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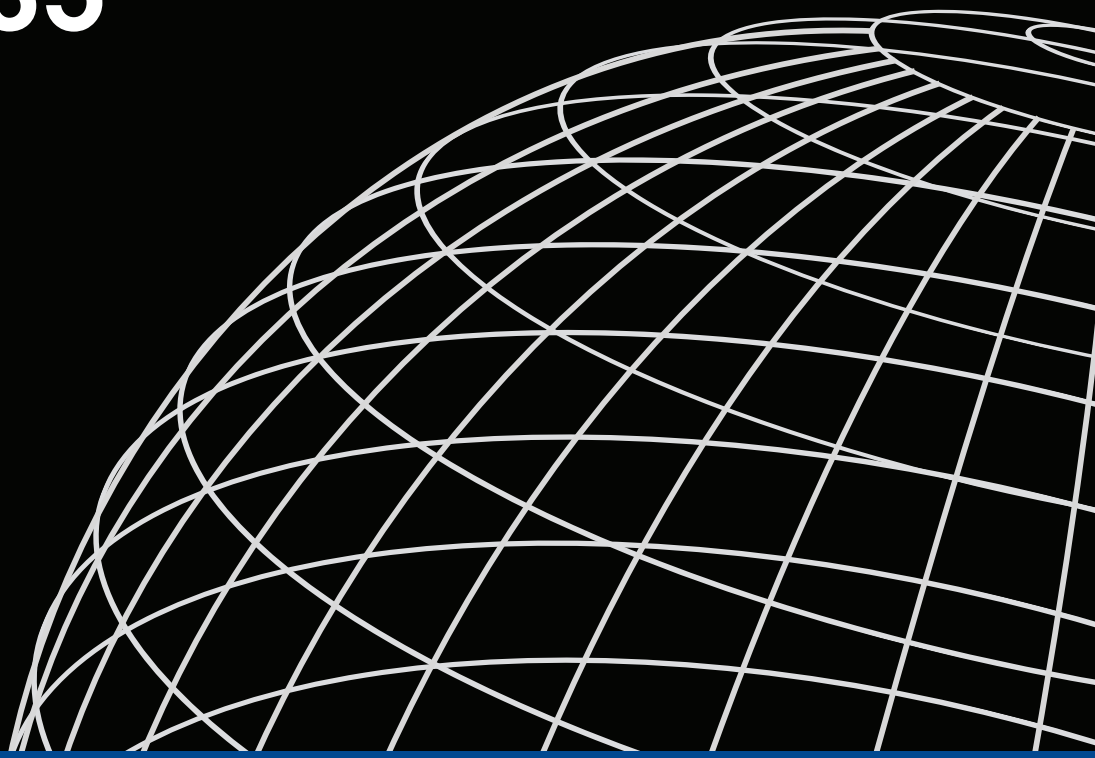
ELECTRIFICATION AND REFRIGERATION: ASSOCIATIONS WITH CHILD NUTRITION AND VACCINATION

DHS ANALYTICAL STUDIES 85



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Electrification and Refrigeration: Associations with Child Nutrition and Vaccination

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PREFACE

The Demographic and Health Surveys (DHS) Program is one of the principal sources of international data on fertility, family planning, maternal and child health, nutrition, mortality, environmental health, HIV/AIDS, malaria, and provision of health services.

One of the objectives of The DHS Program is to analyze DHS data and provide findings that will be useful to policymakers and program managers in low- and middle-income countries. DHS Analytical Studies serve this objective by providing in-depth research on a wide range of topics, typically including several countries and applying multivariate statistical tools and models. These reports are also intended to illustrate research methods and applications of DHS data that may build the capacity of other researchers.

The topics in this series are selected by The DHS Program in consultation with the U.S. Agency for International Development.

It is hoped that the DHS Analytical Studies will be useful to researchers, policymakers, and survey specialists, particularly those engaged in work in low- and middle-income countries.

Sunita Kishor
Director, The DHS Program

ABSTRACT

Ensuring universal, equitable, and reliable access to electricity is a Sustainable Development Goal (SDG) for 2030. Although more than a billion people have gained access to electricity since 2010, nearly 760 million still do not have any access and millions more do not have reliable access. Previous research has found positive associations between access to electricity and health including reduced infant mortality and improved quality of and access to care. This study examines the association between electricity access and refrigerator ownership with underweight children under age 5 and children age 12–23 months who did not receive the first DPT vaccine (zero-dose children). The study uses 54 DHS surveys from 15 sub-Sahara African countries. We examine trends in electricity access, refrigerator ownership among those with electricity, underweight children, and zero-dose children. Trend results show improvements in access to electricity, refrigerator ownership, underweight, and zero-dose children in several countries. However, there are countries with high levels of underweight, zero-dose children, and low levels of electricity, and there are large disparities between urban and rural areas. Further analysis shows a significant negative relationship between electricity access and underweight, even after controlling for child, mother, and household variables. There were less significant findings between zero-dose children, electricity, and the refrigeration models. The associations were not consistent over time, were not always found in the most recent survey, and/or were not significant in both the urban and rural areas in each survey. When significant associations were found, the disparities in the outcomes were relatively large between children with/without electricity and a refrigerator in the household. The study highlights the need for expanding electricity access, especially in rural areas, as well as further study to understand the pathways between electricity and child health outcomes.

Key words: electricity, clean energy, refrigerator, refrigeration, underweight, nutrition, vaccination, zero-dose children

1 INTRODUCTION

1.1 Improvements in Electrification

The Sustainable Development Goals (SDG), which aim to eradicate poverty by 2030 through global action and collaboration, name universal access to electricity (electrification) as a major goal. The SDG target 7.1 aims to ensure universal access to affordable, reliable, and modern energy services by 2030 (United Nations 2015). Since 2010, 1.2 billion people have gained access to electricity for the first time, although 733 million people remained without access in 2020. Of those without access, three in four live in sub-Saharan Africa. During the course of the COVID-19 pandemic, electrification in Africa has decreased for the first time after 6 years of steady improvement. In some areas, access to electricity has been short-lived due to increasing poverty and the increasingly unaffordable cost of continuing access to electricity (International Renewable Energy Agency (IRENA) 2022).

Although most of the increase in electrification since 1990 has occurred primarily in rural areas (Sovacool and Ryan 2016), four in five people in rural areas remain without access to electricity (IRENA 2022). Increasing access to electricity usually occurs through grid expansion with the addition of power plants and power lines that link to new areas. This approach usually makes connecting the most affordably linked rural villages and towns a priority (Sovacool and Ryan 2016). While electrification indicates access to energy, energy poverty is characterized by households that do not get *enough* energy for their household needs. It is important to note that even after the electrification of an area, households may still experience energy poverty (Drago and Gatto 2021). The availability of electricity does not guarantee access, because high connection costs prevent many households from connecting to the power grid (Bos, Chaplin, and Mamun 2018). The reliability of electricity access may negatively affect the benefits of electrification (Irwin, Hoxha, and Grepin 2020) and households may not be aware of those benefits due to low connection rates (Bos, Chaplin, and Mamun 2018). Grid expansion may not include total coverage of households and infrastructures within a newly linked area. For example, some children who do not have electricity at home may have electricity at school, although studies have found that many schools in villages remain without power. Research as recent as 2013 has shown that approximately 188 million children attend schools with no electricity, and half of those children live in Africa (Sovacool and Ryan 2016).

Initiatives that focus on electrification in low- and middle-income countries (LMIC) originate in a variety of international and governmental agencies. There are 60 international initiatives that focus on the advancement of access to electricity in Africa alone. Three of these initiatives include larger, coordinated efforts of the African Development Bank and U.S. Agency for International Development (USAID). The African Development Bank established two initiatives focused on electrification in Africa—the New Deal on Energy for Africa—which focuses on funding energy projects, and Africa50, which funds infrastructure development (Tagliapietra 2018), while USAID coordinates the U.S. government-led partnership—Power Africa—which aims to deliver 30,000 megawatts of reliable electricity and 60 million new connections to homes and business in Africa by 2030. Since 2013, Power Africa has created new connections that have brought 6,000 generated megawatts of reliable electricity to 145.7 million people. Power Africa transaction advisors work directly in Ethiopia, Ghana, Guinea, Kenya, Liberia, Malawi, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Tanzania, Uganda, and Zambia to expand access to electricity, although the initiative has provided assistance in over 40 African countries (USAID 2022b). In addition, USAID has an

initiative focused on the Indo-Pacific region, Asia EDGE, that promotes the upgrading and expanding of current energy systems and accelerating the Indo-Pacific energy market (USAID 2022a).

1.2 Electrification and Health-related Outcomes

Electrification could improve health outcomes directly and indirectly through improved infrastructure and living conditions that may alter the way people live and their access to information. Irwin and colleagues (2020) describe pathways of effect that electrification may have on health-related outcomes with a socioecological model with four levels: individual, household, community, and institutional (health facility characteristics). By distinguishing the mechanisms at each level, and showing differing pathways between electrification and health-related outcomes, the framework developed by Irwin et al. (2020) depicts how individual and household pathways may affect health outcomes. These include the nutritional status of children and the use of health services, such as vaccinations for children. Lenz and colleagues (2017) also described pathways through which electrification at the household, community, or facility level may affect people's well-being.

Individual effects of electrification on health outcomes may occur from changes in access to information and improved home infrastructure. Exposure to television or radio from electrification can be a vital pathway to expose individuals to health education and information. In rural areas, where literacy is lower, audio formats of health information via radio and television are critical assets brought with electricity, while printed information may be inaccessible (Chen, Chindarkar, and Xiao 2019). Electrification affects time allocation through the convenience of electric appliances, which improve the ease of household chores often performed by women. Modern energy can save women's time spent cooking with inefficient fuels and gathering water at the cost of foregoing education or other opportunities (Belmin et al. 2021; López-González, Domenech, and Ferrer-Martí 2020; Sovacool and Ryan 2016). Access to electricity also creates more opportunities for economic endeavors that require energy or increased hours of light after dark, and therefore increase wealth (Fujii, Schonchoy, and Xu 2016). Time spent on educational or economic opportunities may ultimately increase women's socioeconomic status and their financial ability to access medical services. Research has shown that the increase in time availability due to conveniences offered through electrification, known as the time-endowment effect, may result in increased time spent on individual healthcare-seeking behaviors (Chen, Chindarkar, and Xiao 2019; Irwin, Hoxha, and Grepin 2020). Electrification has also increased the probability of utilizing child immunization in rural India (Chen, Chindarkar, and Xiao 2019) and rural Pakistan (Majid 2013).

At the household level, lack of electricity often precludes access to at-home refrigeration. Ownership of refrigerators is associated with dietary diversity and consumption of highly nutritious, perishable foods, such as meat, dairy, and seafood (Martinez et al. 2021). In Bolivia, after controlling for wealth, children whose families owned a refrigerator were taller for their age after 2 years than those without a refrigerator (Martinez et al. 2021). Access to electricity had similar effects on children's height in Bangladesh (Fujii, Schonchoy, and Xu 2016). Having a refrigerator allows families to buy and consume more food, economize their spending on food by buying in bulk, and save time and money through less frequent trips to the market (Fujii, Schonchoy, and Xu 2016; Martinez et al. 2021). Households with electrification have been found to have increased food security through improved food availability, preparation, and preservation (Candelise, Saccone, and Vallino 2021; Gebrehiwot and Hassen 2022; Sola et al. 2016).

Institutional access to electricity may also improve conditions in facilities that deliver healthcare services (Irwin, Hoxha, and Grepin 2020). Health centers in Rwanda cited electrification as important for using medical equipment, storing medicine, and conducting administrative tasks, as well as attracting and recruiting skilled workers (Lenz et al. 2017). Most vaccines must be kept cold, which makes them impractical or unavailable in resource-poor settings with no or unreliable access to electricity (Machingaidze, Wiysonge, and Hussey 2013; Medecins Sans Frontieres 2013). Facilities with refrigerators have been able to increase the number and type of vaccinations they can store (Polansky and Laldjebaev 2021). Health facilities with access to electricity in rural India were found to have increased uptake of vaccination services for children and antenatal care for women (Chen, Chindarkar, and Xiao 2019). Electrification not only improves the conditions of health facilities, but may also create more stable, uninterrupted services for communities. A review of studies (Irwin, Hoxha, and Grepin 2020) found that facilities with unreliable electricity or frequent outages had a negative impact on care-seeking behaviors.

Access to electricity is a component of the wealth index, employed in the population-based Demographic and Health Surveys (DHS) datasets to characterize wealth, and also to measure other household infrastructure necessities, such as access to improved sanitation (Winfrey and Riese 2020). Studies that utilize population-based surveys have examined access to improved sanitation and wealth in relation to child health and nutrition outcomes (Beal et al. 2018; Cumming and Cairncross 2016; Fink, Gunther, and Hill 2011; Headey and Palloni 2019; Vyas et al. 2016). However, few population-based studies have examined the relationship between electricity access, refrigeration, and child health outcomes (Headey and Palloni 2019; Irwin, Hoxha, and Grepin 2020).

This study focuses on two key child health indicators—zero-dose and underweight children. Routine vaccination among children in LMICs has dramatically increased, although many nations have not met the World Health Organization's (WHO) Global Vaccine Action Program target of 90% national vaccination coverage by 2020 (WHO 2013). To highlight where need may be most dire, research has focused on "zero-dose children," or those children who have not had any routine vaccinations (Cata-Preta et al. 2021). Zero-dose children are more likely to be poor, rural, and have mothers who have missed other health services (Santos et al. 2021). The prevalence of zero-dose children highlights patterns in use of health services, while the prevalence of underweight children reflects individual and household health outcomes. Undernutrition is a leading cause of death in children under age 5, with the prevalence of underweight children in LMICs at 17% (UNICEF–WHO–WB 2022), and the highest prevalence in sub-Saharan Africa (Ssentongo et al. 2021). Decreasing child malnutrition is an essential target for SDG 2. While the prevalence of underweight children has decreased since 2000, disparities within countries remain large in some nations (Local Burden of Disease Child Growth Failure Collaborators 2020).

To our knowledge, this is the first study to utilize globally available, population-based survey data to further our understanding of the relationship between electrification, refrigeration, and two key child health indicators: zero-dose and underweight children. The study aims to answer the following research questions:

- Has access to electricity and refrigeration changed over time?
- Have there been improvements over time in children under age 5 that are underweight and children age 12–23 months who are zero-dose children?
- What is the relationship between electricity and refrigeration with underweight and zero-dose children, and has this relationship changed over time?

2 DATA AND METHODS

2.1 Data

DHS data from 15 countries in sub-Saharan Africa were included in the analysis (Table 1). Table 1 also includes the sample sizes for each survey. The inclusion criteria included information on the outcomes of interest, a recent DHS survey no older than 2014, and more than two surveys that span a 10-year period.

Table 1 Surveys included in the analysis

Country	Survey year	Number of de jure residents	Number of de jure children under 5
Benin	2001	29,749	5,173
	2011–12	87,763	14,429
	2017–18	73,728	13,500
Cameroon	2004	49,478	7,216
	2011	70,551	10,718
	2018–19	57,624	8,747
Ethiopia*	2005	66,388	9,270
	2011	75,655	11,626
	2016	73,901	10,862
	2019	40133	5745
Guinea*	2005	37,589	5,637
	2012	44,427	6,583
	2018	49,120	7,430
Kenya*	2003	36,687	5,691
	2008–09	37,870	6,072
	2014	151,093	21,478
Liberia*	2006–07	34,344	6,069
	2013	47,496	7,168
	2019–20	41,423	5,276
Malawi*	2000	62,364	10,952
	2004–05	59,715	10,781
	2010	116,749	18,230
	2015–16	119,326	16,472
Mali	2001	65,544	31,379
	2006	73,045	13,464
	2012–13	57,046	9,927
	2018	54,115	9,982
Nigeria*	2003	35,269	5,599
	2008	155,401	27,069
	2013	177,180	30,071
	2018	186,450	29,770
Rwanda*	2000	44,451	7,398
	2010–11	55,600	8,514
	2014–15	54,017	7,541
	2019–20	55,209	7,738
Senegal*	2005	67,485	10,062
	2010–11	75,523	11,652
	2015	40,618	7,072
	2019	40,015	6,372
Tanzania*	2004–05	48,091	8,232
	2009–10	48,885	8,042
	2015–16	62,515	10,402
Uganda*	2000–01	36,702	6,925
	2006	43,920	7,436
	2011	44,163	7,225
	2016	89,202	14,249

Continued...

Table 1—*Continued*

Zambia*	2001–02	37,191	6,506
	2007	34,909	6,313
	2013–14	81,622	13,772
	2018–19	64,302	10,167
Zimbabwe	1999	27,753	3,753
	2005–06	41,749	5,840
	2010–11	40,811	5,966
	2015	42,058	6,471

* indicates a country is part of the USAID Power Africa Initiative.

2.2 Measures

2.2.1 Main independent variables

The focus of this analysis is examining the effect of electrification and refrigeration on the outcomes of interest. These measures were obtained from the Household Questionnaire in which the household is asked if they have electricity (yes/no) and if they own certain assets such as a refrigerator (yes/no). There are no further questions about the reliability of the electricity. In addition, only a few surveys include country-specific questions about the presence of a generator or solar panels. Therefore, information about availability of electricity relies on the sole question of whether the household has electricity.

To examine the relationship between refrigeration and outcomes, the refrigeration variable was constructed only among those who have electricity. This would attempt to also capture the benefit from owning a functional refrigerator. The limitation is that the electricity may not be available at all times and there are no data that capture the reliability of the electricity source.

The electricity and refrigeration variables were constructed at the population level and among de jure residents or usual residents. All analyses were also limited to the de jure residents.

2.2.2 Outcomes

The analysis examines two separate outcomes: underweight children under age 5 and zero-dose children age 12–23 months. Underweight children under age 5 are children with a z score below −2 standard deviations below the mean on the WHO Child Growth Standards. Anthropometric data for the Benin 2011–12 DHS was suppressed due to data quality issues (INSAE/Bénin and ICF 2013). Zero-dose children are children age 12–23 months who have not received the DPT 1 vaccine, which is the pentavalent vaccine against diphtheria, pertussis, tetanus (DPT), hepatitis B (HepB), and Haemophilus influenza type b (Hib). In the DHS, these indicators are computed among de facto children. However, in this analysis, the indicators were computed among de jure children in the household, since the goal was to capture the resident children's electricity and refrigerator exposure in relation to the outcomes. Information on vaccination is collected only from the children of the interviewed mothers. Therefore, a de jure child in the household whose mother was not interviewed would not be included in zero-dose child outcome, although the child would be included in the underweight outcome. In addition, certain characteristics of the mother are collected only if she was interviewed. This restricts the inclusion of the variables in the underweight logit models as described in the analysis section. The exception is the education level of the mother, because the education level of all household members is collected in the Household Questionnaire. Therefore, the mother's

education would be known if she is reported in the Household Questionnaire even if she is not interviewed herself.

2.2.3 Control variables

Other variables included in the regression analysis are child, mother, and household characteristics. The child characteristics include the child's age in months and the child's sex. The mother's characteristics include education level (none, primary, secondary or more), the mother's media exposure, and her work status (currently working or not). The mother's media exposure was defined as women who reported watching TV or listening to the radio at least once a week. The household characteristics include access to improved sanitation and improved water source, and the number of children under age 5 in the household. The code for producing the improved water and sanitation variables can be found on the DHS GitHub site.[1]

2.3 Analysis

2.3.1 Trends

We examined trends in electricity, refrigerator ownership, and the outcomes overall, and for urban and rural areas separately. This was performed by tests of differences in proportions between consecutive surveys, as well as between the first and last survey in Table 1. The analysis was performed for rural and urban areas separately due to the different distributions of electricity availability between these areas.

2.3.2 Models

Logistic regressions were fit between each outcome and independent variable using the four models as shown in Table 2. This was performed for urban and rural areas separately. The first model is the unadjusted model, which is fit between each outcome and the main independent variable, that was either electricity or refrigeration. The second model adds the child's characteristics. The third model adds the mother's characteristics to the second model. The fourth and final model adds the household characteristics to the third model. As shown in Table 2, the difference in the models between the underweight and zero-dose child outcomes is the mother's characteristics in the model. For the underweight outcome, we only added the mother's education, while for the zero-dose children, we also added the mother's work status and media exposure because that information is obtained from interviewed mothers. However, not all children who were measured and weighed in the Biomarker Questionnaire for the nutrition outcomes had mothers in the household who were interviewed. All children in the household are measured, regardless of whether or not their mother is interviewed. Therefore, restricting the underweight model to the mother's work status and media exposure would have resulted in removing children unnecessarily.

[1] https://github.com/DHSProgram

Table 2 Logistic regression models fit for underweight and zero-dose child outcomes

	Underweight	Zero-dose children
Model I	Electricity or refrigeration	Electricity or refrigeration
Model II	Electricity or refrigeration + child's age + child's sex	Electricity or refrigeration + child's age + child's sex
Model III	Electricity or refrigeration + child's age + child's sex + mother's education	Electricity or refrigeration + child's age + child's sex + mother's education + mother's media exposure + mother's work status
Model IV	Electricity or refrigeration + child's age + child's sex + mother's education + improved sanitation + improved water + number of children under 5 in household	Electricity or refrigeration + child's age + child's sex + mother's education + mother's media exposure + mother's work status + improved sanitation + improved water + number of children under 5 in household

Note: Models were fit for urban and rural areas separately.

All analyses considered the sampling design and sampling weights, and were performed with Stata 17 software.

3 RESULTS

The results first examine trends in the outcomes, underweight and zero-dose children, and the two main independent variables, which are access to electricity and refrigeration. The results are presented for all 15 countries and for the urban and rural areas.

3.1 Trends

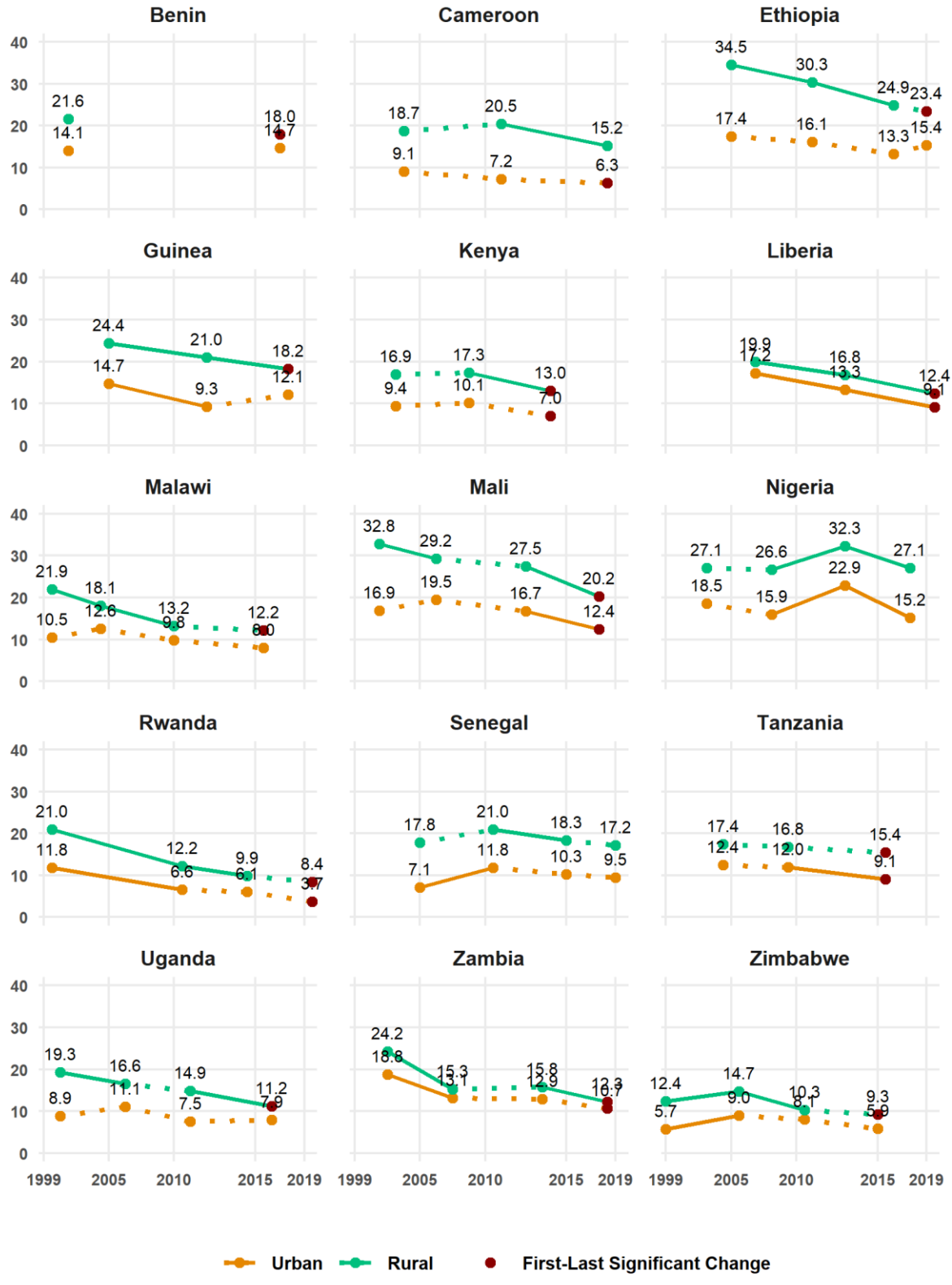
3.1.1 Underweight

Figure 1 shows the trends for underweight children under age 5 for all countries in the analysis and by urban and rural areas. The estimates are also found in Appendix Table 1 along with the total. The solid lines in the figure indicate a significant change between the consecutive surveys and a dotted line indicates a non-significant change. A red circle in the most recent survey indicates a significant change between the first and last survey.

- The highest levels of underweight children were found in Ethiopia, Mali, and Nigeria where approximately 20% or greater of children under age 5 were underweight in the most recent survey.
- The percentage of underweight children decreased among rural and urban children between the first and last survey in Cameroon, Kenya, Liberia, Mali, Rwanda, Tanzania, and Zambia.
- The largest decrease was found in Rwanda, followed by Mali and Zambia with more than a 10 percentage point decrease between the first and last survey and in rural areas.

The highest levels of underweight children were found in Ethiopia, Mali, and Nigeria where approximately 20% or greater of children under age 5 were underweight in the most recent survey (Appendix Table 1). The lowest levels of underweight children were found in Rwanda and Zimbabwe with fewer than 10% underweight children. We also observe higher levels of underweight among rural children compared to urban children with larger gaps in some countries than others (such as Cameroon, Ethiopia, and Nigeria). Figure 1 shows that several countries exhibited a general downward trend in underweight, which was especially found for rural children. The percentage of underweight children decreased among rural and urban children between the first and last survey in Cameroon, Kenya, Liberia, Mali, Rwanda, Tanzania, and Zambia. For these countries, the decrease was not always steady and stalled between some surveys. The largest decrease was found in Rwanda, followed by Mali and Zambia with more than a 10 percentage point decrease between the first and last survey and in rural areas. In Benin, Ethiopia, Guinea, Malawi, and Zimbabwe, the decreases between the first and last survey were only significant among rural children, with the largest decrease found in Ethiopia, which was 35% in the first survey and 23% in the last survey among rural children. In Guinea, we see a significant decrease between the first and second survey among urban children, but this increased again between the second and third survey, although the increase was not significant. There was no significant change between the first and last survey in Senegal among rural or urban children and among rural children in Nigeria.

Figure 1 Trends in underweight de jure children under age 5



Note: Data for the Benin 2011–12 survey is not displayed due to data quality issues in the anthropometric data. Dotted line indicates a non-significant change.

3.1.2 Zero-dose children

- The percentage of zero-dose children was disproportionally high in the most recent survey in Ethiopia, Guinea, and Nigeria.
- The lowest levels of zero-dose children were found in Rwanda followed by Kenya, Malawi, Tanzania, and Zambia.
- Nigeria had the largest significant decrease in zero-dose children in both rural and urban areas between the first and last surveys.
- Significant decreases between the first and last survey were found in Kenya, Mali, Nigeria, and Uganda among rural and urban children, and in Ethiopia, Liberia, Malawi, Rwanda, Tanzania, and Zambia only among rural children.

Figure 2 and Appendix Table 1 summarize the trend results for zero-dose children. In Appendix Table 1, we observe that the percentage of zero-dose children was disproportionally high in the most recent survey in Ethiopia (24%), Guinea (38%), and Nigeria (35%), and was even higher among rural children (30%, 45%, and 45%, respectively). The lowest levels of zero-dose children were found in Rwanda (less than 1% for total, rural, and urban populations). This was followed by Kenya, Malawi, Tanzania, and Zambia, where approximately 3% or less were zero-dose children (except rural children in Tanzania at 4%). The low levels of zero-dose children in these countries suggests that there is little room for improvement.

There were higher levels of zero-dose children in rural compared to urban areas in several countries. In some countries, there was little to no difference such as in Malawi, Rwanda, Senegal, and Tanzania. As shown in Figure 2, Guinea was the only country with a sharp, significant increase in zero-dose children that occurred between the second and third survey among both rural and urban children. In contrast, while still high, Nigeria had the largest significant decrease in zero-dose children in both rural and urban areas between the first and last surveys. For the remaining countries, there was little or no change in zero-dose children in both rural and urban children across the surveys. This is evident in Figure 2 in Benin, Cameroon, Kenya, Malawi, Mali (except for rural children between first and second surveys), Rwanda, Senegal, Tanzania, Uganda, and Zambia. However, significant decreases between the first and last survey were found in Kenya, Mali, Nigeria, and Uganda among rural and urban children, and in Ethiopia, Liberia, Malawi, Rwanda, Tanzania, and Zambia only among rural children. In Benin, Cameroon, Senegal, and Zimbabwe, there was no change in zero-dose children between the first and last survey among rural and urban children.

Figure 2 Trends in zero-dose children among de jure children age 12–23 months

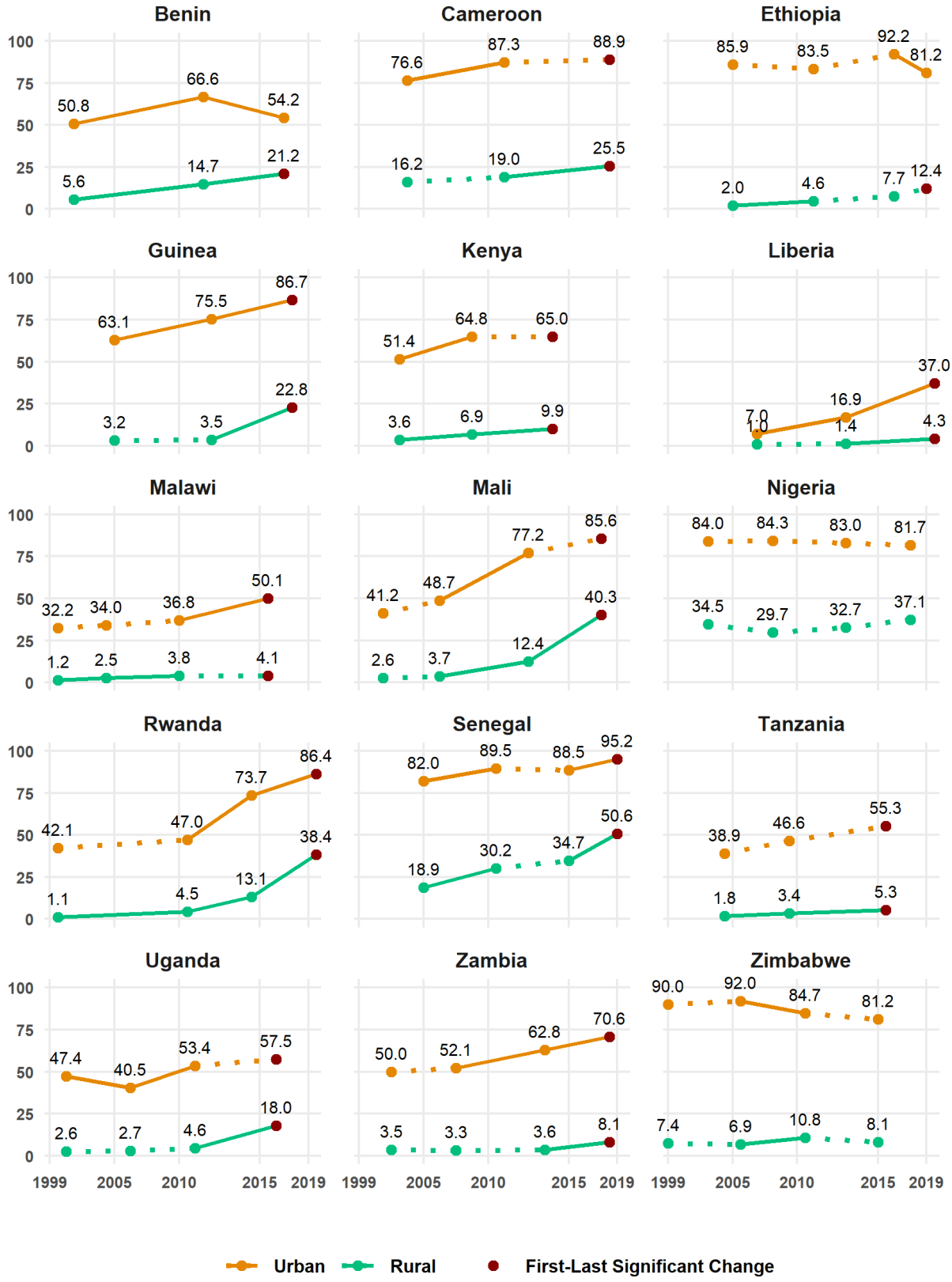
Note: Dotted line indicates a non-significant change.

3.1.3 Access to electricity

Figure 3 and Appendix Table 2 summarize the trends in access to electricity. Figure 3 clearly shows the large gaps in access to electricity between the urban and rural areas. The highest access to electricity was among the urban populations in Cameroon, Ethiopia, Guinea, Mali, Nigeria, Rwanda, Senegal, and Zimbabwe, with over 80% having access to electricity, while the rural population had approximately half or less of the urban level in each country. The lowest access in electricity was found in Liberia, followed by Benin, Malawi, and Tanzania. Only a few countries exhibited a steady improvement in access to electricity including Guinea, Liberia, Mali, Rwanda, and Zambia. This was usually among the urban population. There were improvements in access to electricity between the first and last survey and for both urban and rural populations in all countries except Benin and Ethiopia, which only showed improvements among the rural population, and in Nigeria and Zimbabwe, where there was no change. The largest increase in access to electricity between the first and last surveys was found in Rwanda and Mali. Both countries had a 44 percentage point increase among the urban areas, and there was a 38 percentage point increase in Mali and a 37 percentage point increase in Rwanda among the rural areas. As shown in Figure 3, improvements in access to electricity were small in Benin, Cameroon, Ethiopia, Kenya, Malawi, Nigeria, Senegal, Uganda, and Zimbabwe.

- There were large gaps in access to electricity between the urban and rural areas.
- The lowest access in electricity was found in Liberia, followed by Benin, Malawi, and Tanzania.
- There were improvements in access to electricity between the first and last survey and for both urban and rural populations in all countries except Benin and Ethiopia, which only showed improvements among the rural population, and in Nigeria and Zimbabwe, where there was no change.
- The largest increase in access to electricity between the first and last surveys was found in Rwanda and Mali.

Figure 3 Trends in access to electricity among de jure population



Note: Dotted line indicates a non-significant change.

3.1.4 Refrigerator ownership

- The lowest levels of refrigerator ownership were found in Benin, Ethiopia, Kenya, and Rwanda, with approximately a quarter or less of the urban population having a refrigerator and approximately 10% or less in the rural population.
- Most countries had no or very small improvements over time in refrigerator ownership, and a few countries showed a decline in ownership.
- In Benin, Kenya, Liberia, Mali, Rwanda, and Uganda, we observe significant declines in refrigerator ownership among the urban population, rural population, or both.

Figure 4 and Appendix Table 2 describe the trends in refrigerator ownership among the population with access to electricity. Even with access to electricity, we observe relatively low refrigerator ownership with large gaps between the urban and rural areas. The highest levels of refrigerator ownership were found in Zambia and Zimbabwe with over 70% in the urban areas and close to 50% in the rural areas in the most recent survey. The lowest levels of refrigerator ownership were found in Benin, Ethiopia, Kenya, and Rwanda, with approximately a quarter or less of the urban population having a refrigerator and approximately 10% or less in the rural population. Figure 4 also shows that most countries had no or very small improvements over time in refrigerator ownership, and a few countries showed a decline in ownership. Among countries that did show improvements, there was no more than a 10 percentage point increase overall, with the increase usually in the urban areas (see Appendix Table 2). The exceptions were Malawi and Zimbabwe. Malawi had a large improvement in refrigerator ownership among the rural population between the second and last survey (18 percentage point increase), while there was no change among urban areas. There was no information on refrigeration in the first survey in Malawi. In Zimbabwe, there was more than a 30 percentage point increase overall, and among rural and urban population between the first and last survey. In Benin, Kenya, Liberia, Mali, Rwanda, and Uganda, we observe significant declines in refrigerator ownership among the urban population, rural population, or both. In Uganda, the significant decline was found only among the entire population, as shown in Appendix Table 2.

Figure 4 Trends in refrigerator ownership among de jure population with access to electricity

Note: Dotted line indicates a non-significant change.

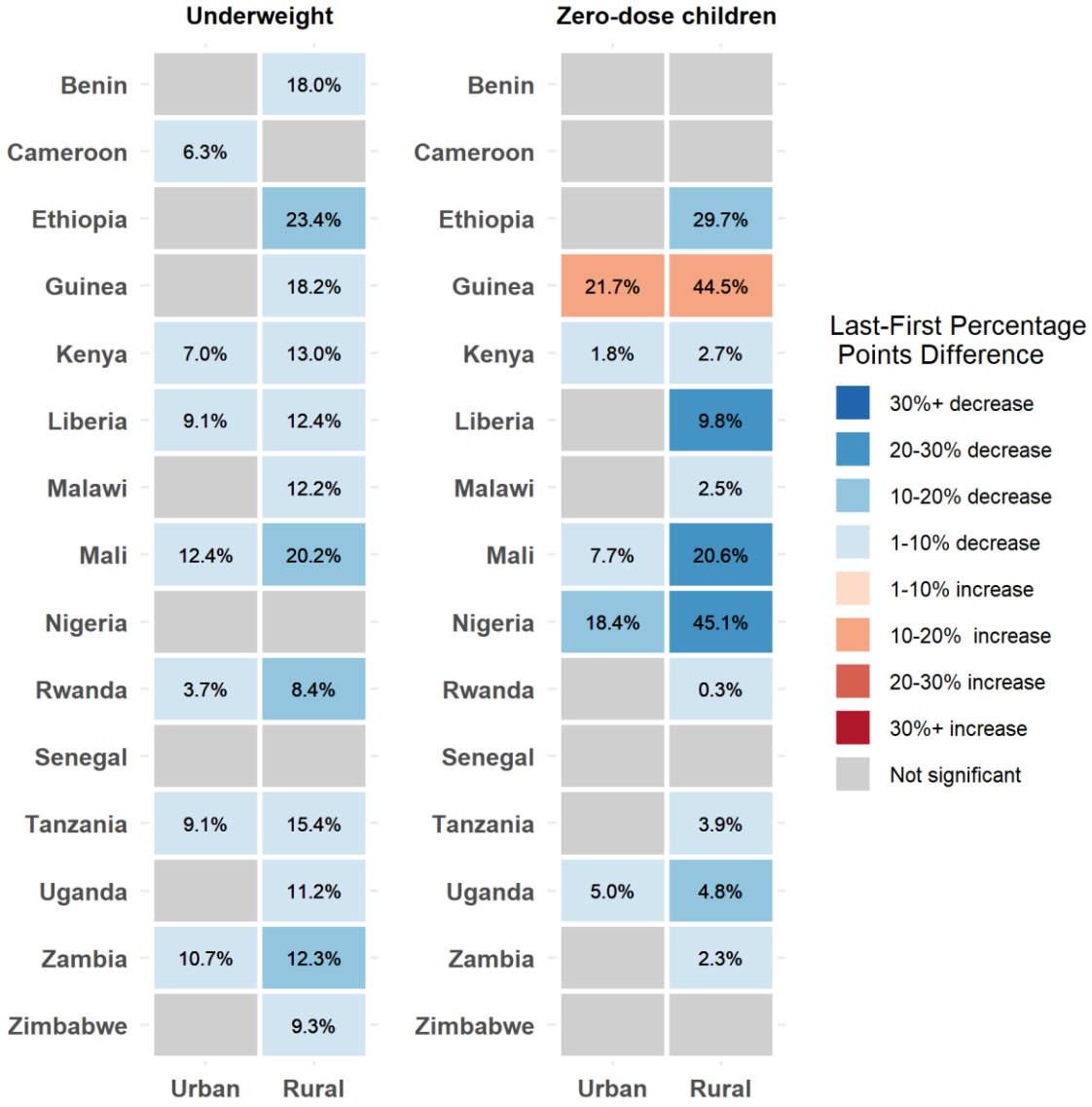
3.1.5 Summary of trends

Figures 5 and 6 below summarize the change in the main indicators and outcomes between the first and last survey in the analysis. The figures show the most recent estimate in the cells, while the colors and legend indicate the percentage point difference between the first and last survey when significant.

Figure 5 shows that percentage of underweight and zero-dose children has decreased significantly in many countries and more so among rural areas compared to the urban areas. However, we also observe many non-significant changes in the approximately 10- to 20-year span examined in the trend analysis. Some countries that showed no improvements also had relatively high levels of the outcomes, such as underweight children in Nigeria and Senegal and zero-dose children in Benin and Cameroon.

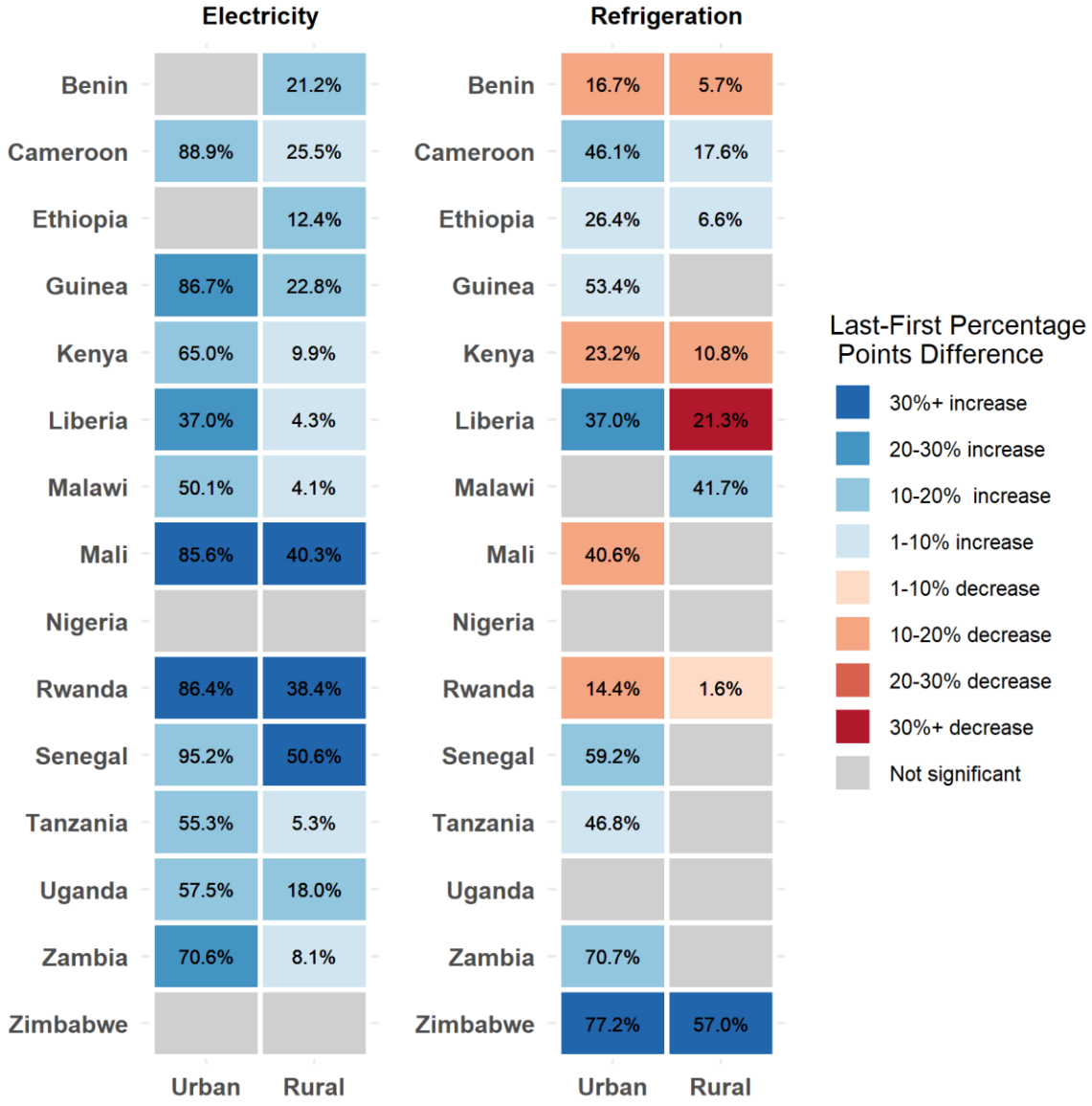
- Percentage of underweight and zero-dose children has decreased significantly in many countries, and more so among rural areas compared to the urban areas.
- Some countries that showed no improvements also had relatively high levels of the outcomes, such as underweight children in Nigeria and Senegal and zero-dose children in Benin and Cameroon.

Figure 5 **Trend summary for underweight and zero-dose children within urban and rural areas. The most recent estimate is indicated in the cells and the percentage point difference between the first and last survey is indicated by color**



In Figure 6 we see that all countries showed significant improvement in electricity access between the first and last survey except for Nigeria and Zimbabwe. Nigeria also did not have any improvements in the outcomes as shown in Figure 5. While almost all countries showed improvement in electricity access among rural areas, there were still very large disparities found in access between rural and urban areas. There was less improvement observed in refrigerator ownership among those with electricity. In some cases, ownership decreased between the first and last survey with the highest decrease in rural Liberia, Mali (especially urban areas), Kenya, Benin, Nigeria, and Rwanda.

Figure 6 **Trend summary for electricity access and refrigerator ownership among those with electricity within urban and rural areas. The most recent estimate is indicated in the cells and the percentage point difference between the first and last survey is indicated by color**



3.2 Regression Results

3.2.1 Underweight

Appendix Tables 3–4 summarize the electricity coefficients from the regression of underweight among children under age 5 in urban and rural areas, and for all four models and surveys. We observe several significant findings especially in Models I and II. However, for most surveys, this significance was lost either after adding the mother's characteristics (Model III) or after adding the household characteristics (Model IV). When the association was significant, it was always negative—children with electricity in the household were less likely to be underweight.

Figure 7 highlights the regression results for underweight, but only for Model IV. The odds ratios (*OR*s) are shown in the cells for each survey. Blue cells are used for *OR*s below one (less likely to have the outcome) and red cells are used for *OR*s above one (more likely to have the outcome). The gradient in the colors indicates the magnitude of the association, with darker colors representing a larger disparity (further away from an OR of one).

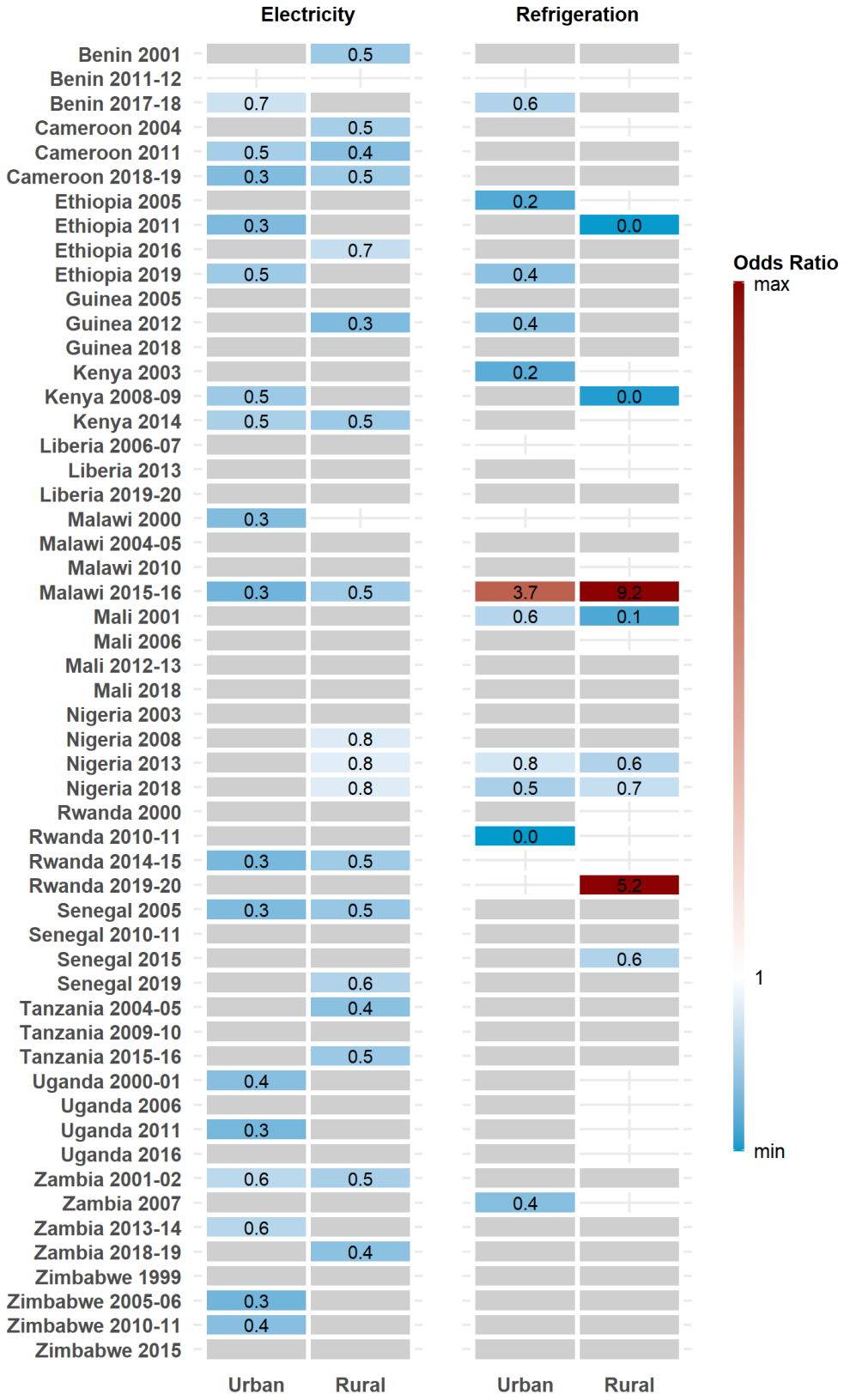
Figure 7 shows that electricity remained significant in several surveys after controlling for child, mother, and household characteristics. However, the significant association was not always persistent across time for each country and also differed between rural and urban children. Figure 7 shows significant negative associations between electricity and underweight in 13 of the 15 countries in one or more surveys for each country. However, these were not always true for the most recent survey, and the significant result was not always found in both urban and rural areas for each country. In eight countries—Benin, Cameroon, Ethiopia, Kenya, Malawi, Rwanda, Senegal, and Zambia—there was a significant negative association between electricity and underweight in both urban and rural areas in Model IV, but not always for the same survey for both areas. In Uganda and Zimbabwe, this significance was found only in the urban areas, and in Guinea, Nigeria, and Tanzania, only in rural areas. There were no significant results in Model IV in Liberia or Mali in any survey.

- Electricity remained significant in several surveys after controlling for child, mother, and household characteristics.
- The significant association was not always persistent across time for each country and differed between rural and urban children.
- Significant negative associations between electricity and underweight in 13 of the 15 countries in one or more surveys for each country.
- In Cameroon, Nigeria, Senegal, Tanzania, and Zambia, children with access to electricity in rural areas were significantly less likely to be underweight in the most recent survey and an earlier survey. This pattern was also observed among the urban children in Cameroon, Ethiopia, Kenya, and Malawi.

In Cameroon, Nigeria, Senegal, Tanzania and Zambia, children with access to electricity in rural areas were significantly less likely to be underweight in the most recent survey and an earlier survey. This pattern was also observed in Cameroon, Ethiopia, Kenya, and Malawi among the urban children. Therefore, this indicated that in these countries, this negative association persisted over time. In Cameroon, we observe a consistent negative association between electricity and underweight for children living in both urban and

rural areas across time. In the most recent survey in Cameroon, children with electricity had 65% lower odds in urban areas ($OR = 0.3$, $p < .001$) and 50% lower odds in rural areas ($OR = 0.5$, $p < .01$) of being underweight compared to children with no electricity. We also observe a significant association between electricity and underweight for both urban and rural children in most recent surveys for Kenya and Malawi. Children living in both urban and rural areas in Kenya, and in rural areas in Malawi, had approximately 50% lower odds of being underweight if they had electricity compared to children who did not. Children living in urban areas in Malawi with electricity had approximately 70% lower odds of being underweight compared to children with no electricity ($OR = 0.3$, $p < .05$). We also find significant associations in both urban and rural areas in Rwanda in the third survey (2014–15), Senegal in the first survey (2005), and in Zambia in the first survey (2001–02).

Figure 7 **Electricity and refrigeration coefficient trends from Model IV of underweight in rural and urban areas**



Note: White cells indicate that there are too few cases or none to fit the model and gray cells indicate a non-significant finding. The Benin 2011–12 results are not displayed due to data quality issues in the anthropometric data in this survey.

Appendix Tables 5–6 summarize the refrigeration coefficients from the regression of underweight in urban and rural areas, respectively, for all models and all surveys. As shown, some surveys or models could not be fit due to the low number of cases. This was the case more often for rural compared to urban areas. This is due to the restricted denominator for these models that are among household with electricity. In these tables, and more so among urban compared to the rural areas, we observe that several surveys where refrigeration was significant in Models I and II lost their significance after the mother's characteristics were included (Model III).

- There were significant negative associations between electricity and refrigerator ownership among those with electricity in 10 of the 15 countries in one or more surveys for each country. However, this significance was not always found in both urban and rural areas for each country or in the most recent survey.
- Only Nigeria has a consistent negative association between refrigeration and underweight in the last two surveys (2013 and 2018) and for both urban and rural children.

Figure 7 shows the results for the refrigeration coefficients in the logistic models for underweight, but only for Model IV. Here we see significant negative associations between electricity and refrigerator ownership among those with electricity in 10 of the 15 countries in one or more surveys for each country. However, the significant result was not always found in both urban and rural areas for each country or in the most recent survey. Only in three countries (Malawi, Mali, and Nigeria) do we see a significant association in both urban and rural areas for the same survey. In Ethiopia, Kenya, and Rwanda, there are also significant findings in both urban and rural areas but they are found in different surveys. In Benin, Guinea, and Zambia, the significant association between underweight and refrigeration was found only in urban areas, and only in rural areas in Senegal. There were no significant results in Cameroon, Liberia, Tanzania, Uganda, and Zimbabwe.

Figure 7 shows that only Nigeria has a consistent negative association between refrigeration and underweight in the last two surveys (2013 and 2018) and for both urban and rural children. Among urban Nigerian children, those with a refrigerator had approximately 20% lower odds ($OR = 0.8$, $p < .01$) of being underweight in the 2013 survey and 50% lower odds ($OR = 0.5$, $p < .001$) in the 2018 survey compared to children with no refrigerator. Among rural children, there was 40% ($OR = 0.6$, $p < .001$) and 30% ($OR = 0.7$, $p < .05$) lower odds of underweight for the 2013 and 2018 surveys respectively for children with a refrigerator compared with those with no refrigerator.

We also see a significant negative association between underweight and refrigeration in the most recent survey among urban areas in Benin and Ethiopia (Benin $OR = 0.6$, $p < .05$; Ethiopia $OR = 0.4$, $p < .05$). However, for the most recent survey in Malawi for both urban and rural areas and in Rwanda among rural areas, we find the only significant positive associations between underweight and refrigeration in the opposite of the expected direction. In Malawi, there were approximately four times greater odds in urban areas and nine times greater odds in rural areas of children being underweight if they had a refrigerator compared to children who did not (both $p < .05$). For rural children in Rwanda, it was approximately five times greater odds ($p < .05$) of underweight for those with refrigeration compared with those with no refrigeration. However, for these models, the significance of refrigeration only appears in Models III or IV,

which indicates that the association of refrigerator ownership with other variables is producing unstable models.

3.2.2 Zero-dose children

Appendix Tables 7–8 summarize the electricity coefficients from the regression of zero-dose children in urban and rural areas respectively and for all four models and surveys. In general, we see fewer significant findings compared to the underweight outcome. In a few surveys, the results for the electricity variable were automatically omitted when attempting to fit the regression model because of the small number of cases. With a few exceptions, electricity was found to be negatively associated with zero-dose children in both urban and rural areas. In several countries, the significance of electricity was retained from Model I to Model IV. This occurred in one of the surveys for Benin, Liberia, Malawi, Rwanda, Senegal, Uganda, and Zambia among urban areas, and Benin, Ethiopia, Mali and Nigeria among rural areas. For some surveys, electricity lost significance after adding the mother's characteristics or household variables.

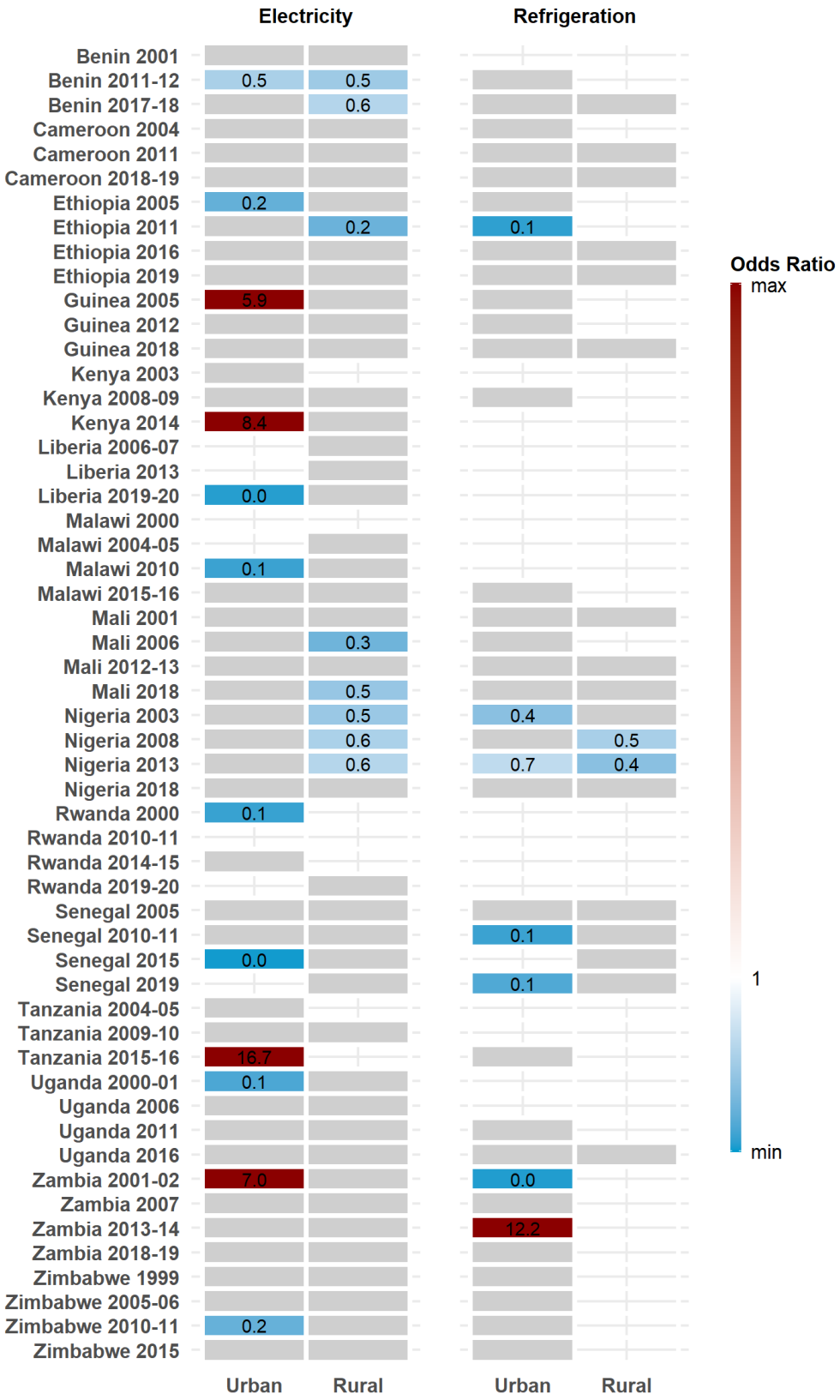
Figure 8 shows significant associations between electricity and zero-dose children in 14 of the 15 countries in one or more surveys for each country. However, this was not in the most recent survey, and the significant result was not always found in both urban and rural areas for each country or in the expected direction. Only in the Benin 2011–12 survey do we observe a significant negative association between electricity and zero-dose children in both urban and rural areas in Model IV for the same survey. For both areas, the *OR* was approximately 0.5 ($p < .05$). In Ethiopia, there were significant associations found in both urban and rural areas, but in different surveys. In Guinea, Kenya, Liberia, Malawi, Rwanda, Senegal, Tanzania, Uganda, Zambia, and Zimbabwe, this significance was found only in urban areas, and in Mali and Nigeria only in rural areas. There were no significant results in Model IV in Cameron in any of the surveys.

- There were significant associations between electricity and zero-dose children in 14 of the 15 countries in one or more surveys for each country. However, this was not always found in both urban and rural areas for each country or in the expected direction.
- Only in the Benin 2011–12 survey do we observe a significant negative association between electricity and zero-dose children in both urban and rural areas for the same survey.
- In rural areas of Nigeria, electricity is significantly negatively associated with zero-dose children after controlling for all variables from 2003-2013.
- In Benin, among rural areas, we observe a significant negative association between electricity and zero-dose children in the two most recent surveys.

Figure 8 also shows that we do not observe any patterns in the trends for most countries. Two exceptions were found among rural children in Benin and Nigeria. In rural areas of Nigeria, electricity is significantly negatively associated with zero-dose children after controlling for all variables from 2003–2013, but this was no longer significant in the 2018 survey. The ORs ranged between 0.5 and 0.6. In Benin, among rural areas, we observe a significant negative association between electricity and zero-dose children in the two most recent surveys (*OR* of 0.5 and 0.6, respectively). Only Kenya, Liberia, and Tanzania among urban

areas had a significant association between electricity and zero-dose children in the most recent survey. In Kenya and Tanzania, this significance was also opposite of the expected direction, with a child who has electricity having greater odds of being a zero-dose child. However, in these surveys, there were a small number of observations in the numerator (see Appendix Tables 7–8) and high associations between electricity and the household variables, which resulted in an unstable model. The same unstable models were also found in the unexpected findings for the Guinea 2005 survey and the Zambia 2011–02 survey. In the Liberia 2019–20 survey, we observe a very large disparity between urban children with and without electricity in the expected direction ($OR = 0.04$, $p < .01$). We also see this significant association in Model I, but this was also based on a small number of cases in the numerator.

Figure 8 **Electricity and refrigeration coefficient trends from Model IV of zero-dose children in rural and urban areas**



Note: White cells indicate that there are too few cases or none to fit the model and gray cells indicate a non-significant finding.

Appendix Tables 9–10 summarize the refrigeration coefficients from the regression of zero-dose children in urban and rural areas respectively for all models and all surveys. Since refrigeration was measured only among those with electricity and because the outcome is only measured among children age 12-23 months, there were many surveys where the model could not be fit due to the few number of cases.

Figure 8 also summarizes the regression results between refrigerator ownership and zero-dose children for Model IV. Only four countries of 15 had a significant association between refrigeration and zero-dose children in either urban or rural areas. Only in Nigeria do we see a significant and negative association between refrigeration and zero-dose children in both urban and rural areas. Among urban Nigerian children, there were lower odds of zero dose children among children with a refrigerator in the 2003 and 2013 surveys, and in the 2008 and 2013 surveys for rural children. No other surveys showed a significant relationship between refrigerator ownership and zero-dose children among rural children.

- Four countries of 15 had a significant association between refrigeration and zero-dose children in either urban or rural areas. Only in Nigeria do we see a significant and negative association between refrigeration and zero-dose children in both urban and rural areas.
- Among urban children, there are significant findings in Ethiopia, Nigeria, Senegal, and Zambia.

Among urban children, there are significant findings in Ethiopia, Nigeria, Senegal, and Zambia. In Senegal, we observe a negative relationship between refrigeration and zero-dose children among urban children in the 2010–11 and 2019 surveys. In Ethiopia, urban children in households that owned a refrigerator with electricity had a higher likelihood of zero-dose children in the most recent survey, However, in Appendix 9, since we see this was not significant in Models I–III, it appears to be the addition of household characteristics that changed the relationship. This indicated that the result is due to the high association between refrigerator ownership and the household variables. There was another significant finding among urban children in the 2011 Ethiopia survey with a negative association between refrigerator ownership and the zero-dose children.

4 DISCUSSION

In this report, we describe trends in access to electricity, refrigeration, under-5 underweight, and zero-dose children and examine the relationships among these variables. Overall, most countries showed declines in underweight and zero-dose children over time, with the declines generally larger for underweight than zero-dose children. During this same period, many countries also showed an increase in access to electricity, although there was less improvement for refrigerator ownership among those with electricity. For some countries, high levels of underweight and zero-dose children and low levels of access to electricity and refrigeration remain a concern in the most recent survey, and especially for the rural population. In the fully adjusted regressions, children were less likely in several countries to be underweight or be zero-dose children if there was electricity in the household. However, there were inconsistent patterns over time for most countries, as well as disparities by urban-rural location. For refrigeration, there were few significant findings across countries for both underweight and zero-dose children. Taken together, the findings show progress on underweight, zero-dose children and access to electricity and refrigeration, and suggest that access to electricity may play a role in improved health and nutrition outcomes for young children.

- Overall, most countries showed declines in underweight and zero-dose children over time.
- During this same period, many countries also showed an increase in access to electricity.
- For some countries, high levels of underweight and zero-dose children and low levels of access to electricity and refrigeration remain a concern in the most recent survey, and especially for the rural population.
- Children were less likely in several countries to be underweight or be zero-dose children if there was electricity in the household.
- However, there were inconsistent patterns over time for most countries, as well as disparities by urban-rural location.

4.1 Underweight

Despite the overall improvements in child underweight over time, the urban-rural divide remains for a few countries and the high levels of underweight are a concern. Globally, underweight has declined from 25% in 1990 to 13% in 2020, although there are no set targets for this indicator (WHO 2022). In fact, many countries are struggling to meet the SDG targets for stunting and wasting (Development Initiatives 2021). Our results reinforce calls for targeted action to address rural-urban disparities and other inequalities, and to advance progress on underweight. This is even more pertinent because of the COVID-19 pandemic, which has increased the risk of child undernutrition (Development Initiatives 2021).

In almost all countries, children in households with electricity were significantly less likely to be underweight regardless of the setting, although this was not always in the most recent survey for each country. Access to electricity can improve undernutrition through various interlinked pathways. Electricity can improve food availability, preservation, and preparation, which enhances household food security

(Candelise, Saccone, and Vallino 2021; Gebrehiwot and Hassen 2022; Sola et al. 2016). Electricity can also reduce morbidities related to food-borne pathogens and use of 'unclean' cooking fuels (Gonzales-Eiras and Rossi 2007; Li et al. 2021). Some studies have also reported an increase in the quantity and quality of diets in households with electricity (Gebrehiwot and Hassen 2022; Sani and Scholz 2022).

Another important pathway is through increased capabilities for childcare. Having electricity can reduce women's time spent on household chores, which can result in improved feeding practices, diets, and growth outcomes for young children (Matare et al. 2021; Tome et al. 2021). Beyond these pathways, household electrification can improve access to health information through television, the internet, and mobile phone use, and can improve a household's overall socioeconomic status as household members have more time to allocate to employment and education (Irwin, Hoxha, and Grepin 2020). Among the surveys that showed no significant relationships between electricity access and underweight, it may that some of the proximal factors included in the regression attenuated any effect. In fact, electricity was significantly associated with underweight in more surveys when there was no adjustment of other variables, although that significance was lost when other variables were included.

In a few countries, we see a negative association between electricity and underweight that persisted over time. This pattern was found in only the rural areas in Nigeria, Senegal, Tanzania, and Zambia, only in urban areas in Ethiopia, Kenya and Malawi, and in both urban and rural areas in Cameroon. These trends over time reinforce the importance of ensuring access to electricity, because our results show a beneficial and persistent effect on child's nutritional status. For example, in some cases, there were significant improvements in older surveys, which may be related to a higher incidence of underweight and more potential to benefit. In the trend results, we see that most countries had improvements in electricity access between the first and last survey in the analysis. However, for many countries, these improvements were not substantial, and disparities between rural and urban areas remained large even in the 10-year span or more in this analysis. This finding is consistent with global data that shows no difference in the pace of electrification between urban and rural areas in sub-Saharan Africa in the last decade (UN 2015). Despite this, the need for expansion of electrification in rural areas is critical because the population of residents with access to electricity ranges between 2–12 times higher in urban areas compared to rural areas (UN 2015). The largest disparities were found in Ethiopia, Kenya, Liberia, Malawi, Tanzania, Zambia, and Zimbabwe. Electrification also remains extremely low among rural areas in many countries that are also part of the USAID Power Initiative.

For refrigeration, in two-thirds of the countries we found significant relationships with underweight, and there were more significant findings in urban than rural areas. Like electricity, the pathways from refrigeration to undernutrition may involve improved food preservation, and better quality and quantity of food (Gonzales-Eiras and Rossi 2007; Martinez et al. 2021). The urban and rural differences may be related to ownership of a refrigerator, which reflects a higher wealth status. Asset ownership is included in the wealth quintile. Another reason could be that electricity is more reliable and of sufficient voltage in urban areas to support refrigerator use. The latter may also partly explain why over time we observed only two significant results, one in urban areas only (Ethiopia) and one in both urban and rural areas (Nigeria). One unexpected finding from our regressions was the positive relationship between refrigeration and underweight in Malawi and rural Rwanda. In both countries, the findings were due to the small number of cases needed to detect variability and/or high associations with the household variables that destabilized the models.

4.2 Zero-dose Children

Trends of zero-dose children declined in all countries except for Guinea, and in several countries zero-dose children was higher in rural areas. Our findings concur with literature that shows that while coverage of routine child immunization expanded since 2000, more recent progress has stalled, and many countries remain below international targets (Cata-Preta et al. 2021; WHO 2020). However, in 7 of 15 countries in our analysis, less than 5% of children were zero-dose children in urban and rural areas. The zero-dose child outcome represents the "last mile" and these communities often face multiple health and socioeconomic inequalities (Cata-Preta et al. 2021). Reaching zero-dose children is a critical step in advancing progress on immunization coverage. This is even more critical now that the COVID-19 pandemic has negatively affected the delivery of routine health services in many LMICs (Arderne et al. 2020; WHO 2020; WHO and World Bank 2021).

In almost all countries, we found significant associations between zero-dose children and electricity, although the direction of the association was not consistent among urban areas. For most countries, children in households with electricity were less likely to be zero-dose children, except in urban areas in Guinea, Kenya, Tanzania, and Zambia. A partial explanation may be the small sizes for the numerator, which make it difficult to detect variability in the relationship of zero-dose children with other variables. Further exploration of these models has also shown high associations between electricity and household variables that have destabilized the models. One plausible pathway between electricity access and immunization is increased access to health information from mass media (Bobo et al. 2022; Irwin, Hoxha, and Grepin 2020). Although not examined in our study, another possibility is that electrification of households may be linked to electrification in health facilities. The latter can result in improved health service delivery and increased service utilization, especially for routine services such as immunizations (Chen, Chindarkar, and Xiao 2019; Majid 2013).

We observed few significant results when examining the regressions over time between zero-dose children and electricity. Of the three countries that showed persistent significant associations over time, Mali and Nigeria were in rural areas only and Benin was in both urban and rural areas. These countries had the greatest potential to benefit over time. For example, Nigeria is a high-priority country where the percentage of zero-dose children is the among highest in the world (WHO 2018), while zero-dose children (WHO 2018) and the percentage of zero-dose children were also high in Mali. Electrification in these countries was relatively low, especially among rural areas, although there were significant improvements in electrification in rural areas of Benin and Mali.

Given the limited sample size, we observed significant associations between zero-dose children and refrigeration in only four countries. Households with refrigerators were less likely to have zero-dose children in Nigeria and urban Senegal, Ethiopia, and Zambia. In the latter two countries, the direction of the association changed in later surveys. Ownership of a refrigerator is related to a higher income. This may be the primary pathway between refrigeration ownership and zero-dose children. Several studies have shown that wealthier households are more likely to receive immunizations (Cata-Preta et al. 2021; Bobo et al. 2022). The wealth index was not included in the models due to its high association with the main indicator of interest, as well as other household variables. In fact, electricity and ownership of assets including a refrigerator, as well as improved water and sanitation, are all included in the construction of the wealth index. The inconsistent direction of association over time in Ethiopia and Zambia may also be a

result of small sample sizes (fewer than 15 observations in numerator for both countries) and associations between electricity and household variables.

4.3 Limitations

Our study is not without some key limitations. The cross-sectional nature of our datasets does not allow us to determine causality. Both electricity access and refrigeration are distally associated with child undernutrition and immunization. Several factors that we adjusted for in the analyses fall within in the pathway to the outcomes and could potentially attenuate any effects of electricity or refrigeration. However, it was necessary to include these factors. There is also some unaccounted residual confounding for several reasons. Households that can afford electricity are likely to have other assets and advantages that were not captured, although we partially addressed this by stratifying our analyses by residence and controlling for sanitation and hygiene variables, as well as women's characteristics. Factors such as children's diet and cooking fuel were not included in the analyses because of likely collinearity and further reductions to the sample size. In addition, DHS surveys do not include information on the source of electricity and its reliability. This could have affected our results in either direction. For example, for sources such as solar energy, without battery storage, electricity will only be available during the day and under the right climatic conditions. Further, several solar panels may be needed to produce sufficient energy for refrigerator use. In addition, we do not have information on the availability of generators, which some communities may be using, especially if the electric grid is not reliable.

Another limitation is the small sample sizes and the associations between the main indicators of interest and other household variables included in the models. For comparability across surveys, we included the same variables in the models. The small sample sizes were also unavoidable, since it was necessary to examine urban and rural areas separately. We also examined refrigeration among those with electricity, which further reduced the sample size. The low prevalence of zero-dose children, which is measured only for children 12–23 months, also contributed to the small samples that would make it difficult to detect variability in the models. These are limitations common to multi-country analyses, and especially in circumstances when avoiding appending data that would mask country-specific findings. Despite these limitations, our study adds to the growing literature that describes the relationship between access to electricity and refrigeration and health outcomes.

4.4 Conclusion

Over the past 20 years, there have been considerable increases in household electrification and routine child immunizations, and declines in child underweight and zero-dose children in many African countries. However, the work continues. Importantly, our study provides empirical evidence of the need for continued expansion of electrification efforts with a focus on rural areas. Future research is needed to better understand the impact of the source of electricity and its reliability on health outcomes. In addition, path analyses may be helpful to better understand the pathways between electrification and health and nutrition outcomes, and to inform programs and policy.

REFERENCES

Arderne, C., C. Zorn, C. Nicolas, and E. E. Koks. 2020. "Predictive Mapping of the Global Power System Using Open Data." *Scientific Data* 7 (1): 19. https://doi.org/10.6084/m9.figshare.11298584

Beal, T., A. Tumilowicz, A. Sutrisna, D. Izwardy, and L. M. Neufeld. 2018. "A Review of Child Stunting Determinants in Indonesia." *Maternal & Child Nutrition* 14 (4): e12617. https://doi.org/10.1111/mcn.12617

Belmin, C., R. Hoffmann, P-P. Pichler, and H. Weisz. 2021. "Fertility Transition Powered by Women's Access to Electricity and Modern Cooking Fuels." *Nature Sustainability* 5 (3): 245253. https://doi.org/10.1038/s41893-021-00830-3

Bobo, F. T., A. Asante, M. Woldie, A. Dawson, and A. Hayen. 2022. "Child Vaccination in Sub-Saharan Africa: Increasing Coverage Addresses Inequalities." *Vaccine* 40 (1): 141150. https://doi.org/10.1016/j.vaccine.2021.11.005

Bos, K., D. Chaplin, and A. Mamun. 2018. "Benefits and Challenges of Expanding Grid Electricity in Africa: A Review of Rigorous Evidence on Household Impacts in Developing Countries." *Energy for Sustainable Development* 44: 6477. https://doi.org/10.1016/j.esd.2018.02.007

Candelise, C., D. Saccone, and E. Vallino. 2021. "An Empirical Assessment of the Effects of Electricity Access on Food Security." *World Development* 141: 105390. https://doi.org/10.1016/j.worlddev.2021.105390

Cata-Preta, B. O., T. M. Santos, T. Mengistu, D. R. Hogan, A. J. D. Barros, and C. G. Victora. 2021. "Zero-Dose Children and the Immunisation Cascade: Understanding Immunisation Pathways in Low and Middle-Income Countries." *Vaccine* 39 (32): 45644570. https://doi.org/10.1016/j.vaccine.2021.02.072

Chen, Y. J., N. Chindarkar, and Y. Xiao. 2019. "Effect of Reliable Electricity on Health Facilities, Health Information, and Child and Maternal Health Services Utilization: Evidence from Rural Gujarat, India." *Journal of Health, Population and Nutrition* 38 (1): 7. https://doi.org/10.1186/s41043-019-0164-6

Cumming, O., and S. Cairncross. 2016. "Can Water, Sanitation and Hygiene Help Eliminate Stunting? Current Evidence and Policy Implications." *Maternal & Child Nutrition* 12 (Suppl 1): 91105. https://doi.org/10.1111/mcn.12258

Development Initiatives. 2021. *2021 Global Nutrition Report: The State of Global Nutrition*. Bristol, UK: Development Initiatives. https://globalnutritionreport.org/

Drago, C., and A. Gatto. 2021. "Gauging Energy Poverty in Developing Countries through Electricity Access." Preprint (Version 1) Research Square. https://doi.org/10.21203/rs.3.rs-1043395/v1

Fink, G., I. Gunther, and K. Hill. 2011. "The Effect of Water and Sanitation on Child Health: Evidence from the Demographic and Health Surveys 19862007." *International Journal of Epidemiology* 40 (5): 11961204. https://doi.org/10.1093/ije/dyr102

Fujii, T., A. S. Schonchoy, and S. Xu. 2016. “Impact of Electrification on Children’s Nutritional Status in Rural Bangladesh.” *IDE Discussion Paper*. Chiba, Japan: Institute of Developing Economies (IDE), JETRO. https://www.ide.go.jp/English/Publish/Reports/Dp/579.html?media=pc

Gebrehiwot, T., and S. Hassen. 2022. “Impact of Energy Access on Food Security and Child Nutrition: Panel Data Evidence from Rural Ethiopia.” *Environment for Development Discussion Paper Series*. Gothenburg, Sweden: Environment for Development (EfD). https://www.efdinitiative.org/publications/impact-energy-access-food-security-and-child-nutrition-panel-data-evidence-rural/

Gonzalez-Eiras, M., and M. A. Rossi. 2007. “The Impact of Electricity Sector Privatization on Public Health.” In *Privatization for the Public Good? Welfare Effects of Private Intervention in Latin America*, edited by A. Chong, 4363. Cambridge, MA: David Rockefeller Center for Latin American Studies.

Headey, D., and G. Palloni. 2019. “Water, Sanitation, and Child Health: Evidence from Subnational Panel Data in 59 Countries.” *Demography* 56 (2): 729752. https://doi.org/10.1007/s13524-019-00760-y

Institut National de la Statistique et de l’Analyse Économique—INSAE/Bénin and ICF International. 2013. *Enquête Démographique et de Santé du Bénin 2011-2012*. Rockville, Maryland, USA: INSAE and ICF. https://dhsprogram.com/publications/publication-fr270-dhs-final-reports.cfm

International Renewable Energy Agency (IRENA). 2022. *Tracking SDG 7: The Energy Progress Report*. Washington, DC, USA: World Bank. https://www.irena.org/publications/2022/Jun/Tracking-SDG-7-2022

Irwin, B. R., K. Hoxha, and K. A. Grepin. 2020. “Conceptualising the Effect of Access to Electricity on Health in Low- and Middle-Income Countries: A Systematic Review.” *Global Public Health* 15 (3): 452473. https://doi.org/10.1080/17441692.2019.1695873

Lenz, L., A. Munyehirwe, J. Peters, and M. Sievert. 2017. “Does Large-Scale Infrastructure Investment Alleviate Poverty? Impacts of Rwanda’s Electricity Access Roll-out Program.” *World Development* 89 (C): 88110. https://doi.org/10.1016/j.worlddev.2016.08.003

Li, J., X. Xu, J. Li, D. Li, Q. Liu, and H. Xue. 2021. “Association between Household Fuel Types and Undernutrition Status of Adults and Children under 5 Years in 14 Low and Middle Income Countries.” *Environmental Research Letters* 16 (5). https://doi.org/10.1088/1748-9326/abf005

Local Burden of Disease Child Growth Failure Collaborators. 2020. “Mapping Child Growth Failure across Low- and Middle-Income Countries.” *Nature* 577 (7789): 231234. https://doi.org/10.1038/s41586-019-1878-8

López-González, A., B. Domenech, and L. Ferrer-Martí. 2020. “The Gendered Politics of Rural Electrification: Education, Indigenous Communities, and Impacts for the Venezuelan Guajira.” *Energy Research & Social Science* 70: 101776. https://doi.org/10.1016/j.erss.2020.101776

Machingaidze, S., C. S. Wiysonge, and G. D. Hussey. 2013. “Strengthening the Expanded Programme on Immunization in Africa: Looking Beyond 2015.” *PLoS Med* 10 (3): e1001405. https://doi.org/10.1371/journal.pmed.1001405

Majid, H. 2013. “Increased Rural Connectivity and Its Effects on Health Outcomes.” *Lahore Journal of Economics* 18 (E): 271281. https://ideas.repec.org/a/lje/journl/v18y2013ispp271-282.html

Martinez, S., J. M. Murguia, B. Rejas, and S. Winters. 2021. “Refrigeration and Child Growth: What is the Connection?” *Maternal & Child Nutrition* 17 (2): e13083. https://doi.org/10.1111/mcn.13083

Matare, C. R., M. N. N. Mbuya, K. L. Dickin, M. A. Constas, G. Pelto, B. Chasekwa, J. H. Humphrey, R. J. Stoltzfus for the Sanitation Hygiene Infant Nutrition Efficacy (SHINE) Trial Team. 2021. “Maternal Capabilities are Associated with Child Caregiving Behaviors among Women in Rural Zimbabwe.” *The Journal of Nutrition* 151 (3): 685694. https://doi.org/10.1111/mcn.13122

Médecins Sans Frontières. 2013. The Right Shot: Extending the Reach of Affordable and Adapted Vaccines. https://marketbookshelf.com/wp-content/uploads/2017/05/The-Right-Shot.pdf

Polansky, J., and M. Laldjebaev. 2021. “Gendered Energy Relations at the Crossroads of Asia: Electrification, Empowerment, and Mixed Outcomes in Northeastern Afghanistan.” *Energy Research & Social Science* 73: 1019928. https://doi.org/10.1016/j.erss.2021.101928

Sani, Y., and M. Scholz. 2022. “Interplay of Water–Energy Security and Food Consumption Patterns Towards Achieving Nutrition Security in Katsina State, North-Western Nigeria.” *Sustainability* 14 (8): 4478. https://doi.org/10.3390/su14084478

Santos, T. M., B. O. Cata-Preta, C. G. Victora, and A. J. D. Barros. 2021. “Finding Children with High Risk of Non-Vaccination in 92 Low- and Middle-Income Countries: A Decision Tree Approach.” *Vaccines (Basel)* 9 (6): 646. https://doi.org/10.3390/vaccines9060646

Sola, P., C. Ochieng, J. Yila, and M. Iiyama. 2016. “Links between Energy Access and Food Security in Sub Saharan Africa: An Exploratory Review.” *Food Security* 8 (3): 635642. https://doi.org/10.1007/s12571-016-0570-1

Sovacool, B. K., and S. E. Ryan. 2016. “The Geography of Energy and Education: Leaders, Laggards, and Lessons for Achieving Primary and Secondary School Electrification.” *Renewable and Sustainable Energy Reviews* 58: 107123. https://doi.org/10.1016/j.rser.2015.12.219

Ssentongo, P., A. E. Ssentongo, D. M. Ba, J. E. Ericson, M. Na, X. Gao, C. Fronterre, V. M. Chinchilli, and S. J. Schiff. 2021. “Global, Regional and National Epidemiology and Prevalence of Child Stunting, Wasting and Underweight in Low- and Middle-Income Countries, 2006-2018.” *Scientific Reports* 11 (1): 5204. https://doi.org/10.1038/s41598-021-84302-w

Tagliapietra, S. 2018. “Electrification in Sub-Saharan Africa: The Role of International Institutions.” *Oxford Energy Forum* 115. https://www.bruegel.org/report/electrification-sub-saharan-africa-role-international-institutions

Tome, J., M. N. N. Mbuya, R. R. Makasi, R. Ntozini, A. J. Prendergast, K. L. Dickin, G. H. Pelto, et al. for the Sanitation Hygiene Infant Nutrition Efficacy (SHINE) Trial Team. “Maternal Caregiving Capabilities Are Associated with Child Linear Growth in Rural Zimbabwe.” *Maternal & Child Nutrition* 17 (2): e13122. https://doi.org/10.1111/mcn.13122

United Nations. 2015. *Transforming Our World: The 2030 Agenda for Sustainable Development*. https://sdgs.un.org/2030agenda

United States Agency for International Development (USAID). 2022a. *Asia Edge*. https://www.usaid.gov/energy/asia-edge

United States Agency for International Development (USAID). 2022b. *Power Africa*. https://www.usaid.gov/powerafrica

Vyas, S., P. Kov, S. Smets, and D. Spears. 2016. "Disease Externalities and Net Nutrition: Evidence from Changes in Sanitation and Child Height in Cambodia, 20052010." *Economics and Human Biology* 23: 235245. https://doi.org/10.1016/j.ehb.2016.10.002

World Health Organization (WHO). 2013. *Global Vaccine Action Plan 2011–2020*. Geneva, Switzerland: WHO. https://www.who.int/publications/i/item/global-vaccine-action-plan-2011-2020.

World Health Organization (WHO). 2018. *Explorations of Inequality: Childhood Immunization*. Geneva, Switzerland: WHO. https://apps.who.int/iris/handle/10665/272864

World Health Organization (WHO). 2020. *Immunization Agenda 2030*. Geneva, Switzerland: World Health Organization. https://www.who.int/docs/default-source/immunization/strategy/ia2030/ia2030-document-en.pdf

World Health Organization (WHO). 2022. *Joint Child Malnutrition Estimates*. Geneva, Switzerland: World Health Organization. https://www.who.int/data/gho/data/themes/topics/joint-child-malnutrition-estimates-unicef-who-wb

World Health Organization (WHO) and World Bank. 2021. *Tracking Universal Health Coverage 2021 Global Monitoring Report Conference Edition*. Geneva, Switzerland: World Health Organization. https://openknowledge.worldbank.org/handle/10986/36724

Winfrey, W., and S. Riese. 2020. *Household Wealth Relative to Community Wealth: Associations with Specific Asset Ownership and Maternal and Child Health Indicators*. DHS Analytical Studies No. 76. Rockville, Maryland, USA: ICF. https://dhsprogram.com/publications/publication-as76-analytical-studies.cfm

APPENDICES

Appendix Table 1 Levels and trends of underweight children under 5 and zero-dose immunization in children 12–23 months

		Underweight									Zero-dose immunization								
Country		sur 1	sur 2	diff. 2-1	sur 3	diff 3-2	sur 4	diff 4-3	diff last-first[a]		sur 1	sur 2	diff 2-1	sur 3	diff 3-2	sur 4	diff 4-3	diff last-first[a]	
Benin	Total	19.1	ND		16.7				-2.4*	v	12.5	14.4	1.9	15.4	1.0			2.9	
	Urban	14.1	ND		14.7				0.6		8.8	11.1	2.3	11.8	0.7			3.0	
	Rural	21.6	ND		18.0				-3.6**	v	14.4	16.7	2.3	17.6	0.9			3.2	
Cameroon	Total	14.6	14.8	0.2	11.2	-3.6**			-3.4**	v	17.7	14.6	-3.1	16.9	2.3			-0.8	
	Urban	9.1	7.2	-1.9	6.3	-0.9			-2.8*	v	9.8	7.1	-2.7	8.5	1.4			-1.3	
	Rural	18.7	20.5	1.8	15.2	-5.3**			-3.5		24.0	19.7	-4.3	23.0	3.3			-1.0	
Ethiopia	Total	33.1	28.5	-4.6***	23.7	-4.8***	21.4	-2.3	-11.7***	v	41.5	36.3	-5.2	26.7	-9.6**	23.6	-3.1	-17.9***	v
	Urban	17.4	16.1	-1.3	13.3	-2.8	15.4	2.1	-2.0		14.8	17.6	2.8	7.6	-10.0	9.9	2.3	-4.9	
	Rural	34.5	30.3	-4.2**	24.9	-5.4***	23.4	-1.5	-11.1***	v	43.7	39.3	-4.4	29.0	-10.3**	29.7	0.7	-14.0***	v
Guinea	Total	22.3	18.0	-4.3**	16.4	-1.6			-5.9***	v	22.4	24.2	1.8	37.8	13.6***			15.4***	^
	Urban	14.7	9.3	-5.4**	12.1	2.8			-2.6		9.3	11.7	2.4	21.7	10.0**			12.4***	^
	Rural	24.4	21.0	-3.4*	18.2	-2.8*			-6.2***	v	25.7	28.3	2.6	44.5	16.2***			18.8***	^
Kenya	Total	15.6	16.1	0.5	11.0	-5.1***			-4.6***	v	10.8	4.2	-6.6***	2.4	-1.8*			-8.4***	v
	Urban	9.4	10.1	0.7	7.0	-3.1			-2.4*	v	5.3	3.2	-2.1	1.8	-1.4			-3.5*	v
	Rural	16.9	17.3	0.4	13.0	-4.3***			-3.9***	v	11.8	4.4	-7.4***	2.7	-1.7			-9.1***	v
Liberia	Total	19.1	15.1	-4.0***	10.7	-4.4***			-8.4***	v	23.9	8.7	-15.2***	8.7	0			-15.2***	v
	Urban	17.2	13.3	-3.9*	9.1	-4.2*			-8.1***	v	10.1	4.9	-5.2*	7.6	2.7			-2.5	
	Rural	19.9	16.8	-3.1*	12.4	-4.4***			-7.5***	v	30.2	12.8	-17.4***	9.8	-3.0			-20.4***	v
Malawi	Total	20.4	17.4	-3.0***	12.7	-4.7***	11.7	-1.0	-8.7***	v	4.1	4.9	0.8	2.6	-2.3**	2.5	-0.1	-1.6*	v
	Urban	10.5	12.6	2.1	9.8	-2.8	8.0	-1.8	-2.5		1.1	1.5	0.4	2.3	0.8	2.3	0.0	1.2	
	Rural	21.9	18.1	-3.8***	13.2	-4.9***	12.2	-1.0	-9.7***	v	4.6	5.4	0.8	2.7	-2.7***	2.5	-0.2	-2.1**	v
Mali	Total	29.1	26.6	-2.5*	25.4	-1.2	18.7	-6.7***	-10.4***	v	35.2	16.9	-18.3***	19.6	2.7	17.9	-1.7	-17.3***	v
	Urban	16.9	19.5	2.6	16.7	-2.8	12.4	-4.3*	-4.5**	v	13.8	12.3	-1.5	7.8	-4.5	7.7	-0.1	-6.1*	v
	Rural	32.8	29.2	-3.6**	27.5	-1.7	20.2	-7.3***	-12.6***	v	41.7	18.6	-23.1***	22.5	3.9	20.6	-1.9	-21.1***	v
Nigeria	Total	24.4	23.2	-1.2	28.8	5.6***	21.8	-7.0***	-2.6*	v	58.0	47.9	-10.1***	49.6	1.7	34.6	-15.0***	-23.4***	v
	Urban	18.5	15.9	-2.6	22.9	7.0***	15.2	-7.7***	-3.3		36.3	28.1	-8.2*	26.3	-1.8	18.4	-7.9***	-17.9***	v
	Rural	27.1	26.6	-0.5	32.3	5.7***	27.1	-5.2***	0.0		68.0	56.5	-11.5***	62.7	6.2**	45.1	-17.6***	-22.9***	v
Rwanda	Total	19.6	11.5	-8.1***	9.3	-2.2**	7.6	-1.7*	-12.0***	v	4.3	1.1	-3.2***	0.9	-0.2	0.3	-0.6	-4.0***	v
	Urban	11.8	6.6	-5.2**	6.1	-0.5	3.7	-2.4	-8.1***	v	3.7	0.3	-3.4*	1.4	1.1	0.6	-0.8	-3.1	
	Rural	21.0	12.2	-8.8***	9.9	-2.3**	8.4	-1.5	-12.6***	v	4.4	1.3	-3.1***	0.8	-0.5	0.3	-0.5	-4.1***	v
Senegal	Total	14.1	17.4	3.3**	15.4	-2.0	14.4	-1.0	0.3		6.7	6.1	-0.6	3.5	-2.6*	3.8	0.3	-2.9*	v
	Urban	7.1	11.8	4.7**	10.3	-1.5	9.5	-0.8	2.4		4.9	5.4	0.5	1.4	-4.0**	2.0	0.6	-2.9	
	Rural	17.8	21.0	3.2	18.3	-2.7*	17.2	-1.1	-0.6		7.8	6.5	-1.3	4.6	-1.9	4.9	0.3	-2.9	
Tanzania	Total	16.4	15.9	-0.5	13.8	-2.1**			-2.6**	v	6.7	4.5	-2.2	3.1	-1.4			-3.6***	v
	Urban	12.4	12.0	-0.4	9.1	-2.9*			-3.3*	v	3.4	1.8	-1.6	0.9	-0.9			-2.5	
	Rural	17.4	16.8	-0.6	15.4	-1.4			-2.0*	v	7.4	5.1	-2.3	3.9	-1.2			-3.5**	v

Continued...

Appendix Table 1—*Continued*

		Underweight									Zero-dose immunization								
Country		**sur 1**	**sur 2**	**diff. 2-1**	**sur 3**	**diff 3-2**	**sur 4**	**diff 4-3**	**diff last-first[a]**		**sur 1**	**sur 2**	**diff 2-1**	**sur 3**	**diff 3-2**	**sur 4**	**diff 4-3**	**diff last-first[a]**	
Uganda	Total	18.3	16.0	-2.3	13.9	-2.1	10.5	-3.4***	-7.8***	v	23.1	10.2	-12.9***	6.9	-3.3*	4.9	-2.0*	-18.2***	v
	Urban	8.9	11.1	2.2	7.5	-3.6	7.9	0.4	-1.0		10.2	6.9	-3.3	5.2	-1.7	5.0	-0.2	-5.2*	v
	Rural	19.3	16.6	-2.7*	14.9	-1.7	11.2	-3.7***	-8.1***	v	24.5	10.6	-13.9***	7.1	-3.5*	4.8	-2.3*	-19.7***	v
Zambia	Total	22.5	14.7	-7.8***	14.8	0.1	11.8	-3.0***	-10.7***	v	5.7	7.1	1.4	3.9	-3.2**	2.0	-1.9**	-3.7***	v
	Urban	18.8	13.1	-5.7**	12.9	-0.2	10.7	-2.2	-8.1***	v	3.8	3.8	0.0	1.8	-2.0	1.3	-0.5	-2.5	
	Rural	24.2	15.3	-8.9***	15.8	0.5	12.3	-3.5***	-11.9***	v	6.5	8.2	1.7	4.8	-3.4*	2.3	-2.5**	-4.2***	v
Zimbabwe	Total	10.4	13.3	2.9**	9.8	-3.5***	8.4	-1.4*	-2.0**	v	11.9	21.7	9.8***	13.2	-8.5***	9.7	-3.5	-2.2	
	Urban	5.7	9.0	3.3*	8.1	-0.9	5.9	-2.2	0.2		6.9	19.5	12.6**	10.2	-9.3*	4.4	-5.8*	-2.5	
	Rural	12.4	14.7	2.3*	10.3	-4.4***	9.3	-1.0	-3.1**	v	14.1	22.6	8.5**	14.2	-8.4**	11.7	-2.5	-2.4	

* Significant at p <.05; ** significant at p < .01; significant at *** p < .001
ND = not displayed
Note: sur 1 to 4 indicates the survey number from oldest to most recent for each country as summarized in Table 1.
[a] Difference is survey 4 − survey 1, or survey 3 − survey 1 depending on the number of surveys used in the analysis as shown in Table 1.
^ indicates a significant increase between the first and last survey and **v** a significant decrease.

Appendix Table 2 Levels and trends among de jure population in electricity and refrigerator ownership among those with electricity

		Electricity									Refrigerator (among those with electricity)								
Country		**sur 1**	**sur 2**	**diff. 2-1**	**sur 3**	**diff. 3-2**	**sur 4**	**diff 4-3**	**diff last-first[a]**		**sur 1**	**sur 2**	**diff. 2-1**	**sur 3**	**diff. 3-2**	**sur 4**	**diff 4-3**	**diff last-first[a]**	
Benin	Total	21.9	36.3	14.4***	34.5	-1.8			12.6***	^	29.3	17.4	-11.9***	12.6	-4.8***			-16.7***	v
	Urban	50.8	66.6	15.8***	54.2	-12.4***			3.4		31.2	20.8	-10.4***	16.7	-4.1**			-14.5***	v
	Rural	5.6	14.7	9.1***	21.2	6.5***			15.6***	^	19.3	6.2	-13.1***	5.7	-0.5			-13.6***	v
Cameroon	Total	45.7	51.3	5.6**	57.5	6.2**			11.8***	^	29.7	30.8	1.1	39.8	9.0***			10.1***	^
	Urban	76.6	87.3	10.7***	88.9	1.6			12.3***	^	33.7	35.2	1.5	46.1	10.9***			12.4***	^
	Rural	16.2	19.0	2.8	25.5	6.5*			9.3**	^	11.6	12.5	0.9	17.6	5.1			6.0*	^
Ethiopia	Total	12.0	18.8	6.8***	20.8	2.0	31.0	10.2***	19.0***	^	14.8	18.8	4.0	22.0	3.2	20.6	-1.4	5.8	
	Urban	85.9	83.5	-2.4	92.2	8.7	81.2	-11.0***	-4.7		17.1	21.1	4.0	30.8	9.7**	26.4	-4.4	9.3*	^
	Rural	2.0	4.6	2.6*	7.7	3.1	12.4	4.7	10.4***	^	0.9	9.6	8.7*	2.7	-6.9	6.6	3.9	5.7*	^
Guinea	Total	20.9	26.9	6.0***	45.0	18.1***			24.1***	^	40.8	37.2	-3.6	38.0	0.8			-2.8	
	Urban	63.1	75.5	12.4**	86.7	11.2***			23.6***	^	44.0	38.7	-5.3	53.4	14.7***			9.4**	^
	Rural	3.2	3.5	0.3	22.8	19.3***			19.6***	^	15.0	21.1	6.1	6.8	-14.3*			-8.2	
Kenya	Total	13.1	18.1	5.0*	28.8	10.7***			15.7***	^	30.9	29.5	-1.4	20.4	-9.1**			-10.5**	v
	Urban	51.4	64.8	13.4**	65.0	0.2			13.6***	^	33.2	36.2	3.0	23.2	-13.0**			-10.0*	v
	Rural	3.6	6.9	3.3*	9.9	3.0*			6.3***	^	22.6	14.5	-8.1	10.8	-3.7			-11.8*	v
Liberia	Total	3.3	10.1	6.8***	23.1	13.0***			19.8***	^	24.4	24.9	0.5	35.8	10.9*			11.4	
	Urban	7.0	16.9	9.9***	37.0	20.1***			30.0***	^	15.1	25.4	10.3	37.0	11.6*			21.9**	^
	Rural	1.0	1.4	0.4	4.3	2.9***			3.3*	^	62.2	16.5	-45.7**	21.3	4.8			-40.9**	v
Malawi	Total	5.6	7.5	1.9	9.1	1.6	10.7	1.6*	5.1***	^	NA	44.3		40.9	-3.4	52.0	11.1**	7.7	
	Urban	32.2	34.0	1.8	36.8	2.8	50.1	13.3**	17.9**	^	NA	52.3		47.0	-5.3	56.9	9.9*	4.6	
	Rural	1.2	2.5	1.3**	3.8	1.3*	4.1	.3	2.9***	^	NA	23.8		30.0	6.2	41.7	11.7**	17.9***	^
Mali	Total	12.8	17.4	4.6**	26.4	9.0***	50.9	24.5***	38.1***	^	50.8	27.0	-23.8***	25.2	-1.8	22.2	-3.0	-28.6***	v
	Urban	41.2	48.7	7.5	77.2	28.5***	85.6	8.4	44.4***	^	57.1	31.0	-26.1***	33.8	2.8	40.6	6.8*	-16.5***	v
	Rural	2.6	3.7	1.1	12.4	8.7***	40.3	27.9***	37.7***	^	15.7	4.4	-11.3*	10.6	6.2*	10.3	-0.3	-5.4	
Nigeria	Total	51.2	47.9	-3.3	52.7	4.8*	56.5	3.8*	5.3		35.9	32.4	-3.5	33.1	0.7	36.6	3.5*	0.7	
	Urban	84.0	84.3	0.3	83.0	-1.3	81.7	-1.3	-2.3		47.2	41.2	-6.0*	41.2	0.0	44.6	3.4	-2.6	
	Rural	34.5	29.7	-4.8	32.7	3.0	37.1	4.4	2.6		21.9	19.9	-2.0	19.5	-0.4	23.0	3.5*	1.1	
Rwanda	Total	7.3	10.2	2.9**	23.2	13.0***	46.6	23.4***	39.3***	^	26.0	14.9	-11.1***	8.5	-6.4***	5.7	-2.8**	-20.3***	v
	Urban	42.1	47.0	4.9	73.7	26.7***	86.4	12.7***	44.3***	^	28.1	19.5	-8.6*	14.2	-5.3	14.4	0.2	-13.7***	v
	Rural	1.1	4.5	3.4***	13.1	8.6***	38.4	25.3***	37.3***	^	10.8	7.4	-3.4	2.0	-5.4***	1.6	-0.4	-9.2***	v
Senegal	Total	46.4	56.8	10.4***	58.2	1.4	70.4	12.2***	24.0***	^	45.9	40.6	-5.3	37.3	-3.3	47.9	10.6**	2.0	
	Urban	82.0	89.5	7.5***	88.5	-1.0	95.2	6.7**	13.2***	^	49.1	47.5	-1.6	42.8	-4.7	59.2	16.4**	10.1*	^
	Rural	18.9	30.2	11.3**	34.7	4.5	50.6	15.9**	31.7***	^	35.2	23.9	-11.3**	26.4	2.5	31.0	4.6	-4.2	
Tanzania	Total	10.5	13.1	2.6*	19.9	6.8***			9.4***	^	37.3	44.5	7.2*	43.4	-1.1			6.1*	^
	Urban	38.9	46.6	7.7	55.3	8.7			16.4***	^	39.3	50.2	10.9**	46.8	-3.4			7.5*	^
	Rural	1.8	3.4	1.6*	5.3	1.9*			3.5***	^	23.8	21.4	-2.4	28.5	7.1			4.7	
Uganda	Total	8.4	7.5	-0.9	11.7	4.2***	26.7	15.0***	18.3***	^	29.4	37.4	8.0*	33.2	-4.2	19.6	-13.6***	-9.8***	v
	Urban	47.4	40.5	-6.9*	53.4	12.9***	57.5	4.1	10.1**	^	34.9	37.9	3.0	38.9	1.0	30.8	-8.1	-4.1	
	Rural	2.6	2.7	0.1	4.6	1.9	18.0	13.4***	15.4***	^	14.3	36.5	22.2**	21.7	-14.8*	9.6	-12.1**	-4.7	

Continued...

Appendix Table 2—*Continued*

Country		Electricity									Refrigerator (among those with electricity)								
		sur 1	sur 2	diff. 2-1	sur 3	diff. 3-2	sur 4	diff 4-3	diff last-first[a]		sur 1	sur 2	diff. 2-1	sur 3	diff. 3-2	sur 4	diff 4-3	diff last-first[a]	
Zambia	Total	20.1	20.7	0.6	26.7	6.0**	32.8	6.1***	12.7***	^	58.0	66.3	8.3	72.4	6.1	66.8	-5.6*	8.8*	^
	Urban	50.0	52.1	2.1	62.8	10.7*	70.6	7.8*	20.6***	^	60.2	70.1	9.9*	74.0	3.9	70.7	-3.3	10.5**	^
	Rural	3.5	3.3	-0.2	3.6	0.3	8.1	4.5***	4.6**	^	40.1	33.0	-7.1	54.2	21.2*	44.8	-9.4	4.7	
Zimbabwe	Total	33.8	33.8	0.0	33.4	-0.4	30.3	-3.1	-3.5		42.6	53.7	11.1***	53.2	-0.5	73.4	20.2***	30.8***	^
	Urban	90.0	92.0	2.0	84.7	-7.3*	81.2	-3.5	-8.8		46.2	58.0	11.8***	59.7	1.7	77.2	17.5***	31.0***	^
	Rural	7.4	6.9	-0.5	10.8	3.9*	8.1	-2.7	0.7		22.0	27.1	5.1	30.7	3.6	57.0	26.3***	35.0***	^

* Significant at p <.05; ** significant at p < .01; significant at *** p < .001
NA = not available
Note: sur 1 to 4 indicates the survey number from oldest to most recent for each country as summarized in Table 1.
[a] Difference is survey 4 − survey 1, or survey 3 − survey 1 depending on the number of surveys used in the analysis as shown in Table 1. Differences for Malawi were computed between survey 4 and survey 2 due to lack of information on refrigeration in survey 1.
^ indicates a significant increase between the first and last survey and **v** a significant decrease.

Appendix Table 3 **Odds ratios from the regression results of Models I–IV of underweight outcome among urban children under age 5 for having electricity**

	Model I				Model II				Model III				Model IV				Unweighted observations (underweight urban)	
Survey	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	**Numer-ator**	**Denomi-nator**
Benin 2001	0.51	0.34	0.78	**.002**	0.51	0.33	0.77	**.002**	0.56	0.34	0.90	**.018**	0.68	0.39	1.19	.177	178	1,260
Benin 2011–12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	638	3,087
Benin 2017–18	0.62	0.50	0.78	**.000**	0.62	0.50	0.78	**.000**	0.70	0.56	0.87	**.001**	0.72	0.57	0.91	**.005**	772	5,150
Cameroon 2004	0.38	0.23	0.63	**.000**	0.37	0.22	0.64	**.000**	0.56	0.32	0.98	**.042**	0.63	0.36	1.11	.110	108	1,386
Cameroon 2011	0.40	0.23	0.68	**.001**	0.36	0.22	0.61	**.000**	0.53	0.31	0.91	**.021**	0.53	0.30	0.95	**.033**	168	2,327
Cameroon 2018–19	0.19	0.11	0.32	**.000**	0.19	0.11	0.32	**.000**	0.29	0.18	0.48	**.000**	0.35	0.20	0.61	**.000**	143	2,219
Ethiopia 2005	0.90	0.52	1.56	.705	0.93	0.53	1.63	.801	1.38	0.73	2.61	.315	1.38	0.69	2.78	.360	92	600
Ethiopia 2011	0.26	0.16	0.41	**.000**	0.25	0.14	0.43	**.000**	0.33	0.19	0.58	**.000**	0.33	0.20	0.53	**.000**	261	1,651
Ethiopia 2016	0.40	0.20	0.79	**.009**	0.40	0.20	0.82	**.012**	0.64	0.29	1.42	.273	0.58	0.25	1.38	.218	237	1,756
Ethiopia 2019	0.64	0.32	1.25	.188	0.62	0.32	1.19	.148	0.63	0.28	1.45	.274	0.49	0.26	0.91	**.025**	206	1,249
Guinea 2005	1.17	0.67	2.06	.577	1.19	0.70	2.04	.518	1.17	0.66	2.06	.587	1.04	0.55	1.96	.905	86	597
Guinea 2012	0.63	0.39	1.04	.070	0.66	0.40	1.07	.089	0.83	0.48	1.43	.497	0.77	0.45	1.31	.326	102	992
Guinea 2018	0.73	0.47	1.13	.151	0.70	0.45	1.09	.115	0.73	0.43	1.22	.222	0.76	0.44	1.32	.330	142	1,168
Kenya 2003	0.65	0.39	1.10	.110	0.62	0.37	1.04	.070	0.74	0.45	1.22	.237	1.40	0.75	2.61	.292	113	1,201
Kenya 2008–09	0.39	0.21	0.73	**.003**	0.40	0.23	0.70	**.002**	0.45	0.25	0.81	**.009**	0.47	0.26	0.85	**.013**	145	1,261
Kenya 2014	0.40	0.29	0.54	**.000**	0.40	0.29	0.54	**.000**	0.50	0.35	0.69	**.000**	0.54	0.38	0.77	**.001**	603	6,321
Liberia 2006–07	0.87	0.38	1.97	.731	0.91	0.41	1.98	.801	0.34	0.13	0.91	**.032**	0.42	0.15	1.17	.096	312	1,810
Liberia 2013	0.57	0.21	1.53	.262	0.54	0.21	1.37	.191	0.64	0.24	1.71	.373	0.86	0.34	2.19	.757	168	1,213
Liberia 2019–20	0.83	0.46	1.52	.544	0.81	0.44	1.50	.500	0.82	0.39	1.76	.614	0.59	0.24	1.46	.252	100	963
Malawi 2000	0.20	0.09	0.46	**.000**	0.20	0.09	0.45	**.000**	0.33	0.16	0.72	**.005**	0.35	0.15	0.81	**.015**	185	1,829
Malawi 2004–05	0.49	0.26	0.94	**.034**	0.47	0.23	0.95	**.035**	0.52	0.27	0.98	**.043**	0.64	0.34	1.20	.163	105	886
Malawi 2010	0.70	0.26	1.89	.482	0.94	0.35	2.53	.902	1.28	0.47	3.48	.629	1.37	0.45	4.19	.580	38	484
Malawi 2015–16	0.27	0.12	0.65	**.004**	0.27	0.11	0.64	**.003**	0.28	0.10	0.78	**.015**	0.27	0.10	0.73	**.010**	85	908
Mali 2001	0.58	0.38	0.88	**.011**	0.59	0.39	0.88	**.011**	0.72	0.46	1.11	.139	0.77	0.49	1.21	.260	354	2,130
Mali 2006	0.74	0.58	0.94	**.015**	0.73	0.56	0.94	**.016**	0.75	0.55	1.02	.065	0.81	0.63	1.05	.106	708	3,503
Mali 2012–13	0.68	0.45	1.02	.064	0.67	0.44	1.02	.064	0.79	0.50	1.25	.318	0.87	0.53	1.42	.577	202	1,185
Mali 2018	0.75	0.50	1.12	.161	0.78	0.50	1.23	.281	0.90	0.55	1.45	.655	1.13	0.68	1.85	.637	305	2,228
Nigeria 2003	0.62	0.40	0.98	**.043**	0.62	0.40	0.98	**.039**	0.82	0.53	1.28	.391	0.97	0.62	1.51	.882	343	1,745
Nigeria 2008	0.67	0.53	0.84	**.001**	0.66	0.52	0.84	**.001**	0.93	0.72	1.20	.583	0.97	0.73	1.27	.803	1,013	5,913
Nigeria 2013	0.86	0.65	1.15	.311	0.86	0.64	1.14	.293	1.11	0.85	1.44	.444	1.03	0.79	1.33	.825	1,843	9,142
Nigeria 2018	0.61	0.48	0.78	**.000**	0.61	0.48	0.77	**.000**	0.74	0.58	0.95	**.018**	0.81	0.61	1.06	.127	706	4,762
Rwanda 2000	0.42	0.21	0.83	**.013**	0.43	0.22	0.85	**.016**	0.53	0.28	0.98	**.042**	0.73	0.36	1.48	.376	160	1,436
Rwanda 2010–11	0.62	0.32	1.22	.164	0.62	0.32	1.21	.155	0.87	0.36	2.11	.754	0.81	0.30	2.20	.678	39	594
Rwanda 2014–15	0.32	0.15	0.66	**.003**	0.33	0.16	0.69	**.004**	0.31	0.14	0.72	**.007**	0.31	0.13	0.71	**.006**	49	796
Rwanda 2019–20	0.35	0.15	0.85	**.020**	0.37	0.15	0.94	**.036**	0.49	0.20	1.17	.107	0.45	0.17	1.18	.104	35	835

Continued...

Appendix Table 3—*Continued*

Survey	Model I				Model II				Model III				Model IV				Unweighted observations (underweight urban)	
	OR	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	Numerator	Denominator
Senegal 2005	0.29	0.16	0.54	**.000**	0.31	0.17	0.56	**.000**	0.33	0.17	0.67	**.002**	0.33	0.15	0.71	**.005**	90	986
Senegal 2010–11	0.87	0.52	1.45	.592	0.91	0.56	1.49	.715	1.04	0.65	1.69	.860	1.34	0.79	2.27	.276	149	1,135
Senegal 2015	0.64	0.39	1.05	.077	0.63	0.39	1.02	.060	0.66	0.40	1.11	.115	0.87	0.47	1.61	.648	218	1,824
Senegal 2019	1.05	0.58	1.91	.859	1.09	0.56	2.10	.796	1.17	0.59	2.31	.644	1.12	0.55	2.29	.750	195	1,719
Tanzania 2004–05	0.62	0.39	0.98	**.042**	0.60	0.37	0.96	**.035**	0.54	0.31	0.95	**.034**	0.59	0.31	1.13	.110	157	1,286
Tanzania 2009–10	0.54	0.35	0.86	**.009**	0.52	0.33	0.81	**.004**	0.73	0.45	1.18	.199	0.95	0.57	1.60	.858	169	1,297
Tanzania 2015–16	0.65	0.44	0.95	**.028**	0.63	0.42	0.94	**.023**	0.88	0.54	1.44	.615	1.06	0.68	1.63	.803	210	2,225
Uganda 2000–01	0.39	0.21	0.70	**.002**	0.38	0.21	0.69	**.002**	0.39	0.21	0.73	**.004**	0.38	0.20	0.72	**.003**	114	1,221
Uganda 2006	0.22	0.08	0.65	**.007**	0.25	0.09	0.71	**.011**	0.37	0.12	1.14	.083	0.32	0.10	1.07	.063	28	259
Uganda 2011	0.49	0.19	1.29	.147	0.49	0.20	1.25	.135	0.37	0.13	1.08	.069	0.30	0.09	0.94	**.038**	34	483
Uganda 2016	0.47	0.25	0.88	**.018**	0.45	0.24	0.83	**.012**	0.72	0.37	1.42	.343	0.63	0.32	1.24	.179	71	853
Zambia 2001–02	0.52	0.39	0.70	**.000**	0.50	0.37	0.68	**.000**	0.54	0.40	0.72	**.000**	0.63	0.44	0.91	**.014**	273	1,483
Zambia 2007	0.60	0.38	0.96	**.034**	0.59	0.37	0.96	**.032**	0.71	0.44	1.14	.157	0.62	0.37	1.05	.073	218	1,760
Zambia 2013–14	0.51	0.41	0.64	**.000**	0.51	0.41	0.63	**.000**	0.58	0.45	0.74	**.000**	0.60	0.47	0.78	**.000**	598	4,486
Zambia 2018-19	0.90	0.63	1.28	.553	0.86	0.61	1.23	.411	0.93	0.64	1.37	.721	0.93	0.64	1.34	.686	299	2,816
Zimbabwe 1999	0.78	0.35	1.73	.541	0.76	0.35	1.67	.495	0.64	0.28	1.46	.286	0.56	0.24	1.32	.182	39	706
Zimbabwe 2005–06	0.34	0.17	0.66	**.002**	0.32	0.16	0.65	**.002**	0.29	0.14	0.60	**.001**	0.28	0.13	0.61	**.002**	98	1,099
Zimbabwe 2010–11	0.42	0.24	0.75	**.004**	0.38	0.21	0.70	**.002**	0.35	0.18	0.67	**.002**	0.38	0.20	0.70	**.002**	103	1,301
Zimbabwe 2015	0.66	0.41	1.08	.101	0.63	0.39	1.02	.059	0.74	0.45	1.21	.228	0.72	0.42	1.21	.213	105	2,005

Blue and bolded cells indicate a significant *p* value.
LB = lower bound
UB = upper bound
ND = not displayed. This this was only for the Benin 2011–12 survey where the anthropometric data had quality issues.

Appendix Table 4 Odds ratios from the regression results of Models I–IV of underweight outcome among rural children under 5 for having electricity

	Model I				Model II				Model III				Model IV				Unweighted observations (underweight rural)	
Survey	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	**Numer-ator**	**Denomi-nator**
Benin 2001	0.34	0.21	0.56	**.000**	0.33	0.20	0.54	**.000**	0.43	0.24	0.77	**.004**	0.47	0.26	0.87	**.016**	596	2,756
Benin 2011–12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1,195	5,282
Benin 2017–18	0.84	0.70	1.01	.071	0.84	0.69	1.01	.070	0.87	0.70	1.07	.190	0.89	0.72	1.11	.305	1,382	7,579
Cameroon 2004	0.34	0.20	0.58	**.000**	0.31	0.18	0.53	**.000**	0.47	0.27	0.80	**.006**	0.52	0.31	0.88	**.015**	360	2,177
Cameroon 2011	0.25	0.16	0.38	**.000**	0.24	0.16	0.38	**.000**	0.40	0.23	0.68	**.001**	0.38	0.22	0.67	**.001**	630	3,351
Cameroon 2018–19	0.36	0.22	0.59	**.000**	0.36	0.22	0.59	**.000**	0.52	0.33	0.82	**.005**	0.49	0.29	0.84	**.009**	362	2,725
Ethiopia 2005	1.01	0.53	1.95	.966	0.99	0.49	2.00	.970	1.04	0.43	2.52	.925	1.04	0.42	2.57	.941	1,220	3,520
Ethiopia 2011	0.64	0.41	1.00	.052	0.61	0.38	0.96	**.032**	0.61	0.38	0.99	**.044**	0.64	0.39	1.03	.064	2,801	8,609
Ethiopia 2016	0.60	0.41	0.86	**.006**	0.59	0.41	0.85	**.005**	0.69	0.48	0.99	**.042**	0.68	0.48	0.97	**.032**	2,190	7,908
Ethiopia 2019	0.55	0.31	0.97	**.038**	0.55	0.31	0.97	**.039**	0.67	0.39	1.14	.138	0.66	0.39	1.12	.125	1,084	4,206
Guinea 2005	1.04	0.46	2.36	.924	1.02	0.45	2.29	.967	1.08	0.47	2.50	.854	1.06	0.42	2.69	.904	500	2,091
Guinea 2012	0.35	0.16	0.73	**.005**	0.34	0.16	0.74	**.006**	0.29	0.11	0.75	**.012**	0.33	0.13	0.86	**.023**	513	2,455
Guinea 2018	0.91	0.70	1.17	.447	0.89	0.69	1.16	.395	0.87	0.66	1.15	.334	0.86	0.65	1.13	.286	525	2,840
Kenya 2003	0.32	0.13	0.79	**.014**	0.33	0.14	0.80	**.014**	0.53	0.20	1.38	.190	0.63	0.24	1.65	.344	670	3,807
Kenya 2008–09	0.42	0.21	0.85	**.017**	0.42	0.21	0.84	**.014**	0.53	0.25	1.13	.099	0.73	0.30	1.78	.481	771	4,263
Kenya 2014	0.34	0.23	0.50	**.000**	0.34	0.23	0.50	**.000**	0.39	0.25	0.59	**.000**	0.47	0.31	0.73	**.001**	2,128	14,058
Liberia 2006-07	0.47	0.14	1.59	.226	0.47	0.14	1.59	.225	0.63	0.17	2.37	.491	0.74	0.21	2.67	.649	699	3,423
Liberia 2013	0.97	0.26	3.53	.959	1.07	0.29	3.91	.921	0.43	0.10	1.77	.240	0.45	0.11	1.91	.279	434	2,599
Liberia 2019–20	0.96	0.41	2.28	.932	0.91	0.38	2.18	.828	1.30	0.50	3.39	.589	1.20	0.44	3.30	.725	269	2,019
Malawi 2000																	1,686	8,086
Malawi 2004–05	0.73	0.46	1.14	.167	0.74	0.47	1.16	.188	0.92	0.57	1.50	.745	1.01	0.61	1.68	.969	1,386	7,937
Malawi 2010	0.47	0.24	0.89	**.021**	0.47	0.24	0.92	**.027**	0.57	0.30	1.09	.090	0.58	0.30	1.13	.108	584	4,411
Malawi 2015–16	0.66	0.38	1.14	.138	0.65	0.38	1.13	.127	0.50	0.26	0.95	**.035**	0.50	0.26	0.97	**.039**	616	4,861
Mali 2001	0.74	0.54	1.02	.067	0.75	0.53	1.07	.116	0.78	0.55	1.12	.182	0.80	0.56	1.16	.240	2,586	7,911
Mali 2006	0.81	0.56	1.19	.287	0.79	0.55	1.15	.225	0.82	0.56	1.20	.298	0.83	0.58	1.20	.329	2,443	8,204
Mali 2012–13	0.76	0.54	1.08	.122	0.76	0.53	1.08	.128	0.84	0.59	1.20	.326	0.92	0.64	1.31	.646	1,016	3,627
Mali 2018	0.81	0.70	0.94	**.005**	0.81	0.70	0.94	**.005**	0.85	0.73	0.98	**.029**	0.87	0.74	1.01	.071	1,440	6,872
Nigeria 2003	0.71	0.52	0.98	**.039**	0.72	0.52	0.99	**.043**	0.86	0.65	1.15	.306	0.92	0.69	1.21	.532	762	2,860
Nigeria 2008	0.60	0.51	0.71	**.000**	0.59	0.50	0.71	**.000**	0.82	0.70	0.96	**.011**	0.81	0.69	0.95	**.009**	3,946	14,712
Nigeria 2013	0.67	0.57	0.80	**.000**	0.66	0.56	0.79	**.000**	0.87	0.75	1.02	.093	0.84	0.72	0.98	**.031**	5,174	17,044
Nigeria 2018	0.58	0.49	0.68	**.000**	0.58	0.49	0.68	**.000**	0.81	0.68	0.96	**.013**	0.82	0.68	0.99	**.037**	1,956	7,514
Rwanda 2000	0.63	0.26	1.54	.308	0.65	0.28	1.55	.332	0.77	0.32	1.83	.549	0.83	0.35	2.01	.683	1,086	5,076
Rwanda 2010–11	0.38	0.17	0.85	**.018**	0.37	0.17	0.82	**.015**	0.47	0.21	1.07	.073	0.50	0.22	1.15	.102	457	3,756
Rwanda 2014–15	0.51	0.30	0.86	**.012**	0.51	0.30	0.87	**.014**	0.47	0.25	0.86	**.015**	0.49	0.27	0.91	**.024**	296	2,985
Rwanda 2019–20	0.72	0.53	0.99	**.042**	0.72	0.53	0.99	**.042**	0.86	0.62	1.19	.360	0.87	0.62	1.21	.399	275	3,173

Continued...

Appendix Table 4—*Continued*

	Model I				Model II				Model III				Model IV				Unweighted observations (underweight rural)	
Survey	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	**Numer-ator**	**Denomi-nator**
Senegal 2005	0.44	0.27	0.72	**.001**	0.43	0.27	0.69	**.001**	0.51	0.32	0.82	**.006**	0.45	0.30	0.68	**.000**	384	2,103
Senegal 2010–11	0.77	0.58	1.01	.061	0.76	0.58	1.02	.064	0.85	0.64	1.14	.287	0.93	0.69	1.25	.607	596	2,718
Senegal 2015	0.80	0.64	1.01	.059	0.80	0.63	1.01	.056	0.85	0.67	1.07	.167	0.94	0.74	1.19	.612	892	4,824
Senegal 2019	0.53	0.42	0.68	**.000**	0.52	0.41	0.67	**.000**	0.52	0.40	0.67	**.000**	0.58	0.44	0.76	**.000**	775	4,333
Tanzania 2004–05	0.24	0.11	0.52	**.000**	0.24	0.11	0.53	**.000**	0.33	0.15	0.69	**.004**	0.39	0.18	0.82	**.013**	1,143	6,366
Tanzania 2009–10	0.80	0.46	1.38	.417	0.77	0.45	1.32	.336	0.87	0.48	1.56	.631	0.93	0.51	1.68	.804	1,090	6,036
Tanzania 2015–16	0.35	0.22	0.55	**.000**	0.36	0.22	0.57	**.000**	0.45	0.27	0.75	**.002**	0.47	0.28	0.79	**.004**	1,186	7,693
Uganda 2000–01	0.42	0.19	0.92	**.031**	0.39	0.18	0.87	**.021**	0.48	0.23	0.99	**.047**	0.52	0.25	1.08	.080	827	4,305
Uganda 2006	0.31	0.12	0.83	**.020**	0.34	0.13	0.91	**.032**	0.50	0.18	1.39	.184	0.59	0.21	1.64	.309	412	2,321
Uganda 2011	0.58	0.22	1.57	.287	0.58	0.21	1.57	.279	0.49	0.15	1.63	.245	0.56	0.17	1.82	.336	296	1,852
Uganda 2016	0.60	0.42	0.84	**.003**	0.60	0.43	0.85	**.004**	0.69	0.47	1.00	.052	0.72	0.49	1.06	.098	492	4,272
Zambia 2001–02	0.48	0.30	0.78	**.003**	0.45	0.29	0.71	**.001**	0.54	0.35	0.84	**.006**	0.54	0.31	0.94	**.028**	1,044	4,350
Zambia 2007	0.47	0.20	1.08	.074	0.47	0.20	1.13	.090	0.51	0.20	1.33	.167	0.53	0.20	1.39	.192	579	3,787
Zambia 2013–14	0.50	0.31	0.79	**.003**	0.49	0.31	0.78	**.002**	0.57	0.37	0.89	**.013**	0.64	0.41	1.00	.051	1,243	7,761
Zambia 2018–19	0.31	0.18	0.53	**.000**	0.30	0.17	0.53	**.000**	0.36	0.20	0.63	**.000**	0.40	0.23	0.70	**.001**	848	6,769
Zimbabwe 1999	0.54	0.31	0.96	**.035**	0.55	0.31	0.96	**.037**	0.60	0.33	1.09	.091	0.72	0.39	1.31	.278	302	2,376
Zimbabwe 2005–06	0.75	0.50	1.11	.146	0.74	0.50	1.10	.139	0.82	0.53	1.25	.348	0.96	0.62	1.50	.861	541	3,768
Zimbabwe 2010–11	1.00	0.70	1.44	.992	1.08	0.74	1.56	.700	1.19	0.80	1.77	.391	1.34	0.89	2.01	.156	429	3,909
Zimbabwe 2015	0.99	0.56	1.76	.980	0.97	0.54	1.73	.910	0.77	0.40	1.51	.452	0.78	0.39	1.59	.499	378	4,013

Blue and bolded cells indicate a significant *p* value.
LB = lower bound
UB = upper bound
ND = not displayed. This this was only for the Benin 2011–12 survey where the anthropometric data had quality issues.
Note: Empty cells indicate that there was missing information or too few cases to fit the model.

Appendix Table 5 **Odds ratios from the regression results of Models I–IV of underweight outcome among urban children under 5 for owning a refrigerator among those with electricity**

	Model I				Model II				Model III				Model IV				Unweighted observations (underweight urban with electricity)	
Survey	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	**Numer-ator**	**Denomi-nator**
Benin 2001	0.58	0.29	1.16	.124	0.57	0.28	1.14	.110	0.66	0.31	1.42	.287	0.70	0.31	1.57	.377	60	601
Benin 2011–12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	310	1,804
Benin 2017–18	0.52	0.33	0.82	**.005**	0.51	0.32	0.80	**.004**	0.61	0.37	0.98	**.042**	0.58	0.35	0.94	**.027**	306	2,601
Cameroon 2004	0.36	0.16	0.80	**.012**	0.37	0.17	0.83	**.016**	0.55	0.23	1.29	.167	0.56	0.23	1.38	.208	60	1,018
Cameroon 2011	0.41	0.23	0.74	**.003**	0.44	0.24	0.78	**.006**	0.53	0.25	1.15	.109	0.55	0.28	1.11	.095	122	1,990
Cameroon 2018–19	0.69	0.38	1.24	.211	0.67	0.37	1.20	.173	0.70	0.38	1.29	.255	0.76	0.41	1.41	.379	87	1,905
Ethiopia 2005	0.10	0.02	0.47	**.004**	0.09	0.02	0.43	**.003**	0.17	0.03	0.96	**.045**	0.16	0.03	0.96	**.045**	74	491
Ethiopia 2011	0.38	0.17	0.84	**.017**	0.40	0.18	0.90	**.027**	0.67	0.32	1.42	.295	0.76	0.32	1.79	.523	159	1,316
Ethiopia 2016	0.32	0.15	0.69	**.004**	0.31	0.15	0.67	**.003**	0.34	0.13	0.90	**.030**	0.39	0.15	1.03	.058	158	1,482
Ethiopia 2019	0.33	0.16	0.69	**.004**	0.34	0.17	0.70	**.004**	0.48	0.20	1.14	.096	0.40	0.17	0.92	**.032**	135	1,017
Guinea 2005	0.79	0.41	1.52	.474	0.87	0.44	1.73	.682	0.98	0.46	2.06	.950	1.02	0.48	2.18	.962	49	333
Guinea 2012	0.36	0.17	0.77	**.009**	0.36	0.17	0.77	**.009**	0.38	0.16	0.94	**.037**	0.38	0.15	0.93	**.035**	59	664
Guinea 2018	0.57	0.35	0.92	**.022**	0.60	0.37	0.98	**.042**	0.61	0.36	1.05	.075	0.62	0.35	1.09	.094	116	978
Kenya 2003	0.17	0.05	0.58	**.005**	0.17	0.05	0.59	**.006**	0.17	0.05	0.61	**.007**	0.19	0.05	0.68	**.011**	35	529
Kenya 2008–09	0.67	0.36	1.25	.206	0.64	0.31	1.30	.213	0.58	0.27	1.25	.163	0.51	0.25	1.05	.067	58	640
Kenya 2014	0.82	0.36	1.86	.633	0.81	0.35	1.85	.617	1.03	0.45	2.34	.951	0.97	0.43	2.19	.947	162	3,023
Liberia 2006–07	0.89	0.10	8.04	.915	0.74	0.06	8.80	.803									11	71
Liberia 2013	0.16	0.01	1.62	.116	0.34	0.03	3.54	.356	0.87	0.08	9.33	.903	4.28	0.27	67.23	.288	12	100
Liberia 2019–20	1.07	0.30	3.90	.912	1.21	0.29	4.99	.788	1.83	0.41	8.13	.420	2.95	0.53	16.26	.209	21	228
Malawi 2000	0.03	0.01	0.06	**.000**													19	404
Malawi 2004–05	0.87	0.25	3.06	.818	0.79	0.25	2.54	.687	0.48	0.11	2.11	.322	0.60	0.11	3.31	.549	19	255
Malawi 2010	0.35	0.08	1.56	.166	0.33	0.06	1.84	.202	0.34	0.06	1.88	.207	0.60	0.14	2.54	.475	9	164
Malawi 2015–16	2.21	0.43	11.33	.336	2.30	0.39	13.55	.354	3.54	1.02	12.25	**.046**	3.69	1.08	12.62	**.038**	24	397
Mali 2001	0.57	0.38	0.86	**.008**	0.54	0.35	0.82	**.004**	0.59	0.38	0.92	**.019**	0.60	0.37	0.95	**.031**	85	837
Mali 2006	0.79	0.56	1.09	.152	0.78	0.56	1.08	.134	0.83	0.59	1.18	.292	0.83	0.59	1.18	.294	260	1,471
Mali 2012–13	0.69	0.42	1.13	.135	0.72	0.44	1.19	.201	0.80	0.47	1.35	.399	0.77	0.45	1.32	.333	145	922
Mali 2018	0.69	0.49	0.98	**.039**	0.69	0.48	1.00	**.048**	0.76	0.53	1.10	.144	0.80	0.56	1.15	.233	222	1,755
Nigeria 2003	0.63	0.44	0.92	**.016**	0.62	0.43	0.90	**.013**	0.82	0.57	1.19	.298	1.03	0.69	1.52	.900	246	1,341
Nigeria 2008	0.69	0.56	0.86	**.001**	0.69	0.56	0.86	**.001**	0.86	0.70	1.06	.154	0.87	0.70	1.08	.198	767	4,750
Nigeria 2013	0.65	0.54	0.79	**.000**	0.65	0.54	0.79	**.000**	0.80	0.66	0.96	**.017**	0.76	0.63	0.91	**.004**	1,457	7,429
Nigeria 2018	0.42	0.32	0.56	**.000**	0.42	0.31	0.56	**.000**	0.53	0.39	0.72	**.000**	0.54	0.40	0.73	**.000**	520	3,770
Rwanda 2000	0.76	0.18	3.16	.704	0.88	0.18	4.20	.867	0.92	0.21	4.04	.906	1.08	0.31	3.74	.907	33	543
Rwanda 2010–11	1.08	0.20	5.72	.929	0.98	0.16	5.90	.982	0.44	0.04	4.99	.498	0.00	0.00	0.00	**.000**	14	269
Rwanda 2014–15	0.69	0.08	5.83	.733	0.85	0.11	6.81	.875									19	547
Rwanda 2019–20																	21	648

Continued...

Appendix Table 5—*Continued*

Survey	Model I				Model II				Model III				Model IV				Unweighted observations (underweight urban with electricity)	
	OR	*LB*	*UB*	*p* value	OR	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	Numer-ator	Denomi-nator
Senegal 2005	0.77	0.33	1.84	.558	0.73	0.31	1.73	.474	0.81	0.32	2.07	.655	0.90	0.39	2.08	.800	49	694
Senegal 2010–11	1.11	0.62	1.98	.729	1.14	0.62	2.12	.673	1.24	0.67	2.30	.485	1.25	0.66	2.38	.495	121	950
Senegal 2015	0.70	0.47	1.04	.076	0.69	0.48	1.00	**.049**	0.79	0.53	1.17	.226	0.80	0.55	1.17	.248	147	1,428
Senegal 2019	0.97	0.64	1.49	.894	0.96	0.63	1.46	.841	1.14	0.79	1.66	.472	1.15	0.76	1.75	.504	180	1,573
Tanzania 2004–05	1.29	0.55	3.05	.551	1.20	0.52	2.78	.669	0.84	0.37	1.93	.678	0.76	0.34	1.70	.490	32	412
Tanzania 2009–10	0.42	0.23	0.79	**.008**	0.39	0.20	0.77	**.007**	0.53	0.25	1.12	.095	0.48	0.22	1.04	.062	59	555
Tanzania 2015–16	0.65	0.38	1.12	.119	0.64	0.38	1.10	.106	0.76	0.42	1.38	.357	0.70	0.38	1.28	.244	94	1,136
Uganda 2000–01	0.82	0.31	2.16	.678	0.80	0.31	2.11	.653	0.94	0.31	2.85	.918	0.79	0.33	1.90	.593	27	432
Uganda 2006	1.39	0.20	9.89	.732	1.11	0.14	8.64	.916	1.14	0.14	9.54	.899	1.82	0.22	14.76	.560	6	107
Uganda 2011	0.20	0.04	1.13	.068	0.13	0.02	0.97	**.046**	0.21	0.03	1.71	.144	0.29	0.03	2.98	.290	13	250
Uganda 2016	0.75	0.26	2.12	.579	0.76	0.27	2.13	.596	1.03	0.36	2.94	.956	0.81	0.26	2.52	.711	27	456
Zambia 2001–02	0.78	0.45	1.35	.366	0.79	0.44	1.43	.435	0.73	0.40	1.31	.287	0.80	0.44	1.45	.457	80	598
Zambia 2007	0.38	0.22	0.67	**.001**	0.38	0.21	0.69	**.002**	0.46	0.25	0.84	**.012**	0.37	0.20	0.69	**.002**	62	670
Zambia 2013–14	0.98	0.66	1.45	.915	0.97	0.65	1.45	.894	1.02	0.66	1.59	.922	1.00	0.64	1.56	.989	184	1,959
Zambia 2018-19	0.71	0.48	1.06	.096	0.72	0.48	1.08	.114	0.78	0.50	1.20	.256	0.75	0.48	1.17	.207	151	1,654
Zimbabwe 1999	1.04	0.46	2.31	.930	1.00	0.46	2.17	.997	1.04	0.47	2.27	.930	0.97	0.44	2.12	.931	33	630
Zimbabwe 2005–06	0.78	0.48	1.26	.303	0.76	0.47	1.24	.270	0.70	0.41	1.20	.190	0.70	0.40	1.25	.225	79	989
Zimbabwe 2010–11	1.20	0.71	2.04	.497	1.25	0.74	2.10	.406	1.44	0.83	2.52	.195	1.37	0.77	2.42	.278	79	1,114
Zimbabwe 2015	0.84	0.40	1.75	.634	0.86	0.39	1.85	.690	1.13	0.53	2.40	.742	1.28	0.60	2.72	.519	78	1,627

Blue and bolded cells indicate a significant *p* value.
ND = not displayed. This this was only for the Benin 2011–12 survey where the anthropometric data had quality issues.
Note: Empty cells indicate that there was missing information or too few cases to fit the model.

Appendix Table 6 **Odds ratios from the regression results of Models I–IV of underweight outcome among rural children under 5 for owning a refrigerator among those with electricity**

	Model I				Model II				Model III				Model IV				Unweighted observations (underweight rural with electricity)	
Survey	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	**Numer-ator**	**Denomi-nator**
Benin 2001	0.38	0.04	3.67	.388	0.31	0.03	2.80	.283	0.36	0.04	3.42	.361	0.29	0.01	6.71	.428	13	145
Benin 2011–12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	143	816
Benin 2017–18	0.86	0.37	1.98	.722	0.87	0.38	2.00	.744	0.89	0.38	2.09	.781	0.91	0.37	2.25	.835	248	1,548
Cameroon 2004																	27	381
Cameroon 2011	0.38	0.08	1.89	.236	0.35	0.07	1.75	.200	0.26	0.03	2.12	.204	0.34	0.04	2.97	.324	50	671
Cameroon 2018–19	0.33	0.10	1.09	.069	0.34	0.11	1.11	.074	0.43	0.12	1.55	.193	0.42	0.12	1.48	.173	51	766
Ethiopia 2005																	30	101
Ethiopia 2011	0.03	0.00	0.23	**.001**	0.03	0.00	0.23	**.001**	0.03	0.00	0.24	**.001**	0.00	0.00	0.35	**.016**	107	499
Ethiopia 2016	1.81	0.23	14.28	.570	1.40	0.22	9.03	.721	1.24	0.20	7.72	.813	1.14	0.17	7.45	.893	128	658
Ethiopia 2019	0.77	0.14	4.21	.756	0.76	0.14	3.99	.741	0.96	0.17	5.39	.966	0.69	0.14	3.26	.630	101	570
Guinea 2005	0.40	0.03	4.73	.448	0.28	0.03	2.37	.226	0.40	0.02	8.64	.538	0.37	0.00	58.54	.680	16	62
Guinea 2012	0.81	0.09	7.43	.841	0.45	0.02	10.81	.599	0.51	0.02	14.44	.670	0.27	0.01	6.13	.378	9	80
Guinea 2018	0.71	0.24	2.14	.544	0.70	0.24	2.01	.501	0.82	0.23	2.91	.752	0.86	0.25	2.95	.811	113	649
Kenya 2003																	7	111
Kenya 2008–09	0.10	0.02	0.48	**.005**	0.10	0.02	0.47	**.005**	0.06	0.01	0.66	**.022**	0.03	0.00	0.99	**.049**	20	207
Kenya 2014	0.18	0.02	1.38	.098	0.19	0.02	1.44	.108									43	824
Liberia 2006–07																	3	29
Liberia 2013																	6	33
Liberia 2019–20	0.28	0.04	1.86	.180	0.36	0.03	4.95	.424	0.78	0.03	22.96	.878	0.37	0.01	23.20	.616	11	82
Malawi 2000																	–	91
Malawi 2004–05	1.00	0.26	3.91	.999	1.01	0.26	3.98	.986	1.73	0.44	6.79	.427	2.46	0.28	21.93	.414	29	195
Malawi 2010																	13	143
Malawi 2015–16	0.98	0.31	3.12	.979	1.04	0.32	3.41	.945	2.55	0.61	10.64	.194	9.19	1.37	61.56	**.023**	19	222
Mali 2001	0.18	0.05	0.61	**.007**	0.13	0.03	0.54	**.005**	0.15	0.04	0.60	**.008**	0.14	0.03	0.61	**.010**	60	214
Mali 2006																	90	328
Mali 2012–13	0.28	0.07	1.20	.086	0.29	0.06	1.41	.125	0.30	0.07	1.31	.109	0.30	0.07	1.31	.108	90	378
Mali 2018	0.48	0.30	0.75	**.001**	0.48	0.30	0.75	**.001**	0.60	0.38	0.95	**.031**	0.62	0.38	1.01	.053	490	2,665
Nigeria 2003	0.82	0.50	1.34	.421	0.81	0.48	1.37	.423	1.00	0.46	2.17	.991	1.26	0.66	2.41	.473	213	903
Nigeria 2008	0.51	0.35	0.73	**.000**	0.50	0.35	0.72	**.000**	0.76	0.53	1.11	.151	0.80	0.55	1.16	.235	747	3,713
Nigeria 2013	0.43	0.32	0.58	**.000**	0.43	0.32	0.58	**.000**	0.58	0.44	0.77	**.000**	0.57	0.43	0.76	**.000**	1,292	5,209
Nigeria 2018	0.46	0.34	0.63	**.000**	0.46	0.33	0.63	**.000**	0.67	0.48	0.94	**.019**	0.69	0.49	0.98	**.036**	562	2,765
Rwanda 2000																	7	49
Rwanda 2010–11																	6	123
Rwanda 2014–15																	20	340
Rwanda 2019–20	2.53	0.48	13.31	.271	2.04	0.56	7.42	0.277	4.61	1.05	20.15	**.042**	5.24	1.25	21.98	**.024**	80	1,174

Continued...

Appendix Table 6—*Continued*

Survey	Model I				Model II				Model III				Model IV				Unweighted observations (underweight rural with electricity)	
	OR	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	Numerator	Denominator
Senegal 2005	1.49	0.63	3.50	.359	1.32	0.55	3.19	.529	1.40	0.62	3.19	.411	1.82	0.79	4.20	.153	45	393
Senegal 2010–11	0.72	0.34	1.52	.387	0.78	0.36	1.69	.522	0.83	0.37	1.86	.646	0.80	0.37	1.77	.585	113	640
Senegal 2015	0.57	0.39	0.83	**.004**	0.57	0.39	0.84	**.005**	0.56	0.36	0.86	**.009**	0.58	0.37	0.89	**.013**	234	1,403
Senegal 2019	0.89	0.55	1.44	.631	0.90	0.56	1.45	.667	1.03	0.64	1.66	.906	1.06	0.66	1.72	.807	262	1,945
Tanzania 2004–05	3.44	0.31	38.48	.246	7.60	0.51	113.27	.112	9.92	1.54	64.11	**.025**	23.21	0.44	1210.99	.096	16	152
Tanzania 2009–10	0.24	0.06	0.88	**.032**	0.26	0.06	1.04	.056	0.18	0.03	1.00	.050	0.31	0.05	1.91	.202	35	242
Tanzania 2015–16	1.12	0.46	2.74	.804	1.34	0.60	3.00	.477	1.03	0.41	2.61	.948	0.80	0.31	2.05	.638	59	492
Uganda 2000–01																	8	79
Uganda 2006																	4	49
Uganda 2011																	4	49
Uganda 2016																	61	763
Zambia 2001–02	0.89	0.35	2.27	.781	1.04	0.34	3.20	.945	0.91	0.33	2.50	.825	0.65	0.14	3.00	.505	15	106
Zambia 2007																	8	108
Zambia 2013–14	0.89	0.38	2.10	.792	1.12	0.43	2.88	.817	1.17	0.39	3.52	.781	1.08	0.27	4.25	.913	24	273
Zambia 2018–19	4.92	1.92	12.56	**.001**	4.54	1.84	11.21	**.001**	3.69	1.11	12.24	**.033**	2.88	0.91	9.12	.072	29	494
Zimbabwe 1999	0.56	0.05	5.95	.626	0.49	0.04	5.55	.558	0.75	0.05	10.84	.831	1.01	0.03	34.01	.998	14	152
Zimbabwe 2005–06	0.16	0.04	0.75	**.021**	0.16	0.03	0.84	**.030**	0.29	0.05	1.83	.184	0.13	0.01	1.26	.078	24	229
Zimbabwe 2010–11	0.37	0.11	1.25	.108	0.31	0.09	1.14	.077	0.44	0.10	1.96	.276	0.60	0.14	2.69	.501	37	348
Zimbabwe 2015	0.73	0.23	2.32	.587	0.80	0.27	2.41	.690	0.52	0.20	1.38	.183	0.58	0.17	1.94	.369	21	268

Blue and bolded cells indicate a significant *p* value.
LB = lower bound
UB = upper bound
ND = not displayed. This this was only for the Benin 2011–12 survey where the anthropometric data had quality issues.
Note: Empty cells indicate that there was missing information or too few cases to fit the model.

Appendix Table 7 Odds ratios from the regression results of Models I–IV of zero-dose immunization outcome among urban children 12–23 months for having electricity

	Model I				Model II				Model III				Model IV				Unweighted observations (zero-dose urban)	
Survey	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	**Numer-ator**	**Denomi-nator**
Benin 2001	0.24	0.05	1.06	.060	0.23	0.05	1.05	.058	0.30	0.06	1.44	.132	0.47	0.10	2.16	.331	27	296
Benin 2011–12	0.28	0.18	0.44	**.000**	0.28	0.18	0.44	**.000**	0.40	0.24	0.67	**.000**	0.55	0.32	0.93	**.025**	117	937
Benin 2017–18	0.47	0.28	0.79	**.005**	0.47	0.28	0.80	**.005**	0.65	0.37	1.13	.123	0.73	0.40	1.32	.291	117	968
Cameroon 2004	0.39	0.18	0.83	**.015**	0.38	0.18	0.83	**.015**	0.62	0.23	1.66	.343	0.70	0.26	1.88	.481	53	564
Cameroon 2011	0.38	0.16	0.90	**.028**	0.38	0.16	0.90	**.028**	0.71	0.26	1.93	.505	0.77	0.27	2.14	.611	55	837
Cameroon 2018–19	0.53	0.23	1.22	.134	0.52	0.23	1.22	.132	1.17	0.53	2.57	.698	0.92	0.35	2.42	.867	67	718
Ethiopia 2005	0.13	0.03	0.61	**.011**	0.11	0.02	0.55	**.007**	0.21	0.03	1.28	.090	0.22	0.06	0.85	**.029**	35	241
Ethiopia 2011	0.15	0.03	0.74	**.020**	0.15	0.04	0.56	**.005**	0.27	0.06	1.32	.105	0.25	0.05	1.20	.082	43	326
Ethiopia 2016	2.06	0.31	13.75	.454	2.24	0.32	15.91	.416	4.01	0.49	32.74	.193	6.81	0.59	78.72	.123	27	386
Ethiopia 2019	0.09	0.03	0.25	**.000**	0.09	0.02	0.33	**.000**	0.15	0.05	0.45	**.001**	0.11	0.01	1.28	.077	29	263
Guinea 2005	1.23	0.42	3.61	.700	1.28	0.41	4.02	.672	2.71	0.67	10.96	.159	5.86	1.33	25.90	**.020**	18	212
Guinea 2012	0.52	0.24	1.10	.087	0.51	0.24	1.08	.078	0.56	0.25	1.23	.144	0.60	0.28	1.29	.189	49	357
Guinea 2018	0.90	0.43	1.89	.779	0.90	0.42	1.92	.786	1.06	0.47	2.35	.892	0.99	0.47	2.11	.989	86	390
Kenya 2003	0.16	0.03	0.80	**.026**	0.18	0.04	0.85	**.031**	0.20	0.03	1.59	.127	0.10	0.01	1.72	.111	19	243
Kenya 2008–09	2.92	0.55	15.52	.205	2.70	0.57	12.83	.210	3.42	0.81	14.43	.093	3.98	0.66	23.98	.130	12	270
Kenya 2014	0.91	0.24	3.51	.890	0.96	0.25	3.70	.955	1.89	0.23	15.36	.550	8.39	1.19	59.16	**.033**	25	1,186
Liberia 2006–07																	40	339
Liberia 2013																	26	438
Liberia 2019–20	0.05	0.01	0.32	**.002**	0.05	0.01	0.33	**.002**	0.05	0.01	0.34	**.003**	0.04	0.00	0.32	**.003**	19	317
Malawi 2000	2.19	0.19	25.18	.526	2.38	0.26	21.62	.438	2.94	0.79	11.02	.108					4	399
Malawi 2004–05																	2	223
Malawi 2010	0.05	0.01	0.49	**.011**	0.05	0.01	0.52	**.012**	0.06	0.01	0.61	**.018**	0.09	0.01	0.73	**.026**	6	362
Malawi 2015–16	0.55	0.07	4.26	.568	0.53	0.06	4.35	.550	0.67	0.17	2.63	.562	0.60	0.18	2.01	.410	13	496
Mali 2001	1.14	0.57	2.28	.713	1.13	0.58	2.21	.725	1.50	0.76	2.96	.240	1.41	0.73	2.74	.307	202	1,420
Mali 2006	0.90	0.56	1.47	.681	0.91	0.56	1.48	.690	1.10	0.67	1.83	.698	1.24	0.62	2.47	.542	68	770
Mali 2012–13	0.90	0.38	2.15	.807	0.88	0.37	2.08	.764	0.91	0.34	2.45	.847	0.94	0.33	2.68	.912	38	459
Mali 2018	0.72	0.23	2.21	.562	0.76	0.25	2.26	.615	1.30	0.47	3.59	.609	1.35	0.50	3.66	.550	91	485
Nigeria 2003	0.19	0.09	0.38	**.000**	0.19	0.09	0.37	**.000**	0.48	0.22	1.07	.072	0.54	0.22	1.34	.179	153	386
Nigeria 2008	0.39	0.24	0.63	**.000**	0.39	0.25	0.63	**.000**	0.99	0.60	1.65	.971	1.13	0.66	1.93	.659	415	1,331
Nigeria 2013	0.68	0.45	1.04	.075	0.69	0.46	1.05	.080	1.14	0.77	1.70	.509	1.24	0.79	1.96	.348	456	1,904
Nigeria 2018	0.42	0.30	0.60	**.000**	0.42	0.30	0.60	**.000**	0.77	0.57	1.05	.095	0.86	0.61	1.20	.376	370	1,993
Rwanda 2000	0.14	0.03	0.66	**.014**	0.14	0.03	0.65	**.013**	0.11	0.02	0.72	**.022**	0.08	0.01	0.66	**.020**	20	309
Rwanda 2010–11																	1	200
Rwanda 2014–15	0.56	0.07	4.51	.583	0.66	0.08	5.83	.707	0.39	0.05	2.77	.337	0.47	0.06	3.42	.445	4	340
Rwanda 2019–20																	1	297

Continued...

Appendix Table 7—*Continued*

	Model I				Model II				Model III				Model IV				Unweighted observations (zero-dose urban)	
Survey	***OR***	**LB**	**UB**	***p* value**	***OR***	**LB**	**UB**	***p* value**	***OR***	**LB**	**UB**	***p* value**	***OR***	**LB**	**UB**	***p* value**	**Numer-ator**	**Denomi-nator**
Senegal 2005	0.33	0.09	1.16	.084	0.36	0.11	1.23	.103	0.46	0.11	1.85	.270	0.47	0.12	1.78	.261	35	705
Senegal 2010–11	0.36	0.12	1.07	.066	0.37	0.12	1.09	.070	0.29	0.08	1.05	.060	0.34	0.08	1.52	.155	28	680
Senegal 2015	0.05	0.01	0.43	**.007**	0.05	0.01	0.40	**.006**	0.03	0.00	0.23	**.001**	0.01	0.00	0.18	**.002**	9	329
Senegal 2019																	7	344
Tanzania 2004–05	1.09	0.09	12.92	.942	1.05	0.11	9.82	.967	0.47	0.13	1.78	.260	0.20	0.04	1.03	.055	7	249
Tanzania 2009–10	0.49	0.03	6.91	.592	0.60	0.05	6.88	.676	1.37	0.07	27.89	.836	1.77	0.12	25.62	.672	6	263
Tanzania 2015–16	2.33	0.30	17.92	.414	2.51	0.36	17.45	.348	2.23	0.75	6.67	.149	16.74	1.39	201.91	**.027**	4	510
Uganda 2000–01	0.10	0.04	0.29	**.000**	0.10	0.03	0.29	**.000**	0.12	0.04	0.40	**.001**	0.14	0.04	0.44	**.001**	35	304
Uganda 2006	0.65	0.12	3.58	.610	0.56	0.09	3.36	.520	0.69	0.10	4.97	.708	0.51	0.10	2.69	.419	10	139
Uganda 2011	0.96	0.26	3.62	.956	0.97	0.25	3.80	.963	1.01	0.26	3.88	.984	0.82	0.17	3.96	.805	15	289
Uganda 2016	0.97	0.35	2.72	.959	0.99	0.38	2.59	.992	1.47	0.67	3.22	.339	1.23	0.49	3.07	.653	25	517
Zambia 2001–02	7.02	1.73	28.44	**.007**	7.16	1.69	30.36	**.008**	11.84	1.79	78.12	**.011**	6.97	1.04	46.50	**.045**	11	290
Zambia 2007	0.81	0.21	3.08	.750	0.79	0.20	3.17	.739	0.38	0.09	1.62	.188	0.89	0.16	5.04	.896	15	365
Zambia 2013–14	0.76	0.29	2.01	.583	0.77	0.29	2.04	.595	1.12	0.34	3.70	.850	0.99	0.37	2.65	.985	19	884
Zambia 2018–19	0.38	0.06	2.34	.295	0.44	0.08	2.57	.362	0.60	0.17	2.17	.433	0.50	0.16	1.52	.221	7	557
Zimbabwe 1999	1.07	0.11	9.92	.953	1.08	0.11	10.48	.945	0.43	0.04	5.04	.492	0.48	0.04	5.21	.538	8	155
Zimbabwe 2005–06	1.85	0.66	5.16	.238	2.04	0.73	5.70	.170	2.73	1.09	6.82	**.032**	2.48	0.93	6.63	.070	46	254
Zimbabwe 2010–11	0.24	0.08	0.75	**.014**	0.22	0.07	0.71	**.012**	0.26	0.06	1.03	.054	0.23	0.06	0.84	**.027**	24	264
Zimbabwe 2015	2.72	0.50	14.74	.243	2.79	0.51	15.29	.236	3.75	0.45	31.08	.218	3.92	0.41	37.20	.232	20	361

Blue and bolded cells indicate a significant *p* value.
LB = lower bound
UB = upper bound
Note: Empty cells indicate that there was missing information or too few cases to fit the model.

Appendix Table 8 **Odds ratios from the regression results of Models I–IV of zero-dose immunization outcome among rural children 12–23 months for having electricity**

	Model I				Model II				Model III				Model IV				Unweighted observations (zero-dose rural)	
Survey	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	**Numer-ator**	**Denomi-nator**
Benin 2001	0.49	0.14	1.68	.253	0.49	0.14	1.70	.258	0.75	0.22	2.55	.643	1.44	0.39	5.30	.584	91	618
Benin 2011–12	0.35	0.18	0.71	**.004**	0.36	0.18	0.71	**.004**	0.45	0.22	0.91	**.027**	0.49	0.24	0.98	**.045**	253	1,535
Benin 2017–18	0.36	0.23	0.58	**.000**	0.36	0.23	0.58	**.000**	0.50	0.31	0.80	**.005**	0.60	0.36	0.99	**.044**	275	1,498
Cameroon 2004	0.48	0.26	0.88	**.017**	0.48	0.27	0.89	**.019**	0.78	0.41	1.49	.452	0.86	0.45	1.63	.634	189	849
Cameroon 2011	0.28	0.14	0.57	**.000**	0.28	0.14	0.55	**.000**	0.60	0.31	1.16	.127	0.65	0.35	1.22	.181	227	1,304
Cameroon 2018–19	0.55	0.34	0.89	**.016**	0.55	0.34	0.89	**.015**	0.73	0.42	1.28	.271	0.98	0.57	1.69	.936	209	947
Ethiopia 2005	0.87	0.41	1.86	.725	0.90	0.42	1.92	.776	0.96	0.44	2.13	.926	0.95	0.45	1.97	.883	671	1,430
Ethiopia 2011	0.18	0.05	0.59	**.005**	0.17	0.05	0.56	**.004**	0.22	0.07	0.69	**.010**	0.25	0.08	0.80	**.020**	560	1,527
Ethiopia 2016	0.71	0.36	1.40	.321	0.70	0.36	1.38	.307	0.75	0.36	1.58	.455	0.86	0.41	1.80	.685	460	1,489
Ethiopia 2019	0.23	0.06	0.88	**.032**	0.24	0.06	0.93	**.039**	0.28	0.07	1.10	.067	0.30	0.08	1.14	.078	247	725
Guinea 2005	0.62	0.20	1.91	.405	0.65	0.21	2.03	.460	0.78	0.25	2.49	.678	0.92	0.31	2.73	.876	222	841
Guinea 2012	0.45	0.13	1.55	.206	0.45	0.13	1.61	.218	0.67	0.20	2.23	.514	0.98	0.27	3.56	.979	264	917
Guinea 2018	0.66	0.47	0.92	**.013**	0.66	0.47	0.92	**.014**	0.71	0.51	1.01	.054	0.79	0.56	1.11	.176	444	960
Kenya 2003																	108	803
Kenya 2008–09	0.06	0.01	0.44	**.006**	0.06	0.01	0.51	**.010**	0.18	0.02	1.56	.120	0.21	0.02	1.86	.162	60	796
Kenya 2014	0.58	0.14	2.36	.449	0.59	0.15	2.37	.458	1.49	0.23	9.71	.674	1.89	0.30	11.88	.497	96	2,706
Liberia 2006–07	1.37	0.15	12.63	.777	1.28	0.15	11.13	.824	1.33	0.12	14.81	.815	3.17	0.28	36.39	.351	185	595
Liberia 2013	0.39	0.04	3.35	.387	0.40	0.05	3.44	.400	0.43	0.05	3.99	.455	0.39	0.04	3.54	.401	138	906
Liberia 2019–20	0.79	0.21	2.95	.721	0.80	0.22	2.93	.739	0.79	0.19	3.36	.754	1.65	0.30	9.19	.563	62	662
Malawi 2000																	77	1,741
Malawi 2004–05	0.28	0.04	2.16	.221	0.28	0.04	2.19	.226	0.43	0.06	3.31	.414	0.45	0.05	3.73	.458	96	1,970
Malawi 2010	1.66	0.33	8.32	.535	1.62	0.32	8.27	.563	2.53	0.46	13.87	.286	2.50	0.49	12.83	.271	77	3,379
Malawi 2015–16	0.71	0.09	5.39	.741	0.71	0.09	5.40	.744	1.08	0.14	8.52	.938	1.10	0.14	8.70	.928	60	2,681
Mali 2001	0.47	0.26	0.83	**.010**	0.49	0.28	0.85	**.012**	0.55	0.31	0.98	**.042**	0.56	0.31	1.01	.054	2,192	4,897
Mali 2006	0.21	0.06	0.72	**.013**	0.23	0.07	0.77	**.017**	0.25	0.07	0.84	**.025**	0.27	0.08	0.89	**.031**	357	1,739
Mali 2012–13	0.74	0.44	1.25	.262	0.76	0.45	1.27	.287	1.01	0.60	1.71	.974	1.27	0.74	2.16	.384	304	1,324
Mali 2018	0.42	0.29	0.60	**.000**	0.42	0.29	0.59	**.000**	0.48	0.34	0.69	**.000**	0.45	0.31	0.65	**.000**	309	1,403
Nigeria 2003	0.39	0.21	0.71	**.002**	0.38	0.21	0.69	**.002**	0.39	0.22	0.70	**.002**	0.47	0.28	0.79	**.005**	395	607
Nigeria 2008	0.33	0.25	0.44	**.000**	0.33	0.25	0.44	**.000**	0.59	0.45	0.75	**.000**	0.55	0.43	0.71	**.000**	2,013	3,559
Nigeria 2013	0.34	0.25	0.45	**.000**	0.34	0.25	0.46	**.000**	0.60	0.45	0.80	**.000**	0.60	0.45	0.80	**.001**	2,223	3,803
Nigeria 2018	0.44	0.34	0.56	**.000**	0.44	0.35	0.56	**.000**	0.79	0.62	1.01	.064	0.92	0.71	1.18	.501	1,643	3,772
Rwanda 2000																	43	976
Rwanda 2010–11																	17	1,369
Rwanda 2014–15																	8	1,159
Rwanda 2019–20	0.78	0.07	8.87	.840	0.73	0.07	8.19	.801	0.71	0.08	6.38	.757	0.90	0.11	7.74	.926	3	1,238

Continued...

Appendix Table 8—*Continued*

Survey	Model I				Model II				Model III				Model IV				Unweighted observations (zero-dose rural)	
	OR	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	Numerator	Denominator
Senegal 2005	0.44	0.21	0.92	**.028**	0.45	0.22	0.94	**.033**	0.65	0.30	1.40	.267	0.55	0.25	1.23	.145	115	1,346
Senegal 2010–11	0.54	0.26	1.10	.091	0.54	0.25	1.12	.098	0.66	0.31	1.40	.273	0.78	0.37	1.64	.510	109	1,583
Senegal 2015	0.74	0.21	2.62	.636	0.74	0.21	2.63	.639	0.90	0.26	3.06	.865	0.92	0.30	2.77	.877	50	919
Senegal 2019	0.63	0.27	1.44	.269	0.62	0.27	1.41	.249	0.74	0.33	1.65	.454	0.90	0.36	2.22	.812	38	803
Tanzania 2004–05																	84	1,268
Tanzania 2009–10	0.05	0.01	0.43	**.006**	0.06	0.01	0.44	**.006**	0.09	0.01	0.76	**.027**	0.17	0.02	1.47	.107	54	1,206
Tanzania 2015–16																	67	1,516
Uganda 2000–01	0.64	0.17	2.34	.493	0.63	0.17	2.29	.479	0.68	0.17	2.68	.581	0.71	0.19	2.68	.612	242	989
Uganda 2006	0.86	0.17	4.45	.856	0.86	0.17	4.43	.860	0.94	0.16	5.68	.945	1.22	0.16	9.33	.851	138	1,346
Uganda 2011	0.32	0.04	2.45	.271	0.34	0.04	2.71	.309	0.31	0.03	3.06	.318	0.24	0.02	2.31	.214	71	1,079
Uganda 2016	1.09	0.57	2.10	.791	1.10	0.57	2.13	.772	1.19	0.63	2.26	.593	1.04	0.52	2.08	.916	104	2,210
Zambia 2001–02	0.32	0.04	2.65	.289	0.32	0.04	2.61	.284	0.44	0.05	3.52	.437	0.79	0.07	8.68	.847	63	987
Zambia 2007	0.47	0.06	3.76	.476	0.48	0.06	3.82	.484	0.71	0.10	4.91	.731	0.53	0.08	3.38	.498	65	846
Zambia 2013–14	0.51	0.07	3.93	.516	0.51	0.07	3.94	.517	0.65	0.07	5.73	.697	0.81	0.09	7.29	.850	75	1,613
Zambia 2018-19	0.55	0.07	4.28	.568	0.55	0.07	4.26	.566	0.69	0.08	5.64	.730	1.06	0.12	9.72	.959	30	1,299
Zimbabwe 1999	1.95	0.94	4.04	.071	1.80	0.88	3.68	.106	1.75	0.71	4.28	.219	1.50	0.52	4.35	.453	61	511
Zimbabwe 2005–06	1.05	0.48	2.32	.894	1.06	0.47	2.35	.895	1.27	0.54	2.98	.579	1.48	0.59	3.66	.400	153	672
Zimbabwe 2010–11	0.56	0.22	1.41	.217	0.54	0.22	1.35	.187	0.57	0.23	1.42	.227	0.64	0.24	1.71	.372	89	716
Zimbabwe 2015	0.59	0.18	1.92	.380	0.58	0.18	1.86	.360	0.66	0.21	2.03	.464	0.53	0.12	2.27	.390	67	691

Blue and bolded cells indicate a significant *p* value.
LB = lower bound
UB = upper bound
Note: Empty cells indicate that there was missing information or too few cases to fit the model.

Appendix Table 9 **Odds ratios from the regression results of Models I–IV of zero-dose immunization outcome among urban children 12–23 months for owning a refrigerator among those with electricity**

	Model I				Model II				Model III				Model IV				Unweighted observations (zero-dose urban with electricity)	
Survey	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	**Numer-ator**	**Denomi-nator**
Benin 2001	0.69	0.06	8.47	.765	0.65	0.06	7.12	.720									5	136
Benin 2011–12	1.87	0.73	4.77	.191	1.64	0.62	4.32	.318	2.90	1.08	7.82	**.035**	2.59	0.90	7.44	.078	41	560
Benin 2017–18	1.26	0.38	4.24	.703	1.32	0.38	4.60	.665	2.11	0.67	6.64	.199	2.12	0.72	6.28	.173	42	517
Cameroon 2004	0.30	0.09	1.00	.051	0.28	0.08	0.94	**.039**	0.34	0.09	1.26	.105	0.33	0.08	1.38	.127	27	412
Cameroon 2011	0.57	0.26	1.26	.167	0.57	0.26	1.24	.155	0.83	0.35	1.94	.661	0.79	0.32	1.96	.605	40	705
Cameroon 2018–19	0.61	0.29	1.28	.187	0.62	0.29	1.29	.198	0.86	0.41	1.81	.698	0.85	0.40	1.81	.667	56	628
Ethiopia 2005	1.08	0.27	4.29	.910	1.18	0.30	4.73	.809	1.83	0.46	7.31	.389	1.54	0.29	8.24	.610	27	212
Ethiopia 2011	0.03	0.00	0.17	**.000**	0.02	0.00	0.14	**.000**	0.07	0.01	0.40	**.004**	0.06	0.01	0.38	**.003**	24	260
Ethiopia 2016	0.05	0.00	0.51	**.012**	0.04	0.00	0.47	**.011**	0.05	0.00	0.69	**.025**	0.14	0.01	1.62	.115	20	331
Ethiopia 2019	2.67	0.31	23.19	.368	4.46	0.58	34.24	.148	7.27	0.72	72.88	.091					14	219
Guinea 2005	0.65	0.14	3.04	.577	0.66	0.14	3.15	.599	0.62	0.09	4.10	.613	1.02	0.12	8.42	.985	10	129
Guinea 2012	0.27	0.08	0.89	**.032**	0.26	0.08	0.85	**.026**	0.32	0.08	1.24	.097	0.29	0.07	1.13	.074	28	243
Guinea 2018	0.53	0.29	0.99	**.046**	0.53	0.29	0.98	**.045**	0.73	0.36	1.46	.371	0.68	0.34	1.36	.274	72	337
Kenya 2003																	2	106
Kenya 2008–09	0.17	0.02	1.73	.132	0.23	0.02	2.16	.194	0.11	0.01	1.70	.113	0.15	0.01	1.79	.130	6	121
Kenya 2014	3.87	0.39	38.70	.249	3.48	0.33	36.93	.300									11	591
Liberia 2006–07																	–	10
Liberia 2013																	–	43
Liberia 2019–20	0.78	0.04	14.68	.863	0.52	0.02	11.86	.662	15.72	0.01	23,676.0	.378					2	74
Malawi 2000	0.02	0.00	0.15	**.000**													1	84
Malawi 2004–05																	–	54
Malawi 2010																	1	114
Malawi 2015–16	5.70	0.46	71.43	.174	6.02	0.40	90.67	.189	8.87	0.37	210.77	.172	5.06	0.62	40.96	.125	3	195
Mali 2001	0.78	0.43	1.40	.398	0.73	0.41	1.29	.276	0.79	0.41	1.51	.469	0.78	0.42	1.43	.414	80	573
Mali 2006	0.53	0.13	2.19	.373	0.60	0.16	2.18	.432	0.76	0.25	2.33	.632	0.76	0.24	2.47	.649	25	335
Mali 2012–13	1.01	0.38	2.69	.981	1.10	0.41	2.93	.848	1.26	0.41	3.82	.682	1.33	0.44	3.98	.608	28	361
Mali 2018	0.16	0.04	0.71	**.016**	0.16	0.04	0.68	**.014**	0.26	0.06	1.19	.081	0.30	0.06	1.45	.132	51	378
Nigeria 2003	0.33	0.19	0.58	**.000**	0.32	0.18	0.57	**.000**	0.47	0.24	0.92	**.029**	0.39	0.20	0.77	**.007**	103	301
Nigeria 2008	0.42	0.29	0.60	**.000**	0.42	0.29	0.60	**.000**	0.74	0.49	1.12	.149	0.75	0.50	1.14	.174	284	1,051
Nigeria 2013	0.37	0.27	0.50	**.000**	0.37	0.27	0.50	**.000**	0.65	0.46	0.90	**.010**	0.65	0.46	0.94	**.021**	347	1,543
Nigeria 2018	0.54	0.38	0.75	**.000**	0.54	0.39	0.76	**.000**	0.83	0.59	1.16	.277	0.83	0.59	1.17	.289	250	1,567
Rwanda 2000																	2	112
Rwanda 2010–11																	–	91
Rwanda 2014–15																	2	220
Rwanda 2019–20																	1	242

Continued...

Appendix Table 9—*Continued*

Survey	Model I				Model II				Model III				Model IV				Unweighted observations (zero-dose urban with electricity)	
	OR	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	Numerator	Denominator
Senegal 2005	0.60	0.15	2.44	.476	0.62	0.16	2.34	.476	0.88	0.24	3.27	.847	1.23	0.31	4.92	.772	20	520
Senegal 2010–11	0.08	0.02	0.34	**.001**	0.08	0.02	0.34	**.001**	0.08	0.02	0.37	**.001**	0.08	0.02	0.36	**.001**	19	573
Senegal 2015																	2	251
Senegal 2019	0.30	0.03	2.62	.268	0.34	0.04	2.62	.294	0.32	0.07	1.39	.127	0.15	0.03	0.70	**.017**	7	319
Tanzania 2004–05																	1	93
Tanzania 2009–10																	1	122
Tanzania 2015–16	1.79	0.10	32.53	.691	1.80	0.07	45.58	.719	1.10	0.01	115.23	.968	0.61	0.05	7.51	.682	2	252
Uganda 2000–01	1.44	0.13	15.88	.761	1.38	0.09	20.95	.811									4	115
Uganda 2006	1.52	0.08	30.26	.776	1.15	0.03	45.87	.939	4.07	0.34	48.88	.242					2	48
Uganda 2011	2.10	0.23	19.43	.508	2.07	0.20	20.98	.532	1.73	0.22	13.82	.601	2.09	0.38	11.60	.394	7	139
Uganda 2016	0.35	0.07	1.71	.190	0.33	0.07	1.62	.170	0.34	0.06	1.88	.214	0.22	0.04	1.27	.089	12	300
Zambia 2001–02	0.04	0.01	0.36	**.005**	0.05	0.01	0.45	**.008**	0.05	0.00	0.41	**.007**	0.03	0.00	0.25	**.002**	8	114
Zambia 2007	0.40	0.05	3.23	.388	0.36	0.04	3.73	.387	0.67	0.05	8.83	.754	0.37	0.03	3.98	.402	6	139
Zambia 2013–14	1.35	0.15	12.21	.788	1.58	0.18	13.99	.677	2.42	0.45	12.88	.300	12.18	2.22	66.74	**.004**	8	383
Zambia 2018–19	0.93	0.06	13.80	.958	1.11	0.07	17.83	.942	1.68	0.05	55.94	.770	0.35	0.02	6.82	.482	3	339
Zimbabwe 1999	1.42	0.27	7.40	.670	1.46	0.28	7.47	.646	0.82	0.11	6.37	.851	0.79	0.10	6.31	.821	7	138
Zimbabwe 2005–06	0.86	0.44	1.66	.648	0.80	0.39	1.62	.531	0.82	0.41	1.64	.565	0.65	0.30	1.41	.270	41	221
Zimbabwe 2010–11	0.82	0.28	2.41	.717	0.82	0.28	2.41	.717	0.94	0.30	2.92	.919	0.93	0.29	2.95	.898	18	234
Zimbabwe 2015	1.32	0.45	3.81	.610	1.27	0.46	3.53	.645	1.53	0.50	4.71	.453	1.61	0.52	4.93	.403	18	298

Blue and bolded cells indicate a significant *p* value.
LB = lower bound
UB = upper bound
Note: Empty cells indicate that there was missing information or too few cases to fit the model.

Appendix Table 10 Odds ratios from the regression results of Models I–IV of zero-dose immunization outcome among rural children 12–23 months for owning a refrigerator among those with electricity

	Model I				Model II				Model III				Model IV				Number of observations (zero-dose rural with electricity)	
Survey	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	***OR***	***LB***	***UB***	***p* value**	**Numer-ator**	**Denomi-nator**
Benin 2001																	3	35
Benin 2011–12																	16	222
Benin 2017–18	1.43	0.16	12.72	.744	1.33	0.14	12.76	.806	1.48	0.13	17.12	.750	2.34	0.23	23.63	.468	24	289
Cameroon 2004																	21	158
Cameroon 2011	0.94	0.18	5.04	.944	0.95	0.18	5.05	.950	3.39	0.48	23.99	.218	5.28	0.69	40.49	.108	21	261
Cameroon 2018–19	0.31	0.08	1.15	.080	0.30	0.08	1.13	.075	0.44	0.09	2.09	.300	0.37	0.07	1.97	.241	41	280
Ethiopia 2005	0.68	0.27	1.73	.384													17	39
Ethiopia 2011																	18	99
Ethiopia 2016	0.04	0.01	0.21	**.000**	0.04	0.01	0.28	**.001**	0.07	0.01	0.68	**.022**	0.07	0.00	4.35	.202	25	125
Ethiopia 2019	0.09	0.01	1.10	.059	0.10	0.01	1.30	.077	0.11	0.01	1.58	.102	0.37	0.05	2.97	.341	19	108
Guinea 2005	2.52	0.29	22.03	.371	1.63	0.10	25.94	.707	2.71	0.30	24.20	.341					5	26
Guinea 2012																	5	32
Guinea 2018	1.23	0.41	3.67	.707	1.28	0.45	3.60	.641	1.51	0.43	5.35	.519	2.81	0.81	9.80	.104	84	223
Kenya 2003																	–	21
Kenya 2008–09																	1	41
Kenya 2014																	3	163
Liberia 2006–07																	2	4
Liberia 2013																	1	12
Liberia 2019–20																	2	27
Malawi 2000																	–	15
Malawi 2004–05																	1	49
Malawi 2010																	2	81
Malawi 2015–16																	1	102
Mali 2001	0.79	0.18	3.47	.755	0.91	0.30	2.74	.859	0.83	0.27	2.53	.731	1.10	0.34	3.50	.874	32	127
Mali 2006	4.70	0.22	100.98	.314	3.96	0.17	93.93	.385	42.29	0.75	2,399.51	.068					5	83
Mali 2012–13	0.16	0.02	1.48	.106	0.16	0.02	1.40	.096	0.11	0.01	1.77	.117	0.14	0.01	2.12	.153	28	161
Mali 2018	0.91	0.35	2.36	.853	0.94	0.36	2.40	.890	1.30	0.49	3.43	.597	1.27	0.46	3.56	.642	71	526
Nigeria 2003	0.38	0.15	0.94	**.038**	0.37	0.16	0.85	**.021**	0.69	0.21	2.25	.532	0.86	0.26	2.81	.794	96	180
Nigeria 2008	0.27	0.16	0.46	**.000**	0.27	0.16	0.46	**.000**	0.57	0.31	1.04	.066	0.53	0.29	0.99	**.046**	319	867
Nigeria 2013	0.22	0.13	0.35	**.000**	0.21	0.13	0.35	**.000**	0.38	0.21	0.66	**.001**	0.39	0.22	0.68	**.001**	486	1,155
Nigeria 2018	0.41	0.28	0.61	**.000**	0.42	0.28	0.62	**.000**	0.73	0.48	1.10	.127	0.76	0.48	1.21	.251	374	1,254
Rwanda 2000																	–	9
Rwanda 2010–11																	–	49
Rwanda 2014–15																	–	146
Rwanda 2019–20																	1	436

Continued...

Appendix Table 10—*Continued*

Survey	Model I				Model II				Model III				Model IV				Number of observations (zero-dose rural with electricity)	
	OR	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	*OR*	*LB*	*UB*	*p* value	Numerator	Denominator
Senegal 2005	0.19	0.03	1.22	.079	0.20	0.04	1.11	.065	0.26	0.05	1.37	.110	0.36	0.06	2.34	.277	11	265
Senegal 2010–11	0.88	0.22	3.61	.862	0.91	0.23	3.66	.898	1.06	0.30	3.84	.923	0.88	0.31	2.50	.814	13	380
Senegal 2015	1.25	0.50	3.11	.622	1.17	0.51	2.72	.702	1.86	0.78	4.39	.156	2.60	0.96	6.98	.059	8	255
Senegal 2019	0.22	0.02	1.91	.166	0.19	0.02	1.65	.130	0.19	0.02	1.49	.111	0.26	0.03	2.34	.226	15	379
Tanzania 2004–05																	–	24
Tanzania 2009–10																	1	50
Tanzania 2015–16																	–	92
Uganda 2000–01	0.21	0.04	0.99	**.048**													3	17
Uganda 2006																	2	19
Uganda 2011																	1	28
Uganda 2016	1.21	0.15	9.96	.857	1.00	0.13	7.69	.998	1.44	0.16	12.60	.740	1.46	0.17	12.94	.730	15	343
Zambia 2001–02																	1	32
Zambia 2007																	1	16
Zambia 2013–14																	1	53
Zambia 2018–19																	1	74
Zimbabwe 1999																	8	37
Zimbabwe 2005–06																	9	41
Zimbabwe 2010–11																	5	69
Zimbabwe 2015	2.80	0.23	34.47	.408	2.91	0.27	30.89	.363									3	56

Blue and bolded cells indicate a significant *p* value.
LB = lower bound
UB = upper bound
Note: Empty cells indicate that there was missing information or too few cases to fit the model.