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International Income Inequality: Measuring PPP bias by estimating Engel curves for food

BY

INGVILD ALMÅS

Norges Handelshøyskole

NORWEGIAN SCHOOL OF ECONOMICS AND BUSINESS ADMINISTRATION

International Income Inequality: Measuring PPP bias by estimating Engel curves for food

Ingvild Almås*

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Abstract

Price-adjusted data on national incomes applied in cross-country comparisons are measured with bias. By studying micro data, this paper finds that the bias is systematic: the poorer a country is, the more its income tends to be overestimated. Consequently, international income inequalities are underestimated.

The bias in the macro price variables (PPPs), is caused by factors analogues to those creating bias in consumer price index numbers (CPIs). Exploiting this fact, the PPP bias is measured by estimating Engel curves for food, a method already established to measure CPI bias.

1 Introduction

Measures of national income and production influence political decisions and are important instruments in evaluating and understanding national and international policies and reforms. In any economic debate on international issues, cross-country comparable indicators, such as real production and real income, are needed. In order to make real production and incomes comparable, it is common to deflate by prices. The standard approach is to use price-adjusted purchasing power parity

*Norwegian School of Economics and Business Administration, Helleveien 30, 5045 Bergen, Norway, e-mail: ingvild.almas@nhh.no. Thanks to Kevin Denny, Steinar Holden, Jo Thori Lind, Peter Neary and Bertil Tungodden for valuable comments and suggestions. The usual disclaimer applies.

(PPP) measures.[1] However, existing methods for calculating such comparable real incomes are far from perfect and researchers as well as policy makers have to work with biased estimates.

This paper measures the bias in the country-specific per-capita real incomes presented in the Penn World Table (PWT), and, moreover, studies the relationship between the bias and national per-capita real income for a country. This is done by first finding the bias in the PWT macro prices, and, consequently, based on the corrected prices, calculates unbiased real incomes. Second, the relationship between national per-capita real income and the measured bias is studied, and a specific focus is given to the question of whether poor countries' incomes are overestimated relative to richer countries' incomes. Finally, this paper investigates whether international income inequality decreases or increases when correcting for the PPP bias.[2]

The paper reports four main findings. First, there are significant and substantial biases in the national incomes given in the PWT. Second, there is a systematic relationship between the PPP bias and the national income of a country: the poorer the country, the more its income tends to be overestimated relative to a base country. Third, the PPP bias causes a significant underestimation of international inequality: the Gini index increases substantially when correcting for the bias. Fourth, the underestimation of international inequality is robust: the distribution of uncorrected real incomes of the PWT Lorenz dominates that of the corrected PWT real incomes.

The problems faced when constructing PPPs are in essence analogous to those faced when constructing consumer price indices (CPIs). One of the novelties of this paper is that it acknowledges and exploits this analogy by applying Hamilton's method for estimating CPI bias to estimate PPP bias (Hamilton, 2001).

Hamilton (2001) proposes to utilize the stable relation between the budget share for food and total expenditure to measure CPI bias. He estimates Engel curves for food by applying US micro data for different years. The macro price variable, CPI, is used in order to make the micro data on total expenditure comparable across years. Both micro and macro data might be measured with bias, and because the macro data are aggregated from the micro data, measurement errors in the micro data carry over to the macro data. However, there is an asymmetry in the quality of estimates from micro and macro data. The micro data is more detailed and no information is lost because of aggregation. Beyond that, macro data might, in general, suffer

[1] The traditional exchange rate-based method simply measures all national incomes in one common currency by using the current exchange rates. Because of cross-country price differences not reflected in the exchange rates, this method fails to measure real incomes correctly.

[2] Throughout the paper, the phrase 'PPP bias' refers to the overall bias in the macro price variable for consumption given in the PWT and the subsequent bias in the measured national per-capita real incomes.

from biases caused by aggregation techniques, such as the Geary-Khamis method underlying the PWT. The method applied in this paper and in Hamilton (2000), utilizes the detailed information in micro data to reveal biases in aggregated macro price data.

This paper adopts Hamilton's (2001) approach by assuming that there is a stable relationship between the budget share for food and real incomes across countries, i.e., that there exists a unique Engel relationship for food in the world. The macro prices from the PWT are applied in order to make real incomes comparable across countries. That is, household real incomes are found by deflating household total expenditure by the macro price variable for consumption given in the PWT. Thus, the household real incomes should be comparable across countries. Any systematic difference in the estimated Engel relationship between a country and a base country, picked up by a country dummy coefficient, reveals the PPP bias for the respective country relative to the base country.

As is standard in this approach, the assumption that there exists a unique Engel curve for food, and the assumption that this curve is estimated correctly, are crucial to the results of the analysis. Because of this, several robustness checks are conducted, one of which tests whether the functional form fits the data in the study. None of the robustness checks change the main findings. We have, thus, no reason to think that misspecification drives the results of this paper.

The PPP bias stems from two problems that are well known within the price index literature: namely, the substitution bias and the bias caused by heterogeneous consumption sets (Costa, 2001; Hamilton, 2001; Hill, 2000; Neary, 2004). Most PPP calculations, among them the Geary–Khamis calculations presented in the PWT, belong to the group of fixed-basket calculations. In a fixed-basket calculation, a set of cross-country comparable macro price variables is constructed, and the real income of a country is constructed by evaluating the realized national consumption bundle at this set of prices and not the actual national specific price levels. Hence, the fact that the consumers would have substituted their consumption away from relatively more expensive goods towards relatively less expensive goods, if faced with the constructed price level, is not taken into account. Thus, if consumers do not have Leontief preferences, both PPP and CPI measures inherit a substitution bias.

Furthermore, in a fixed-basket calculation, a homogenous consumption set for comparison is needed. The problem of constructing this homogenous set is twofold. First, the quality of a particular good may vary across countries. For example, if different brands of cars are available in different countries and the different brands have different prices, it is not clear whether the price differences for cars should be reflected in the price index or whether the price differences simply reflect differences in quality between the brands. Second, the set itself may vary across countries. For example, comparing the price of Pakistani gur, a sugar substitute, to that of Norwegian sugar substitutes is hard, because of the fact that sugar substitutes hardly exist in Norway.

Although an enormous amount of macroeconomic studies rely on the PWT numbers, there are very few studies that focus on the measurement bias in this data set. There are some contributions, however, that focus on the substitution bias in the PWT variables, and they apply macro data to measure it (Dowrick and Akmal, 2005; Hill, 2000; Neary, 2004; Nuxoll, 1994). All these studies find the same trend: international income differences tend to be underestimated in the PWT data. The conclusions of this paper are in line with these studies. The main methodological contributions of this paper are twofold. First, applying micro data from household surveys, inaccuracies because of aggregation techniques are avoided. Second, the specific method based on Engel curve estimation makes it possible to estimate the *overall* PPP bias, and not only the substitution bias. The overall PPP bias includes the substitution bias, the bias caused by heterogeneous consumption sets and any unspecified measurement errors in the PWT data, for which we have no theoretical explanation.

The paper is organized as follows: section 2 describes the empirical methodology in more detail; section 3 describes both the micro data and the macro price variables from the PWT that are applied in the analysis. The analysis and main findings are presented in section 4. Section 5 presents the robustness analysis and section 6 concludes.

2 Empirical Methodology

This paper estimates national Engel curves for food based on household micro data from nine countries, i.e., the relationship between the household budget share for food and household real income. The reason for estimating Engel curves for food and not for other items is that food has two properties that are needed in order to identify the bias. First, food has an income elasticity different from unity. In order to identify the PPP bias, the coefficient for the logarithm of income is needed in addition to the country dummy coefficient. If the income elasticity was equal to unity, however, it would be impossible to estimate such a coefficient.

Second, studies show that the Engel curve for food is stable, both over time and across societies (Banks et al, 1997; Beatty and Larsen, 2005; Blundell et al, 1998; Leser, 1963; Working, 1943; Yatchew, 2003). This stable relationship is exploited in order to measure the bias in the PPP adjusted measured of national real incomes.

In this study the macro price variable for consumption, P_j, given in the PWT, is used to make household incomes comparable across countries. The bias in P_j is by definition country-specific, and hence, the dummy coefficients pick up the biases in the P_j's.

2.1 Empirical framework - Econometric specification

The standard almost ideal demand system specification is the following:

$$m_{h,r,j} = a + b(\ln y_{h,r,j} - \ln P_j) + \gamma(\ln P_{f,r,j} - \ln P_{n,r,j}) + \theta X_{h,r,j} + \epsilon_{h,r,j} \quad (1)$$

where $m_{h,r,j}$ is the budget share for food of household h in region r, country j. $y_{h,r,j}$ is the nominal income of household h in region r, country j, and P_j is the composite price of consumption in country j. $P_{f,r,j}$ is the price of food in region r, country j, and $P_{n,r,j}$ is the price of nonfood items in region r, country j. $X_{h,r,j}$ is a vector of demographic control variables for household h in region r, country j, which includes age of household head, number of children and number of adults in the household.

There are no regional cross-country comparable price data available for the countries in the study and, therefore, the coefficient for relative prices, γ, cannot be estimated. Consequently, the main estimation excludes relative prices between food and nonfood items, and thus, implicitly assumes that the budget share for food is unaffected by relative prices. However, we have observations on national relative prices for five countries and a robustness check for relative price effects is conducted in the robustness analysis in section 5.

When excluding the relative price effect, (1) can be written as:

$$m_{h,j} = a + b(\ln y_{h,j} - \ln P_j) + \theta X_{h,j} + \epsilon_{h,j} \quad (2)$$

Denoting the biased macro price variable for consumption given in the PWT P'_j and the PPP bias for country j, E_j, the unbiased corrected price variable P_j, can be expressed as follows:

$$P_j = P'_j * E_j \quad (3)$$

Equation (2) can, thus, be expressed as follows:

$$
\begin{aligned}
m_{h,j} &= a + b(\ln y_{h,j} - \ln P'_j - \ln E_j) + \theta X_{h,j} + \epsilon_{h,j} \\
&= a + b(\ln y_{h,j} - \ln P'_j) + \theta X_{h,j} + \sum_{j=1}^{J} d_j D_j + \epsilon_{h,j}
\end{aligned}
\tag{4}
$$

where J is the total number of countries and D_j is the country dummy. The country dummy coefficient, d_j, is a function of the PPP bias, E_j, and the coefficient for the logarithm of real income, b:

$$
d_j = -b \ln E_j \tag{5}
$$

The specification given in (4) is the preferred specification of this paper and the PPP bias is, thus, given by[3]:

$$
E_j = e^{-\frac{d_j}{b}} \tag{6}
$$

Because the budget share for food is decreasing in income (i.e., b is negative), the estimated bias is larger than one as long as the country dummy coefficient is positive. Whenever the bias is larger than one, the PWT consumption price is underestimated and thus, the real income of the country is overestimated. The larger the country dummy coefficient, the larger the bias, and the larger the bias, the more the macro price level for consumption is underestimated. Subsequently, the larger the bias, the more national per capita real income is overestimated.

3 Data

The Engel curves are estimated from micro data in order to reveal biases in the macro price variable for consumption in the PWT. This section discusses the micro data and the macro price variables in turn.

3.1 Micro data from household surveys

52 543 households from nine countries are included in the main estimation of the preferred specification. Table 1 gives an overview of the different surveys. The

[3] Alternative specifications are estimated in the robustness analysis of section 5.

household data for Azerbaijan, China, Nicaragua and Côte D'Ivoire are from the World Bank's living standard measurement surveys (LSMS). The data for the USA are from the Consumer Expenditure Surveys (CES), US Bureau of Labor, and the Hungarian data are from the Hungarian Central Statistical Office, Section of Household Budget Survey. Luxembourg Income Studies (LIS) provide the data for France, United Kingdom and Italy.[4] The nine countries have been picked from available nationally representative studies in order to maintain both a geographical spread and a combination of lower and higher income countries.[5]

It is demanding to harmonize data from different studies and, therefore, this analysis relies most heavily on surveys that are available from already harmonized sources, such as the LIS and to some degree the LSMS. There are no panel data available for the lower-income countries and this limits the choice of estimation techniques. Moreover, scarcity of data for some of these countries also limits the inclusion of explanatory variables.

In the main estimation of the preferred specification, all households are included and regressors are included in order to correct for household composition and size. In the robustness analysis, other estimations are conducted - among them an estimation of the preferred specification using the 4968 households with two adults and two children. This robustness check exploits one of the advantages of using micro data: it is possible to analyze households of the same composition and size in order to avoid inaccuracies because of heterogeneous household composition.

[Table 1 about here.]

Many of the households included in the analysis are farm households, and for these households home produced food amount to a considerable part of total household consumption. In order to take this into account, home produced goods are included in the expenditure variables.

3.2 Macro price variables

In the standard AIDS specification, three macro price variables are included. The first, P_j', is a composite price index for all consumption goods in country j, which is constructed by the Geary–Khamis method and presented in the PWT. The other

[4]Detailed information on the different LSMS and LIS studies can be found on the World Bank and LIS websites, respectively (Luxembourg Income Studies, 2006; World Bank, 2005)

[5]All data are constructed to be nationally representative except those from China. For China, no national representative study is available. The Chinese data includes households from the provinces of Hebei and Liaoning, which implies that only rural households are covered.

two macro price variables are the composite price index for food items, $P_{f,r,j}$, and nonfood items, $P_{n,r,j}$, respectively.

The household surveys are conducted in different years, and thus, the macro price variable for consumption in the PWT has to be taken from different years. The consumption price reported in the PWT is given in current prices, and consequently the US exchange rate as well as the US consumer price index are applied in order to make the real income levels comparable across countries and time. The macro price variable for consumption and the exchange rate are taken from the Penn World Table 6.1 (Heston et al, 2002). The CPI of the US is taken from the World Bank's WDI online (World Bank, 2007).

The preferred specification (equation (4)) does not include relative prices between food and nonfood items ($\ln \frac{P_{f,r,j}}{P_{n,r,j}}$). The reason for this is simply a lack of data. Unfortunately, cross-country regional price data for food and nonfood items do not exist. Very few countries report regional price variation, and if they do, it is done relative to a base year. The price in one region is compared to the price level of that same region in a different year. Thus, these cannot be used in cross-regional comparisons for specific years. The same applies to national price indices, e.g., the food price index produced by the World Bank. These are also only defined relative to a base year, and thus, cannot be used to compare relative prices across countries.

The International Comparison Project published cross-country comparable *national* prices for food and nonfood items for the year 1980 (phase IV, can be found at Neary, 2006). Combining these prices with the price indices of the World Bank, comparable *national* relative prices for Hungary, USA, France, United Kingdom and Italy are calculated. It is, however, impossible to identify the coefficient of the relative price within the data set, because we do not have regional price data. To overcome this problem, Costa's (2001) estimated coefficient for relative prices, γ, is applied in one of the robustness checks in section 5. Using Costa's estimated coefficient, *national* relative price levels for the five countries are included and hence the relative price effect is taken into account in this estimation.

4 Analysis and Main Findings

[Table 2 about here.]

The regression results of the main estimation are presented in Table 2.[6] The

[6] The number of households differs substantially among the countries. Despite this, the weight given to each household is the same. Two different weighting techniques have been conducted as a part of the robustness analysis, neither of which changes the main result: a weight equal to the population in the respective household's country and a weight equal to the ratio of observations

estimated income elasticity of food is slightly smaller than in related studies (Costa, 2001; Hamilton, 2001). The US country dummy coefficient is by construction equal to zero, and the dummy coefficients for Azerbaijan, China, Nicaragua, Côte D'Ivoire, Hungary, France, United Kingdom, and Italy are used to measure the PPP bias relative to the US bias. The first main finding in this paper is that the biases in the national incomes given in the PWT are substantial and significant: all country dummy coefficients are significantly different from zero. All countries except for the United Kingdom, have a positive dummy coefficient; i.e., the macro price variables in the PWT underestimate the macro price levels compared to the US macro price level. Thus, all countries' real incomes, except for the United Kingdom's, are overestimated relative to the US real income in the PWT. The estimation shows that the group of non-OECD countries, China, Nicaragua, Azerbaijan and Côte D'Ivoire, have substantially higher dummy coefficients than the OECD countries. China has the highest dummy coefficient, whereas Nicaragua and Azerbaijan have slightly smaller dummy coefficients. The United Kingdom has a negative dummy coefficient, which implies that its real income is underestimated relative to US real income.

[Figure 1 about here.]

Figure 1 presents the second main finding of this paper: there is a decreasing relationship between the PPP bias and national real income levels. The measured bias is much higher for the poorest countries than for the richer. It is clear from Figure 1 that the overestimation of the poorest countries' real income is substantial. For China, Azerbaijan and Nicaragua, the real income is overestimated by a factor of seven compared to the US. However, as we will see from the robustness checks, when taking into account that household size differs and avoiding household composition effects, the measured bias is lower than in the main model, and the poorest countries' incomes are measured to be overestimated by a factor of four. As is seen from the robustness analysis in section 5, however, the ordinal ranking is the same when taking household composition into account. In comparison, Hill (2000) measures the substitution bias only, and he finds that the poorest countries' real incomes are overestimated by a factor of approximately two. The difference may suggest that the PPP bias contains more than a substitution bias and that these additional effects pull in the same direction.

Table 3 reports different measures of international inequality all relying on the Gini index, where the first line gives estimates from the main model. The two first

relative to the population of the country of residence.

columns present the international inequality when assigning the per-capita real income to each country and giving equal weight to all countries. The international inequality measured by the Gini index for these nine countries increases from 0.45 for the PWT measured incomes (given in column 1) to 0.61 for the corrected per-capita incomes (given in column 2). The two last columns present the international inequality when giving each country a weight proportional to its population. The effect on the population weighted Gini index is even larger.[7] The population weighted international inequality assigns the per capita real income to all citizens in each country and gives each country a weight in proportion to its population.

[Table 3 about here.]

[Figure 2 about here.]

It is relevant to discuss whether this observed increase in inequality is robust; will other inequality measures also find an increase in inequality or is the choice of applying the Gini index essential for this finding?

Figure 2 presents the Lorenz curves for the uncorrected and corrected real incomes, respectively. The Lorenz curves form the basis of the fourth main finding: the distribution of real incomes based on the biased macro price variables from the PWT Lorenz dominates that of the corrected real incomes. Hence, we have the robust conclusion that inequality is underestimated in the PWT according to any reasonable inequality measure.[8]

5 Robustness Analysis

Four different tests are conducted in the robustness analysis. The main results are sustained in each of the tests. First, the preferred specification given in (4) is estimated on the subset of households with two children and two adults, in order to test whether differences in household composition influence the main results. Second, an alternative specification is considered by applying the OECD adult equivalence. Third, a semiparametric analysis is conducted in order to study whether the functional form fits the data in the study. Fourth, relative prices are included and the standard AIDS specification given in equation (1) is estimated on the subgroup of our sample where relative prices are available, i.e., on the households in the five

[7] Milanovic (2005), which applies household surveys, is an important contribution on the topic of inequality. The international inequality is equivalent to concept 1 inequality whereas the population weighted inequality is equivalent to concept 2 inequality in Milanovic (2005).

[8] All measures that satisfy the Pigou-Dalton criterion, which is uncontroversial, will support this conclusion (Fields and Fei, 1978; Sen, 1997).

countries in which cross-country comparable relative prices exist. Except for the semiparametric analysis, the figures illustrating the results are presented in the appendix.

5.1 Household composition

The first robustness check is conducted in order to study whether inaccuracies caused by heterogeneous household composition affect the main findings. In order to avoid effects from household composition and size, we restrict our analysis to households consisting of two children and two adults. In the total sample, there are 4968 such households, and equation (4) is estimated on this subsample. The regression results are reported in the second column of Table 2. The four non-OECD countries also have the highest bias in this estimation, and the main picture given in Figure 1, is sustained. Côte D'Ivoire has the highest measured bias in this estimation, and China follows as the country with the second largest bias. Nicaragua and Azerbaijan have slightly smaller measured biases than China. The dummy coefficient for France is no longer significantly different from zero, that is, we cannot statistically distinguish the bias of the macro price variable of France from that of the USA. The Gini indices increase substantially also in this case, from 0.45 to 0.58, and we still obtain Lorenz dominance of the uncorrected measures. Hence, household composition does not seem to be crucial for our results. We also note that the estimated income elasticity is more in line with other related studies than the main estimation (Costa, 2001; Hamilton, 2001).

5.2 Equivalence scaling

The second robustness check is conducted by applying the OECD household equivalent scale, q[9]:

$$m_{h,j} = a + b(\ln y_{h,j} - \ln P'_j - \ln q_{h,j}) + \theta X_{h,j} + \sum_{j=1}^{J} d_j D_j + \epsilon_{h,j} \tag{7}$$

The regression results for this specification are presented in Table 2, column III. We also see in this case that the bias is higher for the four non-OECD countries than for the OECD countries. China has the largest estimated bias, as in the main estimation. The Gini indices for all specifications are given in Table 3: the increase in the Gini index is almost identical for all specifications, and when applying the OECD

[9]The OECD adult equivalence scale gives the value 1 to the first person in the household, 0.7 to each additional adult and 0.5 to each additional child (less than 16 years of age).

adult equivalence scale, the Gini index increases from 0.45 to 0.59. The uncorrected distribution of national incomes also Lorenz dominates that of the corrected distribution in this case. Thus, all four main findings are maintained when applying the OECD adult equivalence scale.

5.3 Functional form - does the semilog specification fit the data?

[Figure 3 about here.]

A main concern with the method applied in this paper is to what extent the functional form specification is restrictive. In order to study the functional form, a semiparametric analysis based on differencing is conducted. All variables except the logarithm of real income are included linearly in the regression. The robustness check, thus, investigates whether the log-linear relationship between the budget share for food and real income fits the data well. Figure 3 shows the kernel regression between budget share for food and the logarithm of real income after the effect from the other variables is differenced away. The kernel regression function is linear where the curve is precisely defined, i.e., where the upper and lower bounds from the bootstrapping coincide with the kernel itself. The semiparametric analysis, thus, confirms that the log-linear relationship between the budget share for food and real income assumed in equation (4) fits the data well. As we would expect, it fits better for the medium to high income levels where we have more observations, than for the fewer observations in the lower tale of the income distribution.

5.4 Including relative price effects

Given that comparable *national* relative prices are available for five of the nine countries in the study, we examine whether including these relative prices changes the main results of this paper. This is done by estimating equation (1) on the subsample of households in the five countries that have such prices available and applying the significant relative price effect estimated in Costa (2001).

Given that the coefficient for the relative price is already estimated in Costa (2001), one new *net* variable is constructed. The left-hand side dependent variable is now the difference between the budget share for food and the effect of relative prices given in equation (8). The coefficient of the logarithm of relative prices is assumed to be equal to 0.006, Costa's estimated coefficient.[10] The new left-hand

[10] The corresponding price elasticity is approximately 0.68. This price elasticity is calculated as $-1 + [(\gamma - \alpha b)/m]$, where α is the share of the food in the US total price index (Costa, 2001).

side variable is defined as:

$$m^c_{h,j} = m_{h,j} - 0.006 * (ln(P_{f,j}) - ln(P_{n,j})) \qquad (8)$$

Based on this variable, a new regression is run, and a new set of dummy coefficients, and subsequently a new set of PPP biases are estimated. The estimation results are given in Table 2, column IV.

The PPP bias is also in this case a function of the coefficient of the logarithm of real income and the country dummy coefficient. In addition to this, it is now a function of the bias in the measured prices for food and nonfood items, and is given by:

$$\ln E_j = \frac{\gamma}{b}(\ln E_{f,j} - \ln E_{n,j}) - \frac{d_j}{b} \qquad (9)$$

where $E_{f,j}$ and $E_{n,j}$ are the biases in the measured prices for food and nonfood items, respectively. We have no method to identify the bias in all three prices at the same time, and it is assumed here that the bias in the price for food cancels out the bias in the nonfood price, i.e., that there is no bias in the *relative* price. Under this assumption, the bias is measured as expressed in equations (3) and (6). This assumption is quite strong and because we cannot identify all the biases, we cannot test whether this assumption is valid. However, we know that the estimated coefficient of relative prices is far lower than the coefficient of real income and thus, the major effect picked up by the country dummy coefficient is from the PPP bias. Despite this, it should be kept in mind that if the bias for the food price is larger than the bias for the nonfood price, the bias is overestimated. The opposite will be true if the bias for the nonfood price is larger than the bias for the food price.

For the five countries in the study, the measured PPP bias is higher the lower the real income. Also, in this case, a negative relationship between the PPP bias and real income can be displayed. Table 3 reports the Gini indices before and after the correction. The Gini index for these countries is 0.17 when using data from the PWT, whereas when correcting for the measured PPP biases, we get a substantial increase of the Gini index to around 0.30. The uncorrected price measures for these countries also Lorenz dominate the corrected ones. Thus, all four main findings are sustained also when relative prices are included in the analysis.

6 Concluding Remarks

This paper has four main findings. First, there are significant and substantial biases in the national incomes given in the PWT. Second, international real income differences between countries are underestimated in the PWT. The lower a country's real income is, the more its real income is overestimated compared to US real income. The overestimation is substantial. Third, as a consequence of the second finding, the Gini index is substantially higher if based on the corrected PWT real incomes than if based on the uncorrected PWT income variables. Fourth, the distribution of the uncorrected national real incomes Lorenz dominates the corrected ones.

Several robustness checks reveal that the main findings are not driven by wrong functional form specification, differences in relative prices or household composition. However, this study, as well as other studies based on micro data (or macro data deduced from micro data), could have benefited if more studies were available and already harmonized. It will be interesting to study future work that uses even more detailed data than what is available right now.

First, if there existed panel data sets for poor countries, as it does for OECD countries, it would be possible to use more sophisticated estimation techniques. Second, if there existed one data set with harmonized data for both rich and poor countries, it would be less demanding to do cross-country comparisons based on micro data and more than nine countries could be included.

Is there a theoretical explanation for the PPP bias measured here? We have, so far, no theoretical explanation when it comes to the direction of the biases caused by heterogeneous consumption sets and substitution bias. Both Dowrick and Akmal (2005) and Nuxoll (1994) provide some theoretical support for the empirical finding that income differences are underestimated in the PWT. Nuxoll (1994) shows that *if* the Geary–Khamis constructed virtual world prices used in the comparisons are closer to the richer countries' prices, income differences are smaller than if they were closer to the poorer countries' prices. Dowrick and Akmal (2005) make quite restrictive assumptions and show that when preferences are Cobb–Douglas, income differences tend to be underestimated when the Geary–Khamis method is applied. It is open for future research to generalize these insights for the Geary–Khamis method. At present, the direction of the bias is an empirical question.

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Appendix

Here, we present some figures from the robustness analysis. Figure 4 presents the relationship between the PPP bias and per-capita real income for three different estimations: one on the subsample of households with two children and two adults; one applying the OECD household equivalence scale; and one including national relative prices. We see that the downward sloping relationship is sustained in all three estimations.

[Figure 4 about here.]

Figures 5, 6 and 7 show that the finding of Lorenz dominance of the corrected distribution is sustained in all the robustness checks conducted in section 5.

[Figure 5 about here.]

[Figure 6 about here.]

[Figure 7 about here.]

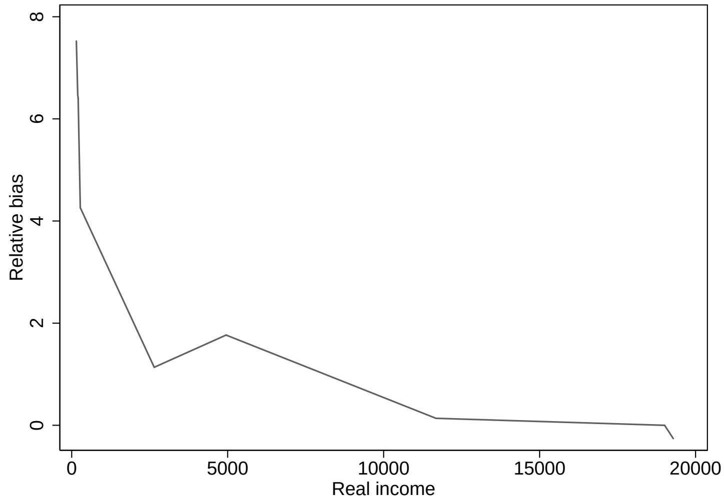

Figure 1: **PPP bias and real income.** The figure presents a declining relationship between PPP bias and corrected real income per capita in international dollars for the nine countries. The bias for country j is measured relative to the US bias, $relativebias_j = E_j - 1 = e^{\frac{-d_j}{b}} - 1$

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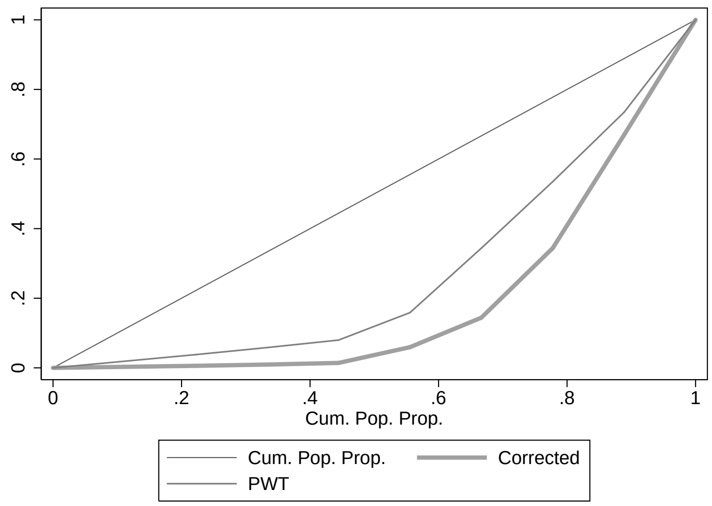

Figure 2: **Lorenz Dominance.** The distribution of the biased real incomes (PWT) Lorenz dominates the distribution of the corrected real incomes (Corrected).

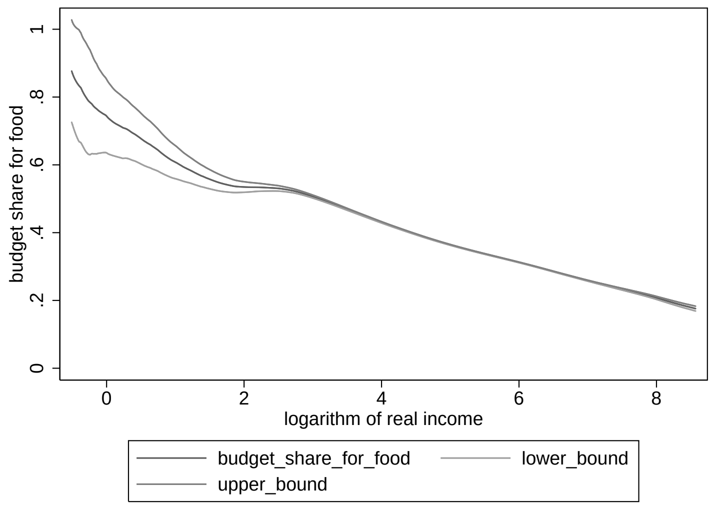

Figure 3: **Kernel regression.** The Kernel relation using the Epanechnikov kernel smoother: the relationship between the budget share for food and the logarithm of real income when the effects from the other explanatory variables are differenced away. A tenth order differencing is conducted based on the optimal differencing weights proposed in Yatchew (2003). The bandwidth is equal to 1.36149. The bandwidth used is found from the formula $bandwidth = 0.15 * (max_{logrealcons} - min_{logrealcons})$ where $max_{logrealcons}$ and $min_{logrealcons}$ are the maximum and minimum values of the real logarithm of expenditure, respectively. The bounds correspond to 95% confidence intervals. We see that for values of the logarithm of real income that are below 2.7 the curve is not precisely defined because of few observations and it is not clear whether the curve is linear in this part or not. However, to the right of this point, the curve is precisely defined and it is linear.

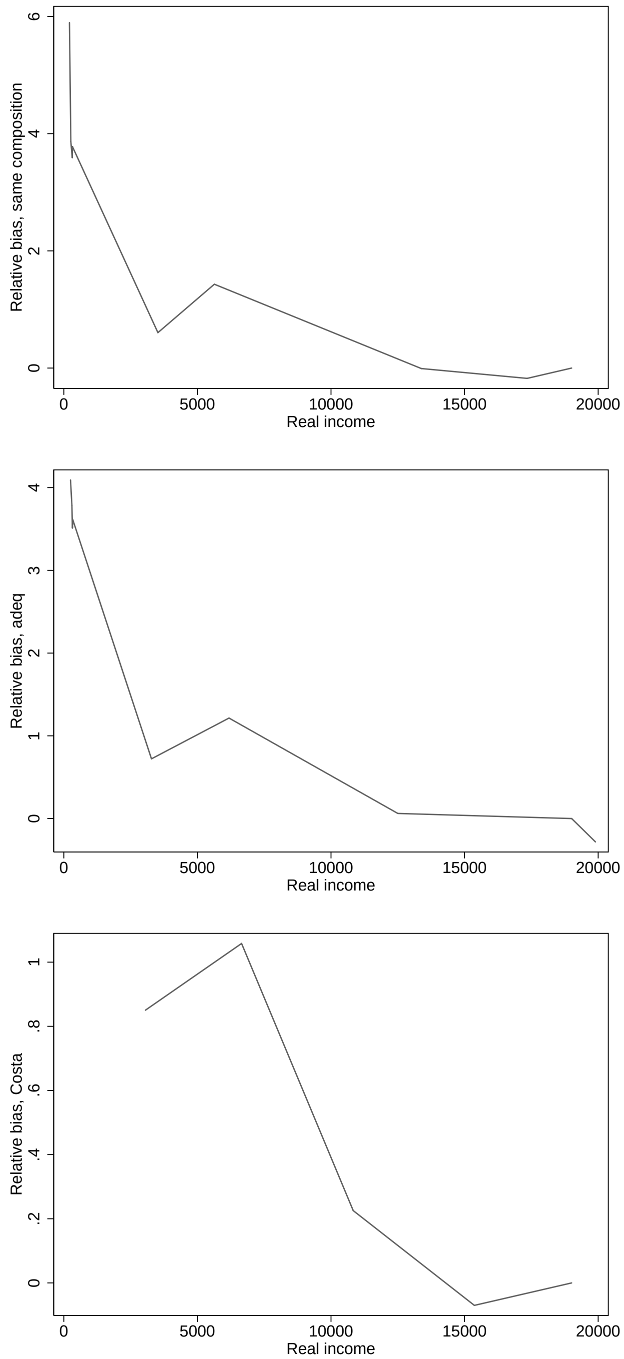

Figure 4: **Relative bias and per-capita real income:** The upper curve illustrates the relationship between measured bias and per-capita real income when only households with two children and two adults are applied in the estimation. The curve in the middle illustrates the same relationship when the OECD adult equivalence scaling is applied, whereas the lower curve presents the same relationship for the five OECD countries when national relative prices are included.

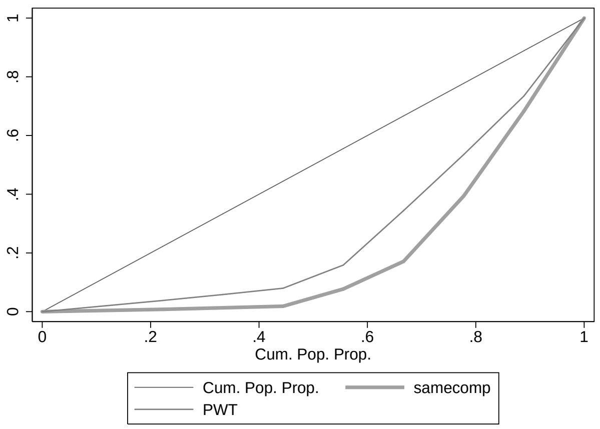

Figure 5: **Lorenz dominance when including households with two children and two adults.** The distribution of the biased real incomes (PWT) Lorenz dominates the Lorenz curve for the distribution of the corrected real incomes (samecomp).

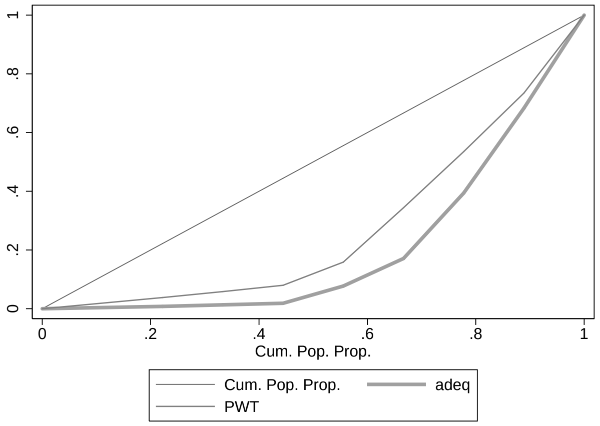

Figure 6: **Lorenz dominance when applying the OECD adult equivalence scale (adeq).** The distribution of the biased real incomes (PWT) Lorenz dominates the Lorenz curve for the distribution of the corrected real incomes (adeq).

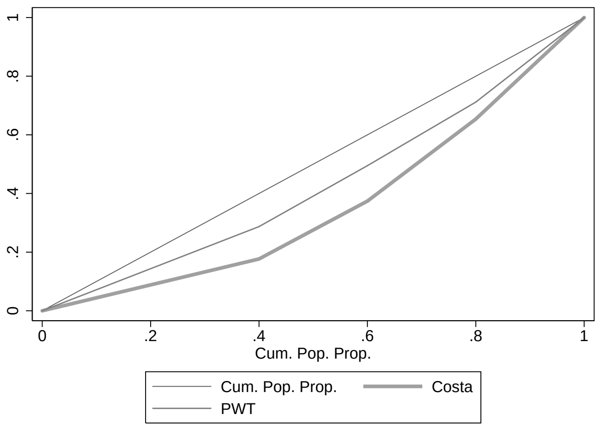

Figure 7: **Lorenz dominance when including relative price effects.** The distribution of the biased real incomes (PWT) Lorenz dominates the Lorenz curve for the distribution of the corrected real incomes (Costa).

	Survey year	Institution	No. of hh	Nat. Repr.
Azerbaijan	1995	SORGU / World Bank	1966	Yes
China	1994	Min. of Agg./World Bank	786	No
Côte D'Ivoire	1986	Inst. Nat. Stat. / World Bank	1573	Yes
France	1995	Inst. Nat. Stat. Étud. Éc. / LIS	9627	Yes
Hungary	1996	Hungarian Cent. Stat. Off.	7528	Yes
Italy	1995	Bank of Italy / LIS	8116	Yes
Nicaragua	1993	INEC / World Bank	3185	Yes
United Kingdom	1995	UK Data Archive / LIS	6789	Yes
United States	1995	CES, US Bureau of Labor	12973	Yes

Table 1: **The different surveys.** This table gives an overview of the nine different surveys included in the study and the institutions that conducted the different studies.

	Main I	Same-Composition II	Adeq III	Costa IV
log of real income	-.085*** (.001)	-.097*** (.003)		-.089*** (.0009)
log of real income (adeq adj.)			-.094*** (.001)	
Azerbaijan	.171*** (.006)	.151*** (.018)	.144*** (.005)	
China	.183*** (.005)	.153*** (.012)	.153*** (.005)	
Nicaragua	.172*** (.005)	.147*** (.011)	.147*** (.004)	
Côte D'Ivoire	.142*** (.007)	.186*** (.019)	.142*** (.005)	
Hungary	.065*** (.002)	.046*** (.007)	.051*** (.002)	.055*** (.002)
France	.011*** (.001)	-.0008 (.004)	.006*** (.001)	.018*** (.001)
United Kingdom	-.026*** (.001)	-.019*** (.004)	-.031*** (.001)	-.006*** (.001)
Italy	.087*** (.002)	.086*** (.005)	.075*** (.002)	.064*** (.002)
children	.012*** (.0009)		-.0002 (.0005)	.021*** (.0006)
adults	.016*** (.001)		-.005*** (.0005)	.029*** (.0006)
age	.0003*** (.00004)	.001*** (.0002)	.0006*** (.00003)	.0006*** (.00003)
cons	.633*** (.006)	.727*** (.020)	.663*** (.006)	.621*** (.006)
Number of observations	52543	4968	52543	45033
Adjusted R-squared	.55	.619	.564	.383

Table 2: **Regression results.** The table reports four sets of estimates. In column I is the estimate of equation (4), including all households. Columns II, III and IV show results from the three robustness checks discussed in section 5: column II shows the results for estimation of equation (4) including only the households with two adults and two children, column III shows the results for the specification that adjusts real incomes by applying the OECD adult equivalent, given in equation (7), and column IV shows the results for the specification that adjusts for relative price effects estimated in Costa (2001), given by the combination of equations (1) and (8).

	Gini PWT	Corr Gini	Gini PWT weighted	Corr Gini weighted
Main	0.45	0.61	0.58	0.74
2+2	0.45	0.58	0.58	0.72
Adeq	0.45	0.59	0.58	0.73
Costa	0.17	0.30	0.06	0.14

Table 3: **Gini Indices.** The table shows the Gini index measured by the PWT data (columns 1 and 3) and the Gini index with corrected real incomes (columns 2 and 4). In columns 1 and 2 the unweighted Gini indices are shown; i.e., each country is given equal weight in the construction of the index. In columns 3 and 4 the population weighted Gini indices are expressed. The last row of Gini indices reported is not comparable to the other rows because of the fact that only five countries are included in this robustness check.

Norges Handelshøyskole

Norwegian School of Economics
and Business Administration

NHH
Helleveien 30
NO-5045 Bergen
Norway

Tlf/Tel: +47 55 95 90 00
Faks/Fax: +47 55 95 91 00
nhh.postmottak@nhh.no
www.nhh.no