (**Table 1**). Among study participants, the proportion of male children was 50.6%. Mean (standard deviation) age of children in months was 17.13 (3.42). About 46% of the mothers were aged between 25 to 34 years old and 40% had no formal education. Almost one third of the mothers were not working at the time of the survey. Majority of the respondents were living in rural areas (70%). Other demographic characteristics of the study participants are presented on **Table 2**. The burden of MOV in rural areas varied from 18.0% (95% CI 14.7 to 21.4) in the Gambia to 85.2% (81.2 to 88.9) in Gabon. Details of the pooled MOV for each country is presented on Table 1**.** In some countries, the prevalence of MOV in rural areas was higher compared to urban areas (**Figure 1**). This was highest in Zambia where the magnitude of MOV in rural areas was 74.4% and 45.9% in urban area with a risk difference of 28.5% (95%CI: 24.6 to 32.4). However, in Namibia, the burden of MOV in rural areas was 22.9%, while in urban areas, it was 43.5%, thus yielding a risk difference of -20.6% (95% CI -26.5 to -14.6). Figure 1 shows details of the variation in MOV among children in rural and urban areas across the 35 countries included in the study.

Magnitude and variations in residence inequality in MOV

Figure 2 shows the risk difference (measure of inequality) between mothers residing in rural and urban areas. Out of the 35 countries included in this analysis, 16 countries showed pro-rural inequality (i.e. MOV is prevalent among mothers living in rural areas), four showed pro-urban inequality (i.e. MOV is prevalent among mothers living in urban areas) and remaining 14 countries showed no significant inequality. Among the countries with significant pro-rural inequality, the risk difference ranged from 5.7% (95% CI 1.1 to 10.4) to 28.5% (95% CI 24.6 to 32.4). The risk difference ranged from -20.6% (95% CI -26.5 to -14.6) in Namibia to -7.8% (95% CI -10.4 to -5.2) in Nigeria (countries with significant pro-urban inequality).

Figure 3 plot the relationship between the magnitude of MOV and inequality for all countries. The countries can be grouped into distinct categories, those with:

- high MOV and high pro-rural inequality such as Zambia
- high MOV and high pro-urban inequality such as Gabon
- low MOV and high pro-rural inequality such as Lesotho and Mozambique
- low MOV and high pro-urban inequality such as the Gambia

Decomposition of residence inequality in MOV

A negative contribution indicates that the determinant was narrowing the relative gap between rural and urban areas and vice versa. The contributions of the compositional 'explained' and structural 'unexplained' components varied across the countries. Compositional effects of the determinants were responsible for most of the inequality in MOV between rural and urban areas in Liberia, Kenya, Ghana, Cote d'ivore, Congo DR and Cameroon. While in Lesotho and Ethiopia structural effects of the determinants were responsible for most of the inequality in MOV between rural and urban areas. Important factors responsible for the inequality varied across the countries. On average, household wealth index was the most important factors in most countries. In Mozambique, the largest contributions to the inequality in MOV was wealth index followed by media access and maternal education. Wealth index and not working were narrowing the inequality in MOV between rural and urban areas in Uganda and Rwanda respectively. **Figure 4** shows the detailed decomposition of the part of the inequality that was caused by compositional effects of the determinants.

DISCUSSION

Main Findings

The magnitude of missed opportunities for vaccination was 90.8% and 85.6% in urban and rural areas of Gabon respectively, and this was the highest among all countries. Swaziland had the lowest level of missed opportunities for vaccination in rural areas, while Zimbabwe had the lowest level in urban areas compared to all countries. There was significant pro-rural inequality in the following countries: Tanzania, Zambia, Niger, Madagascar, Uganda, Cote d'Ivoire, Lesotho, Ethiopia, Kenya, Mozambique, Democratic Republic of Congo, Rwanda, Ghana, Liberia, and Cameroon. Several demographic and socioeconomic factors were found to be responsible for the rural-urban disparity in missed opportunities for vaccination in different countries. The compositional effects of these determinants accounted for the disparity in MOV in six countries namely; Kenya, Liberia, Cote d'Ivoire, Ghana, Democratic republic of Congo, and Cameroon. While structural effects are responsible in Lesotho and Ethiopia. Household wealth index was the most implicated factor responsible for this disparity across the countries.

Policy Implications

Currently a great proportion of households making contact with health facilities fail to get the eligible children vaccinated. This results in missed opportunities for vaccination which invariably affects the overall immunization coverage at regional and national level (9). The magnitude of missed opportunities for vaccination varied from country to country between rural and urban areas. In Tanzania, the gap difference was marked widely. In Zimbabwe, however, missed opportunties for vaccination was low in both areas, and this is consistent with the overall high performance of the immunization system in the country (5). Nevertheless, it is important to note that in rural areas, factors such as low level of education among mothers, low household wealth, high number of children who are less than five years, and high birth order were common factors related to high MOV in rural areas. Similar factors have been found to be associated with MOV in other studies (9, 14).

In this study, high pro-rural inequality was found in 16 countries. Place of residence (rural and urban) is a recognized dimension of inequality, and it has been associated with immunization inequality, with rural areas often disadvantaged(15-17). It is therefore not surprising that more countries had pro-rural inequalities in missed opportunities for vaccination in this study. This can be explained by poor performance of immunization clinics in rural areas due health services-related factors.

Based on our findings, rural-urban disparity in missed opportunities for vaccination within countries are determined by several factors as follows: household wealth, maternal education, media access, number of underfive children, and birth order of the child. Nevertheless, household wealth was found to be an important factor in most of the countries. Children in wealthy households are likely to be taken to less crowded health facilities, and even spend more time, thus resulting in verification of their vaccination status, and subsequent immunization, if needed. The relationship between socioeconomic status and vaccination in Africa has been reported in several studies (18, 19). In fact, household wealth has been found to be a predictor of full immunization coverage in previous studies (20, 21). Maternal education was another factors that was observed in several countries. Other studies have emphasized the role of maternal education in ensuring a child’s vaccination(22, 23). Since mothers in rural areas usually have lower level of education, they are less likely to seek information about vaccination.

Strengths and Limitations of the study

This study is one of the first analysis of rural-urban disparities in missed opportunities for vaccination in Africa, and the use of nationally representative data from each of the 35 countries enhances the confidence in the estimates produced. However, there are limitations. First, causal relationship cannot be inferred from our findings because a cross sectional study design was used. Secondly, MOV was estimated using DHS data which is originally a household survey, although evidence of contact with health facilities was obtained using other variables therein. In addition, surveys conducted at different time points were combined in this study, the earliest being in 2007, and latest in 2016. Due to data limitations, MOV for specific vaccines and vaccine doses could not be determined. A main strength of this study was a proxy measure of wealth using household economic status was developed and used.

METHODS

Study design and data

Data for this cross-sectional study was obtained from Demographic and Health Surveys (DHS), which are nationally representative household surveys conducted in low- and middle-income countries. This study used data from 35 recent DHS surveys conducted between 2007 and 2016 in sub-Saharan Africa available as of December 2017. The DHS uses a multi-stage, stratified sampling design with households as the sampling unit (24). Within each sample household, all women and men meeting the eligibility criteria are interviewed. Because the surveys are not self-weighting, weights are calculated to account for unequal selection probabilities as well as for non-responses. With weights applied, survey findings represent the full target populations. The DHS surveys collects data using a household questionnaire. For eligible individuals within households, interviews are conducted using a woman’s or man’s questionnaire. DHS surveys are implemented across countries with standardized interviewer training, supervision, and implementation protocols.

Outcome variable

We used the World Health Organization (WHO) definition of missed opportunity for vaccination (MOV) as the outcome variable, defined as a binary variable that takes the value of 1 if a child who is eligible for vaccination, 12–23 months had any contact with health services, which does not result in the child receiving one or more of the vaccine doses for which he or she is eligible. Contact with health services was defined using the following five variables: skilled birth attendance, baby postnatal check within 2 months, received vitamin A dose in first 2 months after delivery, has a health card and received medical treatment for diarrhea/ fever/cough.

Main determinant variable

Place of residence which was categorised as rural or urban areas.

Explanatory variables

The following factors were included in the models: child's age, sex (male versus female), high birth order (>4 birth order), number of under five children in the household, maternal age in completed years (15 to 24, 25 to 34, 35 to 49), employment status (working or not working), maternal education (no education, primary or secondary or higher) and media access (radio, television or newspaper). Media access was assessed using the following indicators: access to information measured via frequency of watching television, listening to radio, and reading newspapers/magazine. To allow meaningful analysis, we dichotomized the response levels "less than one week", "at least once a week", and "almost every day" as one group and the response level "not at all" as the other group. We then created an additive media access variable (from 0 to 3) that counted the number of media type each respondent had access to. Wealth index was used as a proxy indicator for socioeconomic position. The methods used in calculating DHS wealth index have been described elsewhere **(25, 26)**. Briefly, an index of economic status for each household was constructed using principal components analysis based on the following household variables: number of rooms per house, ownership of car, motorcycle, bicycle, fridge, television and telephone as well as any kind of heating device. From these criteria the DHS wealth index quintiles (poorest, poorer, middle, richer and richest) were calculated and used in the subsequent modelling.

Statistical analyses

The analytical approach included descriptive statistics, univariable analysis and Blinder-Oaxaca decomposition techniques using logistic regressions. We used descriptive statistics to show the distribution of respondents by the key variables. Values were expressed as absolute numbers (percentages) and mean (standard deviation) for categorical and continuous variables respectively. In the descriptive statistics the distribution of respondents by key variables were expressed as percentages. All cases in the DHS data were given weights to adjust for differences in probability of selection and to adjust for non-response in order to produce the proper representation. Individual weights were used for descriptive statistics in this study.

We calculate risk difference in missed opportunities between the two group, living in rural or urban areas. A risk difference greater than 0 suggests that missed opportunities is prevalent among children living in rural areas (pro-rural inequality). Conversely, a negative risk difference indicates that missed opportunities for vaccination is prevalent among children living in urban areas (pro-urban inequality). Finally, we adopted logistic regression method using the pooled cross-sectional data to investigate the urban-rural disparities in multivariable analyses adjusted for explanatory variables.

The Blinder-Oaxaca decomposition was a counterfactual method with an assumption that "what the probability of missed opportunities for vaccination would be if children living in rural areas had the same characteristics as their urban counterparts?" (27, 28). The Blinder-Oaxaca method allows for the decomposition of the difference in an outcome variable between 2 groups into 2 components (27, 28). The first component is the "explained" portion of that gap that captures differences in the distributions of the measurable characteristics (referred as "compositional" or "endowments") of these groups (27, 28). This illustrates the portion of the gap in missed opportunities for vaccination that is attributed to the differences in observable, measurable characteristics between the two groups. Using this method, we can quantify how much of the gap the "advantaged" and the "disadvantaged" groups is attributable to these differences in specific measurable characteristics. The second component is the "unexplained" part, meaning the portion of the gap due to the differences in the estimated regression coefficients and the unmeasured variables between the two groups (27, 28). This is also referred to in the literature as the "structural" component or the "coefficient" portion of the decomposition. This reflects the remainder of the model not explained by the differences in measurable, objective characteristics. The "unexplained" portion arises from differentials in how the predictor variables are associated with the outcomes for the two groups. This portion would persist even if the disadvantaged group were to attain the same average levels of measured predictor variables as the advantaged group.

The DHS stratification and the unequal sampling weights as well as household clustering effects were considered in the analysis to correct standard errors. All tests were two tailed and $p < 0.05$ was considered significant.

Model fit and specifications

Regression diagnostics were used to judge the goodness-of-fit of the model. They included the tolerance test for multicollinearity, its reciprocal variance inflation factors (VIF), presence of outliers and estimates of adjusted R square of the regression model. We checked for multi-collinearity among explanatory variables examining the variance inflation factor (VIF) (29), all diagonal elements in the variance-covariance (τ) matrix for correlation between -1 and 1, and diagonal elements for any elements close to zero. The largest VIF greater than 10 or the mean VIF greater than 6 represent severe multicollinearity. None of the results of the tests provided reasons for concern. Thus, the models provide robust and valid results.

CONCLUSION

In conclusion, variation exists in the level of missed opportunities for vaccination between rural and urban areas, with widespread pro-rural inequalities across Africa.

Although several factors account for these rural-urban disparities in various countries, household wealth was the most common.

Recommendations are as follows;

a. The variation in magnitude of missed opportunities for vaccination between rural and urban areas necessitates consideration for place of residence in immunization activities to address this problem.
b. Intersectoral collaboration between national immunization programmes and other government ministries and agencies is necessary as several social factors have been found to influence the urban-rural disparity in missed opportunities for vaccination.
c. Multifacted approach which takes local context and other social factors into consideration will be a better approach to closing the gap between rural and urban dweller.
d. There is a need for further research on inequalities in missed opportunities for vaccination in order to identify how it varies by other sociodemographic factors that are likely to cause inequality such as maternal education, wealth among others.

ABBREVIATIONS

DHS: Demographic and Health Survey

DTP3: Third Dose of Diptheria-Tetanus-Pertussis containing vaccine

MOV: Missed Opportunities for Vaccination

WHO: World Health Organization

DECLARATIONS

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Availability of data and materials

The data used in this paper will be available upon request from the Demographic and Health Survey Program.

Authors' contribution

OAU and CSY conceived the study. OAU and CSY obtained funding for the study. OAU collected and analysed initial data. AAA, ABW, CSY, DN, EZS, ABW and OAU participated contributed in refining the data analysis. OAU and AAA wrote the first manuscript. AAA, ABW, CSY, DN, EZS, GB, JO, OAU, TO and SY contributed to further analysis, interpreting and shaping of the argument of the manuscript and participated in writing the final draft of the manuscript. All the authors read and approved the final manuscript.

Ethics approval and consent to participate

This study was based on an analysis of secondary survey data with all identifier information removed. The survey was approved by the Ethics Committee of the ICF Macro at Fairfax, Virginia in the USA and by the National Ethics Committees in their respective countries. All study participants gave informed consent before participation and all information was collected confidentially.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests

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ABSTRACT

Background: In this study, we aimed to explore the rural-urban disparities in the magnitude and determinants of missed opportunities for vaccination (MOV) in sub-Saharan Africa.

Methods: This was a cross-sectional study using nationally representative household surveys conducted between 2007 and 2017 in 35 countries across sub-Saharan Africa. The risk difference in MOV~~missed opportunities~~ between rural or urban dwellers were calculated. Logistic regression method was used to investigate the urban-rural disparities in multivariable analyses. Then Blinder-Oaxaca method was used to decompose differences in MOV between rural and urban dwellers.

Results: The median number of children aged 12 to 23 months was 2113 (Min: 370, Max: 5896). There was wide variation in the the magnitude of MOV among children in rural and urban areas across the 35 countries. The magnitude of MOV in rural areas varied from 18.0% (95% CI 14.7 to 21.4) in the Gambia to 85.2% (81.2 to 88.9) in Gabon. Out of the 35 countries included in this analysis, pro-rural inequality was observed in 16 countries (i.e. MOV is prevalent among children living in rural areas) and pro-urban inequality in five countries (i.e. MOV is prevalent among children living in urban areas). The contributions of the compositional 'explained' and structural 'unexplained' components varied across the countries. However, household wealth index was the most frequently identified factor.

Conclusions: Variation exists in the level of missed opportunities for vaccination between rural and urban areas, with widespread pro-rural inequalities across Africa. Although several factors account for these rural-urban disparities in various countries, household wealth was the most common.

INTRODUCTION

Immunization is one of the most effective public health interventions for preventing common childhood infectious diseases (1). According to estimates from the Global Burden of Disease study in 2017, under-five mortality has significantly reduced between 1970 and 2016 from 16.4 million to 5.0 million respectively (2). This global decline in child mortality is partly attributed to childhood immunization (3). To sustain this, childhood immunization has remained an important global health agenda (4). However, global immunization coverage has stagnated in recent years (5). In 2008, coverage with third dose of diptheria-tetanus-pertussis containing vaccine (DTP3 coverage) was estimated to be 83% (5). This coverage level only increased marginally by 3% in 2015, and remained at same level in 2016 (5). Consequently, an estimated 19.5 million children, which represents about one-fifth of the annual global birth cohort, remain unvaccinated or undervaccinated (6).

In an effort to breach this gap, the World Health Organization (WHO) has reinvigorated efforts to reduce missed opportunities for vaccination (MOV) (7). MOV is defined by the WHO as “any contact with health services by a child (or adult) who is eligible for vaccination (unvaccinated, partially vaccinated or not up-to-date, and free of contraindications to vaccination), which does not result in the individual receiving all the vaccine doses for which he or she is eligible” (8). MOV assessments are conducted in health facilities across Africa and other continents in order to help local stakeholders to plan appropriate interventions (8).

Several social determinants of health that contribute to inequalities in Africa, also affect access to immunization services (9-13). However, there is a dearth of evidence on how underlying inequalities, particularly, rural – urban disparities, affects MOV. Inequality results in disproportionate access to vaccines, therefore impeding progress towards univeral access. Identifying the disparities where they exists will serve as useful information for policy-makers at regional and national level when planning programmes to address MOV and improve immunization coverage. In addition, understanding the factors that influence rural-urban disparities in MOV can foster consideration for context-specific interventions for addressing MOV.

In this study we determined the burden of MOV among children aged 12 – 23 months in rural and urban areas and described the factors associated with rural-urban disparity. The findings from this study advanced current knowledge by exploring the relationship between place of residence and missed opportunities for vaccination in sub-Saharan Africa.

RESULTS

Survey and Sample Characteristics

The surveys were conducted between 2007 and 2017. The median (min,max) number of children aged 12 to 23 months was 2113 (370, 5893) (**Table 1**). Among study participants, the proportion of male children was 50.6%. Mean (standard deviation) age of children in months was 17.13 (3.42). About 46% of the mothers were aged between 25 to 34 years old and 40% had no formal education. Almost one third of the mothers were not working at the time of the survey. Majority of the respondents were living in rural areas (70%). Other demographic characteristics of the study participants are presented on **Table 2**. The burden of MOV in rural areas varied from 18.0% (95% CI 14.7 to 21.4) in the Gambia to 85.2% (81.2 to 88.9) in Gabon. Details of the pooled MOV for each country is presented on Table 1**.** In some countries, the prevalence of MOV in rural areas was higher compared to urban areas (**Figure 1**). This was highest in Zambia where the magnitude of MOV in rural areas was 74.4% and 45.9% in urban area with a risk difference of 28.5% (95%CI: 24.6 to 32.4). However, in Namibia, the burden of MOV in rural areas was 22.9%, while in urban areas, it was 43.5%, thus yielding a risk difference of -20.6% (95% CI -26.5 to -14.6). Figure 1 shows details of the variation in MOV among children in rural and urban areas across the 35 countries included in the study.

Magnitude and variations in residence inequality in MOV

Figure 2 shows the risk difference (measure of inequality) between mothers residing in rural and urban areas. Out of the 35 countries included in this analysis, 16 countries showed pro-rural inequality (i.e. MOV is prevalent among mothers living in rural areas), four showed pro-urban inequality (i.e. MOV is prevalent among mothers living in urban areas) and remaining 14 countries showed no ~~statistically~~ significant inequality. Among the countries with ~~statistically~~ significant pro-rural inequality, the risk difference ranged from 5.7% (95% CI 1.1 to 10.4) to 28.5% (95% CI 24.6 to 32.4). The risk difference ranged from -20.6% (95% CI -26.5 to -14.6) in Namibia to -7.8% (95% CI -10.4 to -5.2) in Nigeria (countries with ~~statistical~~ significant pro-urban inequality).

Figure 3 plot the relationship between the magnitude of MOV and inequality for all countries. The countries can be grouped into distinct categories, those with:

- high MOV and high pro-rural inequality such as Zambia
- high MOV and high pro-urban inequality such as Gabon
- low MOV and high pro-rural inequality such as Lesotho and Mozambique
- low MOV and high pro-urban inequality such as the Gambia

Decomposition of residence inequality in MOV

A negative contribution indicates that the determinant was narrowing the relative gap between rural and urban areas and vice versa. The contributions of the compositional ‘explained’ and structural ‘unexplained’ components varied across the countries. Compositional effects of the determinants were responsible for most of the inequality in MOV between rural and urban areas in Liberia, Kenya, Ghana, Cote d’ivore, Congo DR and Cameroon. While in Lesotho and Ethiopia structural effects of the determinants were responsible for most of the inequality in MOV between rural and urban areas. Important factors responsible for the inequality varied across the countries. On average, household wealth index was the most important factors in most countries. In Mozambique, the largest contributions to the inequality in MOV was wealth index followed by media access and maternal education. Wealth index and not working were narrowing the inequality in MOV between rural and urban areas in Uganda and Rwanda respectively. **Figure 4** shows the detailed decomposition of the part of the inequality that was caused by compositional effects of the determinants.

DISCUSSION

Main Findings

The magnitude of missed opportunities for vaccination was 90.8% and 85.6% in urban and rural areas of Gabon respectively, and this was the highest among all countries. Swaziland had the lowest level of missed opportunities for vaccination in rural areas, while Zimbabwe had the lowest level in urban areas compared to all countries. There was ~~statistically~~ significant pro-rural inequality in the following countries: Tanzania, Zambia, Niger, Madagascar, Uganda, Cote d'Ivoire, Lesotho, Ethiopia, Kenya, Mozambique, Democratic Republic of Congo, Rwanda, Ghana, Liberia, and Cameroon. Several demographic and socioeconomic factors were found to be responsible for the rural-urban disparity in missed opportunities for vaccination in different countries. The compositional effects of these determinants accounted for the disparity in MOV in six countries namely; Kenya, Liberia, Cote d'Ivoire, Ghana, Democratic republic of Congo, and Cameroon. While structural effects are responsible in Lesotho and Ethiopia. Household wealth index was the most implicated factor responsible for this disparity across the countries.

Policy Implications

Currently a great proportion of households making contact with health facilities fail to get the eligible children vaccinated. This results in missed opportunities for vaccination which invariably affects the overall immunization coverage at regional and national level (9). The magnitude of missed opportunities for vaccination varied from country to country between rural and urban areas. In Tanzania, the gap difference was marked widely. In Zimbabwe, however, missed opportunties for vaccination was low in both areas, and this is consistent with the overall high performance of the immunization system in the country (5). Nevertheless, it is important to note that in rural areas, factors such as low level of education among mothers, low household wealth, high number of children who are less than five years, and high birth order were common factors related to high MOV in rural areas. Similar factors have been found to be associated with MOV in other studies (9, 14).

In this study, high pro-rural inequality was found in 16 countries. Place of residence (rural and urban) is a recognized dimension of inequality, and it has been associated with immunization inequality, with rural areas often disadvantaged(15-17). It is therefore not surprising that more countries had pro-rural inequalities in missed opportunities for vaccination in this study. This can be explained by poor performance of immunization clinics in rural areas due health services-related factors.

Based on our findings, rural-urban disparity in missed opportunities for vaccination within countries are determined by several factors as follows: household wealth, maternal education, media access, number of underfive children, and birth order of the child. Nevertheless, household wealth was found to be an important factor in most of the countries. Children in wealthy households are likely to be taken to less crowded health facilities, and even spend more time, thus resulting in verification of their vaccination status, and subsequent immunization, if needed. The relationship between socioeconomic status and vaccination in Africa has been reported in several studies (18, 19). In fact, household wealth has been found to be a predictor of full immunization coverage in previous studies (20, 21). Maternal education was another factors that was observed in several countries. Other studies have emphasized the role of maternal education in ensuring a child's vaccination(22, 23). Since mothers in rural areas usually have lower level of education, they are less likely to seek information about vaccination.

Strengths and Limitations of the study

This study is one of the first analysis of rural-urban disparities in missed opportunities for vaccination in Africa, and the use of nationally representative data from each of the 35 countries enhances the confidence in the estimates produced. However, there are limitations. First, causal relationship cannot be inferred from our findings because a cross sectional study design was used. Secondly, MOV was estimated using DHS data which is originally a household survey, although evidence of contact with health facilities was obtained using other variables therein. In addition, surveys conducted at different time points were combined in this study, the earliest being in 2007, and latest in 2016. Due to data limitations, MOV for specific vaccines and vaccine doses could not be determined. A main strength of this study was a proxy measure of wealth using household economic status was developed and used.

METHODS

Study design and data

Data for this cross-sectional study was obtained from Demographic and Health Surveys (DHS), which are nationally representative household surveys conducted in low- and middle-income countries. This study used data from 35 recent DHS surveys conducted between 2007 and 2016 in sub-Saharan Africa available as of December 2017. The DHS uses a multi-stage, stratified sampling design with households as the sampling unit (24). Within each sample household, all women and men meeting the eligibility criteria are interviewed. Because the surveys are not self-weighting, weights are calculated to account for unequal selection probabilities as well as for non-responses. With weights applied, survey findings represent the full target populations. The DHS surveys collects data using a household questionnaire. For eligible individuals within households, interviews are conducted using a woman’s or man’s questionnaire. DHS surveys are implemented across countries with standardized interviewer training, supervision, and implementation protocols.

Outcome variable

We used the World Health Organization (WHO) definition of missed opportunity for vaccination (MOV) as the outcome variable, defined as a binary variable that takes the value of 1 if a child who is eligible for vaccination, 12–23 months had any contact with health services, which does not result in the child receiving one or more of the vaccine doses for which he or she is eligible. Contact with health services was defined using the following five variables: skilled birth attendance, baby postnatal check within 2 months, received vitamin A dose in first 2 months after delivery, has a health card and received medical treatment for diarrhea/ fever/cough.

Main determinant variable

Place of residence which was categorised as rural or urban areas.

Explanatory variables

The following factors were included in the models: child's age, sex (male versus female), high birth order (>4 birth order), number of under five children in the household, maternal age in completed years (15 to 24, 25 to 34, 35 to 49), employment status (working or not working), maternal education (no education, primary or secondary or higher) and media access (radio, television or newspaper). Media access was assessed using the following indicators: access to information measured via frequency of watching television, listening to radio, and reading newspapers/magazine. To allow meaningful analysis, we dichotomized the response levels "less than one week", "at least once a week", and "almost every day" as one group and the response level "not at all" as the other group. We then created an additive media access variable (from 0 to 3) that counted the number of media type each respondent had access to. Wealth index was used as a proxy indicator for socioeconomic position. The methods used in calculating DHS wealth index have been described elsewhere **(25, 26)**. Briefly, an index of economic status for each household was constructed using principal components analysis based on the following household variables: number of rooms per house, ownership of car, motorcycle, bicycle, fridge, television and telephone as well as any kind of heating device. From these criteria the DHS wealth index quintiles (poorest, poorer, middle, richer and richest) were calculated and used in the subsequent modelling.

Statistical analyses

The analytical approach included descriptive statistics, univariable analysis and Blinder-Oaxaca decomposition techniques using logistic regressions. We used descriptive statistics to show the distribution of respondents by the key variables. Values were expressed as absolute numbers (percentages) and mean (standard deviation) for categorical and continuous variables respectively. In the descriptive statistics the distribution of respondents by key variables were expressed as percentages. All cases in the DHS data were given weights to adjust for differences in probability of selection and to adjust for non-response in order to produce the proper representation. Individual weights were used for descriptive statistics in this study.

We calculate risk difference in missed opportunities between the two group, living in rural or urban areas. A risk difference greater than 0 suggests that missed opportunities is prevalent among children living in rural areas (pro-rural inequality). Conversely, a negative risk difference indicates that missed opportunities for vaccination is prevalent among children living in urban areas (pro-urban inequality). Finally, we adopted logistic regression method using the pooled cross-sectional data to investigate the urban-rural disparities in multivariable analyses adjusted for explanatory variables.

The Blinder-Oaxaca decomposition was a counterfactual method with an assumption that "what the probability of missed opportunities for vaccination would be if children living in rural areas had the same characteristics as their urban counterparts?" (27, 28). The Blinder-Oaxaca method allows for the decomposition of the difference in an outcome variable between 2 groups into 2 components (27, 28). The first component is the "explained" portion of that gap that captures differences in the distributions of the measurable characteristics (referred as "compositional" or "endowments") of these groups (27, 28). This illustrates the portion of the gap in missed opportunities for vaccination that is attributed to the differences in observable, measurable characteristics between the two groups. Using this method, we can quantify how much of the gap the "advantaged" and the "disadvantaged" groups is attributable to these differences in specific measurable characteristics. The second component is the "unexplained" part, meaning the portion of the gap due to the differences in the estimated regression coefficients and the unmeasured variables between the two groups (27, 28). This is also referred to in the literature as the "structural" component or the "coefficient" portion of the decomposition. This reflects the remainder of the model not explained by the differences in measurable, objective characteristics. The "unexplained" portion arises from differentials in how the predictor variables are associated with the outcomes for the two groups. This portion would persist even if the disadvantaged group were to attain the same average levels of measured predictor variables as the advantaged group.

The DHS stratification and the unequal sampling weights as well as household clustering effects were considered in the analysis to correct standard errors. All tests were two tailed and $p < 0.05$ was considered significant.

Model fit and specifications

Regression diagnostics were used to judge the goodness-of-fit of the model. They included the tolerance test for multicollinearity, its reciprocal variance inflation factors (VIF), presence of outliers and estimates of adjusted R square of the regression model. We checked for multi-collinearity among explanatory variables examining the variance inflation factor (VIF) (29), all diagonal elements in the variance-covariance (τ) matrix for correlation between -1 and 1, and diagonal elements for any elements close to zero. The largest VIF greater than 10 or the mean VIF greater than 6 represent severe multicollinearity. None of the results of the tests provided reasons for concern. Thus, the models provide robust and valid results.

CONCLUSION

In conclusion, variation exists in the level of missed opportunities for vaccination between rural and urban areas, with widespread pro-rural inequalities across Africa.

Although several factors account for these rural-urban disparities in various countries, household wealth was the most common.

Recommendations are as follows;

a. The variation in magnitude of missed opportunities for vaccination between rural and urban areas necessitates consideration for place of residence in immunization activities to address this problem.
b. Intersectoral collaboration between national immunization programmes and other government ministries and agencies is necessary as several social factors have been found to influence the urban-rural disparity in missed opportunities for vaccination.
c. Multifacted approach which takes local context and other social factors into consideration will be a better approach to closing the gap between rural and urban dweller.
d. There is a need for further research on inequalities in missed opportunities for vaccination in order to identify how it varies by other sociodemographic factors that are likely to cause inequality such as maternal education, wealth among others.

ABBREVIATIONS

DHS: Demographic and Health Survey

DTP3: Third Dose of Diptheria-Tetanus-Pertussis containing vaccine

MOV: Missed Opportunities for Vaccination

WHO: World Health Organization

DECLARATIONS

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Availability of data and materials

The data used in this paper will be available upon request from the Demographic and Health Survey Program.

Authors' contribution

OAU and CSY conceived the study. OAU and CSY obtained funding for the study. OAU collected and analysed initial data. AAA, ABW, CSY, DN, EZS, ABW and OAU participated contributed in refining the data analysis. OAU and AAA wrote the first manuscript. AAA, ABW, CSY, DN, EZS, GB, JO, OAU, TO and SY contributed to further analysis, interpreting and shaping of the argument of the manuscript and participated in writing the final draft of the manuscript. All the authors read and approved the final manuscript.

Ethics approval and consent to participate

This study was based on an analysis of secondary survey data with all identifier information removed. The survey was approved by the Ethics Committee of the ICF Macro at Fairfax, Virginia in the USA and by the National Ethics Committees in their respective countries. All study participants gave informed consent before participation and all information was collected confidentially.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests

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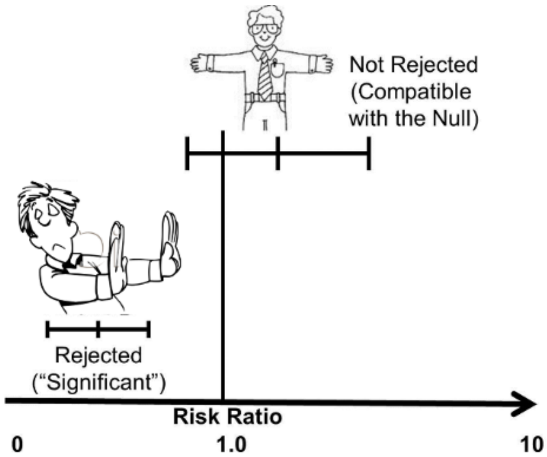
Responses

e. Original Comment. State which threshold of statistical significance was adopted. Are p-values going to be reported? Response. Thanks, we have now added this "All tests were two tailed and p < 0.05 was considered significant." As now been encouraged, we belief like that 'Do Not Over (P) Value Your Research Article', as such we paid attention more to the effect sizes and confidence intervals. **New Comment. This is not the point. Effect sizes and their confidence intervals provide different pieces of information from p-values and both play a role in the interpretation of the findings. Surely one would find that if setting the threshold of significance at 0.1 the interpretation would be different. This is why it should be declared upfront, for the sake of transparency and consistency. Indeed the focus should not be on p-values, but if these were used, then explicitly report how it was done.**	As suggested below, in this revised draft we did not describe the results in terms of statistical significance. We have now deleted 'statistically' throughout the manuscript. It is important to note that "Confidence intervals are calculated from the same equations that generate p-values, so, not surprisingly, there is a relationship between the two, and confidence intervals for measures of association are often used to address the question of "statistical significance" even if a p-value is not reported." 
3. Discussion a. Original Comment. Provide p-values to support the following sentence: "There was statistically significant pro-rural inequality in the following countries"	

Response. As stated above, we did not report the p-value, but there are estimates that the confidence intervals did not cross the line of no effect (zero percent). The p-values were also less than 0.05. **New Comment. The statement "statistically significant" implies that a threshold was used. Therefore, report the information that accompanies the statement (p-value). If not reporting p-values, that is perfectly fine, but then the results should not be described in terms of statistical significance.**	Thanks, in this revised draft we did not describe the results in terms of statistical significance. We have now deleted 'statistically' throughout the manuscript.
b. Original Comment. Table 2. Specify how the child's age is measured: months or years. Same for maternal age. What is the variable media access? Response. It has been indicated on the table that child age was measured in months, and maternal age in year. New Comments. State what the variable "media access" is.	Thanks for pointing this out. We have now described the media access variable in greater detail now "Media access was assessed using the following indicators: access to information measured via frequency of watching television, listening to radio, and reading newspapers/magazine. To allow meaningful analysis, we dichotomized the response levels "less than one week", "at least once a week", and "almost every day" as one group and the response level "not at all" as the other group. We then created an additive media access variable (from 0 to 3) that counted the number of media type each respondent had access to"

Table 1

Table 1: Description of Demographic and Health Surveys data by countries, in sub-Saharan Africa, 2007 to 2016

Country	Survey year	Number of children	MOV (%)	MOV in rural settings (%)
Angola	2016	2740	54.1 (51.3 to 56.9)	52.7 (48.3 to 57.1)
Benin	2012	2540	59.6 (57.2 to 62.0)	59.9 (56.9 to 62.9)
Burkina Faso	2010	2861	22.4 (20.4 to 24.4)	22.8 (20.6 to 25.1)
Burundi	2017	2630	23.8 (21.6 to 26.0)	23.8 (21.5 to 26.1)
Cameroon	2011	2282	45.0 (42.2 to 47.8)	49.2 (45.3 to 53)
Chad	2015	2954	50.4 (47.5 to 53.3)	47.3 (43.9 to 50.7)
Comoros	2012	585	36.4 (31.2 to 41.6)	35.7 (29.2 to 42.2)
Congo	2012	1842	65.6 (61.9 to 69.3)	69.1 (65 to 73.2)
Congo DR	2014	3435	62.7 (59.5 to 66.0)	65.1 (60.8 to 69.3)
Cote d’Ivoire	2012	1447	50.6 (46.7 to 54.6)	56.2 (51.3 to 61.1)
Ethiopia	2016	1940	58.4 (53.9 to 63.0)	59.8 (54.9 to 64.8)
Gabon	2012	1159	93.2 (91.0 to 95.4)	85.2 (81.2 to 88.9)
Gambia	2013	1611	25.7 (21.3 to 30.1)	18.0 (14.7 to 21.4)
Ghana	2014	1113	36.9 (32.9 to 41.0)	41.7 (36.5 to 46.8)
Guinea	2012	1335	55.5 (52.0 to 59.0)	55.3 (51.4 to 59.2)
Kenya	2014	3952	41.8 (39.4 to 44.2)	45.3 (42.6 to 48)
Lesotho	2014	682	40.0 (35.6 to 44.5)	43.4 (38.1 to 48.7)
Liberia	2013	1431	50.6 (46.2 to 54.9)	53.2 (48 to 58.4)
Madagascar	2009	2152	56.2 (53.1 to 59.2)	58 (54.7 to 61.3)
Malawi	2016	3269	46.4 (43.8 to 49.0)	47.2 (44.4 to 50.0)
Mali	2013	1847	61.5 (58.4 to 64.7)	62.1 (58.5 to 65.8)
Mozambique	2011	2282	37.1 (34.1 to 40.1)	40.0 (36.4 to 43.7)
Namibia	2013	968	33.2 (29.4 to 37.0)	23 (19.0 to 27.0)
Niger	2012	2158	53.6 (50.7 to 56.5)	56.4 (53.2 to 59.6)
Nigeria	2013	5893	42.5 (40.3 to 44.6)	39.7 (36.9 to 42.5)
Rwanda	2015	1531	60.7 (57.6 to 63.7)	61.8 (58.4 to 65.3)
Sao Tome Prin.	2009	370	26.6 (20.7 to 32.5)	26.1 (18.7 to 33.5)
Senegal	2011	2353	45.2 (42.4 to 48.1)	46.5 (43.3 to 49.7)
Sierra Leone	2013	2208	36.6 (33.3 to 39.8)	35.4 (31.9 to 38.9)
Swaziland	2007	553	23.7 (20.2 to 27.2)	22.2 (18.4 to 26)
Tanzania	2016	2113	45.5 (42.2 to 48.9)	52.2 (48.3 to 56.1)
Togo	2014	1409	40.7 (37.1 to 44.4)	43.9 (39.1 to 48.7)
Uganda	2016	2815	55.0 (52.6 to 57.5)	55.5 (52.7 to 58.4)
Zambia	2014	2563	64.9 (62.1 to 67.7)	74.4 (71.6 to 77.2)
Zimbabwe	2015	1158	21.8 (18.8 to 24.8)	21.2 (17.6 to 24.8)

Table 2

Table 2: Summary of pooled sample characteristics of the Demographic and Health Surveys data in sub-Saharan Africa

	Number (%)
	72181
Child's age in months (mean (sd))	17.13 (3.42)
Male (%)	36605 (50.7)
High birth order (%)	22493 (31.2)
Under-five children (mean (sd))	2.01 (1.30)
Maternal age in years (%)	
15-24	24790 (34.3)
25-34	33012 (45.7)
35-49	14379 (19.9)
Wealth index(%)	
poorest	18183 (25.2)
poorer	15918 (22.1)
middle	14238 (19.7)
richer	12778 (17.7)
richest	11064 (15.3)
Maternal education (%)	
no education	28723 (39.8)
primary	25640 (35.5)
secondary+	17809 (24.7)
Not working (%)	22190 (30.7)
Media access (%)	
0	25351 (35.1)
1	23131 (32.0)
2	17017 (23.6)
3	6682 (9.3)
Rural (%)	50598 (70.1)

Figure 4

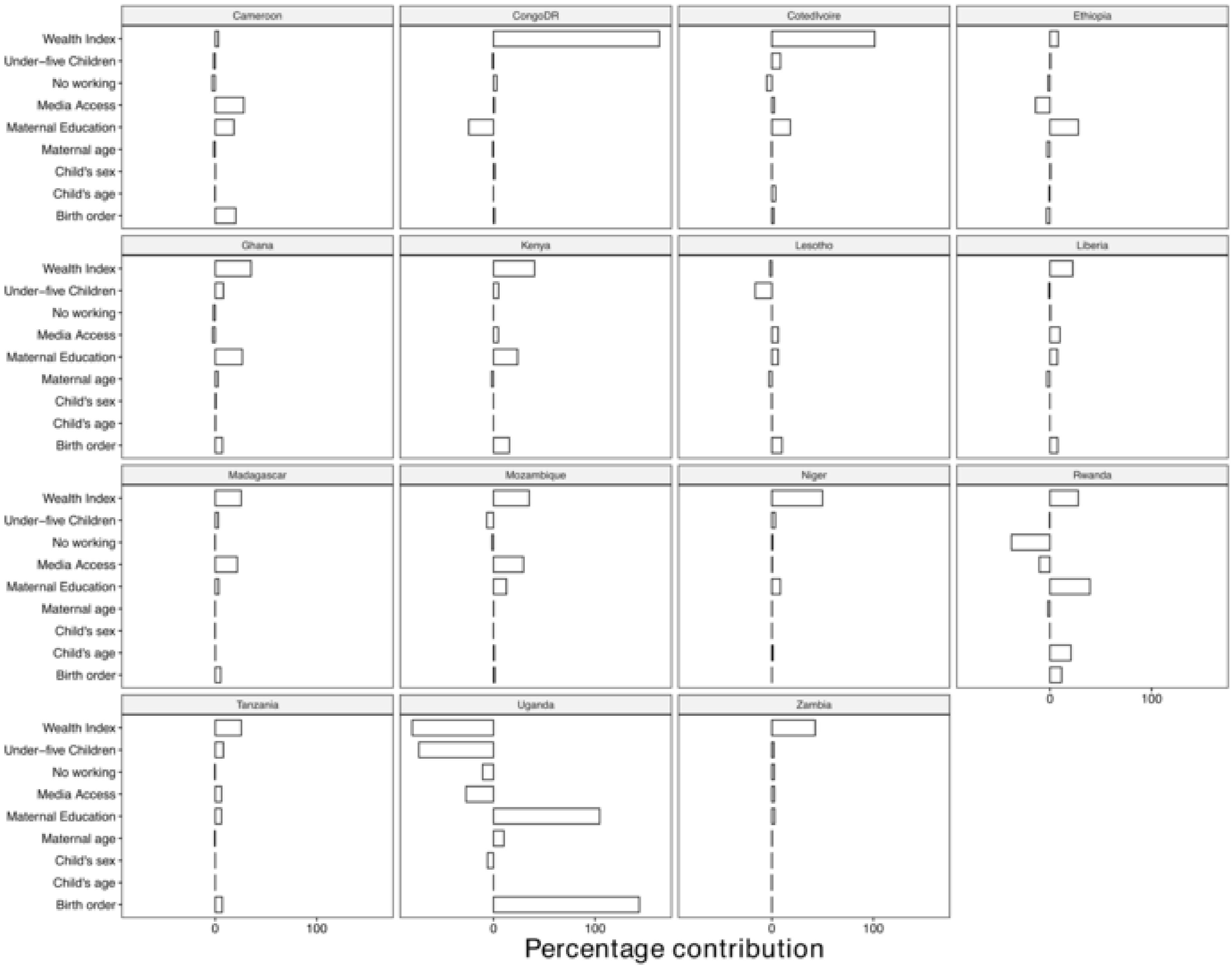

Cameroon
CongoDR
CotedIvoire
Ethiopia
Ghana
Kenya
Lesotho
Liberia
Madagascar
Mozambique
Niger
Rwanda
Tanzania
Uganda
Zambia
Wealth Index
Under−five Children
No working
Media Access
Maternal Education
Maternal age
Child's sex
Child's age
Birth order
0
100
Percentage contribution

Figure 3

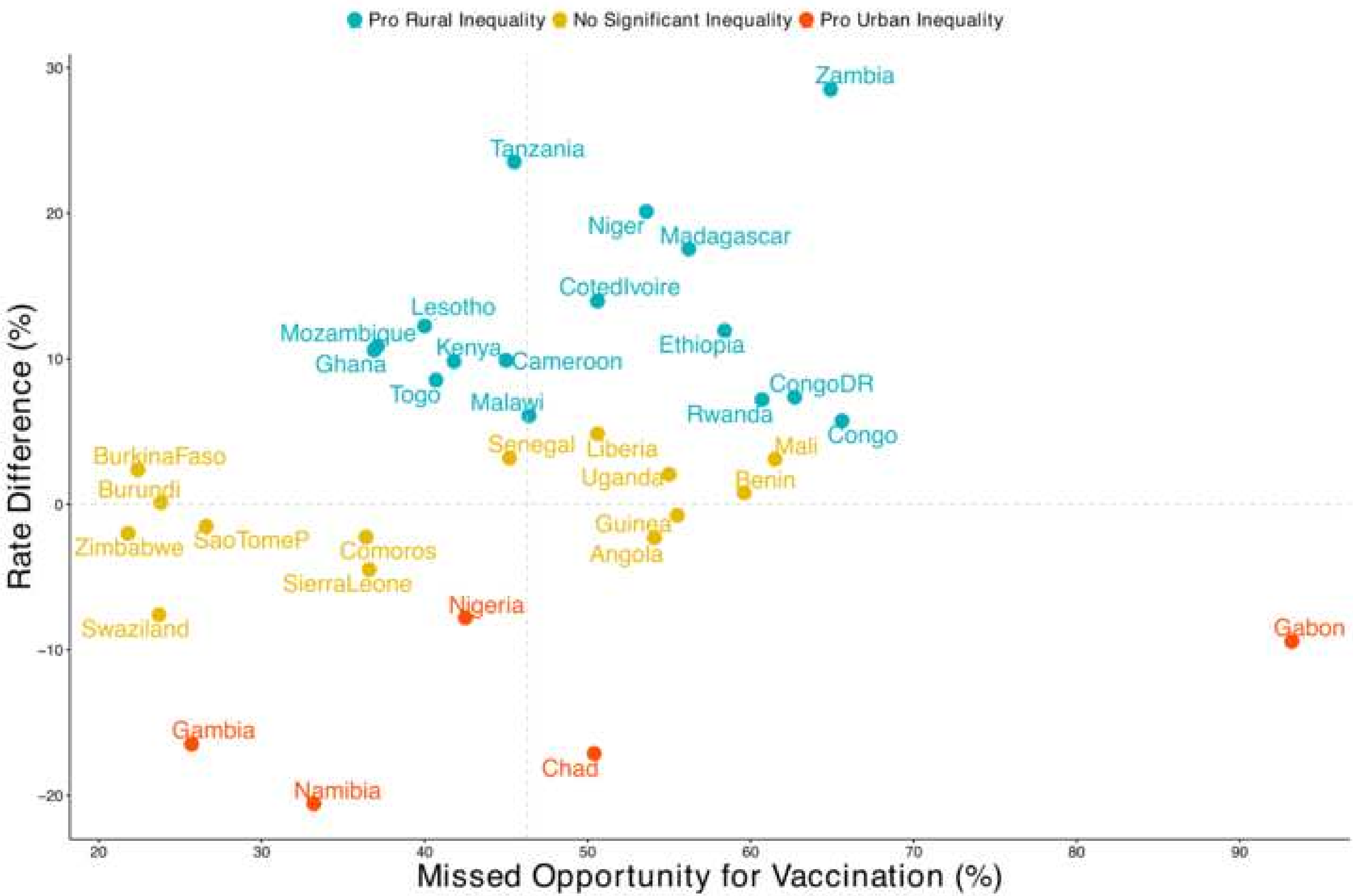
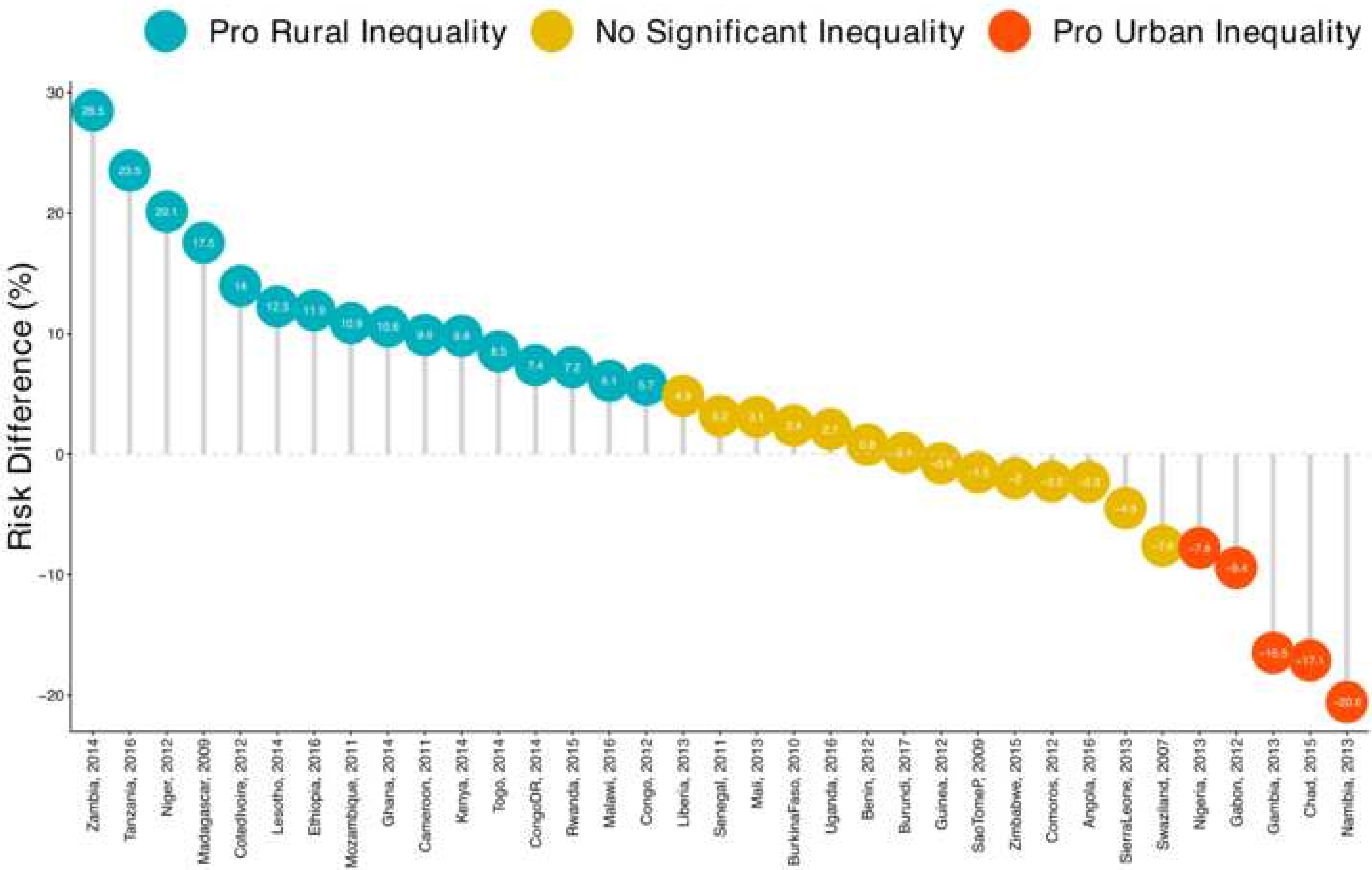

Pro Rural Inequality
No Significant Inequality
Pro Urban Inequality
Rate Difference (%)
Missed Opportunity for Vaccination (%)
30
20
10
0
-10
-20
20
30
40
50
60
70
80
90
Zambia
Tanzania
Niger
Madagascar
CotedIvoire
Lesotho
Mozambique
Ghana
Kenya
Cameroon
Ethiopia
Togo
Malawi
CongoDR
Rwanda
Congo
Senegal
Liberia
Mali
BurkinaFaso
Uganda
Benin
Burundi
Guinea
Zimbabwe
SaoTomeP
Comoros
Angola
SierraLeone
Nigeria
Swaziland
Gabon
Gambia
Chad
Namibia

Figure 2



Pro Rural Inequality
No Significant Inequality
Pro Urban Inequality
Risk Difference (%)
30
20
10
0
-10
-20
Zambia, 2014
Tanzania, 2016
Niger, 2012
Madagascar, 2009
CoteIvoire, 2012
Lesotho, 2014
Ethiopia, 2016
Mozambique, 2011
Ghana, 2014
Cameroon, 2011
Kenya, 2014
Togo, 2014
CongoDR, 2014
Rwanda, 2015
Malawi, 2016
Congo, 2012
Liberia, 2013
Senegal, 2011
Mali, 2013
BurkinaFaso, 2010
Uganda, 2016
Benin, 2012
Burundi, 2017
Guinea, 2012
SaoTomeP, 2009
Zimbabwe, 2015
Comoros, 2012
Angola, 2016
SierraLeone, 2013
Swaziland, 2007
Nigeria, 2013
Gabon, 2012
Gambia, 2013
Chad, 2015
Namibia, 2013

Figure 1

Country, year	Rural %MOV	Urban %MOV	RD	95%-CI
Zambia, 2014	74.4	45.9	28.5	[24.6; 32.4]
Tanzania, 2016	52.2	28.7	23.5	[19.1; 28.0]
Niger, 2012	56.5	36.3	20.1	[14.4; 25.8]
Madagascar, 2009	58	40.5	17.5	[11.0; 24.1]
CotedIvoire, 2012	56.2	42.2	14.0	[8.8; 19.2]
Lesotho, 2014	43.4	31.1	12.3	[4.3; 20.3]
Ethiopia, 2016	59.8	47.9	11.9	[5.2; 18.7]
Mozambique, 2011	40	29.2	10.9	[6.7; 15.1]
Ghana, 2014	41.7	31.1	10.6	[4.9; 16.3]
Cameroon, 2011	49.2	39.3	9.9	[5.8; 14.0]
Kenya, 2014	45.3	35.5	9.8	[6.6; 13.1]
Togo, 2014	43.9	35.4	8.5	[3.3; 13.8]
CongoDR, 2014	65.1	57.7	7.4	[3.8; 10.9]
Rwanda, 2015	61.9	54.6	7.2	[0.7; 13.7]
Malawi, 2016	47.2	41.1	6.1	[1.1; 11.1]
Congo, 2012	69	63.3	5.7	[1.1; 10.4]
Liberia, 2013	53.2	48.3	4.9	[−0.6; 10.3]
Senegal, 2011	46.5	43.3	3.2	[−1.1; 7.5]
Mali, 2013	62.1	59	3.1	[−2.5; 8.7]
BurkinaFaso, 2010	22.8	20.5	2.4	[−1.5; 6.3]
Uganda, 2016	55.5	53.4	2.1	[−2.3; 6.4]
Benin, 2012	59.9	59.1	0.8	[−3.1; 4.7]
Burundi, 2017	23.8	23.7	0.1	[−5.6; 5.9]
Guinea, 2012	55.3	56	−0.8	[−6.8; 5.3]
SaoTomeP, 2009	25.9	27.5	−1.5	[−11.0; 8.0]
Zimbabwe, 2015	21.2	23.2	−2.0	[−7.2; 3.2]
Comoros, 2012	35.7	37.9	−2.2	[−10.6; 6.1]
Angola, 2016	52.7	55	−2.3	[−6.3; 1.7]
SierraLeone, 2013	35.4	39.9	−4.5	[−9.0; 0.1]
Swaziland, 2007	22.2	29.8	−7.6	[−17.2; 2.0]
Nigeria, 2013	39.7	47.5	−7.8	[−10.4; −5.2]
Gabon, 2012	85.2	94.7	−9.4	[−15.3; −3.5]
Gambia, 2013	18	34.5	−16.5	[−20.7; −12.2]
Chad, 2015	47.3	64.4	−17.1	[−21.6; −12.6]
Namibia, 2013	22.9	43.5	−20.6	[−26.5; −14.6]