Policy Research Working Paper 9684

Linking Intra- and Inter-Country Spatial Price Adjustments in Global Poverty Measurement

Urban PPP Bias and Reference Price Mismatch

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WORLD BANK GROUP
Poverty and Equity Global Practice
June 2021

Policy Research Working Paper 9684

Abstract

Measuring global poverty requires two types of spatial price adjustments: inter-country price adjustment based on the international purchasing power parities (PPPs) and intra-country price adjustment to account for cost-of-living variations in different parts of a country, especially between urban and rural areas. Current global poverty measurement lacks an adjustment mechanism for this within-country price variation for many countries, particularly in Sub-Saharan Africa. This paper highlights the need for matching reference prices with those the International Comparison Program (ICP) uses for PPP calculation to avoid poverty estimation bias, largely because many countries collected 2011 ICP price information only in urban areas. Data from four Sub-Saharan African countries are used to show that potential bias in estimated poverty rates due to such reference price mismatches ranges from 0.3 to 6.2 points in absolute terms. A larger bias is observed in countries where gaps between urban and rural prices are greater. The analysis also shows potentially large bias due to lack of intra-country price adjustments. These potential biases underscore the urgent need for conducting within-country price adjustments and matching purchasing power parity reference prices with country spatial price deflators. An important first step is to identify what reference prices the 2011PPPs used for each country, which currently is not clear. The World Bank, with ongoing relationships with National Statistics Offices, is well positioned to take up this task to improve the accuracy of the methodology for estimating poverty at the global, regional, and national levels.

This paper is a product of the Poverty and Equity Global Practice. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The authors may be contacted at snakamura2@worldbank.org and nyoshida@worldbank.org.

Linking Intra- and Inter-Country Spatial Price Adjustments in Global Poverty Measurement: Urban PPP Bias and Reference Price Mismatch*

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Keywords: Global poverty; Poverty measurement; Purchasing power parity; cost of living index
JEL Codes: E31, I32, O15

* This paper is written based on a research project on subnational poverty measurement under the Data for Goals (D4G) program. We would like to thank David Newhouse, Jose Montes, Christoph Lakner, Samuel Kofi Tetteh Baah, Yuri Dikhanov, Nada Hamadeh, and Marko Olavi Rissanen for their useful comments. The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the views of the International Bank for Reconstruction and Development (IBRD) or the World Bank and its affiliated organizations, or those of the Executive Directors of the World Bank or the governments they represent.
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1. Introduction

Price adjustment—both over time and over different locations—is an essential component of welfare and poverty measurement and analysis. Problems of relying on consumer price index (CPI)-based inflation for measuring real income over time are well known; for example, CPI tends to overstate inflation due to substitution bias and several other reasons (Gaddis 2016). Previous studies reveal how CPI approaches overestimate inflation and thus underestimate real income (for example, Nakamura, Steinsson & Liu 2016). Dabalen, Gaddis, and Nguyen (2019) applied this framework to Sub-Saharan African (SSA) countries and found that it has overestimated poverty in many countries. By contrast, spatial price adjustment—both intra- and inter-country—has attracted less attention, yet it is critically important for poverty measurement.

Measuring welfare and poverty in a country requires adjusting for cost-of-living differences across subnational regions. Typically, a spatial price deflator is constructed and used to deflate nominal household consumption expenditures across different subnational regions (Deaton and Zaidi 2002; Chen et al. 2020; Gibson, Le, and Kim 2017).[1,2] Despite the importance, global poverty, such as the proportion of people living below $1.90 per day per capita, is usually estimated without spatial price adjustments in many countries, particularly those in SSA (Ferreira et al. 2016). Introducing spatial deflation is an important step to improving global poverty monitoring, as the potential bias current poverty estimates introduce—particularly at the subnational level—is likely to be significant.

However, global comparison of poverty further hinges on another type of price adjustment—cost of living *across countries*. International purchasing power parities (PPP), calculated by the International Comparison Program (ICP), are often used for such adjustment. The World Bank also relies on the PPP in the 2011 ICP round to measure global poverty in world countries. For example, the global extreme poverty line is converted into the local currency unit of each country through the PPP instead of using the exchange rate (Ferreira et al. 2016).[3] Experts have closely examined the use of PPP in global poverty measurement, particularly after revision of the 2005 PPP (Ferreira et al. 2016; Ravallion 2018; Deaton and Aten 2017; Deaton and Dupriez 2011). Several concerns about the use of the PPP for global poverty measurement have arisen.[4]

To better integrate spatial deflation into global poverty measurement, this paper sheds light on the need for matching reference prices of within-country spatial price deflators with reference prices in

[1] Global poverty is measured based on consumption expenditures in the majority of countries, while income is used for some countries. Despite their theoretical and practical differences, we use consumption expenditures and income interchangeably in this paper for simplicity.
[2] An alternative approach is to set different poverty lines across regions. Examples include Ravallion and Lokshin (2006) for the Russian Federation; Jolliffe, Datt, and Sharma (2004) for the Arab Republic of Egypt, Arndt and Simler (2010) for Egypt and Mozambique, and Marivoet and de Herdt (2015) for the Demogratic Republic of Congo.
[3] Equivalently, consumption expenditures can be spatially deflated and converted into USD in 2011 PPP terms, as explained in Section 2.
[4] Almas (2012) indeed points to the PPP bias, by suggesting that real income tends to be overestimated in poorer countries.

international PPPs to avoid biases.[5,6] The reference prices of within-country spatial price deflators represent national averages. By contrast, the PPPs reflect urban prices as their calculations were based on price data collected predominantly in cities and not adjusted to national average prices. Thus, the poverty line created by such urban PPPs obviously reflects urban prices. This mismatch of reference prices between the poverty line and the deflated household expenditures could bias poverty estimations significantly. Perhaps even worse, not adjusting household expenditures for within-country price variations—as done in many countries—makes the direction of bias unclear. This is because the combined effect of spatial deflation and potential reference area mismatch depends on various factors, such as welfare distributions, urban-to-rural population distributions, urban-to-rural cost-of-living gaps, and spatial correlation between welfare and cost of living.[7]

Looking at a few SSA countries, our empirical analysis finds a potential sizeable bias in international poverty estimates due to: (i) the exclusion of within-country price adjustments, and (ii) the inclusion of within-country price adjustments without matching their reference prices with those of the PPPs. It is important to highlight that we do not know the 2011 PPP reference prices for the countries selected in this paper. The 2011 ICP provides information on where prices were collected but does not tell us whether the PPP reference prices are national average prices—based on some adjustments after data collection—or not. Thus, our analysis can only indicate the potential areas of bias only if those countries *had* mismatches in reference prices.

The potential bias in global poverty estimates underscores the need of within-country spatial adjustments for countries where international poverty rates are currently estimated without such adjustments. In application, however, it is critical to match the reference areas of the PPPs and the spatial price deflators. An important first step is to clarify with each country's national statistics office (NSO) the reference prices of the PPPs. The World Bank is well positioned to conduct such an exercise because of its close engagement with NSOs of all developing countries for estimation of international poverty indicators and in the ICP process.

This paper is structured as follows: The next section 2 explains the theory and practice of global poverty measurement and how the reference price mismatch could affect global poverty estimates. Section 3 describes the empirical approach of this paper. Section 4 presents the results of our analysis. Section 5 concludes.

2. Spatial price adjustment in poverty measurement

The theory of utility-consistent poverty measurement underscores the need for price adjustments, both over time and between different geographic areas (Ravallion 2008). Intuitively, comparing the welfare of individuals requires that cost-of-living differences within a country need be considered. In practice, real consumption expenditures are often calculated by dividing nominal consumption

[5] This paper focuses on global poverty measured with an international poverty line. Thus, unless otherwise noted, "national poverty" refers to global poverty measured at the national level, rather than poverty measured with each country's national poverty line.
[6] This paper does not discuss another important issue—the fact that the spatial price index is not constructed properly. For the sake of consistency with national measures, our empirical analysis for global poverty measurement relies on the same spatial price index as in the national poverty measurement to adjust for within-country price differences. Although it is beyond the scope of this paper, improving the quality of spatial price indices is also important.
[7] However, the fact that price data was collected predominantly in urban areas in some countries is useful for comparing urban cost of living across countries (for example, Nakamura et al. 2019 and 2020).

expenditures by a spatial deflator to account for spatial cost-of-living variation. Real consumption expenditures of individual *i* in region *r* in country A, which we denote as $REXP_{i,r}^{A}$, is calculated as follows:

$$REXP_{i,r}^{A} = NEXP_{i,r} \times (\pi_r^{AN})^{-1} \quad (1)$$

where $NEXP_i$ is the nominal consumption expenditure of the individual and π_r^{AN} is a spatial price deflator that adjusts for cost-of-living differences between region *r* and the national level (N). This real consumption can be compared to the country's poverty line (PL_A) to measure poverty.

$$NEXP_{i,r} \times (\pi_r^{AN})^{-1} \lessgtr PL_A \quad (2)$$

Note that the poverty line indicates the minimum cost of satisfying basic needs, which is expressed in local currency unit at the national level.

In case of official global poverty measurement, cross-country price differentials are further adjusted based on international PPPs (Ferreira et al. 2016). However, the PPPs are available only for specific years. To estimate the global poverty rate for a country for a year, price differentials between the survey year of consumption or income data and the reference year of PPPs (that is, 2011) are adjusted based on the CPI.[8]

More specifically, there are the following two approaches:

1) *Deflating an international poverty line to the survey year.* A global poverty line (GPL_{2011}) can be converted into local currency unit for country A at year *t* as:

$$GPL_{2011} \times PPP_{A,2011} \times CPI_{2011,t}^{A} = GPL_{2011} \times (EXR_{A,USA,2011} \times PLR_{A/USA,2011}) \times CPI_{2011,t}^{A} \quad (3)$$

where $EXR_{A,USA}$ indicates the currency exchange ratio between country A and the United States and $PLR_{A/USA,2011}$ indicates the ratio of price levels between country A and the United States. This converted global poverty line is compared to real consumption expenditures of individual *i* in region *r* in country A at year *t*:

$$NEXP_{irt} \times (\pi_{rt}^{AN})^{-1} \lessgtr GPL_{2011} \times PPP_{A,2011} \times CPI_{2011,t}^{A} \quad (4)$$

2) *Deflating household consumption expenditures to 2011.* Alternatively, household consumption expenditures can be converted so that both the expenditures and the global poverty line are expressed in US$ in 2011 PPP terms as follows:

$$NEXP_{irt} \times (\pi_{rt}^{AN})^{-1} \times (CPI_{2011,t}^{A})^{-1} \times (PPP_{A,2011})^{-1} \lessgtr GPL_{2011} \quad (5)$$

Since Inequalities (4) and (5) are equivalent, poverty rates defined by these inequalities are identical.

International PPPs

The ICP is a global statistical program designed to collect comparable price data and estimate PPPs for the world's economies. To calculate PPPs, the ICP collects price data for comparable products and services and compiles national accounts expenditure data to use as weights. Each NSO collects

[8] As mentioned earlier, the use of CPI for temporal price adjustments may cause a bias in poverty estimation. See Dabalen, Gaddis and Nguyen (2019).

underlying data for each economy. The last three rounds of PPP data collection took place in 2005, 2011, and 2017, and current global poverty measurement is based on the revised version of the 2011 PPPs (Castaneda et al. 2020).

Among the different types of PPPs prepared by the ICP, including those for GDP and its components, the global poverty monitoring uses PPPs for household final consumption expenditures. There are some caveats for using PPPs for global poverty measurement. First, PPPs are primarily designed to measure and compare the size of world economies, instead of comparing or adjusting cost of living between them (Deaton and Heston 2010). Second, the basket of items used for the PPP calculations are not necessarily what low-income households typically consume.[9] Despite these caveats, PPPs are the best indicator to adjust for cross-country price variations.

Another aspect of PPPs is important to note. Ideally, prices should be collected nationwide to create nationally representative PPPs. However, due to the limited coverage of regular price data collection for national CPI and/or resource shortage, many countries opted to collect price data predominantly from urban areas for the 2011 ICP. In fact, according to ICP-prepared meta data, most high-income countries, including the United States, collected price data only in urban areas. While the PPPs of those countries with well-integrated economies and high population shares in urban areas are less susceptible to urban bias, urban-rural price gaps in low and middle-income countries, where global poverty concentrates, are too high to ignore.

Unfortunately, it is unclear which references prices are used for the PPPs; the 2011 ICP lacks the meta data to determine what references prices were used where. For the 2011 ICP, at least 53 low- and middle-income countries collected price data predominantly from urban areas (Table 1), but this metadata about the geographic coverage of price data collection is incomplete in some countries. Besides, the metadata does not include information about which countries' PPPs are adjusted to address the limited geographic coverage in data collection for the 2011 ICP.

Table 1. Countries where 2011 PPP price data was collected predominantly in urban areas

Region	Country
Sub-Saharan Africa (SSA)	Angola, Benin, Burkina Faso, Chad, Comoros, Congo Rep., Gabon, Kenya, Madagascar, Mali, Mauritania, Mozambique, Namibia, Senegal, Seychelles, South Africa, Togo, Zambia, Zimbabwe
Middle East and North Africa (MENA)	Algeria, Bahrain, Djibouti, Iraq, Jordan, Kuwait, Oman, West Bank and Gaza, Qatar, Saudi Arabia
East Europe and Central Asia (ECA)	Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Ukraine, Albania, Georgia
South Asia (SAR)	Pakistan
Latin America and Caribbean (LAC)	Bolivia, Brazil, Costa Rica, Dominical Republic, Ecuador, El Salvador, Honduras, Nicaragua, Paraguay, Peru, Venezuela, RB

Note: High-income and/or small island countries are excluded. List of countries is not exhaustive.
Source: World Bank International Comparison Programs

Spatial deflation and reference areas

For poverty measurement, both consumption expenditures and the poverty line need to be expressed in the same prices. In other words, the reference areas of the spatial deflator (π_r^A in Inequality 2) and poverty line (PL_A in Inequality 2) need to match. Let us consider a case of global

[9] Dikhanov et al. (2017) examine this issue.

poverty measurement that does not satisfy this condition—that is, the case of "reference area mismatch".

Recall Equation (3) and Inequality (4), in which a global poverty line is deflated to the year of the household budget survey (t). Suppose the international PPPs are calculated based on urban prices, the PPPs are urban biased. To make it explicit, we use $PPP_{AU,2011}$ —instead of $PPP_{A,2011}$—in Inequality (4)':

$$NEXP_{irt} \times (\pi_{rt}^{AN})^{-1} \lessgtr GPL_{2011} \times PPP_{AU,2011} \times CPI_{2011,t}^{A} \qquad (4)'$$

where $PPP_{AU,2011}$ refers to the PPP for country A in 2011 with urban prices as the reference prices of country A. Then assume that the reference prices of the within-country spatial price index are national average prices (π_{rt}^{AN}).

A problem in Inequality (4)' is that while the left-hand side reflects household expenditures assessed as national average prices, the poverty line on the right-hand side is assessed at urban prices. One way to correct this mismatch is to adjust the PPP by the price ratio between national and urban prices in 2011 ($PLR_{AN/AU,2011}$):

$$NEXP_{irt} \times (\pi_{rt}^{AN})^{-1} \lessgtr GPL_{2011} \times \left(PPP_{AU,2011} \times PLR_{AN/AU,2011}\right) \times CPI_{2011,t}^{A} \qquad (4)''$$

As urban prices tend to be higher than rural prices (that is, $PLR_{AN/AU,2011} < 1$), this inequality clearly shows that the urban-bias in the international PPPs raises the poverty line by the degree of the urban-to-national cost-of-living, thus overestimating poverty rates. In other words, using Inequality (4)" to correct the urban bias lowers the poverty rate.

Let us consider another expression of mismatches in reference prices. Recall Inequality (5), in which household consumption expenditures are converted to US$ in 2011 PPP terms. If the PPPs are urban biased, we instead have the following:

$$NEXP_{it} \times (\pi_{rt}^{AN})^{-1} \times (CPI_{2011,t}^{A})^{-1} \times (PPP_{AU,2011})^{-1} \lessgtr GPL_{2011} \qquad (5)'$$

The first three terms of the left-hand side present household expenditures assessed at national average prices in 2011. However, $PPP_{AU,2011}$ is a conversion rate of country A's urban prices—rather than national average prices—to the US dollar in 2011. Since urban prices are usually higher than national average prices, $PPP_{AU,2011} > PPP_{A,2011}$. As a result, the mismatch in reference prices increases poverty rates. This mismatch can be corrected by either (a) adjusting the urban-biased PPPs with the urban-to-national price ratio ($PLR_{A/AU,2011}$):

$$NEXP_{irt} \times (\pi_{rt}^{AN})^{-1} \times (CPI_{2011,t}^{A})^{-1} \times (PPP_{AU,2011} \times PLR_{AN/AU,2011})^{-1} \lessgtr GPL_{2011} \qquad (5)''$$

or (b) changing the reference area of the within-country deflator from national average prices to urban average prices:

$$NEXP_{irt} \times (\pi_{rt}^{AU})^{-1} \times (CPI_{2011,t}^{A})^{-1} \times (PPP_{AU,2011})^{-1} \lessgtr GPL_{2011} \qquad (5)'''$$

where the spatial price deflator π_{rt}^{AU} converts consumption expenditures in region *r* into urban prices. In both (5)" and (5)"', the left-hand side is household consumption expenditures expressed in US$ in 2011 PPP terms, which is comparable across countries.[10]

Several points require highlighting:

First, the price ratio used to correct the urban bias in the PPP—$PLR_{A/AU,2011}$ in Inequalities (4)" and (5)"—should reflect the urban-national price ratio in 2011. In practice, the price ratio should be calculated based on the within-country spatial price deflator from the household budget survey (HBS) collected in a year closest to 2011. In some cases, however, the price ratio may need to be calculated based on the latest HBS (that is, $PLR_{A/AU,t}$) because of the lack of an HBS collected around 2011 or the availability of a higher quality, within-country spatial price deflator in the latest survey.

Second, the issue around the gap in the survey year and 2011 is also applied to the adjustment of the within-country spatial price deflator by changing the reference area in Inequality (5)"'. If the spatial price structures are very different in 2011 and the current survey year, using π_{rt}^{AU} as the within-country spatial deflator may create another bias.

Third, as long as the adjustments for the within-country deflators and PPPs are made based on the current HBS—that is, π_{rt}^{AU} and $PLR_{A/AU,t}$—, Inequalities (4)", (5)", and (5)"' result in the same poverty estimates.

Fourth, the size of the bias from the urban bias and resulting mismatch of reference areas depends on the gap in prices between urban and rural areas. A wider gap in their prices makes smaller the price ratio $PLR_{A/AU,2011}$ in Inequalities (4)" and (5)". Thus, we expect a larger change in the poverty rate when correcting the urban PPP bias in such cases.

Fifth, correcting the urban bias in the PPP based on the price ratio ($PLR_{A/AU,2011}$ in country A) is unlikely to affect the poverty *trend* in the country. As shown in Inequality (4)", the correction is expected to lower the global poverty line for the country and thus reduce the poverty rate. As long as the price ratio is calculated based on the same HBS around 2011 and then applied to subsequent surveys, the poverty trend would not change.

Sixth, as discussed earlier, it is not known which countries have had the PPP reference prices adjusted to be national average prices. Thus, we describe possible combinations of reference prices for within-country spatial price deflators and PPPs. Let us first consider the scenarios where PPP reference prices are national average prices (PPP_N) in panel A in Table 2. Poverty rates based on the within-country spatial price deflators with national (π^N) and urban reference prices (π^U) are expressed as H_N and H_U, respectively. In this case, the size of the bias due to the mismatch is $H_U - H_N$. In case of urban PPPs in Panel B, the size of the bias due to the mismatch is $H_N - H_U$. Therefore, the bias in absolute terms is $|H_U - H_N|$ irrespective of the PPP reference prices. Furthermore, as long as the urban prices are higher than the rural prices, $H_U < H_N$; therefore, $|H_U - H_N| = H_N - H_U$.

[10] Transforming the within-country spatial deflator, π_{rt}^{A}, into a multilateral price index (for example, through a GEKS transformation) does not solve the urban-bias and mismatch problem, as the urban-biased PPP—$PPP_{AU,2011}$ in Inequalities (4)' in (5)'—remains.

Lastly, Table 2 also shows the bias due to exclusion of the within-country spatial price deflator. Table 2 refers to the case where the spatial price deflator is not used as "NA" and its poverty rate as H_{NA}. If the PPP reference prices are national average prices, then the bias is $H_{NA} - H_N$. The sign of the bias is not known. If the PPP reference prices are urban average prices, then the bias is $H_{NA} - H_U$. The sign of this bias at the national level is positive if urban prices are higher than rural prices, but it is not known for the rural and urban areas.

Table 2. Status of reference price mis/matches

Reference prices of				
Spatial price deflators	PPPs	Poverty rate	Mismatch?	Bias
(A) PPP reference prices: national average prices (PPP_N)				
π_N	PPP_N	H_N	Matched	$H_U - H_N$
π_U	PPP_N	H_U	Mismatched	
NA	PPP_N	H_{NA}	Not available	$H_{NA} - H_N$
(B) PPP reference prices: urban average prices (PPP_U)				
π_N	PPP_U	H_N	Mismatched	$H_N - H_U$
π_U	PPP_U	H_U	Matched	
NA	PPP_U	H_{NA}	Not available	$H_{NA} - H_U$

Note: NA refers to the case with no within-country spatial price adjustment.

Current practice on price adjustments around the world

Current practices for price adjustments for the global poverty index vary across regions and countries. For global poverty measurement in Latin American and the Caribbean (LAC) countries, where PPPs are anchored to urban prices, rural households' incomes are inflated by 15 percent uniformly to reflect price differences between urban and rural areas (Ferreira et al, 2016). This matches the reference areas of PPPs with spatial price adjustments, but the assumption that the price differences between urban and rural areas is fixed at 15 percent for all countries may be too simplified. In ECA countries, within-country price variations are adjusted for by a Paasche price index based on food unit values; however, the reference areas of the PPPs and the spatial price adjustments are not matched. PPP calculation is based on urban prices, but the spatial price index is referenced to the national average. Most SSA governments measure poverty based on spatially deflated consumption expenditures (Chen et al. 2020), but global poverty indices measurement is mostly based on nominal consumption expenditures with no intra-country spatial price adjustment in most countries.

Ideally, a spatial price deflator should have the following features

- First, it should account for the spatial differences in both food and non-food prices, the latter including housing costs. A food price index may not capture spatial price differences well.
- Second, spatial price deflators should be constructed based on the price data that have good item coverage (particularly goods and services of lower quality that poor people typically consume), good geographic coverage (particularly rural and/or isolated areas), and detailed product specifications that allow comparison of like with like. Relying on unit values may not be a desirable option due to the lack of detailed product information.
- Third, the linkage between a spatial price index and utility should be theoretically backed up, such as with the Paasche price index (Deaton and Zaidi 2002) and the Fisher price index (Diewert 1976).

- Fourth, in case of application to global poverty measurements, spatial price deflators should be consistent at least within each region—this may be particularly hard to achieve SSA in the short term.
- Finally, transparency and replicability in the construction and application of spatial price deflators are also important.

3. Empirical approach

This paper looks at the data from four SSA countries—Madagascar, Mozambique, Angola, and Ethiopia—to illustrate the influence of spatial deflation on global poverty estimates and the potential bias from reference price mismatches between PPPs and spatial price deflators, Given that it is unknown which countries use national or urban PPPs due to the lack of meta data in the 2011 ICP, we estimate the size of potential bias due to both (i) the exclusion of the within-country spatial price deflator, and (ii) its inclusion with reference price mismatches.

As shown in Table 3, this paper estimate three global poverty rates measured at the $1.90 per day, per capita poverty line:

- First, we simply estimate national, urban, and rural poverty rates based on nominal consumption expenditures—that is, no spatial deflation (Column 1). This is the existing method for global poverty monitoring for Ethiopia, Madagascar, and Mozambique.
- Second, we estimate global poverty rates at the national, urban, and rural levels by using spatial deflators with national average prices as the reference prices (π^N) (Column 2).
- Third, we estimate global poverty rates by setting the reference prices of the spatial deflators as urban prices (π^U) (Column 3).

The comparisons between the poverty rates in Columns (1), (2), and (3) show the potential impact of including spatial price adjustments on poverty estimates and correcting the reference price mismatches:

- Column (4) shows the difference in poverty between Columns (1) and (2), which indicates the bias of poverty estimates due to the exclusion of spatial price deflators if the PPP reference prices are national average prices.
- Column (5) points to the difference in poverty between Columns (1) and (3), which indicates the bias of poverty estimates due to the exclusion of spatial price deflators if the PPP reference prices are urban prices.
- Finally, Column (6) reports the difference in poverty between Columns (2) and (3), which indicates the bias due to the mismatches of reference prices if the PPP reference prices are urban prices (Panel B in Table 2). As we discussed, if the PPP reference prices are instead national average prices (Panel A in Table 2), the bias is in the opposite direction.

Table 3. Poverty estimates in different scenarios

		Poverty headcount ratio (percent)			Bias (percentage points)		
		Nominal (1)	Deflated by π^N (2)	Deflated by π^U (3)	Bias from no deflation $[PPP_N]$ (4) = (1) - (2)	Bias from no deflation $[PPP_U]$ (5) = (1) - (3)	Bias from reference price mismatch $[PPP_U]$ (6) = (2) - (3)
Country A	National (a)	[1a]	[2a]	[3a]	[4a]	[5a]	[6a]
	Urban (b)	[1b]	[2b]	[3b]	[4b]	[5b]	[6b]
	Rural (c)	[1c]	[2c]	[3c]	[4c]	[5c]	[6c]

We use the World Bank's Global Monitoring Database (GMD), a set of harmonized household budget surveys used for global poverty estimation. Table 4 summarizes the consumption variable statistics, HBSs, and spatial price deflators we used for our analysis.

Table 4. Summary statistics of per capita daily consumption expenditures (US$ in 2011PPP terms)

		N	Mean	SD	Min	Max
Madagascar 2012	National	77,560	1.490	1.554	0	35.51
	Urban	17,207	2.871	2.530	0	35.51
	Rural	60,353	1.208	1.065	0	24.51
Mozambique 2014	National	163,571	2.596	6.836	0	699.0
	Urban	90,559	4.537	11.35	0	699.0
	Rural	73,012	1.695	2.458	0	230.2
Angola 2018	National	60,504	3.078	8.400	0.043	496.9
	Urban	38,396	4.015	10.54	0.090	496.9
	Rural	22,108	1.624	1.981	0.043	77.86
Ethiopia 2015	National	125,149	3.109	2.680	0.208	111.8
	Urban	74,124	5.202	4.652	0.283	111.8
	Rural	51,025	2.616	1.579	0.208	34.38

Source: Global Monitoring Database
Note: No within-country spatial deflation is applied. Observations are at the individual level.

Madagascar: The global poverty estimate for Madagascar in 2012 is based on *Enquête Nationale Sur le Snivi des Objectifs du Millènaire Pour le Dèveloppement Â Madagascar* (ENSOMD) 2012/13. The spatial price deflator is constructed as a Paasche price index based on food unit values (World Bank 2016).[11] The deflator distinguishes cost of living across 44 geographic areas (urban and rural areas of 22 regions). The original deflator has the urban area of the Analmanga region as the reference area.

Mozambique: Mozambique's global poverty is estimated based on *Inquérito Sobre o Orçamento Familiar* (IOF) 2014/15. While the government estimates poverty using regional poverty lines, the World Bank constructed an alternative spatial price deflator (World Bank 2018). This study uses this WB deflator, which is constructed as a Paasche price index at the household level based on food unit values. The Paasche price index is referenced to the national average.

Angola: The latest global poverty for Angola is estimated using *Inquérito de Despesas, Receitas e Emprego em Angola* (IDREA) 2018/19. The spatial price deflator is calculated as a Fisher price index based on food and non-food unit values, varying across 11 regions (6 urban and 5 rural) (World Bank 2020b).[12] The Fisher price index is referenced to the national average. As this index is calculated for each quarter within the survey period, we take an average of index values over the 4 quarters.

Ethiopia: Ethiopia's latest global poverty is estimated based on Household Consumption Expenditure Survey (HCES) 2015/16. The government constructed the spatial price deflator for poverty measurement, distinguishing cost of living (both food and non-food) across 39 geographic

[11] Spatial Paasche price index is calculated as $P = \frac{\Sigma_{j=1}^{J} q_{ij} p_{ij}}{\Sigma_{j=1}^{J} q_{ij} p_{kj}}$, where k indicates the base region, i indicates every other region, and j indicates each item in the consumption basket, and q and p are quantities and prices, respectively.

[12] The spatial Fisher price index is calculated as a geometric mean of the Paasche and Laspeyres price indexes, the latter is calculated as $L = \frac{\Sigma_{j=1}^{J} q_{kj} p_{ij}}{\Sigma_{j=1}^{J} q_{kj} p_{kj}}$, where k indicates the base region, i indicates every other region, and j indicates each item in the consumption basket, and q and p are quantities and prices, respectively.

areas (22 major cities, 7 other urban areas, 10 rural areas) (National Planning Commission 2017; World Bank 2020c). The reference of the spatial price deflator is national average prices.

4. Results

In this section, we conduct a series of analyses to see how spatial price adjustments and mismatches with reference prices could affect poverty estimation.

Adjusting within-country spatial deflators or PPPs

As explained, it is possible to correct reference area mismatches by either adjusting the within-country spatial price deflators or the urban-biased PPPs. In our empirical analysis, we make both adjustments based on the current years and thus obtain the same results.[13] For illustration, we first adjust the within-country spatial deflators.

For each country, we convert the reference prices of the original spatial price deflator to national average prices using the following steps. First, we calculate the average value of the original spatial deflator. Second, we divide the original spatial price deflator by the average value calculated in the first step. In case of converting the reference prices of the original spatial deflator to urban prices, we calculate the average value of the original price deflator in urban areas at the first step.

Table 5 shows the distribution of deflator values for both of the original deflators, deflators with national average prices as reference (π^N) and deflators with urban prices as reference (π^U). By definition, once the reference is shifted to the national or urban average prices, the national or urban average of the deflator becomes 1 (see highlighted cells in Table 5). Shifting the reference prices to urban average prices could substantially change the national average value of deflators. For the Ethiopia data, shifting the reference to urban average prices reduces the national average value of the deflator by 11 percent—which corresponds to $PLR_{A/AU}$ in Inequalities (4)" and (5)". This means that real household expenditures decline more than10 percent by changing the reference prices. However, the reference shift does not have the same magnitude of impact for all countries. In the case of Mozambique, the reference shift reduces the national and urban averages of the deflator by only 1 percent, implying almost no difference in poverty estimation.

Table 5. Spatial price deflators before and after adjustments

		Percentile					mean	mean
		p10	p25	p50	p75	p90	(national)	(urban)
Madagascar	Original	0.71	0.74	0.82	0.93	1.00	0.85	0.91
	Adjusted to national (π^N)	0.84	0.88	0.96	1.10	1.18	1.00	1.08
	Adjusted to urban (π^U)	0.78	0.82	0.90	1.02	1.10	0.93	1.00
Mozambique	Original	0.94	0.96	1.00	1.00	1.01	0.99	0.99
	Adjusted to national (π^N)	0.96	0.98	1.01	1.01	1.03	1.00	1.01
	Adjusted to urban (π^U)	0.95	0.97	1.01	1.01	1.02	0.99	1.00
Angola	Original	0.89	0.97	1.10	1.12	1.14	1.05	1.09
	Adjusted to national (π^N)	0.85	0.93	1.05	1.07	1.08	1.00	1.04
	Adjusted to urban (π^U)	0.82	0.89	1.01	1.03	1.04	0.96	1.00
Ethiopia	Original	0.84	0.89	0.97	1.01	1.12	0.98	1.09
	Adjusted to national (π^N)	0.86	0.91	1.00	1.04	1.15	1.00	1.12
	Adjusted to urban (π^U)	0.77	0.82	0.89	0.93	1.02	0.89	1.00

Note: Reference prices are highlighted.

[13] For example, we calculate for Ethiopia the urban-to-national price ratio based on the 2015/16 HCES instead of calculating it based on the 2011 survey and applying to the 2015/16 survey.

Alternatively, we can correct reference price mismatches by correcting the urban-bias PPP (Table 6). We multiply the urban biased PPP (column 1) with the urban-to-national price ratios (column 2). We then apply the adjusted PPPs (column 3) to the poverty line (Inequality 4") or household consumption expenditures (Inequality 5") to estimate poverty.[14]

Table 6. International PPPs before and after adjustments

Country	Original PPP (1)	Urban-to-national price ratio (2)	Adjusted PPP (3) = (1) * (2)
Madagascar	700.22	0.93	651.07
Mozambique	15.82	0.99	15.70
Angola	80.93	0.96	77.85
Ethiopia	5.57	0.89	4.98

Table 7 summarizes the results of our poverty estimation following the framework we introduce in Table 3. For ease of interpretation, Figure 1 visually presents the results.

Bias from the exclusion of spatial deflation

We first look at poverty with no spatial deflation (Column 1 in Table 7). The poverty rates correspond to the official rates reported in PovcalNet (as of October 2020). Global poverty headcount ratios measured at $1.90 (2011 PPPs) per person, per day are 78.8 percent in Madagascar, 63.7 percent in Mozambique, 49.7 percent in Angola, and 30.8 percent in Ethiopia.

We next estimate poverty rates adjusted by spatial deflators with national average prices as the reference. Overall, poverty rates with spatial deflation (Column 2 in Table 7) are lower than those without spatial deflation in Column (1).

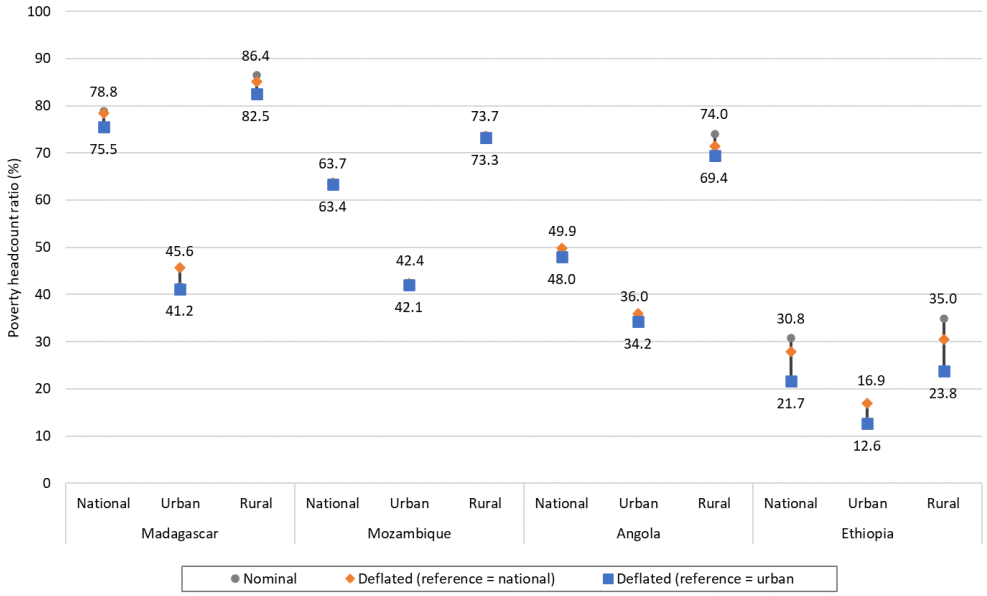
We then estimate poverty rates adjusted by spatial deflation with urban average prices as the reference (Column 3 in Table 7). Except for Mozambique, the numbers are lower for both the poverty estimates with no deflation in Column (1) and deflation with national average prices as the reference in Column (2). Mozambique shows no difference because spatial price deflators do not change much after shifting the reference price.

Table 7. Summary of poverty estimation results

		Poverty headcount ratio (percent)			Bias (percentage points)		
		Nominal (1)	Deflated by π^N (2)	Deflated by π^U (3)	Bias from no deflation $[PPP_N]$ (4) = (1) - (2)	Bias from no deflation $[PPP_U]$ (5) = (1) - (3)	Bias from reference price mismatch $[PPP_U]$ (6) = (2) - (3)
Madagascar 2012	National	78.8	78.4	75.5	0.4	3.4	3.0
	Urban	41.8	45.6	41.2	-3.9	0.5	4.4
	Rural	86.4	85.1	82.5	1.3	4.0	2.7
Mozambique 2014	National	63.7	63.7	63.4	-0.0	0.3	0.3
	Urban	42.0	42.4	42.1	-0.3	0.0	0.3
	Rural	73.7	73.6	73.3	0.1	0.5	0.3
Angola 2018	National	49.7	49.9	48.0	-0.2	1.7	1.9
	Urban	34.0	36.0	34.2	-2.0	-0.2	1.8
	Rural	74.0	71.4	69.4	2.6	4.7	2.1
Ethiopia 2015	National	30.8	27.8	21.7	3.0	9.1	6.2
	Urban	13.2	16.9	12.6	-3.7	0.6	4.2
	Rural	35.0	30.4	23.8	4.5	11.2	6.6

[14] Note that, as we have explained in the previous section, we do not intend to indicate that these countries have urban PPPs.

Figure 1. Global poverty headcount rates under three scenarios



Source: Authors' calculations.

Now we turn to the bias from the exclusion of spatial price adjustments in Columns (4) and (5), showing the difference in poverty rates between those with and without spatial deflation. Figure 2 also visually summarizes the results. In the cases of PPPs with national average prices as the reference (Column 4 in Table 7), the bias from the lack of spatial deflation raises rural poverty rates for all countries. Ethiopia (4.5 points) shows the largest bias in rural poverty, followed by Angola (2.6 points), and Madagascar (1.3 points). There is no significant change in rural poverty for Mozambique.

Given that official global poverty rates are currently calculated without spatial price adjustments, this result suggests that global poverty rates will decline when applying spatial price adjustments, whichever prices are used as reference. This is because the spatial deflation raises real expenditures among people in rural areas where poverty concentrates. The impact of spatial price adjustments on national poverty rates are minimal in some countries because the biases on rural and urban poverty rates offset.[15] Nonetheless, this empirical analysis still shows a sizeable bias in national poverty rates in Ethiopia.

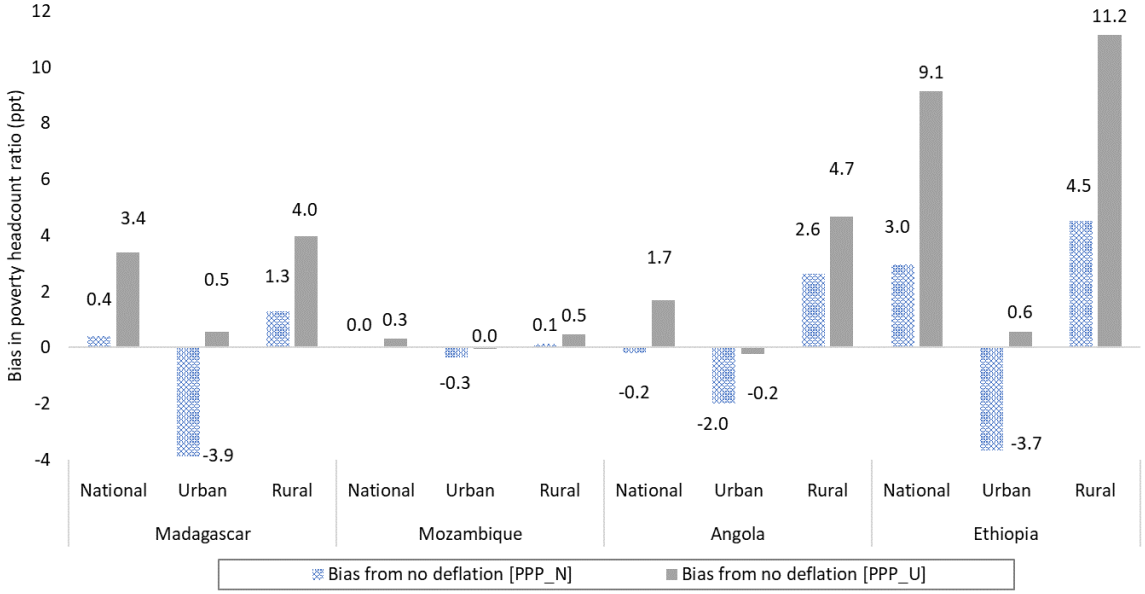
Column (5) in Table 7 shows the potential bias from the lack of spatial deflation when the PPPs are referenced to the urban average prices. The bias significantly raises national poverty rates for most countries: by 9.1 points in Ethiopia, 3.4 points in Madagascar, and 1.7 points in Angola.[16] The bias raises rural poverty rates by an even wider margin: by 4.0 points in Madagascar, 4.7 points in

[15] Introducing spatial deflations with the national reference prices slightly increases Angola's national poverty rate (0.2 percentage points). Spatially deflating household consumption expenditures generally increases poverty in urban areas—where cost of living tends to be higher—and reduces poverty in rural areas. Thus, the urban-rural population share is an important factor determining the net effect. According to the household budget survey, Angola has indeed a very high urban population share: 60 percent. Other countries have a lot lower urban population shares (for example, 19 percent in Ethiopia).

[16] The size of the impacts of spatial deflation found for the four Sub-Saharan African countries is similar to what is found for seven South Asian countries in Castaneda et al. (2018), where the rural poverty rate declines by 7.8 points in India.

Angola, and 11.2 points in Ethiopia. The exception is Mozambique, where national poverty increases only minimally.[17]

Figure 2. Bias in poverty estimations from the exclusion of spatial deflation



Source: Authors' calculations.
Note: The numbers indicate the bias in poverty estimates from the exclusion of spatial deflation when PPP reference prices are national average prices and urban average prices, respectively.

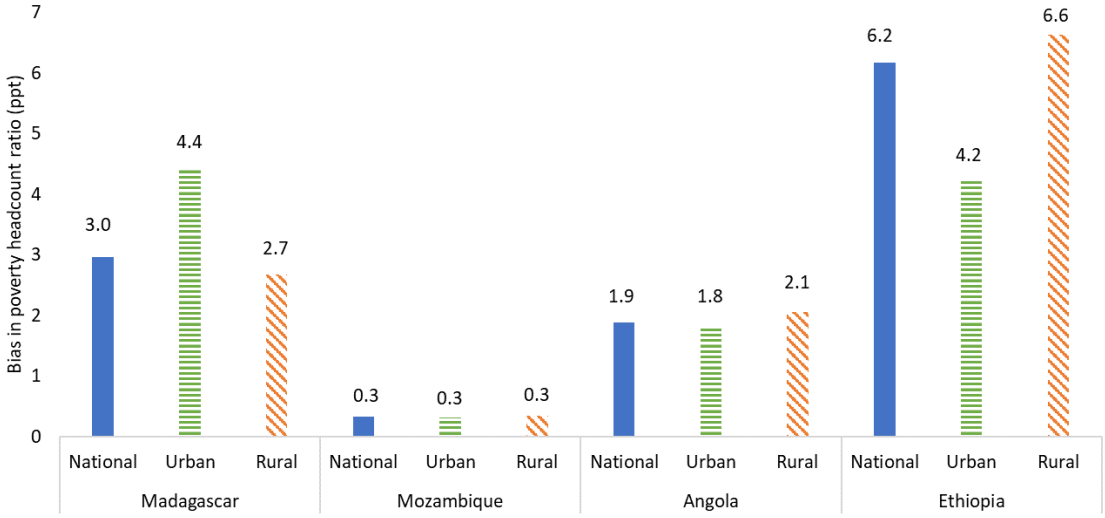
Bias from the reference price mismatch

We now move to the next question—How do reference price mismatches affect the estimation of poverty?

Column (6) of Table 7 compares the poverty rates deflated by spatial deflators with national prices as reference (π^N) and urban prices as reference (π^U). As we discussed, the difference between them indicates the size of bias due to reference price mismatches if using urban PPP reference prices. Our results show that reference price mismatches cause overestimation of poverty rates for national, urban, and rural areas (see also Figure 3). The bias in national poverty rates ranges from 0.3 percentage points (Mozambique), to 1.9 percentage points (Angola), to 3.0 percentage points (Madagascar), and to 6.2 percentage points in Ethiopia. As we pointed out, if the PPP reference prices are national average prices, the bias in absolute terms is the same but the sign is the opposite.

[17] Angola shows a slight negative bias in urban poverty (0.4 percentage points). We can decompose this bias into the effect of spatial price deflation with the national reference prices (column 4 in Table 7) and the effect of reference price mismatches (column 6). The former increases poverty in urban areas due to their higher cost of living; the latter increases real consumption expenditures of all households to the extent of urban-national price gap. Thus, the increase in urban poverty due to the exclusion of spatial deflations is somehow offset by the decrease in urban poverty due to reference price mismatches. The net effect is unknown a priori, as the magnitude of the former bias still depends on regional variations in cost of living and consumption distributions among urban households.

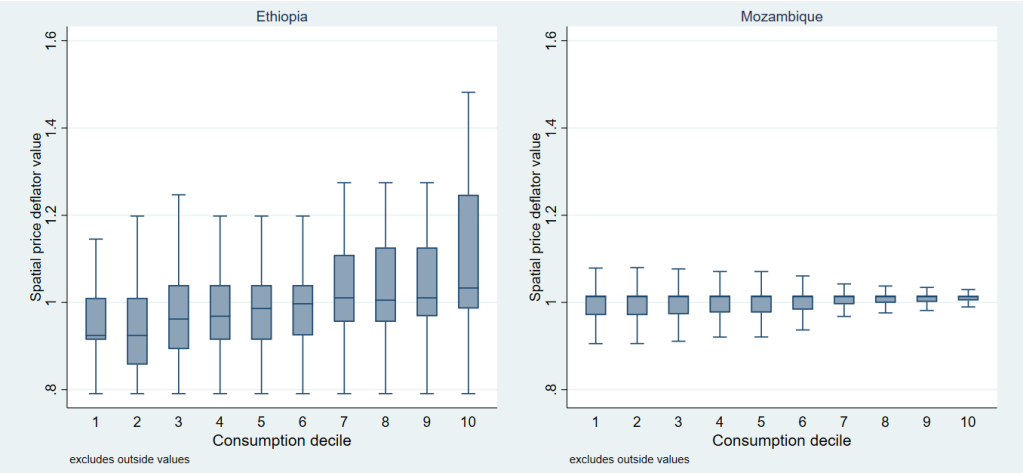
Figure 3. Bias in poverty estimations from reference price mismatches if PPP reference prices are urban average prices



Source: Authors' calculations.
Note: The numbers indicate the bias in poverty estimates from the mismatches in the reference prices between within-country price deflators and PPPs.

Why did we not observe any poverty impact from reference area mismatches in Mozambique? Spatial deflation does not affect poverty incidence much in Mozambique, as the deflator values applied to households near the poverty line are small (Figure 4). Reference area mismatch makes no difference, mainly because the mean values of urban and rural spatial deflator values are almost identical—although their distributions are quite different. By contrast, Ethiopia's spatial deflator indicates a lot higher cost of living mainly because it distinguishes disaggregated geographic areas (major cities, other urban areas, and rural areas for each region) and takes account of non-food prices.[18] In other words, we expect to see a large impact of reference area mismatch for countries with a wider gap between urban and rural prices.

Figure 4. Spatial deflators of Ethiopia and Mozambique



Source: Authors' calculations.

[18] For example, Ethiopia's spatial deflator value in the most expensive area—Addis Ababa—is 1.24 for food prices and 1.62 for non-food prices (National Planning Commission 2017).

5. Conclusion

This paper shows how spatial price adjustments potentially affect global poverty rates measured at the $1.90 per day, per capita poverty line, focusing on potential bias stemming from having a mismatch of PPP reference prices with spatial deflators. Our analyses use data from four SSA countries: Ethiopia, Madagascar, Mozambique, and Angola. It is worth noting that the global poverty rates are currently estimated without any spatial price adjustments for most SSA countries, as well as for some countries in other regions. Findings from this study imply how much global poverty rates would change if applying spatial price adjustments. Also, it underscores the urgent need to investigate the PPP reference areas in the 2011 ICP data.

Our key findings are:

First, the application of spatial price adjustments can significantly decrease poverty rate estimates in some countries. This is irrespective of whether the PPP reference prices are urban prices or national average prices. However, the size of decrease is bigger if PPP reference prices are urban prices. Since rural prices tend to be lower than urban prices, spatial price adjustments reduce rural poverty rates. However, the impact on national poverty rates is less dramatic since increases in urban poverty offset the decreases in rural poverty. The size of impact on national poverty rates when using urban price deflators depends on urban and rural poverty levels and population distributions between them. Our analysis shows a discernible decrease in national poverty in Ethiopia compared to current global calculations, but less so in other countries.

Second, if PPP reference prices are urban prices, correcting the mismatches in reference prices between intra-country spatial deflators and inter-country spatial deflators (that is, PPPs) would reduce poverty rate estimates, not only at the national level but also in urban and rural areas. Indeed, our empirical analysis of the four countries confirmed this, except for Mozambique where prices are similar in both urban and rural areas. This result also implies that if PPP reference prices were national average prices, correcting the mismatches in reference prices would increase poverty rates.

Third, it is critical to identify the PPP reference prices to make within-country spatial price adjustments. Our analysis confirms that bias due to mismatches of reference prices between within-country spatial price deflators and PPPs could be significant; but to eliminate the bias, we need to know what are the PPP reference prices. Based on its close engagement with NSOs of almost all SSA countries, the World Bank is well positioned to work with NSOs to clarify the PPP reference prices. This represents a first step for making spatial price adjustments. Once this is done, we can avoid the bias by adjusting the reference prices of the spatial price deflators accordingly.

We conclude this paper with some remarks on methodological issues:

First, while this study focuses on a cross-sectional analysis, spatial deflation could also affect poverty *trends*. As explained in Section 2, correcting the PPP urban bias based on a price level ratio between the urban and national averages would not affect a country's poverty trend. However, introduction of spatial deflation can affect the poverty trend, as its impact on poverty in each survey year depends on its urban-to-rural differences in consumption distribution, population share, and price levels.

Second, this study underscores the importance of within-country spatial deflation, in line with recent studies (Gibson, Le, and Kim 2017; Chen et al. 2020). Typical spatial price deflators, which tend to rely on food prices and ignore housing costs, may have underestimated urban cost of

living. Relatedly, proper transparent documentation of spatial deflation methodologies is required to correct for regional or global reference price mismatch.

Third, the definition of urban areas matters. This study follows each country's administrative definition used for their household budget surveys. For global comparison of subnational poverty, however, it is essential to use a globally consistent urban measure.[19]

Fourth, correcting the bias stemming from the use of urban PPPs and the reference price mismatch could also change the global extreme poverty line. The global extreme poverty line was calculated based on poverty lines in the poorest 15 countries, but some of those countries have urban-biased PPPs. Nevertheless, shifting the poverty line does not affect the comparability of global poverty estimates across countries. As our primary concern in this paper is the lack of comparability stemming from mismatched reference prices, we leave this issue for future studies.

Fifth, since the international PPP is calculated as a multilateral price index (World Bank 2015a, 2015b, 2020a), our findings affect PPP calculation for all countries. While we propose an approach to adjusting the urban biased PPPs based on the urban-to-national price ratio, such correction for some countries would require recalculation for all countries.

Lastly, while the new 2017 round PPP has been published (World Bank 2020a), global poverty measures continue to rely on the 2011 PPP (Atamanov et al. 2020). Thus, the urban bias in PPP-based poverty estimates remains a problem worth keeping in mind. The next step would be to investigate which countries have urban PPPs in the 2011 ICP.

[19] The Degree of Urbanization approach is an example of globally comparable urban measurements (see Dijkstra et al. 2020).

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