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Abstract

International poverty estimates for countries in Africa commonly rely on national consumer price indexes to adjust trends in nominal consumption over time for changes in the cost of living. However, the consumer price index is subject to various types of measurement bias. This paper uses Engel curve estimations to assess bias in the consumer price index and its implications for estimated poverty trends. The results suggest that in 11 of 16 Sub-Saharan African countries in this study, poverty reduction may be understated because of consumer price index bias. With correction of consumer price index bias, poverty in these countries could fall between 0.8 and 5.7 percentage points per year faster than currently thought. For two countries, however, the paper finds the opposite trend. There is no statistically significant change in poverty patterns after adjusting for consumer price index bias for the other three countries.

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CPI Bias and Its Implications for Poverty Reduction in Africa*

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I. Introduction

Consumer price indexes (CPIs) play an important role for our understanding of poverty trends in Africa. This is because international poverty estimates rely on national CPIs to express nominal consumption estimates from household surveys in real terms and the base year of the international poverty line.[1] However, there are concerns that CPIs may not always adequately reflect changes in the cost of living. Recent studies suggest that consumption growth and poverty reduction in Sub-Saharan Africa in the recent past may have been stronger than widely believed (see Kenny 2011; Young 2012; Pinkovskiy and Sala-i-Martin 2014), though others have challenged this notion (see Harttgen, Klasen and Vollmer 2013). Underlying these differing views about levels and trends in poverty and living standards in the region are often concerns about missing or inaccurate data, including concerns about the accuracy of measured inflation (see Beegle et al 2016).

There are several reasons why CPIs may not correctly measure changes in the cost of living. The most well-known causes, which have received considerable attention in the United States and other developed countries, are commodity substitution bias, outlet substitution bias, quality change bias and bias from the introduction of new goods (Schultze and Mackie 2002; Hausman 2003). Additional caveats arise for CPIs in Sub-Saharan Africa, due to weaknesses in country statistical systems, and when CPIs are used specifically for the purpose of measuring poverty trends (Beegle et al 2016). These include concerns about the representativeness of CPI weights for the poor (see Günther and Grimm 2007) and urban bias of the underlying input data (see Gaddis 2016).

The Engel curve method introduced by Costa (2001) and Hamilton (2001) attempts to address some of the above biases, mostly commodity and outlet substitution bias. Engel's law arises from the observation that the food budget share in household consumption declines with the increase in real household income. This suggests that movements in the food budget share over time can reveal changes in real incomes, conditional on changes in relative prices and household characteristics. As a corollary, among demographically similar households at the same level of real income, differences in food budget shares at different points in time might signal mismeasurement of the true change in cost of living.

[1] The current international poverty line stands at $1.90 per person per day in 2011 international dollars. See PovcalNet for the latest international poverty estimates: http://iresearch.worldbank.org/PovcalNet/.

This paper studies the direction and magnitude of CPI bias for 16 Sub-Saharan African countries using the Engel curve method and estimates the implications of this bias on the measured change in the incidence of poverty. This Engel curve method has been applied to different countries in the world, such as Australia (Barrett and Brzozowski 2010), Brazil and Mexico (De Carvalho Filho and Chamon 2012), Canada (Beatty and Larsen 2005), China (Chamon and De Carvalho Filho 2014; Nakamura, Steinsson and Liu 2016), Indonesia (Olivia and Gibson 2013), the Republic of Korea (Chung, Gibson and Kim 2010), New Zealand (Gibson and Scobie 2010), Norway (Larsen 2007), the Russian Federation (Gibson, Stillman, and Le 2008), and the United States (Costa 2001, Hamilton 2001, Logan 2009). However, to the best of our knowledge, no such analysis exists for countries in Africa. The contribution of this paper is to provide comparable estimates of CPI bias for 16 countries in Sub-Saharan Africa to further our understanding of price changes and their implications on poverty trends in the region.

Using comparable consumption data from 16 Sub-Saharan African countries, namely, Burkina Faso, Cameroon, Côte d'Ivoire, Democratic Republic of Congo, Ethiopia, Ghana, Madagascar, Mauritius, Mozambique, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Togo, and Uganda, combined with monthly food, non-food, and overall CPI data from the respective national statistical offices (NSOs) our results suggest that the official CPIs mostly overestimate increases in the cost of living. In the 13 countries where our results indicate that CPIs overestimate inflation, the average annual CPI upward bias ranges from 0.7 percent in Cameroon to 43.9 percent in Nigeria. Three countries, Burkina Faso, Ghana, and Uganda, experience a negative bias between -8.9 percent a year in Burkina Faso and -5.8 percent in Ghana. These estimates of CPI bias are statistically significant, except for Cameroon and Ghana.

Armed with these estimates of bias in national CPIs, we study the implications for measured trends in international poverty. Correcting for CPI bias, poverty falls significantly faster than suggested by current international poverty numbers in 11 countries. Based on our estimates, the difference in poverty reduction resulting from CPI-bias adjustment could be as large as -5.7 percentage points per year in Tanzania between 2008 and 2012. Only two countries, Uganda and Ghana, experience significantly slower poverty reduction rates with the correction of CPI bias. The change in poverty trend due to CPI bias correction is statistically insignificant in Mauritius, Cameroon, and Burkina Faso. While we advise to interpret individual country estimates and the magnitude of point

estimates with a degree of caution, this is suggestive evidence that African countries may have been more successful in reducing poverty than currently thought.

The paper is organized as follows. Section II explains why CPIs in Sub-Saharan Africa may be biased and outlines the Engel curve method. Section III describes our empirical methodology, while section IV describes the data sources. Section V shows estimates of the CPI bias and conducts several robustness checks. Section VI assesses the implications of CPI bias for measured poverty trends. Section VII concludes.

II. Literature review

CPI bias in Sub-Saharan Africa

The CPI measures the rate at which the prices of a specific basket of goods and services change from month to month. To compute the CPI, NSOs require price and quantity data for a variety of goods and services. Virtually all NSOs in Sub-Saharan Africa run regular monthly consumer price data collection programs, which form the basis for computing the CPI. In addition, estimating a weighted average of price changes relative to a base period requires data on consumed quantities as budget shares. These quantity data typically come from nationally representative household budget surveys (HBS), which most NSOs field in irregular intervals (see Beegle et al 2016).[2]

Most NSOs use a fixed-base Laspeyres-type index and staged aggregation approach to compute the CPI (see United Nations 2009). In a first step, individual price quotations are combined to elementary aggregates that represent broad goods categories purchased by consumers in a specific locality and type of outlet. In the second step, elementary aggregates are combined to commodity-group indexes (for example, food and beverages, apparel, transport) and ultimately the all-item CPI using weights (budget shares) estimated from the HBS for a base period.

It is well-known that Laspeyres indexes tend to overstate changes in the cost of living. This is because they hold quantities fixed in the base period and disregard consumer substitution behavior

[2] The term HBS is used to denote national household surveys collecting consumption data, this includes a range of surveys that go by different labels, e.g. Living Standards Survey, Income, Expenditure and Consumption Survey, etc.

towards goods that have become relatively cheaper over time (Deaton 1998). This *commodity substitution bias* may be particularly relevant in Sub-Saharan Africa, where many countries lack regular HBS programs. According to metadata of the International Labour Organization (ILO 2013), which depict national practices in computing CPIs as of July 2012, 13 percent of the population in the region was living in countries in which the baskets were based on data from the 1990s, and an additional 23 percent was living in countries were basket weights dated between 2000 and 2004 (see Beegle et al 2016).

A related issue is that CPIs often do not reflect differences in the prices of the same product purchased at various outlets if distribution channels change over time. This is referred to as the *outlet substitution bias*. In many African countries, for example, the popularity of supermarkets that offer discounted prices has been growing, at least in urban areas. Because the CPI does not account for the shift among consumers towards these more economic retail outlets (for items previously purchased in traditional stores), it overstates actual inflation.

CPIs also do not account for changes in the quality of existing goods and services in the basket, which leads to a *quality change bias*. Over the years, as technology has evolved, many products have exhibited dramatic improvements (for example, greater functionality or safety, greater nutritional value, and so on). However, it is typically very difficult to separate out how much of the price change recorded for a specific product is associated with a change in quality and how much is associated with actual inflation.[3] Similarly, it often takes many years until newly available goods and services are introduced into the CPI computation, the *new product bias*. Because the CPI fails to capture the benefits to consumers from greater availability of products and brands, changes in the cost of living are typically overstated.

The CPIs in many countries in Sub-Saharan Africa suffer from additional sources of bias and measurement error. An important example is *urban bias*. Because a number of NSOs in the region collect price data solely in urban areas, their CPIs reflect changes in prices experienced by the urban population, in some cases, the population living in the capital city only. For example,

[3] NSOs in developed countries often use splicing procedures, which attribute a certain fraction of the overall price change to quality, or rely on hedonic estimation techniques, which explicitly model quality. Nonetheless, there is evidence that some degree of quality improvement is typically not captured and that quality change bias often leads to an overestimation of inflation (Boskin et al 1996, 1998; Hausman 2003).

Tanzania's national CPI reflects the prices surveyed in urban areas in 21 regions across the country. Meanwhile, Madagascar's national CPI reflects the prices of goods and services in the capital, Antananarivo, only. Similarly, before 2011, the National Statistical Institute of the Democratic Republic of Congo did not collect prices in any administrative province except Kinshasa, the capital. When price data in rural areas are not available, CPIs are based on urban price data only, with the (arguably strong) assumption that urban and rural prices move in parallel. What is more, even when HBS data are nationally representative, some countries compute budget shares for urban households only. In Tanzania, for instance, CPI weights until 2009 were based on consumption patterns among urban households in the 2001 HBS. In 2010, as part of the process of rebasing the index to the HBS 2007, the reference population for the weights was broadened to include rural households (Tanzania NBS 2010).

Finally, for the purpose of poverty analysis, concerns arise over the fact that the weights are not representative of poor households' consumption patterns. CPI weights are computed as the consumption shares of an aggregate reference population, which attaches a weight to each household in proportion to its total expenditures. Because of this plutocratic bias, CPI weights reflect consumption patterns of households at the upper end of the distribution (Nicholson 1975, Deaton 1998). In times of changing relative prices, such as during food price shocks, inflation measured by the CPI can then differ from the inflation experienced by poorer population groups (Günther and Grimm 2007).

The Engel curve method

The Engel curve method attempts to address some of the above biases, mostly the commodity and outlet substitution biases.[4] The method takes as a starting point Engel's Law and the idea that movements in food budget shares that cannot be explained by changes in relative prices and household characteristics reveal changes in real incomes. As a result, any systematic difference over time in the food budget shares of demographically similar households at the same level of real income (CPI deflated) and facing the same relative prices is assumed to reflect mismeasurement in the CPI. This Engel curve method was first introduced by Costa (2001) and

[4] According to Hausman (2003), the method only accounts for commodity and outlet substitution bias. Beatty and Larsen (2005), however, argue that it also captures some quality change bias arising from increased durability.

Hamilton (2001). Using nationwide consumption surveys between 1888 and 1994 in the United States, Costa (2001) finds that the CPI underestimated increases in the true cost of living until 1919, but consistently overestimated them thereafter. Hamilton (2001), using a different set of data, the Panel Study of Income Dynamics between 1974 and 1991 in the United States, finds a similar trend. In particular, he estimates the annual CPI upward bias at approximately three percentage points between 1974 and 1981 and slightly less than one percentage points between 1981 and 1991. The results of Costa (2001) and Hamilton (2001) are also broadly consistent with the findings of Boskin et al (1996, 1998), who calculate the contribution of each source of CPI bias and conclude that between 1979 and 1995 the United States CPI exhibited an upward bias of 1.1 percentage points per year.

Since then the Engel curve method has been applied to various other countries. In two papers referring to Canada, Beatty and Larsen (2005) and Brzozowski (2006) find that the Canadian CPI overstated changes in the cost of living among specific demographic groups. Similarly, Barrett and Brzozowski (2010), in a study on the Australian CPI, show there was cumulative upward bias of 34 percent between 1975 and 2003, although the magnitude of the bias varies by household type and time period considered. In New Zealand, Gibson and Scobie (2010) argue that the country's CPI overestimated inflation by an amount similar to the bias in the United States. In contrast, Larsen (2007), following the same method but using data on Norway in the 1990s, concludes that the CPI understated the increase in the cost of living.

More recently, the application of the Engel curve method has been extended to developing and transitional economies in Asia and Latin America. De Carvalho Filho and Chamon (2012) argue that post-reform growth in real household incomes in Brazil and Mexico was underestimated because the CPI overstated the increase in the cost of living. Gibson, Stillman, and Le (2008) obtain similar results using data from Russia during the transition period between 1992 and 2001. In Indonesia, Olivia and Gibson (2013) find that the CPI bias was negative during the 1997–98 financial crisis, but consistently positive since 2000. In China, Nakamura, Steinsson and Liu (2016) find that official inflation rates show less variability over time than actual inflation rates.

While Engel curve estimates have become a widely used methodology to cross-triangulate official inflation trends, the method is not without limitations. Its major weakness is that any drift in the Engel curve that cannot be explained by the covariates in the regression model is attributed entirely

to CPI bias. This assumption may not hold if there are additional, unobserved forces that shift the Engel curve - such as changes in preferences, or variations in the way consumption data are collected. Analysis in Gibson, Le and Kim (2016), for example, suggests that the method does not perform well in a spatial context. A similar concern is that even though the method controls for changes in household characteristics, biases can arise from assumptions about the nature of relationship between these covariates and the food share. For example, Logan (2009) argues that the effect of household size on demand varies over time and that this is not captured by the standard Engel curve estimation because of the way demographic effects are modeled. Using household survey data on the United States from 1888 and 1935, Logan (2009) finds that when changing household size effects are taken into account, estimates of CPI bias are reduced by 25 percent.[5]

A related critique is that Engel curve estimates conflate various types of CPI bias and are hence difficult to interpret. As noted earlier, Engel curve estimations are used primarily to tackle biases arising from commodity and outlet substitution. However, as argued by Beatty and Crossley (2012), the method may conflate the above form of CPI bias with inflation inequality across the distribution (plutocratic bias). This may be problematic, in particular, if Engel curve estimations are used to make statements and recommendations referring to the quality of the CPI and its methodology. Plutocratic weights, for example, are preferred for some purposes of the CPI, such as the deflation of economic aggregates (Pollak 1998) and are hence (at least partly) an explicit component in the design of the index.[6]

III. Empirical methodology

Our starting point is the Leser-Working form of the food Engel curve, which is defined as a linear function of the log of real total expenditure and a relative price term, as follows:

$$w_{i,j,t} = \phi + \gamma\left(\ln P_{F,j,t} - \ln P_{N,j,t}\right) + \beta\left(\ln Y_{i,j,t} - \ln P_{j,t}\right) + \mathbf{X}'\theta + u_{i,j,t} \qquad (1)$$

[5] However, it is unclear whether the household size correction decomposes or modifies CPI bias estimates.

[6] It is not entirely clear how important plutocratic bias is in practice. Case studies show that distributional differences in inflation can be significant in times of rapidly changing prices, e.g. after a drought or other supply side shock (Günther and Grimm 2007). Studies for the US, on the other hand, often find little systematic inequality in inflation across the income distribution (Kokoski 2000; Kaplan and Schulhofer-Wohl 2016).

where $w_{i,j,t}$ is the food budget share of household i in region j at time t; $P_{F,j,t}$ is the true price of food items; $P_{N,j,t}$ is the true price of non-food items; and $P_{j,t}$ is the true price of all goods, which is a weighted average of $P_{F,j,t}$ and $P_{N,j,t}$; $Y_{i,j,t}$ is total household expenditure; $\mathbf{X}$ is a vector of individual household characteristics, and u is the residual.

Hamilton (2001) decomposes any observed price level, $P_{j,t}$, into the true price level and an error term, under the assumption that the error term is uniform across region j, as follows:

$$\ln P_{j,t} = \ln P_{j,0} + \ln\left(1 + \Pi_{j,t}\right) + \ln\left(1 + E_t\right). \tag{2}$$

where $P_{j,0}$ is the true price at time *0*; $\Pi_{j,t}$ is the cumulative percent increase in the CPI from year *0* to year t; and E_t is the cumulative percent measurement error in the CPI from year *0* to year t.

Inserting equation (2) into equation (1) leads to the following:

$$\begin{aligned} w_{i,j,t} = {} & \phi + \gamma\left[\ln\left(1 + \prod_{F,j,t}\right) - \ln\left(1 + \prod_{N,j,t)}\right)\right] + \beta\left[\ln Y_{i,j,t} - \ln\left(1 + \prod_{j,t}\right)\right] + \mathbf{X}'\theta + \\ & \gamma\left[\ln\left(1 + E_{F,t}\right) - \ln\left(1 + E_{N,t}\right)\right] - \beta \ln\left(1 + E_t\right) + \gamma\left(\ln P_{F,j,0} - \ln P_{N,j,0}\right) - \beta \ln P_{j,0} + u_{i,j,t} \end{aligned} \tag{3}$$

If cross-sectional household consumption data and a cross-sectional CPI for food, non-food and all items over the entire sample period are available, the following equation can be estimated:

$$\begin{aligned} w_{i,j,t} = {} & \hat{\phi} + \gamma\left[\ln\left(1 + \prod_{F,j,t}\right) - \ln\left(1 + \prod_{N,j,t}\right)\right] + \beta\left[\ln Y_{i,t} - \ln\left(1 + \Pi_t\right)\right] \\ & + \mathbf{X}'\theta + \sum_{t=1}^{T} \delta_t D_t + \sum_{t=1}^{J} \delta_j D_j + u_{i,j,t}. \end{aligned} \tag{4}$$

where D_t is a dummy variable equal to 1 in year t; D_j is a dummy equal to 1 for region j; and $\hat{\phi}$ is the constant term from equations (1) and (3), plus the coefficients of the omitted time and the omitted region dummies.

The time dummy variables, δ_t, are used to measure the CPI bias as follows:

$$\delta_t = \gamma\left[\ln\left(1 + E_{F,t}\right) - \ln\left(1 + E_{N,t}\right)\right] - \beta \ln\left(1 + E_t\right) \tag{5}$$

If the relative bias in food and non-food prices, $r = \frac{\ln(1+E_{F,t})}{\ln(1+E_{N,t})}$, is constant throughout the sample period, the CPI bias for all goods, ln(1+E_t), can be identified by:

$$\ln(1 + E_t) = \frac{-\delta_t}{\beta - \frac{\gamma(1-r)}{1-\alpha(1-r)}} \tag{6}$$

where α is the food share in the CPI.

Assuming that either the CPI bias in food and non-food prices is equal, r=1, or that changes in the relative price ratio of food to non-food items do not affect the food budget share, γ=0, equation (6) can be re-written as follows:

$$\ln(1 + E_t) \approx \frac{-\delta_t}{\beta} \tag{7}$$

However, if (1-r) and γ are different from zero, then (7) gives a biased estimate of the CPI bias. The bias is positive if (1-r) and γ are of the same sign and negative otherwise.

From (7), the cumulative percent CPI bias between time *t* and time 0 can be calculated as:

$$Bias_t = 1 - \exp\left(\frac{-\delta_t}{\beta}\right) \tag{8}$$

Following Barrett and Brzozowski (2010), the correction factor that multiplies the measured CPI in time *t* to give the true cost of living index in time *t* is given by:

$$Correction_t = 1 - Bias_t = \exp\left(\frac{-\delta_t}{\beta}\right) \tag{9}$$

If data on the cross-sectional variation in relative food prices are not available, which is often the case in Sub-Saharan African countries, equation (4) cannot be estimated because the coefficient γ for the relative prices of food and non-food items in each region *j* cannot be identified. Using temporal movements in the national price index for food items relative to non-food items is equally not possible because this period-to-period variation is perfectly correlated with the time dummy variables, D_t. However, it is possible to estimate a simple model of the food budget share:

$$w_{i,j,t} = \hat{\phi} + \beta\left[\ln Y_{i,j,t} - \ln(1+\Pi_t)\right] + \mathbf{X}'\theta + \sum_{t=1}^{T}\delta_t D_t + \sum_{j=1}^{J}\delta_j D_j + u_{i,t} \quad (10)$$

In this case, the coefficient δ_t of the time dummy variables, D_t, measures both the CPI bias in equation (4) and the effect on the budget share of the intertemporal variation in the observed prices for food relative to non-food items. Thus, the cumulative percent CPI bias at time *t* is given by:

$$Bias_t = 1 - \exp\left\{\frac{\delta_t - \bar{\gamma}\left[\ln(1+\pi_{F,t}) - \ln(1+\pi_{N,t})\right]}{-\beta}\right\} \quad (11)$$

where $\pi_{F,t}$ and $\pi_{N,t}$ are the cumulative percent increase in the food and non-food CPI, respectively, between time 0 and time t, and $\bar{\gamma}$ must be obtained from outside the estimated parameters in equation (4) as described in section VI.[7]

To estimate the implication of CPI bias for poverty in time *t* in a given country *c*, we revise the international poverty line, currently $1.90 per person per day in 2011 dollars, by adjusting for CPI bias estimated according to equation (8) or equation (11). First, we convert the international poverty line to local currency units in time *0*, that is the year of the sample period closest to 2011 (the year that anchors the poverty line and Purchasing Power Parity exchange) for a given country *c*. Next, we update the poverty line in time *t*, that is the other year of the sample period, using the correction factor described in equation (9).[8] The adjusted poverty line in time *t* for country *c* is then [9]:

$$AdjustedPovline_{c,t} = \frac{1.90PPP_{c,2011}}{(1+\Pi_{c,2011})(1+\Pi_{c,t}Correction_{c,t})} \quad (12)$$

[7] Without cross-sectional CPI data, $\pi_{F,t}$ and $\pi_{N,t}$ are constants.

[8] Time *0* could be the beginning year or the end year of the sample period. For example, for Rwanda 2005-2010, time *0* is 2010. In the case of Nigeria 2011-2013, time *0* is 2011.

[9] Equation (12) applies to most countries in our sample where time 0 is earlier than 2011. In some special cases where time *t* < 2011 < time *0* (Congo, D.R. 2004-2012, Ghana 2005-2012, Mauritius 2006-2012, Tanzania 2008-2012, Tanzania 2010-2012, and Uganda 2009-2012), the adjusted poverty line is calculated as:
$AdjustedPovline_{c,t} = \frac{1.90PPP_{c,2011}(1+\Pi_{c,2011})}{(1+\Pi_{c,t}Correction_{c,t})}$.
In a special case where 2011 < time *0* < time *t* (Nigeria 2011-2013), the adjusted poverty line is calculated as:
$AdjustedPovline_{c,t} = 1.90PPP_{c,2011}(1+\Pi_{c,2011})(1+\Pi_{c,t}Correction_{c,t})$.

where $PPP_{c,2011}$ is the Purchasing Power Parity conversion factor in year 2011 for country c; $\Pi_{c,2011}$ is the cumulative percent increase in the CPI from time *0* to year 2011; $\Pi_{c,t}$ is the cumulative percent increase in the CPI from time *0* to time t; and $Correction_{c,t}$ is the correction factor for country c in time t, estimated from equation (9).

IV. Data

The Engel curve method requires detailed monthly CPI data on food and non-food items at regional levels and comparable consumption surveys in multiple years. However, data in Sub-Saharan Africa are challenging in terms of availability and quality. Of the 48 countries in the region, only half has two or more HBSs since the early 2000s (Beegle et al 2016). Among these, only a limited number collect consumption data using the same (or at least similar) survey design and methodology, thereby rendering the consumption aggregates comparable over time. Obtaining detailed CPI series adds another layer of difficulty. In some of the countries with comparable HBSs, detailed CPI data are either unavailable during the periods of interest or the continuity of the series has been disrupted due to political unrest or other factors, as, for example, in the case for Sierra Leone.

For the purpose of this study we obtain household consumption and CPI data for 16 countries in Sub-Saharan Africa that account for 70 percent of the regional population.[10] These countries are Burkina Faso, Cameroon, Côte d'Ivoire, Democratic Republic of Congo, Ethiopia, Ghana, Madagascar, Mauritius, Mozambique, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Togo, and Uganda. For Nigeria and Tanzania we use panel data from the Living Standards Measurement Study–Integrated Survey on Agriculture (LSMS-ISA), partly to address quality concerns with other consumption surveys (World Bank 2014, 2015).[11] Only household survey series considered as comparable over time (in terms of the broad data collection method for consumption data and

[10] We use consumption rather than income because it is generally thought to be a better measure of permanent income and is also easier to measure in economies with large agricultural or other informal sectors (see Deaton 1997).

[11] See LSMS-ISA (database), World Bank, Washington, DC, http://go.worldbank.org/BCLXW38HY0.

seasonality) are included in the analysis (see Beegle et al 2016). Table 1 provides a list of the microdata used in this study.

We obtain monthly national CPI data disaggregated into food and non-food components from the respective NSOs. In terms of geographical coverage, all countries, except Nigeria and Rwanda, only collect prices in urban areas. In other words, the national CPIs in these countries reflect the prices paid by urban residents. Conversely, the national CPIs in Nigeria and Rwanda reflect both rural and urban prices. In terms of the availability of cross-sectional CPIs, regional CPI data are available for only four countries – Ethiopia, Ghana, Mozambique, and Uganda. These data allow us to estimate the CPI-bias based on equation (4). The remaining countries only have national CPIs, and we are therefore required to apply equation (10) for the CPI-bias estimation. Table 2 lists the CPI data used in this study.

Detailed expenditure data are aggregated into two broad groups: food expenditure and total expenditure. Food expenditure is defined as expenditure for the consumption of food, nonalcoholic beverages, alcoholic beverages, and tobacco from own-production, market purchase, and gifts. Total household expenditure includes spending on food and non-food expenditure, such as clothing, housing, household furnishings and equipment, health and personal care, education, transport, communications, recreation, and miscellaneous goods and services. We then merge the consumption data for each household with the monthly CPI during the period when the household was interviewed. This allows for temporal variations in inflation patterns.

We use several criteria to select our analysis sample. First, to minimize the effect of extreme outliers, which may indicate data quality problems, households with a food budget share of less than 2 percent or greater than 95 percent are excluded. Second, to render household demographics more homogeneous, we exclude households in which the household head is younger than 21 years of age or older than 75 years of age. These restrictions are similar to those used by Costa (2001), Gibson, Stillman, and Le (2008) and Hamilton (2001). Finally, rural households in all the countries in this study, except Mauritius, Nigeria, and Rwanda, are dropped because the CPIs in these countries reflect prices faced by urban populations only.[12] Because of this, our estimates of CPI

[12] While the national CPIs for Mauritius reflects urban prices only, the Household Budget Survey for Mauritius does not identify households' location – either urban or rural areas. Therefore, all households must be included for the estimates of CPI bias in the case of Mauritius.

bias should be interpreted as the wedge between CPI inflation and the change in the cost of living experienced by the average urban household. This difference may reflect substitution bias of the CPI, but also some degree of inflation inequality across the distribution.

Engel's Law postulates a negative relationship between a household's food budget share and real income for any homogeneous population group facing the same relative prices. Besides our main explanatory variables – CPI-deflated total consumption, relative food prices, regional and time dummy variables – we also control for key characteristics of the household (e.g. household size and the share of children) and its head (e.g. age, gender, education, and marital status).

V. Estimation results

Table 3 provides summary statistics of the data used in our analysis. As stated in Engel's Law, the average household food share falls as income rises. Thus, we can see that the average budget share devoted to food could be as low as 30 percent in upper middle income countries such as Mauritius and as high as 74 percent in low income countries such as Madagascar.

To show how the food budget share changes over time, the averages of the variables in different survey periods are reported for each country. All countries except Ghana experienced a decline in the share of food in total consumption between the first and the last survey periods. According to Engel's Law, this drop in the budget share of food may indicate improved living standards.

Figure 1 plots Engel curves for 16 Sub-Saharan African countries. The graphs are based on households with a food budget share between 2 percent and 95 percent of total consumption and with household heads aged between 21 and 75 years. The solid (reference) lines are the Engel curves of the oldest survey in each country. The dotted lines are the Engel curves for subsequent survey years.[13]

All countries in our study show movements of the Engel curves over time. In 13 of the 16 countries, namely, Burkina Faso, Cameroon, Côte d'Ivoire, Democratic Republic of Congo, Ethiopia, Madagascar, Mauritius, Nigeria, Rwanda, Senegal, South Africa, Tanzania, and Togo, the dotted

[13] These are bivariate graphs without any controls.

curve lies below the solid reference curve. This indicates that Engel curves have drifted to the left, a signal that the national CPIs in these countries may overstate the increase in cost of living. In Ghana, Mozambique, and Uganda the direction of the CPI bias does not seem consistent across the income distribution. In Ghana, for example, the CPIs appear downward-biased among those people at the lower end of the income distribution, while they appear biased in the opposite direction among people at the upper end of the distribution. The pattern is reversed in Mozambique and Uganda.

While the illustrations in Figure 1 show a clear drift in the Engel curves for the countries in our study, movements in food budget shares could also be attributed to changes in relative prices, household characteristics, etc. Thus, we use regression analysis to condition on these potentially confounding influences and assess the actual drift in the food Engel curve.

Table 4 reports the results of ordinary least square (OLS) regressions of the Engel functions. All regressions are weighted by population-level sampling weights (as discussed later in this section, unweighted regressions are run as a robustness check). As explained in section III, we apply equation (4) to Ethiopia, Ghana, Mozambique, and Uganda (linked to the availability of cross-sectional price data) and equation (10) to the rest of the countries. We also limit our sample to urban populations for all countries except Mauritius, Nigeria, and Rwanda.

Across all countries, the estimated regression coefficients for CPI-deflated total expenditure are negative and statistically significant. These results are consistent with Engel's Law that food budget shares decline as households become richer. The coefficients of the various household characteristics show that, in general, food shares are higher among households of larger size, with younger children, and with heads who are married or older. Food shares decline among households in which the heads have higher educational attainment. There is no clear pattern across countries between the gender of the household head and the food budget share.

The signs of the time dummy variables in Table 4 are consistent with the shifts in the food Engel curves illustrated in Figure 1. They suggest a drift to the left in the food Engel curves in Cameroon, Côte d'Ivoire, the Democratic Republic of Congo, Ethiopia, Madagascar, Mauritius, Mozambique, Nigeria, Rwanda, Senegal, South Africa, Tanzania, and Togo. This drift suggests that growth in real consumption is underestimated. Meanwhile, the food Engel curves in Burkina Faso, Ghana,

and Uganda seem to shift to the right, suggesting an overestimation of real consumption growth. The coefficients of the time dummies for Burkina Faso and Cameroon are not statistically significant at the 5 percent level.

Table A1 in appendix 1 shows the results of two robustness checks. The first is to add to the existing model the quadratic log of CPI-deflated total consumption to account for Engel curvature – that is non-linearity in the relationship between a household's real income and its food share. This concept is first introduced by Costa (2001) as an extension of Hamilton's work. The second robustness check is to run unweighted regressions, because there has been some debate about the use of sampling weights in regression analysis (see Deaton 1997). Both specifications show similar results for the time dummy variables similar to our main specification in Table 4 (for ease of comparison, repeated in Table A1 under the column OLS). The only exception is Mozambique, where the sign of the time dummy coefficient changes when sampling weights are disregarded, which suggests significant heterogeneity in region-specific bias in this country. Further investigation reveals that the observed results are mostly driven by the bias in urban cities in Namputa province, the most populous province in the country which accounts for approximately 20 percent of the weighted population. In fact, if we drop Namputa from our sample, the regression results are similar regardless of whether sampling weights are used.

Finally, to obtain estimates of CPI bias for the 12 countries that lack cross-sectional CPI data, it was necessary to estimate $\bar{\gamma}$ in order to remove any effect of differential inflation rates on food and non-food items in the budget share of food. Appendix 2 explains these calculations in detail.

Table 5 presents estimates of $\bar{\gamma}$ for all countries that do not have cross-sectional CPI data. Overall, $\bar{\gamma}$ is estimated to range from 0.17 to 0.24, compared with the values of $\bar{\gamma}$ = 0.044 used by Olivia and Gibson (2013) for Indonesia, 0.109 by Gibson and Scobie (2010) for New Zealand, 0.19 by Gibson, Stillman, and Le (2008) for Russia, and 0.037 used by Hamilton (2001) for the United States. Because we do not have sufficient data to measure $\bar{\gamma}$ for the Democratic Republic of Congo, we assign the country the regional average of 0.22.

Finally, columns 1, 2 and 3 in Table 6 show the cumulative CPI bias, its standard error and p-value computed using the delta method for the 16 countries in our study. We assume that in each country

this bias is constant over the sample period to calculate the average annual bias presented in column 4. The correction factor, that is the CPI multiplier to estimate true inflation, is shown in column 5.

The CPI bias is positive and statistically significant for the sample periods in 12 of the 16 countries in our study, namely, Côte d'Ivoire, the Democratic Republic of Congo, Ethiopia, Madagascar, Mauritius, Mozambique, Nigeria, Rwanda, Senegal, South Africa, Tanzania, and Togo. In these countries, households allocated their budget share on food as if their true cost of living was increasing more slowly than the rate indicated by the CPI. The upward bias ranges from 2.8 percent a year in Ethiopia between 2004 and 2010 to 43.9 percent a year in Nigeria between 2011 and 2013. Meanwhile, two countries experienced the opposite trend in the CPI bias, ranging from -7.5 percent a year in Uganda between 2009 and 2012 to -8.9 percent a year in Burkina Faso between 1998 and 2003. The bias is not statistically significant in Cameroon and Ghana.

VI. Implications of CPI bias for poverty trends in Africa

Consumer price indexes (CPIs) play a pivotal role for the measurement of poverty trends in Sub-Saharan Africa. The World Bank's international poverty estimates currently use an international poverty line of $1.90 per person per day at 2011 international prices. This poverty line is affected by CPI bias, because CPIs are used to deflate the poverty line between the year of the household survey and 2011 (the benchmark year of the purchasing power parity exchange rates). In addition, some countries in Sub-Saharan Africa use the CPI to update their national poverty lines. National poverty lines are usually based on the Cost of Basic Needs (CBN) approach which aims to compute the cost of maintaining some basic living standard. A typical CBN poverty line is calculated from the cost of a food basket that meets certain food energy requirements – for example 2,100 calories per person per day – and observed spending on non-food essentials such as clothing and household items (Ravallion 1998). Anyone living below this poverty line is considered poor. Some countries – for example Uganda and Mauritania – use the CPI to update their national poverty lines over time.[14]

[14] Other countries have used the CPI in the past, for example Ethiopia (before the 2010 update) and Zambia (before the 2009 revision of 1996-2006 poverty estimates).

In this section, we re-assess poverty estimates for the 16 countries in our study to account for the cumulative CPI bias estimated in the previous section. In countries where the CPI overstates the increase in cost of living, the poverty lines adjusted for CPI bias will show a more moderate increase over time (in nominal terms) than the ones typically reported, therefore increasing measured poverty reduction. The opposite effect occurs in countries where the CPI understates inflation. For the purpose of evaluating the poverty implications of CPI bias, we make the strong assumption that in the 14 countries where prices are only collected in urban areas, the estimated CPI bias also applies to rural areas.[15]

The calculation of the adjusted poverty lines is described in equation (12). Table 7 presents official inflation rates and estimates of inflation adjusted for CPI bias. Table 8 illustrates the implications of this CPI bias for poverty reduction in all countries in our study.

The correction factors in Table 7 range widely, from 0.045 in South Africa to 1.45 in Burkina Faso. Relative to the base year, the official CPI for the other year of the sample period multiplied by the correction factor indicates the true cost of living for that year. For example, in Côte d'Ivoire, the correction factor is estimated at 0.48 in 2002, which means, relative to the 2008 base period, the official CPI for 2002 multiplied by 0.48 shows the actual price level in 2002. In other words, the CPI level in 2002 was overestimated by 52 percent. Similarly, in Uganda, with the correction factor of 1.37, the price level is understated by 37 percent in 2009.

How relevant is this CPI bias for estimated poverty trends? Since the CPI bias is measured in percentage terms, a large bias is more consequential if the underlying cumulative inflation is higher. For example, in the case of Burkina Faso, the CPI is estimated to significantly understate the true cost of living by 44.7 percent between 1998 and 2003 (i.e. the correction factor is 1.447 in Table 7). However, the reported cumulative inflation during the same period is only 6.4 percent, so that the adjusted inflation increases only moderately to 9.2 percent. Therefore, the difference in poverty reduction based on the official inflation rate vs. the CPI-bias adjusted inflation rate is marginal. On the other hand, a comparable, though opposite, 51.4 percent CPI bias in the Democratic Republic of Congo leads to a cumulative bias-adjusted inflation rate of 136.7 percent, compared with the official inflation rate of 281.3 percent. As a result, the bias-adjusted poverty

[15] These countries are Burkina Faso, Cameroon, D.R. Congo, Côte d'Ivoire, Ethiopia, Ghana, Madagascar, Mauritius, Mozambique, Senegal, South Africa, Tanzania, Togo, and Uganda.

reduction in annual terms is 1.7 percentage points faster than the one based on the official inflation rate.

Overall, for countries experiencing an upward bias, our estimates of CPI bias suggest that the international poverty rate (bias-adjusted) fell faster than currently thought by somewhere between 0.8 percentage point per year in Mozambique and 5.7 percentage points per year in Tanzania (2008 – 2012) (Figure 2). Ghana, and Uganda are the two countries having the opposite trend. Correcting for the CPI bias, the annual reduction in international poverty is 2 percentage-points slower in Uganda, and 5.3 percentage-point slower in Ghana than indicated by current international poverty numbers. In Mauritius, Cameroon, and Burkina Faso, the change in poverty trend due to the correction of CPI bias is not statistically significant.

VII. Conclusion

In this paper, we estimated Engel curves for demographically similar households in 16 Sub-Saharan African countries. If Engel's law holds, the coefficients of these curves should not change over time, controlling for relative prices. However, we observe that the Engel curves drift to the left in the majority of countries in this study. Burkina Faso, Ghana, and Uganda are the three countries experiencing the opposite trend. We estimate that the average annual CPI upward bias ranges between 0.7 percent in Cameroon and 43.9 percent in Nigeria. Conversely, the official CPI understates inflation in Burkina Faso, Ghana, and Uganda by somewhere between 5.8 and 8.9 percent annually. This CPI bias, however, is not statistically significant in Cameroon and Ghana.

After adjusting for the effect of this bias, measured international poverty falls faster than currently thought in countries where the CPI overstates changes in the true cost of living – by up to 5.7 percentage points per year as in the case of Tanzania between 2008 and 2012. Conversely, for countries experiencing downward bias, the progress in poverty reduction is estimated to be slower by as much as 5.3 percentage points per year as in the case of Ghana.

The weakness of this indirect method of estimating the CPI bias is that it is based on the assumption that the Engel curves hold over time. In other words, the observed shift in the Engel curves is attributed entirely to the CPI bias. Thus, the estimation does not take into account other issues that

may contribute to the unexplained movement of the budget share of food such as changes in tastes, omitted variables, and so on. In addition, we also assume that the CPI bias has a uniform effect across the income distribution, and across all geographical locations in a given country. Hence, while we regard the estimates in this paper as cautious evidence that international poverty rates in Africa might have fallen faster than indicated by current numbers, additional work would be needed to corroborate the Engel curve estimation results (for example, using the methods outlined in Hausman 2003).

Tables and Figures

Table 1: Household Surveys, by Country, Sub-Saharan Africa, 1998–2013

Country	*Household survey*	*Year*
Burkina Faso	Enquête Burkinabé sur les Conditions de Vie des Ménages	1998–2003
Cameroon	Enquête Camerounaise Auprès des Ménages	2001–2007
Congo, D.R.	Questionnaire de l'enquête	2004-2012
Côte d'Ivoire	Enquête Niveau de Vie des Ménages	2002–2008
Ethiopia	Welfare Monitoring and Household Income Expenditure Survey	2004–2010
Ghana	Ghana Living Standards Survey	2005–2012
Madagascar	Enquêtes Périodiques auprès des Ménages	2001-2005-2010
Mauritius	Household Budget Survey	2006–2012
Mozambique	Inquérito aos Agregados Familiares Sobre Orçamento Familiar	2002–2008
Nigeria	General Household Survey	2011–2013
Rwanda	Enquête Intégrale sur les Conditions de Vie des Ménages	2005–2010
Senegal	Enquête de Suivi de la Pauvreté au Sénégal	2005–2011
South Africa	Income and Expenditure Survey	2005–2010
Tanzania	Household Budget Survey	2000–2007
Tanzania	Living Standards Measurement Study	2008-2010-2012
Togo	Questionnaire des Indicateurs de Base du Bien-être	2006–2011
Uganda	National Household Survey	2009–2012

Table 2: Consumer Price Indexes, by Country, Sub-Saharan Africa, 1998–2013

Country	*Consumer Price Index*	*Year*	*Coverage*	*Availability of regional CPIs*
Burkina Faso	Indice harmonisé des prix à la consommation	1998–2003	Urban	No
Cameroon	National consumer price index	2001–07	Urban	No
Congo, D.R.	Consumer Price Index	2004-2012	Urban	No
Côte d'Ivoire	Indice harmonisé des prix à la consommation	2002–08	Urban	No
Ethiopia	Country and regional consumer price indexes	2004–10	Urban	Yes
Ghana	Consumer price index	2005–12	Urban	Yes
Madagascar	National consumer price index	2001-2005-2010	Urban	No
Mauritius	Consumer price index	2006–12	Urban	No
Mozambique	Índice de preços no consumidor	2002–08	Urban	Yes
Nigeria	Country composite index	2011–13	National	No
Rwanda	All Rwanda consumer price index	2005–10	National	No
Senegal	Indice harmonisé des prix à la consommation	2005–11	Urban	No
South Africa	Consumer price index	2005–10	Urban	No
Tanzania	National consumer price index	2000–12	Urban	No
Togo	Indice harmonisé des prix à la consommation	2006–11	Urban	No
Uganda	National (composite) consumer price index	2009–12	Urban	Yes

Source: "Consumer Price Indices," Laborsta Internet, International Labour Organization, Geneva, http://laborsta.ilo.org/applv8/data/SSM1_NEW/E/ALL%20COUNTRIES_CPI_Descriptions%20-2013.pdf

Table 3: Summary Statistics, by Country, Sub-Saharan Africa, 1998–2013

Country	Survey year	Food share (mean)	Standard deviation	Log of household consumption (mean)	Standard deviation
Burkina Faso	1998	0.591	0.172	13.184	0.824
	2003	0.554	0.198	13.291	0.770
Cameroon	2001	0.467	0.178	13.532	0.745
	2007	0.461	0.167	13.345	0.730
Congo, DR	2004	0.658	0.140	12.651	0.772
	2012	0.640	0.154	12.613	0.742
Cote d'Ivoire	2002	0.520	0.192	14.063	0.817
	2008	0.470	0.197	13.791	0.800
Ethiopia	2004	0.586	0.137	9.237	0.528
	2010	0.514	0.131	9.207	0.558
Ghana	2005	0.596	0.171	8.239	0.726
	2012	0.731	0.246	7.501	0.741
Madagascar	2001	0.775	0.177	13.350	0.789
	2005	0.722	0.146	13.359	0.633
	2010	0.735	0.155	13.184	0.653
Mozambique	2002	0.608	0.202	9.792	0.840
	2008	0.586	0.188	9.946	0.831
Mauritius	2006	0.309	0.112	12.133	0.579
	2012	0.291	0.101	12.150	0.588
Nigeria	2011	0.691	0.162	12.853	0.644
	2013	0.652	0.173	12.783	0.684
Rwanda	2005	0.678	0.197	13.427	0.929
	2010	0.610	0.170	13.566	0.843
Senegal	2005	0.583	0.132	14.645	0.742
	2011	0.536	0.153	14.636	0.678
South Africa	2005	0.421	0.154	11.478	1.137
	2010	0.269	0.180	10.973	1.029
Tanzania	2000	0.713	0.122	12.457	0.672
	2007	0.629	0.121	12.760	0.670
Tanzania	2008	0.634	0.123	13.256	0.738
	2010	0.605	0.122	13.266	0.730
	2012	0.581	0.121	13.281	0.756
Togo	2006	0.573	0.173	13.586	0.713
	2011	0.457	0.162	13.678	0.801
Uganda	2009	0.474	0.137	14.774	0.752
	2012	0.437	0.122	14.871	0.726

Source : Household surveys

Table 4: Regression Results, by Country, Sub-Saharan Africa, 1998-2013

	Burkina Faso	Cameroon	Congo, D. R.	Cote d'Ivoire	Ethiopia	Ghana	Madagascar	Madagascar	Mauritius	Mozambique
ln(relative food inflation)					-0.147***	-0.032				0.244***
					(0.007)	(0.023)				(0.083)
ln(real total consumption)	-0.117***	-0.056***	-0.078***	-0.071***	-0.095***	-0.077***	-0.093***	-0.079***	-0.117***	-0.091***
	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)	(0.003)	(0.003)	(0.002)	(0.001)	(0.002)
Time dummy	0.004	-0.004*	-0.032***	-0.043***	-0.063***	0.026***	-0.090***	-0.042***	-0.015***	-0.043**
	(0.004)	(0.002)	(0.003)	(0.003)	(0.001)	(0.009)	(0.003)	(0.003)	(0.001)	(0.020)
Sample size	4,992	12,830	14,566	11,151	44,600	8,852	8,834	11,480	12,736	8,852
Adjusted R2	0.306	0.237	0.294	0.184	0.228	0.353	0.316	0.268	0.412	0.353
Availability of regional CPI	*No*	*No*	*No*	*No*	*Yes*	*Yes*	*No*	*No*	*No*	*Yes*
Sample coverage	*Urban*	*Urban*	*Urban*	*Urban*	*National*	*Urban*	*Urban*	*Urban*	*National*	*Urban*
Year of survey rounds	*1998, 2003*	*2001, 2007*	*2004, 2012*	*2002, 2008*	*2004, 2010*	*2006, 2012*	*2001, 2010*	*2005, 2010*	*2006, 2012*	*2002, 2008*

Note: Regressions are controlled for household size, share of household younger than 5 year old, share of household between 5 and 10 year old, share of household between 10 and 17 year old, head's age, head's gender, head's education, head's marital status, and regional dummies.

*Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent*

(continued)

	Nigeria	Rwanda	Senegal	South Africa	Tanzania	Tanzania	Tanzania	Togo	Uganda
ln(relative food inflation)									-0.714***
									(0.196)
ln(real total consumption)	-0.013***	-0.089***	-0.090***	-0.074***	-0.040***	-0.044***	-0.049***	-0.069***	-0.082***
	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)	(0.004)
Time dummy	-0.033***	-0.064***	-0.050***	-0.220***	-0.072***	-0.056***	-0.021***	-0.101***	0.026***
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.007)
Sample size	8,824	19,715	11,002	25,969	20,990	3,612	4,499	4,832	2,986
Adjusted R2	0.297	0.341	0.337	0.492	0.197	0.161	0.121	0.331	0.262
Availability of regional CPI	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*
Sample coverage	*National*	*National*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*
Year of survey rounds	*2011, 2013*	*2005, 2010*	*2005, 2011*	*2005, 2010*	*2001, 2007*	*2008, 2012*	*2010, 2012*	*2006, 2011*	*2009, 2012*

Note: Regressions are controlled for household size, share of household younger than 5 year old, share of household between 5 and 10 year old, share of household between 10 and 17 year old, head's age, head's gender, head's education, head's marital status, and regional dummies.

*Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent*

Table 5: Estimates of $\bar{\gamma}$ for Countries without Cross-sectional CPI Data

country	Survey period	$\bar{\gamma}$	Cumulative CPI-bias
Burkina Faso	1998-2003	0.231	-0.447
Cameroon	2001-2007	0.226	0.040
Cote d'Ivoire	2002-2008	0.223	0.517
Madagascar	2001-2010	0.202	0.718
Madagascar	2005-2010	0.208	0.281
Mauritius	2006-2012	0.167	0.330
Nigeria	2011-2013	0.216	0.878
Rwanda	2005-2010	0.234	0.623
Senegal	2005-2011	0.231	0.627
South Africa	2005-2010	0.205	0.955
Tanzania	2000-2007	0.220	0.942
Tanzania	2008-2012	0.234	0.877
Tanzania	2010-2012	0.236	0.623
Togo	2006-2011	0.239	0.899

* Note: There is insufficient data to estimate $\bar{\gamma}$ for Congo, D.R. Thus, we use the average of all $\bar{\gamma}$ estimates (0.22) for this country.

Table 6: Cumulative CPI Bias, by Country, Sub-Saharan Africa, 1998–2013

Country	Survey period	Cumulative CPI bias	Standard error	P-value	Average annual CPI bias	Correction factor
		(1)	(2)	(3)	(4)	(5)
Burkina Faso	1998-2003	-0.447	0.055	0.000	-0.089	1.447
Cameroon	2001-2007	0.040	0.038	0.298	0.007	0.960
Congo, D.R.	2004-2012	0.514	0.020	0.000	0.064	0.486
Cote d'Ivoire	2002-2008	0.517	0.024	0.000	0.086	0.483
Ethiopia	2004-2010	0.169	0.012	0.000	0.028	0.831
Ghana	2005-2012	-0.407	0.164	1.000	-0.058	1.407
Madagascar	2001-2010	0.718	0.013	0.000	0.080	0.282
Madagascar	2005-2010	0.281	0.025	0.000	0.056	0.719
Mauritius*	2006-2012	0.330	0.009	0.000	0.055	0.670
Mozambique	2002-2008	0.378	0.135	0.005	0.063	0.622
Nigeria*	2011-2013	0.878	0.060	0.000	0.439	0.122
Rwanda*	2005-2010	0.623	0.014	0.000	0.125	0.377
Senegal	2005-2011	0.627	0.010	0.000	0.105	0.373
South Africa	2005-2010	0.955	0.002	0.000	0.191	0.045
Tanzania	2000-2007	0.942	0.007	0.000	0.135	0.058
Tanzania	2008-2012	0.877	0.021	0.000	0.219	0.123
Tanzania	2010-2012	0.623	0.033	0.000	0.311	0.377
Togo	2006-2011	0.899	0.012	0.000	0.180	0.101
Uganda	2009-2012	-0.373	0.110	0.001	-0.075	1.373

** national CPI bias*

Table 7: Estimated 'True' Inflation, by Country, Sub-Saharan Africa, 1998–2013

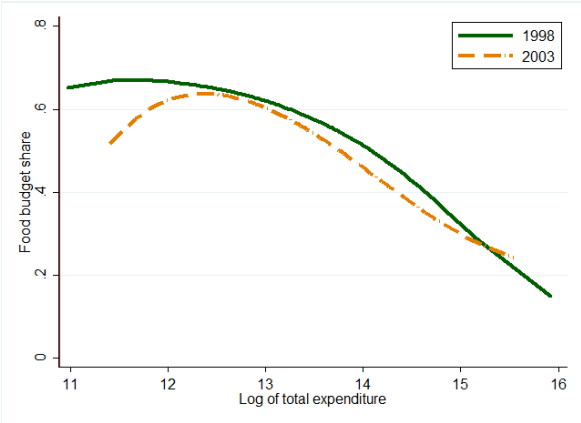
		Reported inflation		Correction factor	True inflation	
Country	Survey period	(cumulative %)	(annual %)		(cumulative %)	(annual %)
Burkina Faso	1998-2003	0.064	0.013	1.447	0.092	0.018
Cameroon	2001-2007	0.127	0.021	0.960	0.122	0.020
Congo, D.R.	2004-2012	2.813	0.352	0.486	1.367	0.171
Cote d'Ivoire	2002-2008	0.224	0.037	0.483	0.108	0.018
Ethiopia	2004-2010	1.630	0.272	0.831	1.355	0.226
Ghana	2005-2012	1.254	0.179	1.407	1.765	0.252
Madagascar	2001-2010	1.435	0.159	0.282	0.405	0.045
Madagascar	2005-2010	0.545	0.109	0.719	0.392	0.078
Mauritius	2006-2012	0.330	0.055	0.670	0.221	0.037
Mozambique	2002-2008	0.842	0.140	0.622	0.524	0.087
Nigeria	2011-2013	0.233	0.116	0.122	0.028	0.014
Rwanda	2005-2010	0.636	0.127	0.377	0.240	0.048
Senegal	2005-2011	0.178	0.030	0.373	0.067	0.011
South Africa	2005-2010	0.068	0.014	0.045	0.003	0.001
Tanzania	2000-2007	0.456	0.065	0.058	0.027	0.004
Tanzania	2008-2012	0.507	0.127	0.123	0.063	0.016
Tanzania	2010-2012	0.283	0.142	0.377	0.107	0.053
Togo	2006-2011	0.210	0.042	0.101	0.021	0.004
Uganda	2009-2012	0.403	0.134	1.373	0.554	0.185

Table 8: Poverty Implication, by Country, Sub-Saharan Africa, 1998–2013

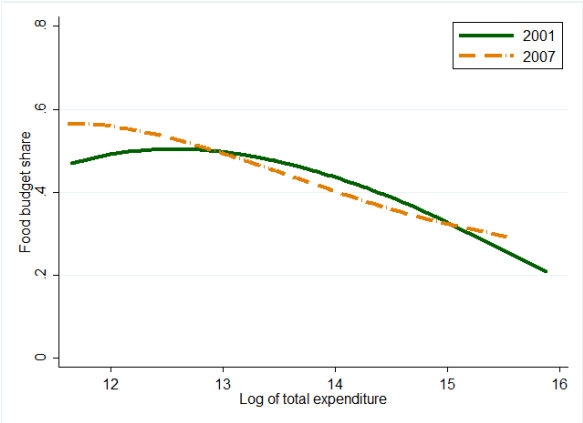
country	Survey period	Official poverty reduction				Poverty reduction from correction of CPI bias			
		Cummulative (% pt.)	Annual (% pt)	Standard errors	P-value	Cummulative (% pt.)	Annual (% pt)	Standard errors	P-value
Burkina Faso	1998-2003	-24.35	-4.87	0.697	0.000	-23.89	-4.78	0.70	0.000
Cameroon	2001-2007	6.15	1.02	0.590	0.000	6.10	1.02	0.59	0.000
Congo, D.R.	2004-2012	-0.28	-0.03	0.477	0.557	-13.63	-1.70	0.43	0.000
Cote d'Ivoire	2002-2008	5.99	1.00	0.574	0.000	0.83	0.14	0.59	0.158
Ethiopia	2004-2010	-2.77	-0.46	0.431	0.000	-14.66	-2.44	0.44	0.000
Ghana	2005-2012	-28.15	-4.02	0.497	0.000	8.71	1.24	0.29	0.000
Madagascar	2001-2010	13.08	1.45	0.642	0.000	-3.83	-0.43	0.57	0.000
Madagascar	2005-2010	7.70	1.54	0.530	0.000	2.08	0.42	0.51	0.000
Mauritius	2006-2012	0.11	0.02	0.119	0.343	-0.12	-0.02	0.13	0.371
Mozambique	2002-2008	-11.57	-1.93	0.621	0.000	-16.34	-2.72	0.60	0.000
Nigeria	2011-2013	4.86	2.43	1.006	0.000	-5.40	-2.70	0.98	0.000
Rwanda	2005-2010	-8.35	-1.67	0.656	0.000	-14.75	-2.95	0.64	0.000
Senegal	2005-2011	0.40	0.07	0.695	0.562	-5.39	-0.90	0.70	0.000
South Africa	2005-2010	-6.57	-1.31	0.368	0.000	-23.58	-4.72	0.40	0.000
Tanzania	2000-2007	-12.70	-1.81	0.445	0.000	-20.14	-2.88	0.40	0.000
Tanzania	2008-2012	0.53	0.13	1.103	0.633	-22.43	-5.61	1.08	0.000
Tanzania	2010-2012	-0.79	-0.40	1.061	0.455	-11.02	-5.51	1.06	0.000
Togo	2006-2011	-1.37	-0.27	0.885	0.121	-8.74	-1.75	0.87	0.000
Uganda	2009-2012	-8.17	-2.72	0.825	0.000	-2.17	-0.72	0.81	0.008

Figure 1: Engel Curves, Sub-Saharan Africa, 1998–2013

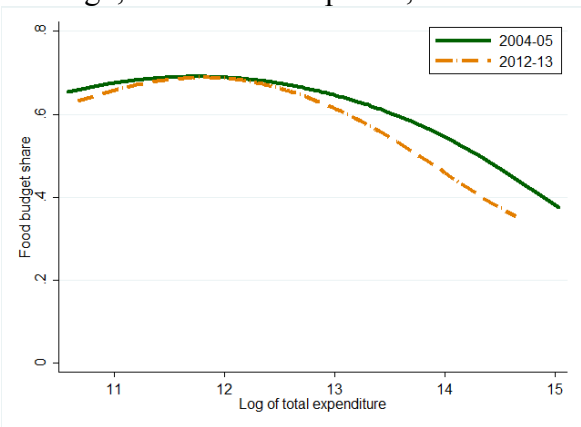
a. Burkina Faso, 1998–2003



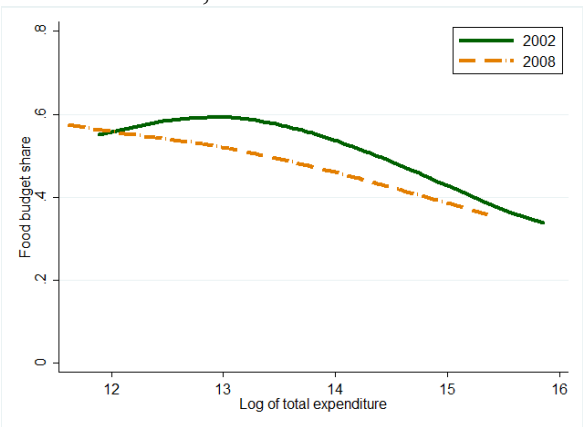
b. Cameroon 2001-07



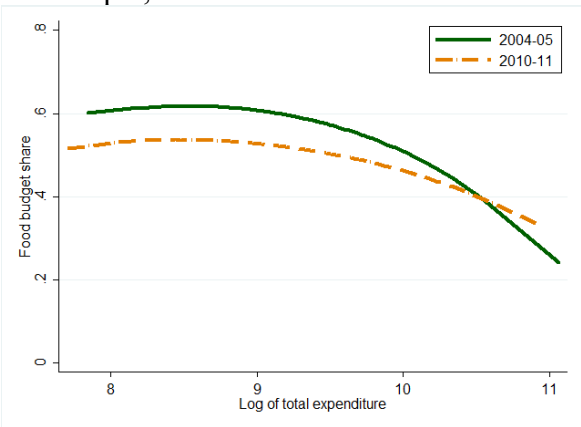
c. Congo, Democratic Republic, 2004-2012



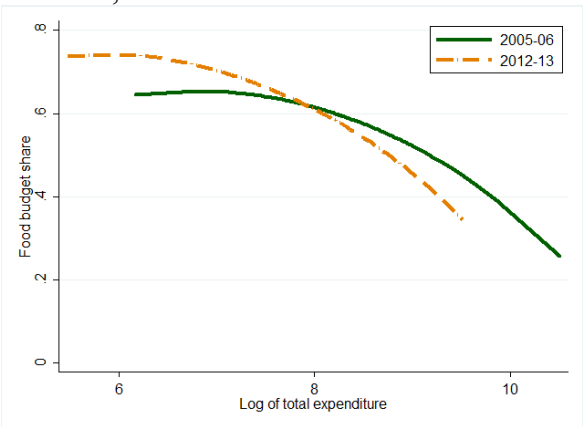
d. Côte d'Ivoire, 2002–08



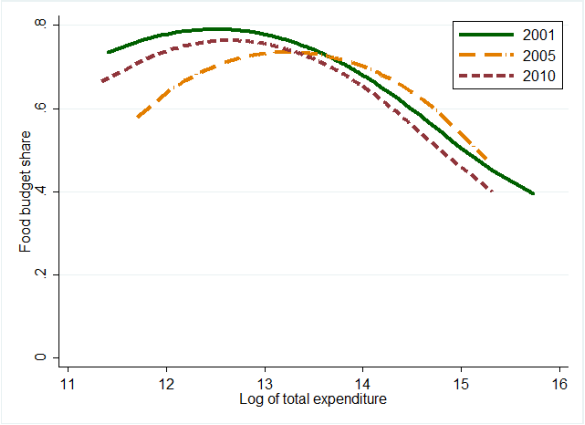
e. Ethiopia, 2004–10



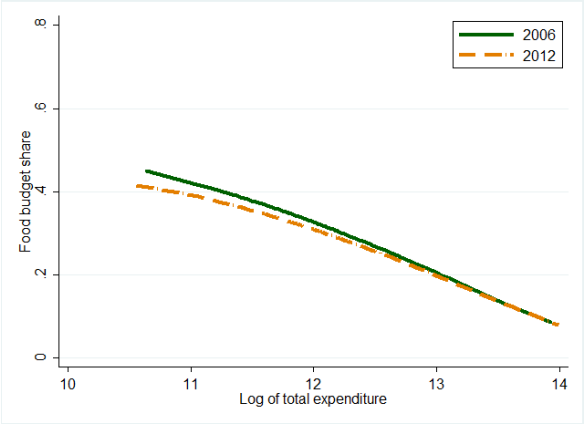
f. Ghana, 2005–12



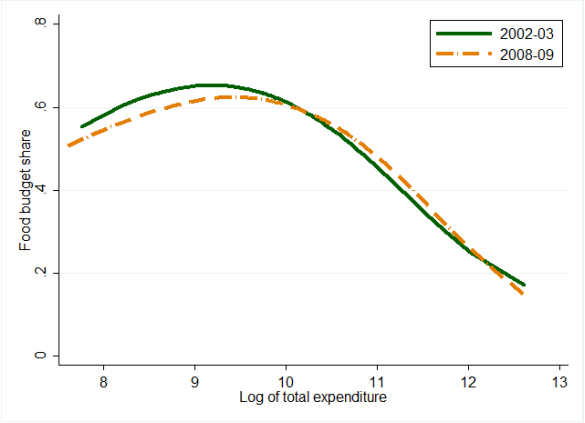
g. Madagascar, 2001, 2005, 2010



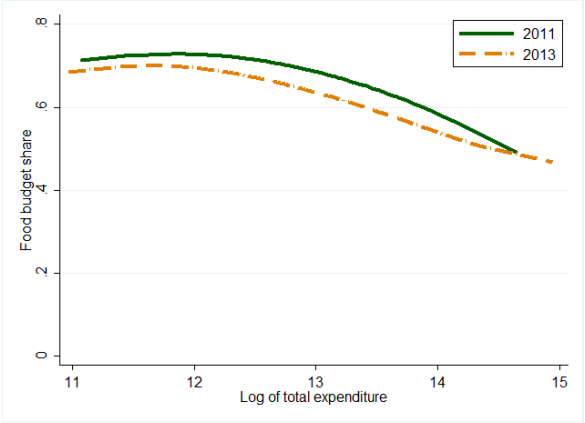
h. Mauritius, 2006–12



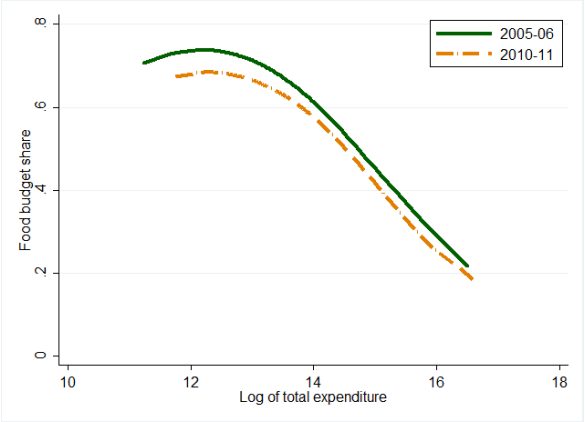
i. Mozambique, 2002–08



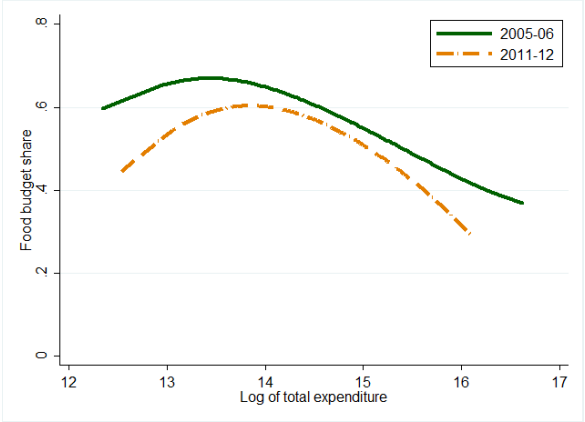
j. Nigeria, 2011–13



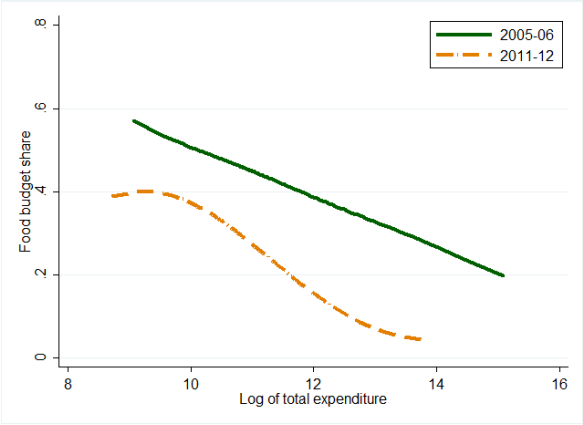
k. Rwanda, 2005–10



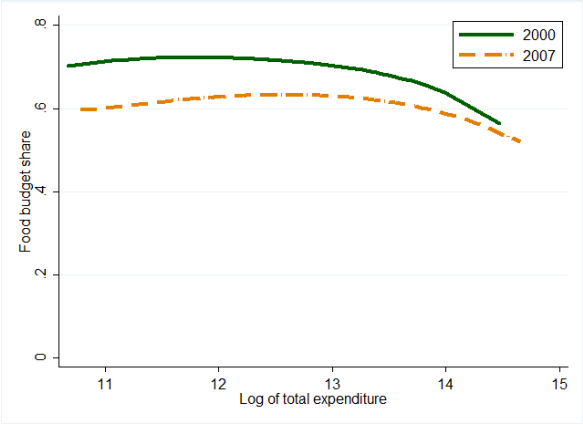
l. Senegal, 2005–11



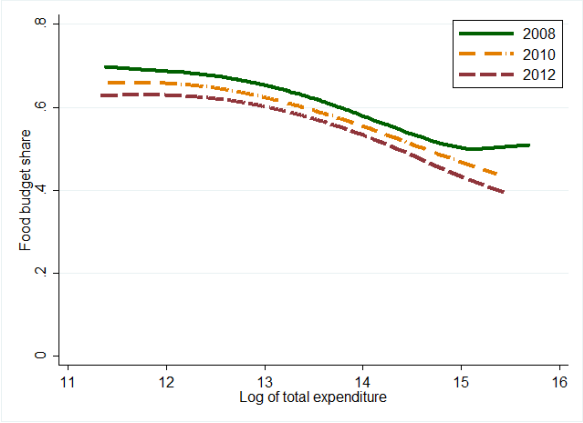
m. South Africa, 2005–10



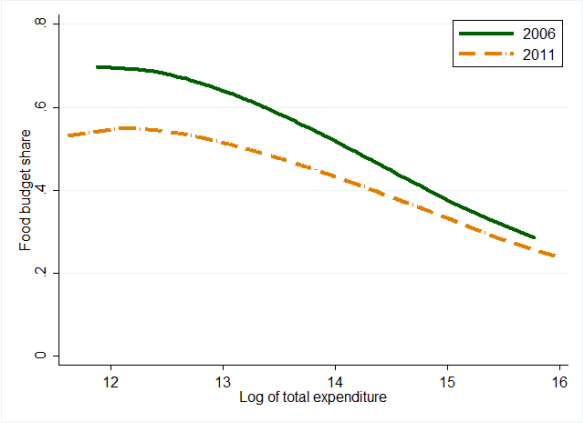
n. Tanzania, 2000–07



o. Tanzania, 2008, 2010, 2012



p. Togo, 2006–11



q. Uganda, 2009–12

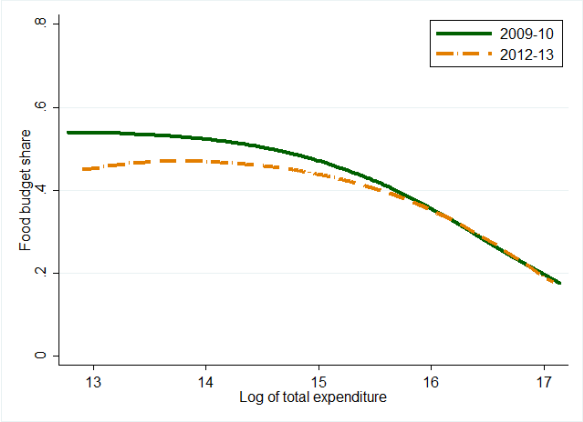
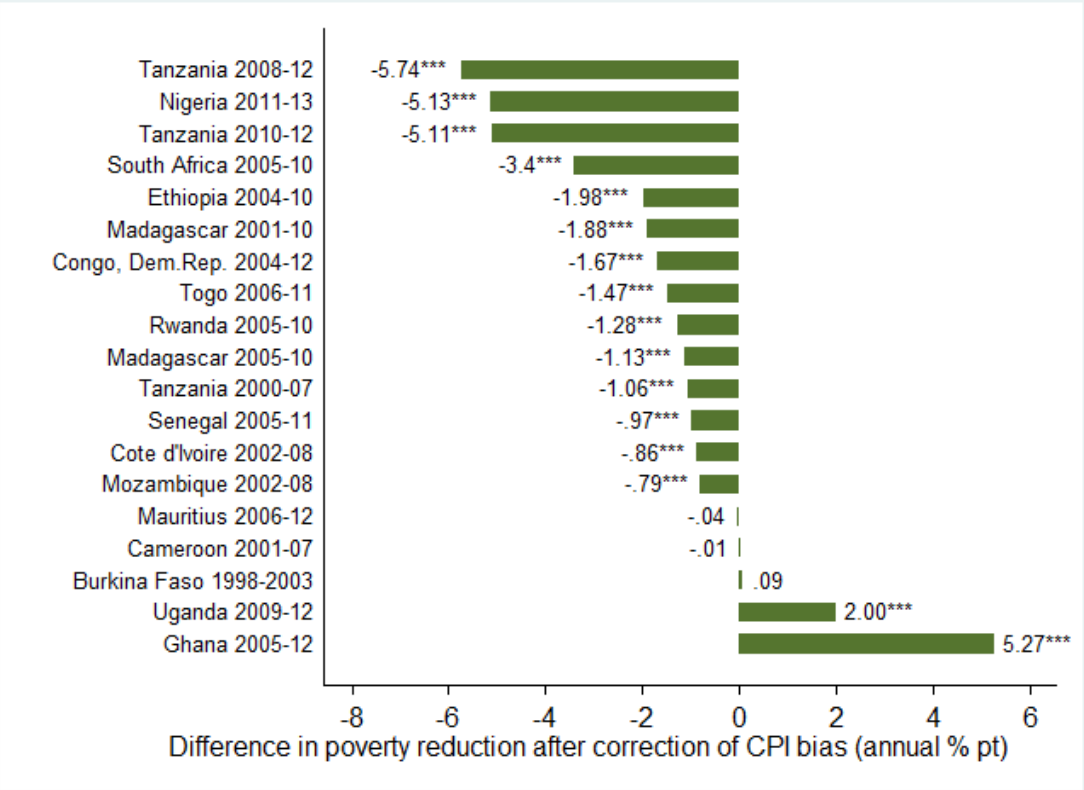


Figure 2: Difference in Poverty Reduction Resulting from Correction of CPI bias (percentage points per year)



Appendix 1

Table A1: Sensitivity Analysis

	Burkina Faso			Cameroon			Congo, D.R.			Cote d'Ivoire		
	OLS	**Quadratic**	**Ignoring weights**	**OLS**	**Quadratic**	**Ignoring weights**	**OLS**	**Quadratic**	**Ignoring weights**	**OLS**	**Quadratic**	**Ignoring weights**
ln(relative food inflation)												
ln(real total consumption)	-0.117***	0.107*	-0.116***	-0.056***	0.217***	-0.052***	-0.078***	0.398***	-0.066***	-0.071***	0.225***	-0.073***
	(0.003)	(0.057)	(0.003)	(0.002)	(0.042)	(0.002)	(0.002)	(0.039)	(0.002)	(0.002)	(0.050)	(0.002)
ln(real total consumption)^2		-0.008***			-0.010***			-0.018***			-0.011***	
		(0.002)			(0.001)			(0.001)			(0.002)	
Time dummy	0.004	0.001	0.016***	-0.004*	-0.005**	-0.022***	-0.032***	-0.031***	-0.014***	-0.043***	-0.044***	-0.038***
	(0.004)	(0.004)	(0.004)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Sample size	4,992	4,992	4,992	12,830	12,830	12,830	14,566	14,566	14,566	11,151	11,151	11,151
Adjusted R2	0.306	0.308	0.360	0.237	0.239	0.235	0.294	0.301	0.286	0.184	0.186	0.176
Availability of regional CPI	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*
Sample coverage	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*
Year of survey rounds	*1998, 2003*	*1998, 2003*	*1998, 2003*	*2001, 2007*	*2001, 2007*	*2001, 2007*	*2004, 2012*	*2004, 2012*	*2004, 2012*	*2002, 2008*	*2002, 2008*	*2002, 2008*

Note: Regressions are controlled for household size, share of household younger than 5 year old, share of household between 5 and 10 year old, share of household between 10 and 17 year old, head's age, head's gender, head's education, head's marital status, and regional dummies.

*Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent*

	Ethiopia			Ghana			Madagascar			Madagascar		
	OLS	**Quadratic**	**Ignoring weights**	**OLS**	**Quadratic**	**Ignoring weights**	**OLS**	**Quadratic**	**Ignoring weights**	**OLS**	**Quadratic**	**Ignoring weights**
ln(relative food inflation)	-0.123***	-0.119***	-0.091***	-0.032	-0.060***	-0.072***						
	(0.007)	(0.007)	(0.007)	(0.023)	(0.023)	(0.025)						
ln(real total consumption)	-0.143***	0.015	-0.141***	-0.077***	0.205***	-0.068***	-0.093***	0.855***	-0.088***	-0.079***	1.288***	-0.060***
	(0.001)	(0.019)	(0.001)	(0.003)	(0.028)	(0.003)	(0.003)	(0.053)	(0.003)	(0.002)	(0.050)	(0.002)
ln(real total consumption)^2		-0.008***			-0.017***			-0.035***			-0.050***	
		(0.001)			(0.002)			(0.002)			(0.002)	
Time dummy	-0.026***	-0.028***	-0.033***	0.026***	0.015*	0.013	-0.090***	-0.095***	-0.091***	-0.042***	-0.041***	-0.063***
	(0.002)	(0.002)	(0.002)	(0.009)	(0.009)	(0.010)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)
Sample size	26,439	26,439	26,439	8,852	9,770	9,770	8,834	8,834	8,834	11,480	11,480	11,480
Adjusted R2	0.374	0.376	0.369	0.353	0.265	0.219	0.316	0.340	0.281	0.268	0.312	0.230
Availability of regional CPI	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*No*	*No*	*No*	*No*	*No*	*No*
Sample coverage	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*
Year of survey rounds	*2004, 2010*	*2004, 2010*	*2004, 2010*	*2006, 2012*	*2006, 2012*	*2006, 2012*	*2001, 2010*	*2001, 2010*	*2001, 2010*	*2005, 2010*	*2005, 2010*	*2005, 2010*

Note: Regressions are controlled for household size, share of household younger than 5 year old, share of household between 5 and 10 year old, share of household between 10 and 17 year old, head's age, head's gender, head's education, head's marital status, and regional dummies.

*Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent*

Appendix 1

Table A1: Sensitivity Analysis (continued)

	Mauritius			Mozambique			Nigeria			Rwanda		
	OLS	**Quadratic**	**Ignoring weights**	**OLS**	**Quadratic**	**Ignoring weights**	**OLS**	**Quadratic**	**Ignoring weights**	**OLS**	**Quadratic**	**Ignoring weights**
ln(relative food inflation)												
ln(real total consumption)	-0.117***	0.089***	-0.113***	0.244***	0.209***	-0.274***	-0.013***	0.554***	-0.007***	-0.089***	0.573***	-0.086***
	(0.001)	(0.034)	(0.001)	(0.083)	(0.081)	(0.094)	(0.003)	(0.059)	(0.003)	(0.002)	(0.023)	(0.002)
ln(real total consumption)^2		-0.008***			-0.026***			-0.022***			-0.024***	
		(0.001)			(0.001)			(0.002)			(0.001)	
Time dummy	-0.015***	-0.015***	-0.015***	-0.043***	-0.037***	0.062***	-0.033***	-0.032***	-0.034***	-0.064***	-0.066***	-0.063***
	(0.001)	(0.001)	(0.002)	(0.020)	(0.019)	(0.022)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Sample size	12,736	12,736	12,736	8,852	8,852	8,852	8,824	8,824	8,824	19,715	19,715	19,715
Adjusted R2	0.412	0.414	0.401	0.353	0.377	0.358	0.297	0.304	0.250	0.341	0.368	0.361
Availability of regional CPI	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*
Sample coverage	*National*	*National*	*National*	*Urban*	*Urban*	*Urban*	*National*	*National*	*National*	*National*	*National*	*National*
Year of survey rounds	*2006, 2012*	*2006, 2012*	*2006, 2012*	*2002, 2008*	*2002, 2008*	*2002, 2008*	*2011, 2013*	*2011, 2013*	*2011, 2013*	*2005, 2010*	*2005, 2010*	*2005, 2010*

Note: Regressions are controlled for household size, share of household younger than 5 year old, share of household between 5 and 10 year old, share of household between 10 and 17 year old, head's age, head's gender, head's education, head's marital status, and regional dummies.

*Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent*

	Senegal			South Africa			Tanzania			Tanzania		
	OLS	**Quadratic**	**Ignoring weights**	**OLS**	**Quadratic**	**Ignoring weights**	**OLS**	**Quadratic**	**Ignoring weights**	**OLS**	**Quadratic**	**Ignoring weights**
ln(relative food inflation)												
ln(real total consumption)	-0.090***	0.999***	-0.061***	-0.074***	-0.260***	-0.072***	-0.040***	0.517***	-0.041***	-0.044***	0.192***	-0.054***
	(0.002)	(0.044)	(0.002)	(0.001)	(0.010)	(0.001)	(0.001)	(0.029)	(0.002)	(0.003)	(0.061)	(0.003)
ln(real total consumption)^2		-0.037***			0.008***			-0.022***			-0.009***	
		(0.001)			(0.000)			(0.001)			(0.002)	
Time dummy	-0.050***	-0.053***	-0.032***	-0.220***	-0.219***	-0.211***	-0.072***	-0.071***	-0.102***	-0.056***	-0.056***	-0.062***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)
Sample size	11,002	11,002	11,002	25,969	25,969	25,969	20,990	20,990	20,990	3,612	3,612	3,612
Adjusted R2	0.337	0.372	0.263	0.492	0.498	0.450	0.197	0.211	0.238	0.161	0.164	0.210
Availability of regional CPI	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*
Sample coverage	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*
Year of survey rounds	*2005, 2011*	*2005, 2011*	*2005, 2011*	*2005, 2010*	*2005, 2010*	*2005, 2010*	*2001, 2007*	*2001, 2007*	*2001, 2007*	*2008, 2012*	*2008, 2012*	*2008, 2012*

Note: Regressions are controlled for household size, share of household younger than 5 year old, share of household between 5 and 10 year old, share of household between 10 and 17 year old, head's age, head's gender, head's education, head's marital status, and regional dummies.

*Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent*

Appendix 1

Table A1: Sensitivity Analysis (continued)

	Tanzania			Togo			Uganda		
	OLS	**Quadratic**	**Ignoring weights**	**OLS**	**Quadratic**	**Ignoring weights**	**OLS**	**Quadratic**	**Ignoring weights**
ln(relative food inflation)							-0.714***	-0.683***	-0.740***
							(0.196)	(0.192)	(0.221)
ln(real total consumption)	-0.049***	0.352***	-0.057***	-0.069***	-0.101***	-0.074***	-0.082***	0.777***	-0.074***
	(0.003)	(0.062)	(0.003)	(0.003)	(0.064)	(0.004)	(0.004)	(0.082)	(0.004)
ln(real total consumption)^2		-0.015***			0.001			-0.028***	
		(0.002)			(0.002)			(0.003)	
Time dummy	-0.021***	-0.021***	-0.025***	-0.101***	-0.101***	-0.111***	0.026***	0.025***	0.033***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.007)	(0.007)	(0.007)
Sample size	4,499	4,499	4,499	4,832	4,832	4,832	2,986	2,986	2,986
Adjusted R2	0.121	0.129	0.177	0.331	0.330	0.320	0.262	0.289	0.241
Availability of regional CPI	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*
Sample coverage	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*	*Urban*
Year of survey rounds	*2010, 2012*	*2010, 2012*	*2010, 2012*	*2006, 2011*	*2006, 2011*	*2006, 2011*	*2009, 2012*	*2009, 2012*	*2009, 2012*

Note: Regressions are controlled for household size, share of household younger than 5 year old, share of household between 5 and 10 year old, share of household between 10 and 17 year old, head's age, head's gender, head's education, head's marital status, and regional dummies.

*Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent*

Appendix 2

Calculation of CPI bias estimates for countries without cross-sectional CPI data

We follow the calculation of estimates of the CPI bias described in Gibson, Stillman, and Le (2008). First, we obtain the own-price elasticity of food demand using the method introduced by Frisch (1959), as follows:

$$e_{ii} = \frac{1}{\omega}\eta_i(1-w_i\eta_i) - w_i\eta_i. \tag{13}$$

where w is the average budget share of food; η is the expenditure elasticity of food demand (calculated as $1+\beta/w$); and ω is the flexibility of money. The estimate of the flexibility of money is derived from the relationship proposed by Lluch, Powell, and Williams (1977) of $\omega \approx -36X^{-0.36}$, where X is the gross national product per capita in 1970 U.S. dollars.[16]

Equipped with the estimate of the own-price elasticity of food demand, e_{ii}, together with the estimated value of the coefficient for CPI-deflated total expenditure, β, from equation (9), the average budget share of food, $\overline{w}$, and the share of food component in the CPI, α, obtained from the NSOs, we are able to calculate the relative prices between food and non-food $\bar{\gamma}$, as follows: Rearranging equation (14) gives:

$$e_{ii} = -1 + \frac{\bar{\gamma} - \alpha\beta}{\overline{w}} \tag{14}$$

We then incorporate estimates of $\bar{\gamma}$ into the estimation of CPI bias using equation (10).

$$\bar{\gamma} = (1+e_{ii})\overline{w} + \alpha\beta \tag{15}$$

[16] We use gross domestic product (GDP) estimates rather than gross national product. To obtain *X*, we take the average of per capita GDP (in constant 2005 U.S. dollars) between two survey periods and combine with the GDP deflator in 2005 and 1970.

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