Remoteness, Urbanization and Child Nutrition in sub-Saharan Africa

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Abstract:

Reducing undernutrition requires improving access to goods and services from a wide range of economic and social sectors, including agriculture, education and health. Yet despite broad agreement on the multisectoral nature of the global burden of undernutrition, relatively little research has analyzed how different dimensions of accessibility, such as urbanization and travel times to urban centers, affect child nutrition and dietary outcomes. In this paper we study these relationships in sub-Saharan Africa, a highly rural continent still severely hindered by remoteness problems. We link spatial data on travel times to 20,000 person cities to survey data from 10,900 communities in 23 countries. We document strong negative associations between nutrition indicators and rural livelihoods, but only moderately strong associations with remoteness to cities. Moreover, the harmful effects of remoteness and rural living largely disappear once education, wealth, and social/infrastructural services indicators are added to the model. This implies that the key nutritional disadvantage of rural populations stems chiefly from social and economic poverty. Combating these problems requires either an acceleration of urbanization processes, or finding innovative cost-effective mechanisms for extending basic services to isolated rural communities.

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Abstract

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Key words: Undernutrition; Stunting; Roads; Transport infrastructure; Urbanization; Remoteness; Diets; Dietary diversity.

Introduction

Child undernutrition is an extremely costly public health burden in developing countries, having been linked to 45 percent of all childhood mortality, to impaired cognitive development, reduced school attainment, lower wages in adulthood and slower economic growth (Grantham-McGregor, et al., 2007, Black, et al., 2008, Black, et al., 2013, Hoddinott, et al., 2013a, Hoddinott, et al., 2013b). The underlying causes of undernutrition are complex, however, and estimates from the *2013 Lancet Nutrition Series* suggest that scaled up nutrition-specific interventions will only address 20% of the global problem. This implies that improvements in a wide range of socio-economic and environmental factors are critical drivers of improved child nutrition outcomes (Ruel and Alderman, 2013). As a result, significant bodies of research have assessed the relative roles of wealth, income and economic growth (Haddad, et al., 2003, Headey, 2013, Ruel and Alderman, 2013, Vollmer, et al., 2013), parental education (Desai and Alva, 1998, Alderman and Headey, 2017b, Vollmer, et al., 2017), household and community sanitation (Fink, et al., 2011, Spears, 2013, Spears, et al., 2013), demographic factors (Rutstein, 2005, Jensen, 2012), and access to health services (Headey and Hoddinott, 2015).

However, very little research has assessed why some populations can access the markets or public services that deliver wealth, health and education, or how access varies with either urbanization and proximity to urban areas. Economists studying agricultural markets have developed an extensive literature on what is generically referred to as "market access" (Chamberlin and Jayne, 2013), including substantive research on road infrastructure, travel times and agricultural productivity (Dercon, et al., 2009, Jacoby and Minten, 2009, Dorosh, et al., 2012, Stifel, et al., 2012). More recently agricultural economists have also started to explore the importance of market access for dietary diversification and child nutrition, either as a mediator in the relationships between production diversity and dietary diversity (Hoddinott, et al., 2015, Sibhatu, et al., 2015, Hirvonen and Hoddinott, 2016), or as mediator in the relationship between agricultural shocks and child nutrition (Mulmi, et al., 2016, Darrouzet-Nardi and Masters, 2017). Other research recognizes, however, that urbanization also typically entails improved access to non-food markets of some importance, including schools, health clinics and non-farm labor markets that improve income stability (Smith, et al., 2004, Headey, et al., 2010, Srinivasan, et al., 2013). This research only focuses on urbanization, however, not on the different gradients of remoteness experienced by rural populations.

In this study we therefore adopt a more unified approach to these issues, to explore whether urbanization and travel times to large towns or cities do indeed have positive associations with child nutrition outcomes and diets, as well as which mechanisms might explain these associations. We analyze these relationships in 23 sub-Saharan African countries with Demographic Health Surveys (DHS) that record nutritionally relevant indicators as well as survey cluster coordinates. Urban status in the DHS is defined by national sources, which vary considerably, but city access is defined as travel times to cities of 20,000 people or more, as defined by Geographic Information System (GIS) data that we merge with the DHS. This two-dimensional approach allows us to estimate nutritional differences between:

(i) rural and urban clusters;

(ii) between urban clusters of varying degrees of remoteness to cities, and

(iii) between rural clusters of varying degrees of remoteness to cities.

This study therefore introduces several innovations over previous research, including a more multi-dimensional view of accessibility, extensive geographical coverage, and systematic exploration of the mechanisms linking urbanization, remoteness and nutrition outcomes.

The remainder of this paper is structured as follows. Section 2 describes our data and methods. Section 3 presents our core empirical results on child stunting, while Section 4 presents an extension to child dietary diversity. Section 5 concludes.

2. Data and methods

Data

In this paper we merge DHS data (ICF-International, 2015) for 23 sub-Saharan African countries with GIS data on travel times to nearest cities and other geographical indicators. Table 1 reports means for the key variables of interest for all areas, and rural and urban areas separately. We also report intra-cluster correlation (ICC) coefficients to examine the extent to which different factors cluster within survey localities. In the text below we describe the key features of this synthetic DHS-GIS dataset.

[insert Table 1 about here]

The DHS are nationally representative data that include child anthropometric measurements as well as a wide range of socioeconomic characteristics thought to influence nutrition outcomes. Our primary outcomes of interest are the standardized height-for-age z-score (HAZ) of children between the ages of 24 and 59 months collected in the DHS, and a dichotomous indicator of whether children are stunted (a HAZ score less than 2 standard deviations below the mean of the reference population). A child's height relative to the height of the reference population of the same age (WHO, 2006) is an indicator of a her long-term nutritional status, as child height represents an outcome that is affected by prolonged exposure to a poor diet or infections. In this paper we follow the recommendation of Alderman and Headey (2017a) to only include children aged 24-59 months in our regression analysis because these children have already passed the first 1000 days of life –

from conception to 23 months – when nutritionally vulnerable children experience accelerated growth faltering (Victora, et al., 2009).[1]

As illustrated in Table 1 and Figure 1, children in the 23 African countries are generally excessively short for their age. The average HAZ in the pooled sample of 23 countries is a low -1.78 (Table 1) [2], and the density estimate of the observed HAZ is noticeably shifted to the left of the density for the healthy reference population (Figure 1). Furthermore, based on country-definitions of urban areas, we see that undernutrition is substantially worse in rural areas than in urban areas. The mean rural HAZ is -2.00 compared to -1.28 for urban areas (Table 1), and the distribution of HAZ is almost everywhere lower in rural areas than urban areas (Figure 1).

[insert Figure 1 about here]

An important secondary outcome of interest is dietary diversity. Dietary quality is hypothesized to be one of the main pathways linking access to markets and child nutrition outcomes (Section 1). Further, the dietary diversity score (in this case the number of food groups consumed by a child in the past 24 hours) is a simple measure of a high quality diet that is highly correlated with more complex measures of food and nutrient intake, as well as child growth outcomes (Ruel, et al., 2013). In phases 5 and 6 of the DHS, mothers were asked about children's consumption of 12 food groups, which were then classified into 7 major food groups following WHO recommendations (WHO, 2010). As illustrated in Table 1, dietary diversity for young children is extremely low throughout Africa (1.63 food groups on average), and is even lower in rural areas (1.51 food groups). These

[1] Including children in the 0-23 month age range would be tantamount to including children not fully exposed to the full costs of remoteness, or the full benefits of urbanization. Alderman and Headey (2017a) show that using children 0-23 month in regression analysis of stunting leads to underestimation of most coefficients.

[2] We calculate averages in this study using the DHS sampling weights for each country-survey multiplied by the population of that country as a share of the combined population of the 23 countries.

averages are well below the internationally recognized minimum acceptable number of food groups, which is four food groups (WHO, 2010).

As noted above, an innovation in this study is the derivation of a full set of indicators capturing the combination of urbanness and remoteness from cities of different sizes. This is possible because each DHS cluster in our data records latitude and longitude coordinates. Moreover, we exclude surveys more than 4 years apart from the year in which road data were mapped, since these road networks are the most important underlying source of variation in the travel time estimates. A full list of the timing of the DHS surveys and the timing of the road mapping is presented in Appendix Table A1, along with the various country-specific definitions of urbanness.

We use these road maps to define accessibility to human settlements with populations of at least 20,000, 50,000, 100,000, 250,000 or 500,000 people. While spatial proximity can be represented in many ways (e.g., distance, travel time or transport cost), perhaps the most common metric of accessibility is the straight-line distance. However, this Euclidian distance measure rarely reflects the actual path that people travel since it does not account for variation in terrain or transportation infrastructure. Including the influences of such variables as land cover and road networks to estimate travel times enables a more accurate estimation of accessibility. To do so, we start with road length, which is the kilometer distance of roads from the midpoint of the 5-minute gridcell (10km at the equator) encompassing the DHS cluster in question,[3] to the midpoint of the nearest city. We then use data on road networks, land cover type and elevation to estimate vehicular and pedestrian travel speeds for each pixel. The details of these estimation methods are provided in Guo and Hawkins (2016), but are relatively standard in the GIS literature on this subject.

[3] An important technical issue related to the GIS data is worth highlighting. First, we chose the area around the clusters in a way that makes the characteristics of the biophysical variables more representative of the clusters. In order to protect the privacy of the sample households, the DHS randomly move the cluster coordinates within a 5-to-10 km range of the true coordinates. As such, we needed to use a relatively large circumference around each approximate clustr location reported in the DHS survey data to capture the characteristics of that cluster. As the resolution of the spatial data layers are mostly 5 minutes (about 10km at the equator) or 30 seconds (about 1km at the equator), we decided to use a 10 km grid cell/pixel as the standard spatial unit to summarize or average the values of the variables.

Our indicators of access to cities combine indicators travel time with the country-specific definitions of urbanness reported in Appendix Table A1. Indeed, one sound reason for doing this is that definitions of urbanness vary substantially across countries and are at least somewhat arbitrary. It may be that many "rural" populations reside so close to cities that they are primarily engaged in non-farm occupations and more generally well-integrated into the urban economy. At the same time, national definitions of urbanness may impart genuine information that distinguishes urban settlements smaller than 20,000 people from genuinely rural villages.

To combine measures of urbanness with travel times, we first use non-parametric local polynomial plots of child HAZ against travel times to cities of various sizes, as reported in Appendix Figure A1. We found that city size seemed to have only a minimal influence on the relationship between remoteness and HAZ, [4] and therefore selected travel times to cities of 20,000 people as our main travel time indicator. We plot HAZ relationships with this indicator for the full sample for both rural and urban populations in order to first establish potential thresholds (results reported below). We use these non-parametric plots to allocate both rural and urban clusters into one of three travel time categories: 0-2 hours, 2-5 hours or 5+ hours. Table 1 shows that amongst urban children around 90 percent reside in or near 20,000+ person cities, and another 8 percent reside in small urban settlements 2-5 hours from a 20,000+ person city, with just 1% residing in urban clusters more than 5 hours from a 20,000+ person city. Among rural populations there is a much more even distribution across remoteness categories. Around half of children living in rural clusters in this sample live within 2 hours of a 20,000+ person city; just under a third live 2-5 hours away, and a fifth live in extremely remote rural settlements.

As noted above, the DHS provide data on a wide range of intermediate determinants of nutrition, which may also be influenced by remoteness/urbanization, and hence may be viewed as potential

[4] The coefficients on travel time in separate regressions of child HAZ on travel time from each of the five city sizes (20, 50, 100, 250 and 500 thousand inhabitants) were not statistically different from each other.

mechanisms linking remoteness/urbanization to nutrition outcomes. We classify these indicators into different groups: mother and child characteristics, agroclimatic factors, socioeconomic status, and social/infrastructural services.

The first two categories include child age, gender and birth interval, as well as maternal age and height, how many children she has given birth to, and whether she is a household head.

Agro-climatic indicators constitute an important set of confounding variables if roads are more likely to be built in areas with greater agricultural potential. Hence we also measure various climatic, demographic and agricultural characteristics of the 5-minute gridcells encompassing each DHS cluster. A good broad measure of crop potential (in terms of yield and sequential cropping) is the length of the growing period (LGP).[5] In addition, the average level and variability (coefficient of variation) of rainfall in the cluster allow us to control for water availability and predictability during the particular year in which the survey was conducted. We include a measure of soil fertility is the agroecological potential index, which is the combined suitability of land in a pixel for rainfed agriculture or pasture production. Both the LGP and agroecological potential estimates come from the Global Agroecological Zone project (Fischer, et al., 2002).

For socioeconomic status, we use four types of variables. We construct our own wealth index based on ownership of consumer durables (radio, TV, motorcycle, car, fridge) and housing characteristics (electricity, improved roofing), following the principal components approach advocated by Filmer and Pritchett (2001).[6] We disaggregate this index into 5 wealth quintiles to capture potential non-linearities. However, since rural populations also keep livestock as a measure of wealth, we measure ownership of chickens and cattle. Parental engagement in non-farm occupations may also

[5] LGP is the total length of time that rainfall exceeds evapotranspiration, leaving sufficient excess water to support the growth of crops. LGPs of less than 70-80 days are typically too short for crop cultivation. Some traditional cereal varieties need growing seasons of up to 180 days to reach maturity, while some perennial crops require LGPs in excess of 270 days.

[6] One difference is that we constructed an index with common weights across the 23 countries. We initially constructed an index based on country-specific weights, but we found this to have a very high correlation with the country-specific indices, or around 0.97, suggesting that, for this African sample at least, the underlying associations between these assets and the latent measure of wealth is quite common across countries.

be an important mechanism for stabilizing household income and food consumption, even beyond its contribution to wealth accumulation, so we measure a dummy variable if either parent cites non-farm employment as her/his primary occupation. We measure years of education for mothers and fathers using two brackets (7-9 years and 10+ years), with 0-6 years as an omitted base category, following the recent analysis of parental education and child nutrition by Alderman and Headey (2017b). Table 1 shows that there are large rural-urban wealth and education differences in sub-Saharan Africa, and that wealth tend to be highly clustered with an ICC of 0.40.

Among health/infrastructural services we record a range of standard DHS indicators, including antenatal care (1-3 visits or 4+ visits relative to no visits), a dummy for medical attendance at the child's birth, electricity access, toilet ownership (none, unimproved toilet, flush toilet), and the source of drinking water. As with wealth and education, there are some sizeable differences in rural and urban access to health and infrastructural services, and in some cases reasonably high degrees of clustering (ICCs of between 0.2 and 0.3).

Modelling framework

Our econometric approach for exploring the potential benefits of proximity to urban centers is a simple stepwise regression framework. Our baseline model regresses a nutrition outcome (N) for child i in cluster j of country k against the vector of travel time dummies ($\boldsymbol{T}$), country fixed effects ($\boldsymbol{\mu_k}$), with the standard error term (e):

$$(1)\ N_{i,j,k} = \boldsymbol{\beta_{T1}} \boldsymbol{T}_{i,j,k} + \boldsymbol{\mu_k} + e_{i,j,k}$$

The key parameters of interest in $\boldsymbol{\beta_{T1}}$ reflect the weighted average across 23 within-country travel time estimates. These parameters can be thought of as the total benefits of travel time based on all the potential causal mechanisms linking market access to nutrition, and any confounding associations with other geographical characteristics, such as agricultural potential.

In equations (2) through (6) we successively add maternal and child characteristics (D), agro-climatic conditions (A), household wealth and parental education (W), and access to social/infrastructural services (H), though in equation 5 we add just access to social/infrastructural services (H) to equation 3 to assess the importance of this group of characteristics relative to household wealth and parental education (W):

$$(2)\ N_{i,j,k} = \boldsymbol{\beta_{T2}T}_{i,j,k} + \boldsymbol{\beta_{D2}D}_{i,j,k} + \boldsymbol{\mu_k} + e_{i,j,k}$$

$$(3)\ N_{i,j,k} = \boldsymbol{\beta_{T3}T}_{i,j,k} + \boldsymbol{\beta_{D3}D}_{i,j,k} + \boldsymbol{\beta_{A3}A}_{i,j,k} + \boldsymbol{\mu_k} + e_{i,j,k}$$

$$(4)\ N_{i,j,k} = \boldsymbol{\beta_{T4}T}_{i,j,k} + \boldsymbol{\beta_{D4}D}_{i,j,k} + \boldsymbol{\beta_{A4}A}_{i,j,k} + \boldsymbol{\beta_{W4}W}_{i,j,k} + \boldsymbol{\mu_k} + e_{i,j,k}$$

$$(5)\ N_{i,j,k} = \boldsymbol{\beta_{T5}T}_{i,j,k} + \boldsymbol{\beta_{D5}D}_{i,j,k} + \boldsymbol{\beta_{A5}A}_{i,j,k} + \boldsymbol{\beta_{H5}H}_{i,j,k} + \boldsymbol{\mu_k} + e_{i,j,k}$$

$$(6)\ N_{i,j,k} = \boldsymbol{\beta_{T6}T}_{i,j,k} + \boldsymbol{\beta_{D6}D}_{i,j,k} + \boldsymbol{\beta_{A6}A}_{i,j,k} + \boldsymbol{\beta_{W6}W}_{i,j,k} + \boldsymbol{\beta_{H6}H}_{i,j,k} + \boldsymbol{\mu_k} + e_{i,j,k}$$

Comparisons of $\boldsymbol{\beta_T}$ across these equations yield insights regarding possible mechanisms linking urbanness and proximity to cities to child nutrition and dietary outcomes. This approach is sometimes used in economics, but very common in the public health literature where it is variously referred to as mediation or suppression effects (MacKinnon, et al., 2000).

An obvious limitation of our approach is that we do not address the potential endogeneity of travel times to cities, or for that matter urban status. This endogeneity takes several forms. First, road placement may be determined by factors that are difficult to accurately observe (e.g. economic potential) and that are also correlated with nutrition. Second, through migration, populations can self-select into different localities, and migrants might have unobservable characteristics that influence nutrition (e.g. intelligence). While the literature on road construction has attempted to address the first of these problems (Stifel and Minten, 2008, Jacoby and Minten, 2009, Russ, et al., 2017), the self-selection problem with migration is far more intractable. We therefore interpret our regression analysis as a series of associations that are informative about causal relations, without being directly indicative of them.

3. Main results

Core regression results

A bivariate nonparametric regression of child HAZ on travel time to cities with 20,000 or more inhabitants shows that children in more remote areas are substantially more undernourished (Figure 2). However, this relationship is highly non-linear, with the largest reduction in HAZ occurring in the range of communities that are within 2 hours of a city. When we disaggregate the sample into rural and urban areas, much of the observed drop in heights appears to be driven by urban/rural differences, with less explained by the extent of remoteness within rural areas. Indeed, predicted child heights are universally higher on average in urban areas regardless of travel time to large cities, and the HAZ-travel time gradient is less steep in both urban and rural areas than in the pooled sample, though it is still mostly downward sloping.

[insert Figure 2 about here]

To understand these relationships better, we turn to least squares regression estimates for the pooled sample. Results for HAZ scores are reported in Table 2. We start with the descriptive base model that includes country-region fixed effects but no other controls (Model 1). Consistent with the nonparametric regressions, we observe a large penalty for HAZ among children in rural areas compared to those in cities and in smaller urban areas close to cities (the omitted category). Indeed, children living in rural areas close to cities (< 2 hours) have average HAZ scores that are 0.41 standard deviations below those in cities. This difference is statistically significant at the 1 percent level and is consistent with Figure 2, as is the average difference between those in semi-isolated rural areas and cities (0.46 standard deviations). The average difference for rural children living in isolated areas (5+ hours) is not statistically different from those living in semi-isolated rural areas (2-5 hours). Children living in isolated and small urban clusters are also shorter on average compared to those living in cities, although the magnitudes of this difference is smaller (0.36 standard deviations).

To account for potential omitted variable bias and to explore possible mechanisms linking remoteness to undernutrition, we progressively add controls to the base model. The coefficients in Model 1 are relatively robust to the inclusion of mother and child characteristics in Model 2, and to agro-climatic conditions in Model 3. The coefficients on mother and child characteristics tend to be highly statistically significant, whereas among the agro-climatic variables only agricultural potential yields a significant coefficient. Conditional on these characteristics, children living close to cities are 0.37 standard deviations shorter compared to those living in cities, whereas in semi-isolated and isolated areas children are 0.41 and 0.42 standard deviations shorter. As is the case with Model 1, the latter two point estimates are not statistically different from each other, though they are statistically different from those close to cities ($p = 0.08$).

Much larger changes in coefficients occur when we add controls for household assets, non-farm occupations and parents' education (Model 4). Not only do the estimates of the relationship between isolation and HAZ in rural areas fall by more than half, they are also no longer statistically different from each other within rural areas. That is, conditioning on household assets and parents' education results in children in rural areas being just 0.14 standard deviations shorter on average than their counterparts who live in cities, regardless of how far they are from cities. This effect is statistically significant at the 1 percent level, and is similar to the effect for children living in isolated small urban areas (0.19 standard deviations shorter).

In Model 5, when we add controls for health and infrastructural services to Model 3 instead of household wealth and parental education, we find similarly large decreases in the magnitudes of the travel time estimates. As with Model 4, conditioning on these services results in travel time to large cities no longer having a significant association on the stature of children in rural areas. They are 0.17 standard deviations shorter on average than their counterparts in cities regardless of distance. Coefficients on access to health services and toilet type tend to have highly significant coefficients (and flush toilets have a reasonably large coefficient of 0.17), but sources of water do not. The similarities between Models 4 and 5 follow from the positive association between the wealth and education status of households and their ability to purchase or otherwise access health and infrastructural services in their areas of residence.

Finally, Model 6 includes controls for both household assets, non-farm occupations and parents' education as well as indicators of access to health and infrastructural services. Relative to Models 4 and 5, the coefficients are not much changed, but only slightly attenuated.

These results suggest that a substantial part of the negative association between isolation and child HAZ that we observe in Model 1 is driven by the simultaneous relationship between isolation and socioeconomic status on the one hand, and between socioeconomic status and HAZ on the other. Our results on this second association between socioeconomic status and HAZ are broadly consistent with the previous literature. Our estimates of the nutritional returns to parental education and household wealth are close to those of Alderman and Headey (2017b).[7] It is also common to find tight relationships between wealth indices and child nutrition (Sahn and Stifel, 2003a), though the wealth index used in this paper is not country-specific, which allows us to look at pooled results.

To look at this further, we plot non-parametric graphs of socioeconomic indicators against travel time to 20,000+ cities, as we did in Figure 2 for HAZ. The results in Figure 3 are quite consistent

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[7] We estimate that a woman with 10+ years of education is expected to have a child 0.31 standard deviations taller than a mother with 0-6 years of education, while children form the richest asset quintile are 0.51 standard deviations taller than children from the lowest asset quintile. These results are similar to those reported by Alderman and Headey (2017).

with Figure 2. We observe an especially steep gradient between the asset index and travel times, with the largest difference observed between households in communities that are within 2 hours of a city and those that farther away. Similarly, parental education is positively associated with child HAZ as indicated by the positive and increasing coefficients on both mother's and father's education. Furthermore, urban localities have a major advantage in educational attainment, having roughly two extra years of schooling for both mothers and fathers. Once in rural areas, however, there is little relationship between distance from cities and average years of parents' schooling. Rather similar results are observed for access to health and sanitation services: for example, nearly 70 percent of mothers in urban areas reported 4 or more antenatal visits during the most recent pregnancy compared to 34 percent in rural areas (Table 1).

[insert Table 2 about here]

[Insert Figure 3 about here]

A limitation of the HAZ results in Table 2 is that they have no immediately obvious public health interpretation, whereas reducing child stunting is now a widely recognized global target. We therefore use linear probability regressions to estimate Models (1) through (6) with child's stunting status (HAZ less than -2). We can thus interpret the results that appear in Table 3 more intuitively as changes in the probability of stunting associated with one-unit changes in the covariates. The pattern of stunting results is very similar to the HAZ results reported above. Controlling only for country fixed effects in Model (1) implies that children in rural areas and isolated urban areas are 11-14 percent more likely to be stunted compared to those living in cities with at least 20,000 residents. However, the inclusion of socioeconomic controls or health/infrastructural controls reduces the rural-urban stunting gap to 3-5 percentage points in Models (4), (5) and (6), and there is no significant additional penalty for remoteness in rural areas, though there is still a significant penalty for residing in an isolated urban area (6 points).

[insert Table 3 about here]

Exploring the sources of nutritional differences between rural and urban clusters

The results above definitively imply that the isolation gradient across rural clusters is, on average, close to zero once socioeconomic and/or health and infrastructure services access are controlled for. Instead, the fundamental dimension of "accessibility" appears to be whether or not a cluster is rural or urban. This raises the question, however, of which factors account for the differences in average HAZ scores *between* rural and urban.[8] In order to gauge this, we employ an Oaxaca-Blinder type decomposition, as described in Jann (2008). This procedure estimates separate rural and urban regressions for model 6 in Table 2, and then uses these models to simulate how the average HAZ scores in rural areas are predicted to differ when the individual covariates change from rural mean values to urban mean values (endowment effects), and how they differ when the parameter estimates change from rural values to urban values (returns effects). For the endowment effects, we only simulate changes in HAZ for those covariates for which the parameter estimates are statistically significant and for which the average endowments differ statistically between urban and rural areas (at the 10 percent level). Similarly, for the returns effect, we only simulate changes for covariates for which the urban and rural parameters differ at a statistically significant level.

At the top of Table 4 we observe a large 0.73 standard deviation difference in HAZ scores across rural and urban areas. The remainder of the table attempts to answer how much of that difference

[8] Nutritional research has examined this issue previously, but only through tests of coefficient differences across rural and urban areas (Smith, et al., 2004).For another example of a more rigorous Oaxaca-type decomposition of nutritional differences in rural and urban areas, see Srinivasan, et al. (2013).

is explained by returns effects or endowment effects. Consistent with a much earlier analysis (Smith, et al., 2004), we find few large and significant differences in the nutritional returns to the various explanatory variables, though some exceptions include the fifth wealth quintile, medically attended births, and toilet access. In contrast, there are large endowment effects irrespective of whether rural or urban coefficients/returns are used to simulate the impacts of allocating rural children the endowments of urban children. Using coefficients/returns from the rural sample, endowment differences across rural and urban children account for 59% of the observed HAZ differences between them. This rises to 78% using coefficients/returns form the urban sample. Unsurprisingly, given the results in Tables 2 and 3, socioeconomic differences between rural and urban children account for most of the observed HAZ difference between them. Household assets and nonfarm activities for almost half of the total endowment effect using urban coefficients, followed by parental education (most maternal education differences), and health/infrastructural differences.

[insert Table 4 about here]

4. Extension to child dietary diversity

As we noted in our introduction, growing interest in the importance of market access for child nutrition often stems from the presumed benefits of accessing a more diverse and stable supply of food. In Table 5 we therefore replicate the regression modelling approach above to child dietary diversity. Given that previous research has often cited market access as a critical determinant of dietary diversity (often conditional upon local agroecology), we hypothesized that the associations between travel times and children's dietary diversity would be stronger than the associations with stunting, even after controlling for socioeconomic status and health/infrastructural services. In other words, remoteness from cities might have sizeable effects on dietary diversity independent of its effects on socioeconomic status, health and infrastructure access.

Contrary to our expectations, the results in Table 5 are remarkably similar to the child growth results from the previous section. Model 1 suggests that the largest penalty associated with remoteness is living in any type of rural cluster, but this penalty is reduced by two-thirds once assets, education and non-farm activities are added to the model, or once social/infrastructural services are added. In other words, it appears that remoteness does have much independent influence on dietary diversity. Indeed, if anything the results in Table 5 are somewhat more emphatic in this regard: unlike the results in Tables 3 and 4, there is no longer any remoteness penalty for smaller urban areas once socioeconomic and health/infrastructural access variables are added to the model.

[insert Table 5 about here]

5. Discussion

A rapidly growing literature on the economics of nutrition has often hypothesized that "market access" is an important determinant of dietary diversity and hence child nutrition, while a range of nutritional analyses have made note of the sizeable disparities in nutritional health across rural and urban areas (Smith, et al., 2004, Srinivasan, et al., 2013), including studies specific to sub-Saharan Africa (Sahn and Stifel, 2003b). In this paper we set out to more systematically explores the linkages between urbanization, proximity to cities and child nutrition in sub-Saharan Africa, a continent still at an early stage of urbanization, and still characterized by high degrees of rural remoteness.

We find the expected result that rural populations are typically characterized by worse nutrition outcomes than urban populations, but the somewhat unexpected result that more remote rural populations do not have substantially worse nutrition outcomes than less remote rural populations. Furthermore, and broadly in keeping with previous analyses of rural-urban inequality in nutrition, it appears that the majority of this nutritional disadvantage is explained by differences in wealth and human capital across rural and urban areas, and as well as by differences in health and infrastructure services. Perhaps surprisingly, these conclusions also apply to dietary diversity: after controlling for socioeconomic status and health/infrastructural services, remoteness imposes no additional penalty on dietary diversity in either rural or urban localities.

These findings are in keeping with a growing literature that identifies household wealth accumulation and improvements in parental education as the two strongest predictors of stunting reduction in a wide variety of settings (Headey, et al., 2015, Headey and Hoddinott, 2015, Zanello, et al., 2016, Headey, et al., 2017). However, our results on dietary diversity are somewhat in contrast with a separate literature emphasizing the importance of market access. Our results suggest that reducing remoteness to cities will have little impact on dietary diversity beyond the resultant socioeconomic benefits.

There may be several explanations of these results, including methodological limitations. Our definition of remoteness is specific to estimated travel times to 20,000 person towns. This involves an arbitrary cut-off, but also considerable measurement error given that travel times are based on GIS-based estimates rather than survey data. We also don't measure access to food markets specifically, or the affordability and accessibility of foods in different types of markets and urban agglomerations. This is an important area for future research. Lastly, while our analysis is motivated by the dearth of research on infrastructure, market access and nutrition, our analysis is observational, and travel times to towns/cities are clearly not randomly allocated across clusters. Specifically, we would expect travel times to be a function of both historical and recent investments in road infrastructure, as well as endogenous migration decisions wherein household self-select into different localities based on ability, entrepreneurship and other unobservables. So while these results help explain why remote and non-remote communities have different nutritional profiles, they do not tell us about the nutritional impacts of reducing remoteness through road infrastructure, migration or other interventions.

Bearing these caveats in mind, these results strongly suggest that socioeconomic inequality is the root cause of rural-urban inequality in nutrition. However, the policy implications of this finding are not unambiguous. In economics, the clustering of economically disadvantaged people in particular geographic areas was the subject of an influential paper by Ravallion and Wodon (1999) – appropriately entitled *Poor Areas, or only Poor People?* – and of a large subsequent literature employing poverty mapping in developing countries. Moreover, Ravallion and Wodon (1999) show that the clustering of poverty in Bangladesh is not entirely accounted for by observable household characteristics, implying that the returns to household characteristics (such as human capital) at least partly account for spatial inequality.

If that is the case, then the persistence of spatial inequality remains something of a puzzle. Low returns to labor, land or human capital should motivate migration to more productive areas. Some experimental evidence from Bangladesh suggests that there are high returns to migration, but that information asymmetries inhibit welfare-enhancing migration (Bryan, et al., 2014). Most other research sees spatial inequality as some form of governance failure, such as underinvestment in agriculture (Bezemer and Headey, 2008), problems with accessing sufficient farm land (Jayne, et al., 2014) or neglect of secondary towns and cities (Christiaensen and Todo, 2014). Still another literature emphasizes the steep cost of extending infrastructure into rural African areas characterized by both remoteness and low population density, although "urban bias" in political structures is another plausible explain of rural neglect (Headey, et al., 2010). An alternative solution to "nutritional remoteness" is to develop innovative institutional structures to deliver basic "last mile" services on maternal and child healthcare and sanitation. Countries such as Nepal and Ethiopia, for example, pursued these strategies through frontline community health workers and volunteers (Bhutta, et al., 2013). Nepal even uses transport subsidies to encourage greater uptake of neonatal services in remote areas (Headey and Hoddinott, 2015).

In practice, reducing the stark rural-urban inequality in nutrition in sub-Saharan Africa will likely require some combination of rural economic development, out-migration and innovative delivery of basic health and infrastructural services. One important question for future research is how road infrastructure influences these different development mechanisms. While a sizeable literature assesses the productivity benefits of rural roads, little is known about how road connection influences migration or the cost of public service delivery, even though these more indirect benefits may be sizeable.

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Tables and Figures

Table 1. Summary Statistics of Key Variables Used in the Study

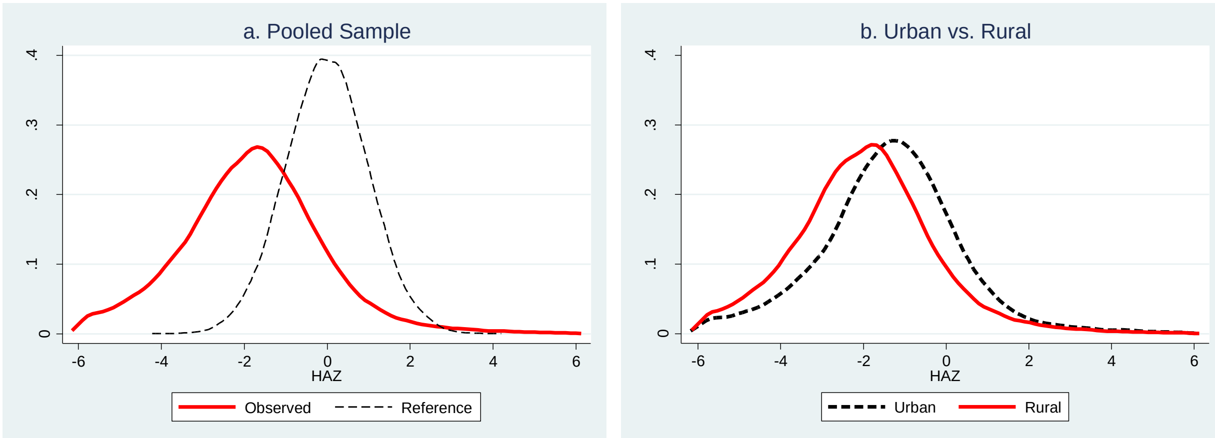
	All areas Intra-cluster correlation	All areas Mean	Urban Mean	Rural Mean
Dependent variables				
Height-for-Age Z-score (HAZ)	0.07	-1.78	-1.28	-2.00
Stunted (share with HAZ < -2)	0.07	0.45	0.31	0.51
# food groups consumed (max = 7)+	0.13	1.63	1.93	1.51
Access to cities of 20K or more				
Large urban & close (0-2 hrs)	0.26	0.278	0.904	
Small urban semi-isolated (2-5 hrs)	0.07	0.025	0.081	
Small urban isolated (5+ hrs)	0.19	0.005	0.015	
Rural close (0-2 hrs)	0.13	0.338		0.488
Rural semi-isolated (2-5 hrs)	0.08	0.220		0.318
Rural isolated (5+ hrs)	0.23	0.134		0.194
Child Characteristics				
Boy (dummy)	<0.01	0.503	0.504	0.502
Age 36+ months (dummy)	<0.01	0.668	0.662	0.671
Mother's Characteristics				
Birth interval under 24 months	0.02	0.192	0.176	0.199
Mother has 3-4 kids	0.01	0.328	0.358	0.314
Mother has 5+ kids	0.03	0.430	0.354	0.463
Mother under age 20	0.02	0.159	0.124	0.175
Mother over age 40	<0.01	0.041	0.037	0.043
Mother's height under 145 cm	0.02	0.016	0.007	0.020
Mother's height 145-150 cm	0.04	0.067	0.042	0.079
Mother's height 150-155 cm	0.04	0.213	0.173	0.230
Mother is household head	0.08	0.128	0.0.152	0.117
Agro-climatic Conditions				
Rainfall - avg (mm) for survey year	NA	1,037.5	1,105.6	1,007.2
Rainfall - Coeff Var for survey year	NA	91.9	87.8	93.8
Agroecological potential index	NA	49.6	49.8	49.5
Length of growing period (days)	NA	201.6	210.4	197.7
Parents' Education				
Mother's education - 7-9 years	0.13	0.090	0.127	0.074
Mother's education - 10+ years	0.18	0.178	0.394	0.082
Father's education - 7-9 years	0.10	0.085	0.083	0.086
Father's education - 10+ years	0.19	0.299	0.543	0.190
Socio-economic status				
Asset index (2nd quintile)	0.40	0.208	0.055	0.276
Asset index (3rd quintile)	0.40	0.194	0.104	0.234

Asset index (4th quintile)	0.40	0.235	0.409	0.158
Asset index (5th quintile)	0.40	0.161	0.404	0.053
Owns chickens	0.14	0.491	0.259	0.594
Owns cows	0.35	0.285	0.053	0.388
HH engaged in nonfarm activities	0.19	0.534	0.858	0.391
Health / Infrastructural Services				
Antenatal visits (1-3)	0.15	0.202	0.159	0.221
Antenatal visits (4+)	0.14	0.443	0.686	0.336
Medically attended birth	0.28	0.430	0.715	0.303
Electricity access	0.32	0.374	0.771	0.198
Flush toilet	0.19	0.118	0.306	0.034
No latrine/toilet	0.31	0.303	0.131	0.380
Drinking water - Piped	0.29	0.159	0.290	0.101
Drinking water - Tubewell	0.23	0.254	0.359	0.207
Drinking water - Dug well	0.19	0.269	0.172	0.312
Drinking water - Surface water	0.15	0.278	0.073	0.369
Number of observations		74,398	21,185	53,213

Data Sources: DHS & GIS (multiple sources); see text for details.

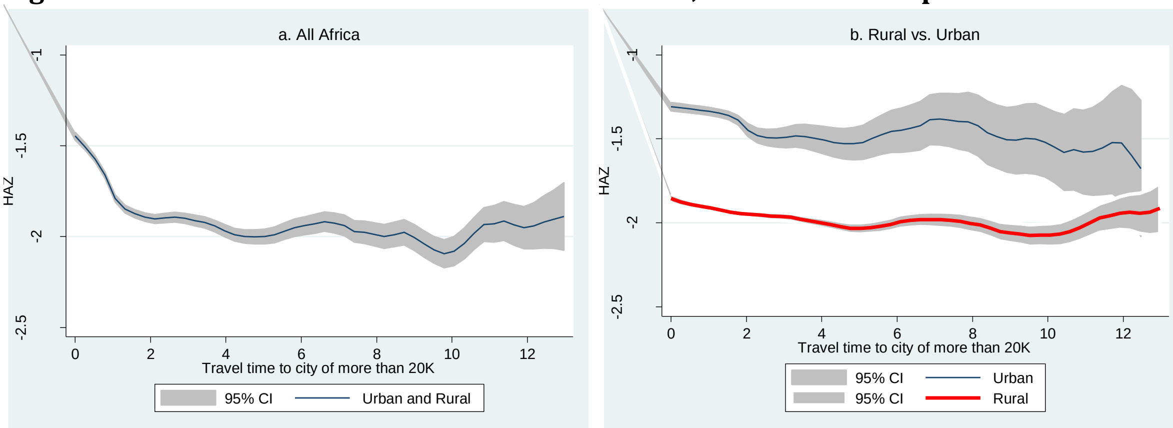
Notes: Unit of Analysis = Child of age 24-59 months + Sample sizes for number of food groups consumed are 34,447, 8,988, and 25459, respectively. NA refers to not applicable since agroclimatic indicators are measured at the cluster level itself.

Figure 1. Distribution of Child Height-for-Age Z-scores (HAZ) in 23 African Countries



Notes: These are kernel density plots implemented on the samples reported in Table 1.

Figure 2. Child HAZ and Travel Times to Cities of 20,000 or More People



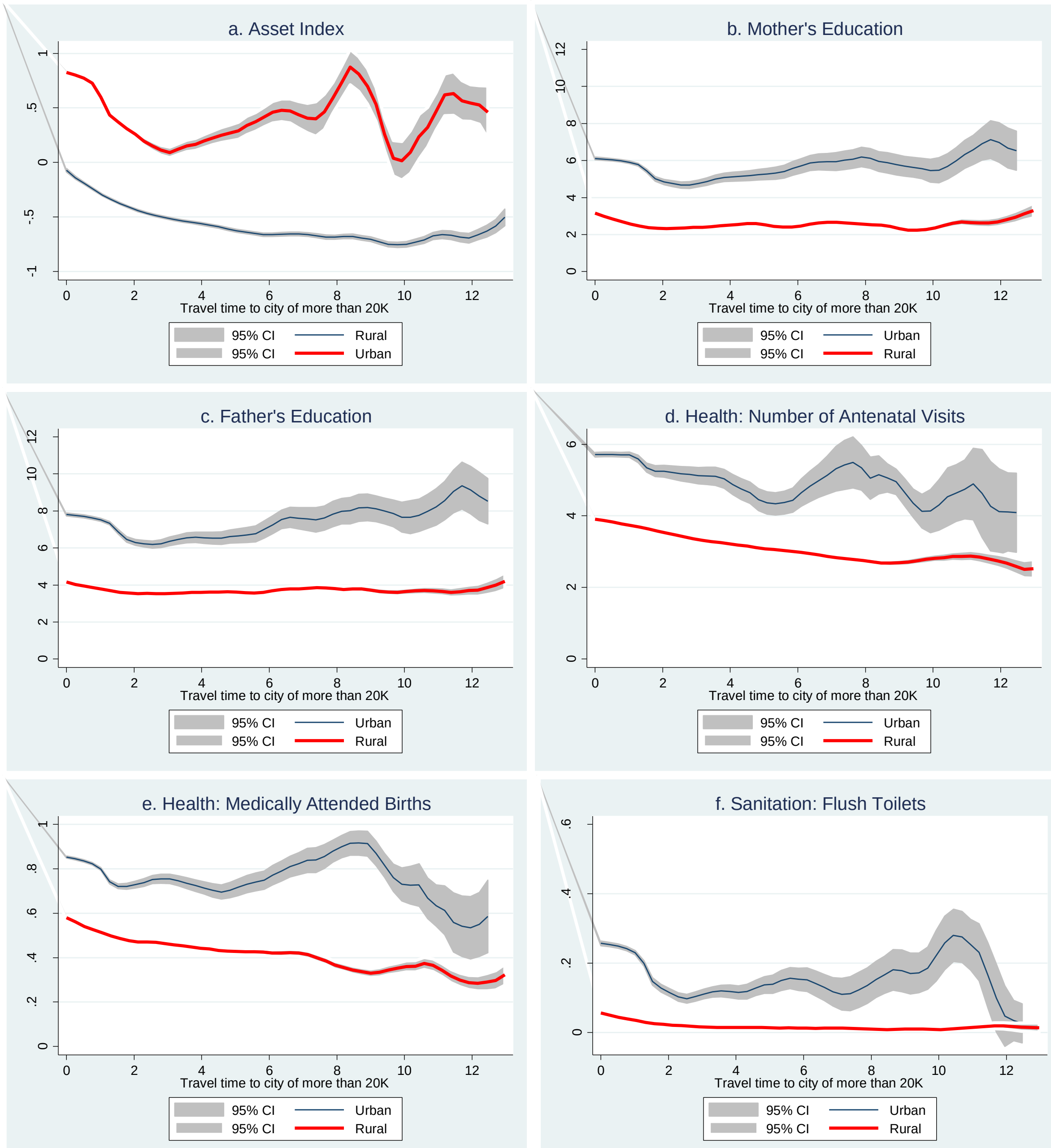
Notes: These are local polynomial plots with 95% confidence intervals implemented on the samples reported in Table 1.

Table 2. Least squares HAZ models for children 24-59 months of age in 23 African Countries

		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
Travel time to cities of 20,000+ (dummies)							
Small urban – close	(0-2 hours)						
(omitted category)							
Small urban - semi-isolated	(2-5 hours)	-0.10	-0.08	-0.08	0.05	0.02	0.06
		(0.08)	(0.08)	(0.08)	(0.08)	(0.07)	(0.07)
Small urban - isolated	(5+ hours)	-0.34***	-0.31***	-0.32***	-0.19**	-0.21***	-0.17**
		(0.09)	(0.09)	(0.09)	(0.08)	(0.08)	(0.08)
Rural - close	(0-2 hours)	-0.41***	-0.37***	-0.37***	-0.14***	-0.17***	-0.11***
		(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)
Rural - semi-isolated	(2-5 hours)	-0.46***	-0.41***	-0.41***	-0.14***	-0.17***	-0.10***
		(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Rural - isolated	(5+ hours)	-0.48***	-0.42***	-0.42***	-0.13***	-0.16***	-0.09***
		(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)
Country-Region Fixed Effects (μ)		Yes	Yes	Yes	Yes	Yes	Yes
Maternal & Child Characteristics (D)			Yes	Yes	Yes	Yes	Yes
Agricultural Conditions (A)				Yes	Yes	Yes	Yes
Household Wealth & Parental Education (W)					Yes		Yes
Social / Infrastructural Services (H)						Yes	Yes
R^2		0.01	0.03	0.03	0.05	0.05	0.05
Number of observations		74,398	74,398	74,398	74,398	74,398	74,398

Notes: Statistical significance denoted at *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$ based on robust standard errors (in parentheses).

Figure 3. Associations between travel times to cities of 20,000+ people and various household characteristics



Notes: These are local polynomial plots with 95% confidence intervals.

Table 3. Linear probability stunting models for children 24-59 months of age in 23 African Countries

		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
Travel time to cities of 20,000+ (dummies)							
Small urban – close *(omitted category)*	(0-2 hours)						
Small urban - semi-isolated	(2-5 hours)	0.04**	0.04**	0.04**	0.000	0.01	-0.003
		(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Small urban - isolated	(5+ hours)	0.11***	0.10***	0.10***	0.06**	0.07***	0.06**
		(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)
Rural - close	(0-2 hours)	0.12***	0.10***	0.10***	0.04***	0.05***	0.03***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Rural - semi-isolated	(2-5 hours)	0.13***	0.12***	0.12***	0.04***	0.05***	0.03***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Rural - isolated	(5+ hours)	0.14***	0.12***	0.13***	0.04***	0.05***	0.03***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Country-Region Fixed Effects (μ)		Yes	Yes	Yes	Yes	Yes	Yes
Maternal & Child Characteristics (D)			Yes	Yes	Yes	Yes	Yes
Agricultural Conditions (A)				Yes	Yes	Yes	Yes
Household Wealth & Parental Education (W)					Yes		Yes
Social / Infrastructural Services (H)						Yes	Yes
R^2		0.01	0.03	0.03	0.05	0.05	0.05
Number of observations		74,398	74,398	74,398	74,398	74,398	74,398

Notes: Statistical significance denoted at *** p < 0.01, ** p < 0.05, * p < 0.10 based on robust standard errors.

Table 4. Oaxaca-Type Decomposition of Rural-Urban Differences in Child HAZ

<u>Actual HAZ differences</u>	**Rural sample**	**Urban sample**
Mean HAZ scores	-2.00	-1.28
Difference		0.73
<u>Returns Effects[a]</u>	**Using rural means**	**Using urban means**
Distance from Cities (20,000+ residents)	-0.03	0.00
Child Characteristics	0.04	0.04
Mother's Characteristics	-0.05	-0.04
Agroclimatic Conditions	0.00	0.00
Parents' Education	0.00	0.00
Household Assets & Nonfarm Activities	0.01	0.07
Health / Infrastructural Services	-0.02	-0.03
Total returns effects (βu-βr)	*-0.05*	*0.04*
Share of HAZ difference explained:	0%	6%
<u>Endowment Effects[b]</u>	**Using rural coefficients**	**Using urban coefficients**
Distance from Cities (20,000+ residents)	0.00	0.00
Child Characteristics	0.00	0.00
Mother's Characteristics	0.05	0.06
Agroclimatic Conditions	0.00	0.00
Parents' Education	0.12	0.14
Household Assets & Nonfarm Activities	0.16	0.28
Health / Infrastructural Services	0.10	0.08
Total Endowment Effect (μu-μr)	0.43	0.57
Shareof HAZ difference explained:	59%	78%

Notes: a. Returns effects are the differences in coefficients across rural and urban samples multiple by either the sample mean form the rural sample (reported in Column 1) or the sample mean from the urban sample (reported in Column 2). b. Endowments effects are the differences in means across rural and urban samples multiplied by either the coefficients from the rural sample (reported in Column 1) or the coefficients estimated from the urban sample (reported in Column 2).

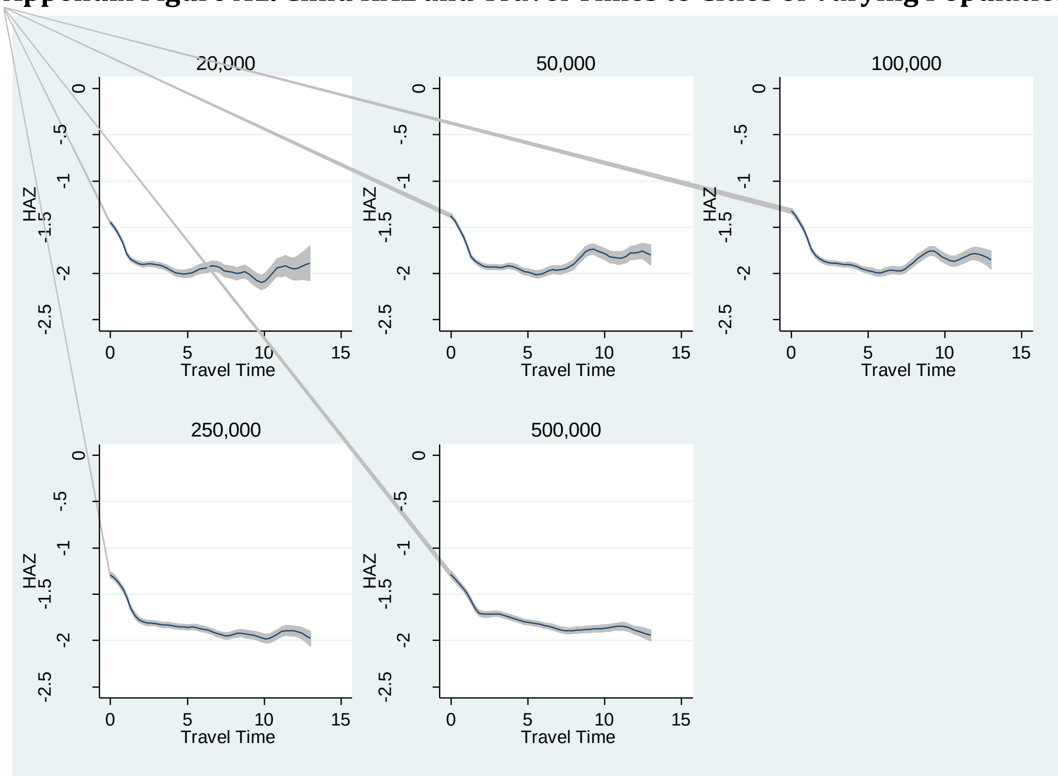
Table 5. Least squares dietary diversity models for children 24-59 months of age in 23 African Countries

		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
Travel time to cities of 20,000+ (dummies)							
Small urban – close	(0-2 hours)						
(omitted category)							
Small urban - semi-isolated	(2-5 hours)	-0.15*	-0.14*	-0.14*	-0.05	-0.04	-0.03
		(0.08)	(0.08)	(0.08)	(0.07)	(0.7)	(0.07)
Small urban - isolated	(5+ hours)	-0.06	-0.03	-0.03	0.07	0.07	0.08
		(0.12)	(0.12)	(0.12)	(0.13)	(0.12)	(0.12)
Rural - close	(0-2 hours)	-0.32***	-0.29***	-0.29***	-0.14***	-0.13***	-0.10***
		(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Rural - semi-isolated	(2-5 hours)	-0.35***	-0.32***	-0.32***	-0.13***	-0.12***	-0.09**
		(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)
Rural - isolated	(5+ hours)	-0.37***	-0.34***	-0.34***	-0.14***	-0.12**	-0.09
		(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Country-Region Fixed Effects (μ)		Yes	Yes	Yes	Yes	Yes	Yes
Maternal & Child Characteristics (D)			Yes	Yes	Yes	Yes	Yes
Agricultural Conditions (A)				Yes	Yes	Yes	Yes
Household Wealth & Parental Education (W)					Yes		Yes
Social / Infrastructural Services (H)						Yes	Yes
R^2		0.01	0.03	0.03	0.05	0.05	0.05
Number of observations		74,398	74,398	74,398	74,398	74,398	74,398

Notes: Statistical significance denoted at *** p < 0.01, ** p < 0.05, * p < 0.10 based on robust standard errors.

Appendix

Appendix Figure A1. Child HAZ and Travel Times to Cities of Varying Population Sizes



Note: Non-parametric regressions estimated with local polynomial smoother. The shaded region represents the 95th percent confidence interval.

Table A1. Countries Used in the Analysis and Definitions of Urban

	Country	DHS Year	GIS Roads Time Stamp	Definition of Urban*
1	Benin	2012	2009	Localities with 10,000 inhabitants or more.
2	Burkina Faso	2010	2012	Localities with 10,000 inhabitants or more and with sufficient socio-economic and administrative infrastructures.
3	Burundi	2010	2009	Commune of Bujumbura.
4	Cameroon	2011	2009	Administrative centers of territorial units (district, sub-division, division or province) or/and any locality with more than 5,000 inhabitants and with sufficient socio-economic and administrative infrastructures.
5	Comoros	2012	2010	Administrative centers of 'prefectures' and localities with 5,000 inhabitants or more.
6	Cote d'Ivoire	2012	2009	Agglomerations with 10,000 inhabitants or more; agglomerations with populations ranging from 4,000 to 10,000 inhabitants with more than 50 per cent of the households engaged in non-agricultural activities; and the administrative centers of Grand Lahoun and Dabakala.
7	DR Congo	2014	2010	NA
8	Ethiopia	2011	2012	Localities with 2,000 inhabitants or more.
9	Gabon	2012	2009	As of the 1993 census, towns with 3,000 inhabitants or more.
10	Ghana	2008	2012	Localities with 5,000 inhabitants or more.
11	Guinea	2012	2010	As of 1983, administrative centers of 'prefectures'.
12	Kenya	2009	2010	Municipalities, town councils, and other urban centers with 2,000 inhabitants or more. Due to substantial changes in the 1999 census delineations of urban areas, only the population for the "urban core" is considered to ensure consistency with previous censuses.
13	Lesotho	2009	2007	District headquarters and other settlements with rapid population growth and with facilities that tend to encourage people to engage in non-agricultural economic activities.
14	Liberia	2013	2010	Localities with 2,000 inhabitants or more.
15	Madagascar	2009	2009	Centers with 5,000 inhabitants or more.
16	Malawi	2010	2009	Townships, town planning areas and district centers.
17	Mali	2013	2009	For censuses up to 1987, localities with 5,000 inhabitants or more and district centers. Due to several historical changes in definition of urban areas, urban is defined in this publication as localities with 30,000 inhabitants or more in 1998

				and 2009 censuses.
18	Mozambique	2011	2011	From 1950 to 1970: Conselho of Maputo and Beira; in the 1980 census: 12 cities (Maputo, nine provincial capitals and the cities of Nacala-Porto and Chokwe); in the 1997 and 2007 censuses: 23 cities and 68 towns/villas. Estimates prior to 1980 were slightly adjusted to take into account other urban settlements.
19	Namibia	2007	2007	The district headquarters and other settlements of rapid population growth with facilities that encourage people to engage in non-agricultural activities.
20	Nigeria	2013	2012	Towns with 20,000 inhabitants or more.
21	Rwanda	2010	2012	Kigali (capital), administrative centers of prefectures and important agglomerations with their surroundings.
22	Senegal	2011	2007	Agglomerations of 10,000 inhabitants or more.
23	Sierra Leone	2013	2010	Towns with 2,000 inhabitants or more.

Note: * United National World Urbanization Prospects, 2014 Revision

Table A2: Wealth Index Components and Index Weights

	Mean	Weight
Electricity	0.375	0.234
Radio	0.629	0.053
TV	0.334	0.268
Refrigerator	0.120	0.094
Bicycle	0.234	-0.007
Motorcycle	0.289	0.032
Car	0.062	0.048
Floor - low quality	0.558	-0.199
Wall - high quality	0.416	0.205
Roof - low quality	0.381	-0.133
Phone	0.024	0.015