International Income Inequality: Measuring PPP Bias by Estimating Engel Curves for Food

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Abstract

Purchasing power adjusted incomes applied in cross-country comparisons are measured with bias. In this paper, we estimate the purchasing power parity (PPP) bias in Penn World Table incomes. The bias is substantial and systematic: the poorer a country is, the more its real income tends to be overestimated. Consequently, international income inequality is substantially underestimated.

Our methodological contribution is to exploit the analogies between the PPP bias and the bias in consumer price indices (CPIs). The PPP bias is measured by estimating Engel curves for food, which is an established method of measuring CPI bias. (*JEL*: D1, E31, F01)

1 Introduction

There are large differences between rich and poor people in the world. This is of major concern to economists, as well as to the public. The magnitude of the differences, however, depends on the measure used for comparisons. To illustrate, (per capita) income

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in China is five times larger if one uses Penn World Table (PWT) incomes rather than exchange rate based (EX) incomes.

In this paper, we study PWT incomes and identify the bias in them by estimating Engel curves for food. The PWT reports purchasing power parity (PPP) adjusted incomes, and therefore we refer to the associated bias as the PPP bias. Having estimated the PPP bias, we provide new estimates of real national incomes which are referred to as Engel curve (EC) incomes. By comparing the EC incomes and the PWT incomes, we study how the PPP bias affects international inequality measures. Finally, we discuss whether EX incomes provide better estimates of real income than PWT incomes.

This paper incorporates three main findings. First, there is a significant, substantial, and systematic bias in the PWT incomes; the poorer the country is, the more its income tends to be overestimated. Second, the PPP bias causes a significant and robust underestimation of international inequality; the Gini index increases substantially when one adjusts for the bias. Third, EX incomes are better estimates of real income than PWT incomes for poorer countries, whereas the opposite seems to be true for richer countries.

Although many studies rely on PWT incomes, few focus on the bias in this dataset. However, some contributors focus on one component of the bias, the so-called substitution bias, and use macro data to measure this bias (Dowrick and Akmal, 2005; Hill, 2000; Neary, 2004; Nuxoll, 1994). In these studies, it is shown that, because of the substitution bias, international income differences tend to be underestimated by the PWT data. However, there is another potential bias component that has not been identified empirically, known as the quality bias, and hence the issue of underestimation of international inequality cannot be robustly investigated without finding a way of measuring the overall PPP bias. One important methodological contribution of this paper is that the specific method based on Engel curve estimation enables estimation of the overall PPP bias, and subsequently, the calculation of bias corrected real incomes, i.e., the EC incomes. Furthermore, this paper applies micro data from household surveys, and hence eliminates the inaccuracies that arise from using aggregation techniques.

The difficulties of constructing cross-country PPP price indices are analogous to those of constructing time series consumer price indices (CPIs). A novelty of this paper is that it acknowledges and exploits this analogy by applying to the estimation of the PPP bias the method of Hamilton (2001) for estimating CPI bias. Country specific Engel curves for food are estimated by using micro data from nine countries. We make the Engel curves comparable by deflating household total expenditure by the macro price variable for consumption from the PWT. We then exploit Engel's law, i.e., that there is a stable relationship between the budget share for food and household real income, to identify the PPP bias. More specifically, we take any systematic difference between the estimated Engel curve between a particular country and the base country, in our case the United States, as evidence of a PPP bias for that country relative to the United States.

The paper is organized as follows. Section 2 discusses the causes of the PPP bias and why we should expect it to be systematically biased. Section 3 describes the empirical methodology in detail. Section 4 presents both the micro data and the macro data applied in the analysis. The analysis and main findings are provided in Section 5, whereas Section 6 provides robustness tests. Section 7 extends the analysis by using UN aggregate consumption data, and Section 8 evaluates and compares EX incomes and PWT incomes. Section 9 concludes the paper.

2 Explaining the Bias

The PPP bias stems from two problems that are well documented in the price index literature, namely the quality bias and the substitution bias (Costa, 2001; Hamilton, 2001; Hill, 2000; Neary, 2004). The Geary–Khamis calculations that underlie the PWT are fixed-basket calculations. Fixed-basket calculations rely on using a set of homogenous goods, which generates the quality bias, and using a reference price vector for making comparisons, which generates the substitution bias.

First, the quality of goods varies both over time and across countries. For example, it is not clear whether the observed price difference of cars between Poland and the United States reflects a difference in the quality of the brands available in the two countries or represents a real price difference. Furthermore, some goods might be unavailable in some countries. For example, sugar substitutes are not consumed in all countries, and hence in practice, sugar substitutes and sugar must be included in the same broad goods category, i.e., goods of different quality are incorporated in the same goods category.

Second, the substitution bias arises because a reference price vector is applied to evaluate different countries' *realized* consumption bundles. Hence, the fact that the consumers, unless they have Leontief preferences, would have substituted their consumption away from relatively more expensive goods towards relatively less expensive goods, if faced with a reference price vector different from their own price vector, is not taken into account. Consequently, the use of a reference price vector creates a substitution bias in the estimates of real income. We expect both the quality bias and the substitution bias to be systematic. Poorer countries tend to have products of lower quality than richer countries, and thus we expect that failing to adjust for quality causes poorer countries' incomes to be overestimated. We should also expect the substitution bias to cause an overestimation of poorer countries' incomes relative to richer countries' incomes. Independent of the income level, the substitution bias will lead to an overestimation of a country's income but, importantly, this overestimation is increasing in the difference between the country's actual price vector and the reference price vector (Nuxoll, 1994). The Geary–Khamis reference price vector is by construction closer to the national prices of the countries with larger total income (see Figure 1 for an illustration), and thus it follows that the substitution bias is greater for countries with lower total incomes.

[Figure 1 about here.]

This relationship also holds true for per capita income (see Figure 2 for an illustration).

[Figure 2 about here.]

In sum, we should expect both the quality bias and the substitution bias to lead to an overestimation of poorer countries' incomes (relative to richer countries' incomes).

3 Empirical Methodology

We start by using household micro data from nine countries to estimate national Engel curves for food.[1] The basic idea is that if two households, say one in China and one in the United States, have the same PWT measured income level and have the same demographic characteristics, any difference in the budget shares for food is attributed to PPP bias.

There are several advantages of using food as the indicator good. First, because the income elasticity differs substantially from unity, the budget share is sensitive to the level of household income and, subsequently, to the PPP bias. Second, food is a nondurable good, which implies that expenditures in one period cannot provide a flow of consumption goods in another period. Third, studies for different countries and over different periods, as well as this paper, yield evidence that the Engel curve for food is log-linear and 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).

3.1 Empirical framework—econometric specification

The Engel curve of the standard almost ideal demand system (AIDS) (Deaton and Muellbauer, 1980) is:

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

where $m_{h,r,j}$ is the budget share for food, $y_{h,r,j}$ is nominal household income measured in 1995 USD, and $X_{h,r,j}$ is a vector of demographic control variables consisting of the age of the household head and the numbers of children and adults in the household, for

[1] See e.g., Varian (1992), for aggregation properties of Engel curves.

household h in region r in country j. P_j is the composite price of consumption in country j. $P_{f,r,j}$ is the price of food and $P_{n,r,j}$ is the price of nonfood items in region r in country j.

Regional cross-country comparable price data are unavailable for the countries under study, and thus the coefficient for relative prices, γ, cannot be estimated. Consequently, the main estimation equation excludes relative prices between food and nonfood items and, therefore, implicitly assumes that the budget share for food is unaffected by relative prices. However, as is shown in the robustness analysis in Section 6, the results are very robust to relative price effects. When excluding the relative price effect, (1) can be simplified to:

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

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

$$P_j = P'_j E_j. \qquad (3)$$

Equation (2) can therefore be expressed as:

$$m_{h,j} = a + b(\ln y_{h,j} - \ln P'_j) + \theta X_{h,j} + \sum_{j=1}^{N} d_j D_j + \varepsilon_{h,j}, \qquad (4)$$

where 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 household real income, b:

$$d_j = -b \ln E_j. \qquad (5)$$

In the analysis, (4) is our preferred specification, and hence the PPP bias is given by:[2]

$$E_j = e^{-\frac{d_j}{b}}. \qquad (6)$$

[2]In the robustness analysis, alternative specifications are estimated; see Section 6.

The budget share for food is decreasing in household income (i.e., b is negative), and thus the estimated bias exceeds unity if the estimated country dummy coefficient is positive. If the bias exceeds unity, the PWT consumption price is underestimated and, therefore, the real income of the country is overestimated. The larger the estimated country dummy coefficient is, the larger the estimated bias is, and consequently, the more the per capita real income is overestimated.

With this framework in place, we can now provide more precise definitions of the different measures of national income:

$$Y_j^{EX} = Y_j \quad , \quad Y_j^{PWT} = \frac{Y_j}{P'_j} \quad , \quad Y_j^{EC} = \frac{Y_j}{P_j} = \frac{Y_j}{P'_j E_j}.$$

The exchange rate measured income of country j, Y_j^{EX}, is simply the nominal per capita income of country j, given in USD, Y_j. The PWT measured income of country j, Y_j^{PWT}, is given by Y_j deflated by the PWT measured macro price for consumption, P'_j, whereas the EC measured income is given by Y_j deflated by the bias corrected price level, P_j. If a country's measured price level is equal to that of the United States, i.e., $P'_j = 1$, and if the measured price level is unbiased, i.e., $E_j = 1$, all three income measures coincide.

3.2 An extended model

For most countries in the world, we do not have sufficiently detailed data to identify the bias and the EC incomes by the procedure outlined above. However, we extend the model by using the nine countries as benchmark countries and then apply UN aggregate data (country household means) for other countries. Given a country's household mean PWT income, we attribute any difference between the household mean budget share for food, and the Engel curve estimated budget share for food, to PPP bias. From equation (2) and aggregating to household mean budget shares (see, e.g., Denton and Mountain (2004)), it follows that:

$$\overline{m_j} = a + b\frac{\overline{\frac{y_j}{P_j}\ln(\frac{y_j}{P_j})}}{\overline{\frac{y_j}{P_j}}} + \theta\overline{X_j}, \tag{7}$$

where $\overline{V}$ indicates the mean value of variable V. The household mean demographic characteristics consist of the mean age of the household head, and mean number of adults and children in the household.

By applying the estimated coefficients from our benchmark model, $\widehat{a}$, $\widehat{b}$, and $\widehat{\theta}$, we predict the term $\kappa_j = \frac{\overline{\frac{y_j}{P_j}\ln(\frac{y_j}{P_j})}}{\overline{\frac{y_j}{P_j}}}$:

$$\widehat{\kappa_j} = \frac{\overline{m_j} - \widehat{a} - \widehat{\theta}\overline{X_j}}{\widehat{b}}. \tag{8}$$

It can be shown that: $exp(\frac{\widehat{\kappa}}{\kappa'}) = \frac{\widehat{P_j}}{P'_j}$, where $\kappa'_j = \frac{\overline{\frac{y_j}{P'_j}\ln(\frac{y_j}{P'_j})}}{\overline{\frac{y_j}{P'_j}}}$. Hence, by using (3), the PPP bias can be expressed by:[3]

$$\hat{E}_j = exp(\frac{\widehat{\kappa}}{\kappa'}) \tag{9}$$

4 Data

The data used in the estimation of the benchmark model are discussed in Sections 4.1 and 4.2, whereas the data used in the estimation of the extended model are discussed in Section 4.3.

4.1 Micro data from household surveys

The full sample of the micro data comprises observations on households from nine countries. Table 1 provides an overview of the different surveys. The household data for Azerbaijan, China, Nicaragua, and Côte D'Ivoire are from the World Bank's Living Standard

[3]As $\overline{\frac{y_j}{P_j}\ln(\frac{y_j}{P_j})}$ is generally different from $\frac{\overline{y_j}}{P_j}\ln(\frac{\overline{y_j}}{P_j})$, the former is simulated by assuming lognormal distributions of income and using national specific income distributions from Sala-i-Martin (2006).

Measurement Surveys (LSMS). The data for the United States are from the Consumer Expenditure Surveys and the United States Bureau of Labor. The Hungarian data are from the Hungarian Central Statistical Office (Household Budget Survey Section). Luxembourg Income Studies (LIS) provide the data for France, the United Kingdom, and Italy.[4] The nine countries in the study publish nationally representative surveys, and represent a geographical spread that includes both high- and low-income countries.[5]

It is difficult to harmonize data from different surveys, and therefore our analysis relies primarily on sources that present harmonized analysis, such as the LIS and, to a lesser extent, the LSMS. The choice of estimation technique is limited by the lack of panel data on lower-income countries. In addition, data limitations for some countries restrict the choice of explanatory variables.

In the main specification, we estimate equation (4) on the subsample of households with two children and two adults. Hence, we exploit an advantage of micro data, which is that they can be used to analyze households of the same composition and size to avoid the inaccuracies generated by heterogeneous household composition. For robustness analysis, we also estimate equation (4) on the whole sample.

[Table 1 about here.]

Many of the households included in the sample are farm households, for which home-produced food accounts for much of total household consumption. We account for this by incorporating the estimated market value of home-produced goods in the expenditure variable.

[4]Detailed information on different LSMS and LIS studies is provided on the World Bank and LIS websites (Luxembourg Income Studies, 2006; World Bank, 2005).

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

4.2 Macro price variables

In the standard AIDS specification, three macro price variables are included. The first, P'_j, is the PWT macro price for consumption in country j that is a composite price index for all consumption goods in country j, constructed using the Geary–Khamis method. The other two macro price variables are the composite price index for food items, $P_{f,r,j}$, and for nonfood items, $P_{n,r,j}$.

The household surveys are conducted in different years, and thus the P'_j's relate to different years. As the consumption price in the PWT is reported in current prices, we use the United States exchange rate and CPI to construct comparable P'_j's. The macro price variable for consumption and the exchange rate are taken from Penn World Table 6.1 (Heston et al., 2002). The United States CPI is taken from the World Development Indicators (World Bank, 2007).

Because of a lack of data, the preferred specification (represented by equation (4)) does not include relative prices between food and nonfood items. Unfortunately, no cross-country comparable regional price data for food and nonfood items exist.[6] However, cross-country comparable prices for food and nonfood items for 1980 (phase IV) from the International Comparison Project are reported by Neary (2006). Combining these data with the price indices from the World Bank yields comparable national relative prices for Hungary, the United States, France, the United Kingdom, and Italy. However, because we have no regional price data, the coefficient for relative price cannot be identified. To overcome this problem, in Section 5, we use Costa's (2001) estimated coefficient for relative prices, γ, for a robustness check. Using Costa's estimated coefficient enables inclusion of national relative price levels for these five countries. In this way, the estimation incorporates the relative price effect.

[6]Few countries report regional price variation, and those that do report them do so relative to a base year. Hence, they cannot be used to compare relative prices across countries.

4.3 Data used in the extended model

We extend our analysis by using mean household data from the UN Statistics Division (Common Database). Thirty-three observations on mean household consumption and budget shares are included, covering 33 countries (1995 data). We use data on final household expenditure in national currencies at current prices.[7] As for the benchmark model, we use the PWT price of consumption and the exchange rate to make final household consumption comparable across countries.

In the simulation of the distribution of income, we apply the distributions estimated by Sala-i-Martin (2006). Information on demographic controls are also obtained from the UN. The number of children and adults, and subsequently the OECD's adult equivalence scaling, can be calculated directly (Series code 13681 and 1070). The age of the household head is predicted from observations on mean age of male citizens (UN Statistics Division, series code 13630). The difference between the mean age of household head in the micro data and mean age of male citizens from the UN for the nine benchmark countries is equal to 5.93 years, and hence, we predict the mean age of the household head by adding 5.93 years to the UN observations on the mean age of male citizens.

The PWT income is defined as the consumption level, measured by the consumption share of real gross domestic product per capita, $cgdp$. The EX income is constructed by multiplying this income by the price of consumption from the Penn World Table 6.1 (Heston et al., 2002), i.e., by eliminating the price deflation.

5 Analysis and Findings

In this section, the PPP bias is estimated by using household surveys from nine countries, and the findings from this model are discussed in detail.

[7]We use Table 3.2 in the UN statistics division, Common Database, and include all series in the 1993 SNA, i.e., series 100, series 200, series 300, and series 400, where we have data on mean age of adult male population, and mean household number of children and adults. We have to drop Azerbaijan and Namibia, the former because final household consumption does exclude some direct purchases, and the latter because there is a discrepancy between the components of consumption and final household consumption.

[Table 2 about here.]

The regression results are presented in Table 2. The preferred specification estimates equation (4) on the subsample of households with two children and two adults. The estimated income elasticity for food is in line with previous studies (Costa, 2001; Hamilton, 2001; Beatty and Larsen, 2005; de Carvalho Filho and Chamon, 2006). By construction, the United States country dummy coefficient is equal to zero, whereas all the other dummy coefficients are used to measure the PPP bias when comparing incomes with the United States. All these 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 relative to the United States. Therefore, according to the EC method, all countries' real incomes, except that of the United Kingdom, are overestimated, relative to the United States, in the PWT. The estimates also show that the poorer countries, China, Nicaragua, Azerbaijan, and Côte D'Ivoire, have substantially higher dummy coefficients than the richer countries. The systematic relationship between bias and national income is illustrated in Figure 3 (northwestern panel): The poorer the country is, the larger the bias. This finding is in line with the discussions of Section 2.

Finally, both from Table 2 and Figure 3, we observe that the bias is substantial. As expected, our estimates of the bias exceed those of other studies that focus solely on the substitution bias (such as that of Nuxoll, 1994). The dummy coefficients indicate a substantial PPP bias. Côte D'Ivoire has the largest bias, and its real income is overvalued by a factor of six. China's dummy coefficient indicates that its real income is overvalued by a factor of four in the PWT. In sum, we have established our first main finding: the PPP bias is significant, substantial, and systematic.

[Figure 3 about here.]

Table 3 provides an overview of all three income measures for the nine countries in the study.[8] We observe that, for the poorer countries, the EC incomes are far closer to the EX incomes than the PWT incomes. Hence, our PPP bias correction seems to almost completely close the gap between PWT and EX incomes for the poorest countries. For the richer countries, however, the EC incomes are closer to the PWT incomes than to the EX incomes. [9]

[Table 3 about here.]

The second main finding is that international inequality (among the nine countries in the study), as measured by the Gini index, is substantially underestimated (see Table 4). The unweighted Gini index increases from 0.45 to 0.58 after adjusting for the bias, and the population weighted Gini index increases from 0.58 to 0.73.[10] As shown in XXX (2008), the PWT incomes Lorenz dominate the EC incomes, and hence the conclusion of underestimation of inequality is a robust finding and not dependent on the choice of the Gini index as an inequality measure.

[Table 4 about here.]

Table 4 also reveals that the measured international inequality from the EC incomes is far closer to that based on the EX incomes than that based on the PWT incomes. We will return to a more detailed discussion of the different income measures in Section 8.

6 Robustness Analysis

In this section, we provide several robustness checks of the main results in each of the tests. First, the preferred specification given in (2) is estimated using the whole sample

[8]For reasons of comparability with the extended version of the paper and Table 6 (where OECD adult equivalence scaling is used), we report the EC incomes estimated for the whole sample (also using OECD adult equivalence scaling). However, as is shown in Section 6, these estimates are very similar to those of the main model.

[9]Italy seems to be an outlier in two ways. First, the PWT and EX incomes are very similar for this country, and second, the difference between the EC and PWT incomes is larger than for the other richer countries.

[10]For a general discussion of these inequality concepts, see Milanovic (2005).

and the OECD adult equivalence scale. Second, a semiparametric analysis is conducted to study whether the functional form fits the data used in the study. Third, relative prices are included and the standard AIDS specification given in equation (1) is estimated on the subgroup of our sample for which relative prices are available. Fourth, we include within-country location effects.

6.1 Household composition

The first robustness check is conducted by including all households rather than only a subset of households of the same composition and size. This yields a much larger sample of households, and hence more information for the analysis (65,987 households versus 6,173 households). To make incomes comparable among households, we apply the OECD equivalence scale.[11] The regression results are reported in the second column of Table 2. Again, the four poorer countries have the highest estimated bias, and the main result is confirmed (see Figure 3, northeastern panel). Hence, using only a subsample of households does not seem to be crucial for our results.

6.2 Functional form analysis

[Figure 4 about here.]

A major concern with the method applied in this paper is that the functional form specification may be restrictive. There are two ways the functional form specification could be restrictive. First, the log-linear relationship might not fit the data, and second, the slope of the Engel curves might differ across countries.

In order to study the functional form, a semiparametric analysis is conducted. All variables, except the logarithm of household real income, are included linearly in the

[11] The OECD adult equivalence scale gives a weight of unity 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). The number of households differs substantially between countries. Despite this, the weight given to each household is the same. Two different weighting techniques were used for the robustness analysis; we used a weight equal to the population in the respective household's country and a weight equal to the ratio of observations relative to the population of the country of residence. Neither weighting scheme changes the results.

regression. This robustness check, therefore, investigates whether the log-linear relationship between the budget share for food and household real income fits the data well. Figure 4 shows the kernel regression between the budget share for food and the logarithm of household real income after removing the effects of the other variables by tenth order differencing (see, e.g., Yatchew (2003)). The kernels for the specific countries seem log-linear, perhaps with one exception, namely Nicaragua, where the curve looks concave for the poorest households. For the whole sample, the kernel regression function is linear in the interval where the curve is precisely defined, i.e., where the upper and lower bounds from the bootstrapping coincide with the kernel itself.[12] Because of the imprecise kernel estimates for the lowest income levels, we have estimated the model on the subsample of households belonging to the income interval where the kernel is precisely estimated, i.e., we drop the households with a logarithm of EC income lower than 8.2. This estimation gives even higher overestimation of the poorer countries, and the main findings of this paper are unchanged.

The mean slope of the kernels are given in Table 5, and we observe that the slopes do not vary much across the countries. The largest negative slope is equal to –0.13, whereas the smallest negative slope is equal to –0.08. More importantly, however, we do not observe any correlation between slope and estimates of real income, or between slope and measured bias.

[Table 5 about here.]

The semiparametric analysis, therefore, confirms that the log-linear relationship between the budget share for food and real income assumed in equation (4) fits the data nicely. Furthermore, studying each country separately gives no evidence of substantially different slopes across countries, and thus we have no reason to expect that the functional form specification drives the results of this paper. The conclusions are more robust in

[12]In order to investigate further whether the Engel relationship is concave, we have included the square of the logarithm of household real income in the estimation of the main model. The estimated coefficient for this squared term was insignificant, however, and this gives additional support to the log-linear functional form.

medium to high income levels, for which we have more observations than for the poorer households.

6.3 Including relative price effects

Comparable national relative prices are available for five of the nine countries in the study, and we examine whether including these relative prices changes the main results. This is done by estimating equation (1) on the subsample of households in the five countries that have such prices available, and by applying the statistically significant relative price coefficient (equal to 0.006) estimated by Costa (2001).

We construct a new *net* dependent variable; the difference between the budget share for food and the estimated effect of relative prices:

$$m^c_{h,j} = m_{h,j} - 0.006(ln(P_{f,j}) - ln(P_{n,j})). \quad (10)$$

Based on this variable, we repeat our analysis and estimate a new set of dummy coefficients and the subsequent PPP bias. The estimation results are given in the third column of Table 2.

The PPP bias is no longer only a function of the coefficient of the logarithm of real income and the country dummy coefficient, but also a function of the bias in the measured prices for food and nonfood items. In total, the PPP bias is now given by:

$$\ln E_j = \frac{\gamma}{b}(\ln E_{f,j} - \ln E_{n,j}) - \frac{d_j}{b}, \quad (11)$$

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 for identifying the biases in all three prices simultaneously, and we follow Hamilton (2001) and Costa (2001) by assuming that the bias in the price for food cancels out the bias in the nonfood price, i.e., by assuming that there is no bias in the *relative* price. Under this assumption, the total bias is measured as in equation (6). This assumption is quite strong, and because we cannot identify all the biases, we cannot test its validity. However, we know that the estimated coefficient of relative prices is well below the coefficient of real income and, therefore, the major effect picked up by the country dummy coefficient is from the PPP bias.

We observe from Table 2 (third column) that the country dummies do not change much from the main estimation when including relative prices. This is also confirmed by Figure 3 (southwestern panel). Therefore, our analysis is robust to the inclusion relative prices.

6.4 Allowing for within-country location effects

One way to adjust for possible regional price variation within countries is simply to include regional dummies in the estimation of the Engel curves. The country dummy coefficient of country j in this specification is the population weighted sum of the regional dummies of country j. The estimation results of such a procedure are given in the fourth column of Table 2 (the 62 regional coefficients are suppressed because of space limitations). In this estimation, all households are included, and the OECD adult equivalence scale is used to adjust for family size.[13] We observe from Figure 3 (southeastern panel) that the estimated biases are almost identical to the estimates based on whole sample with no regional dummies. Hence, we have no reason to believe that different prices within countries affect the results of the analysis.

[13] The reason for this is simply that the estimation requires 62 regional dummies, and hence we would be left with very few observations in each region in some countries if only households with two children and two adults are included. The main results also hold however, if estimating on the subsample of households with two children and two adults.

7 Generalizing the Results

By applying the extended model of Section 3, we estimate and report in Table 6 the PPP bias and EC incomes for 33 countries in 1995. All the PPP bias estimates are significant. We observe that although the generalization relies on national accounts data, which would usually give significantly different income estimates than survey data (Deaton, 2005), the estimates of the PPP bias are not very different from those estimated by the benchmark model (provided in parentheses).

As reported in Figure 5, Table 7, and Table 4, our first and second main findings hold: there is a highly significant negative relationship between the PPP bias and EC income, and the EC income reveals a substantially higher income inequality than the PWT among the 33 countries in the extended model.

[Table 6 about here.]

[Figure 5 about here.]

[Table 7 about here.]

8 Comparing the Different Income Measures

Historically, international comparisons of income relied on the exchange rate based method, which involves simply transforming all incomes into a common currency, such as the USD. As for the PWT incomes, we have reasons to expect that the EX incomes are biased. First, if PPP does not hold, and price levels differ across countries, using the exchange rate yields biased estimates of real incomes. Second, the quality bias also alters the EX incomes. We would expect these two components of the EX bias to be systematic, but importantly, to work in opposite directions. As price levels tend to be lower in poorer countries, we should expect that failing to adjust for price level differences causes poorer countries' incomes to be underestimated. On the other hand, as stated in Section 2, the quality of goods tends to be lower in poorer countries, and hence we should expect that failing to adjust for quality causes poorer countries' incomes to be overestimated. In sum, we expect EX incomes to be biased, but because we have two components of the bias expected to work in opposite directions, we do not know whether or not to expect the EX incomes to be *systematically* biased.

Because we expect both the PWT incomes and the EX incomes to be biased, an interesting empirical issue is which approach provides the best estimate of a country's real income, and subsequently, international income inequality. In this section we investigate this issue by identifying the EX bias and comparing it with the PPP bias. The EX bias is identified by estimating Engel curves for food and making the country specific Engel curves comparable by using the exchange rate. More specifically, we identify the EX bias by estimating the following specification:

$$m_{h,j} = a + b' \ln y_{h,j} + \theta X_{h,j} + \sum_{j=1}^{N} d'_j D_j + \varepsilon_{h,j}. \tag{12}$$

The EX bias is then given by:

$$E_j^{EX} = e^{-\frac{d'_j}{b'}}. \tag{13}$$

Figure 6 shows the relationship between the estimated EX bias and EC income, as well as that of the estimated PPP bias and EC income (identified in Section 5).

[Figure 6 about here.]

The question of whether the EX incomes give more precise estimates of real incomes than the PWT incomes can be answered by investigating the mean (of the absolute values of the) bias of the two methods.[14] Table 8 reports the mean bias, and the mean bias for the PWT is larger than the mean bias for the EX method for the whole samples. However, when dividing the samples into OECD countries and non-OECD countries, we observe that the EX incomes provide more precise estimates for the non-OECD countries, whereas the opposite is the case for the OECD countries.

[Table 8 about here.]

[14] The mean bias is calculated as $mean(|(bias - 1)|)$.

9 Concluding Remarks

In this paper, we used household surveys from nine countries and UN mean household data to provide initial estimates of the overall PPP bias in the PWT. Although the PWT incomes are extensively used by economists, there are few studies that investigate the bias in this dataset. We provided evidence of a significant, systematic, and substantial bias, where poorer countries' incomes are overestimated relative to those of richer countries. Consequently, the PPP bias causes a significant and robust underestimation of international inequality.

In fact, the PPP bias is so substantial that applying the traditional exchange rate based method, which implicitly assumes that PPP holds and prices for nontraded goods do not differ among countries, yields better estimates of poorer countries' incomes and also of international inequality. Hence, it seems better to assume that purchasing power parity holds, rather than trying to adjust for purchasing power differences by using the PWT. However, if studying subgroups of richer countries, it seems better to use the PWT incomes rather than the EX incomes.

Several robustness checks showed that the main findings are not driven by the misspecification of functional form, differences in relative prices, household composition, or regional effects. However, this study, as well as other studies based on micro data (or macro data based on micro data), could have benefited from a greater availability of already harmonized data. There are two reasons for this. First, if panel data were available for poor countries, as is the case for OECD countries, more sophisticated estimation techniques could be used. Second, the availability of harmonized data for rich and poor countries would facilitate cross-country comparisons based on micro data, and consequently, more than nine countries could be used to estimate the Engel curve.

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Figure 1: **Weights in the construction of PWT reference prices as a function of PWT total income.** Country j's weight is defined by the difference between the Geary–Khamis reference prices when including all countries and the reference prices when including all countries but country j: $w_j = \frac{\sqrt{(\sum_i^{11}(x_i - y_{ij})^2)}}{\sum_i^{11} x_i^2}$, where x_i is the reference price of good i when all countries are included in the construction of them, and y_{ij} is the reference price of good i when all countries but country j are included in construction. There are in total 11 categories of goods applied in the International Comparison Project. The solid line represents the fitted line from regressing the logarithm of the difference on the logarithm of per capita income, the coefficient being 0.906 ($p - value = 0.000$).

Figure 2: **Weight in the construction of PWT reference prices as a function of per capita income.** Country j's weight is defined by the difference between the Geary–Khamis reference prices when including all countries and the reference prices when including all countries but country j: $w_j = \frac{\sqrt{(\Sigma_i^{11}(x_i - y_{ij})^2)}}{\Sigma_i^{11} x_i^2}$, where x_i is the reference price of good i when all countries are included in the construction of them, and y_{ij} is the reference price of good i when all countries but country j are included in the construction. There are in total 11 categories of goods applied in the International Comparison Project. The two solid lines represent the fitted line from regressing the logarithm of the difference on the logarithm of per capita income; the upper line displays the result of this regression when weighting by population size (the coefficient being 0.84 (*p-value* = 0.000)) whereas the lower line shows the result of an unweighted regression (the coefficient being 0.420 (*p-value* = 0.024)). The unweighted regression relates directly to the unweighted inequality measure (of Section 5), whereas the population weighted regression relates directly to the population weighted international inequality measure (of Section 5).

Figure 3: **PPP bias and EC income.** The northwestern panel of the figure illustrates the relationship between the PPP bias and EC income for the nine benchmark countries estimated by the main specification. The northeastern panel of the figure illustrates the same relationship using the whole sample and applying the OECD adult equivalence scale. The southwestern panel of the figure shows the relationship for the five OECD countries when including relative price effects, whereas the southeastern panel of the figure shows the relationship when including regions. The reference line indicates unbiased PWT income relative to the United States.

Figure 4: **Kernel regression.** The upper panel displays the kernel relation using the Epanechnikov kernel smoother when including all countries: the relationship between the budget share for food and the logarithm of household income when the effects of the other explanatory variables are removed by differencing. Tenth-order differencing is conducted based on the optimal differencing weights proposed in Yatchew (2003). The bandwidth is obtained from the formula $bandwidth = 0.15(max(logofincome) - -min(logofincome))$ and is equal to 1.36149. The bounds correspond to the 95% confidence intervals. The United States is used as the base country. The lower panel displays the same kernel relationship for each country. In order for the functional forms not to be too dependent on extreme values (i.e., not to display the kernel smoother where observations are very scarce and hence many linear approximations would be necessary) the 5% top and bottom observations on real income are removed.

Figure 5: **The relationship between the PPP bias and EC income—extended model.** The figure illustrates the relationship between the PPP bias and EC income based on the 33 observations in the extended model. The reference line indicates the PPP bias level where the PWT income is unbiased relative to the United States.

Figure 6: **The relationship between the EX bias and EC income and the PPP bias and EC income.** The northwestern panel illustrates the relationship between the EX bias and EC income for the benchmark countries, whereas the northeastern panel illustrates the relationship between the PPP bias and the EC income for the benchmark countries. The southwestern panel illustrates the relationship between the EX bias and EC income for the extended model, whereas the southeastern panel illustrates the relationship between the PPP bias and EC income for the extended model.

	Survey year	Institution	No. of hh	Nat. Repr.
Azerbaijan	1995	SORGU / World Bank	4,581	Yes
China	1994	Min. of Agg./World Bank	798	No
Côte D'Ivoire	1986	Inst. Nat. Stat. / World Bank	4,860	Yes
France	1995	Inst. Nat. Stat. Étud. Éc. / LIS	9,627	Yes
Hungary	1996	Hungarian Cent. Stat. Off.	7,531	Yes
Italy	1995	Bank of Italy / LIS	8,116	Yes
Nicaragua	1993	INEC / World Bank	4,145	Yes
United Kingdom	1995	UK Data Archive / LIS	6,789	Yes
United States	1995	CES, US Bureau of Labor	19,545	Yes

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

	Main specification	Whole sample	With prices	With regions	Exchange rate
Log of income	-0.109	-0.107	-0.098	-0.111	-0.109
	(0.012)	(0.006)	(0.007)	(0.012)	(0.003)
Azerbaijan	0.130	0.106		0.101	-0.058
	(0.023)	(0.013)		(0.014)	(0.043)
China	0.152	0.143		0.136	-0.027
	(0.026)	(0.015)		(0.016)	(0.045)
Nicaragua	0.174	0.151		0.150	0.045
	(0.019)	(0.012)		(0.013)	(0.033)
Côte d'Ivoire	0.198	0.114		0.117	0.096
	(0.022)	(0.015)		(0.016)	(0.031)
Hungary	0.011	0.010	0.028	0.006	-0.064
	(0.018)	(0.010)	(0.009)	(0.011)	(0.025)
France	0.037	0.028	0.047	0.028	0.060
	(0.003)	(0.002)	(0.003)	(0.002)	(0.004)
UK	0.015	-0.012	0.038	-0.014	0.018
	(0.004)	(0.002)	(0.003)	(0.002)	(0.003)
Italy	0.117	0.090	0.111	0.088	0.115
	(0.008)	(0.004)	(0.006)	(0.004)	(0.008)
Age	0.004	0.001	0.002	0.001	0.004
	(0.0008)	(0.0002)	(0.0002)	(0.0002)	(0.0008)
Children		0.002		0.000	
		(0.003)		(0.003)	
Adults		-0.012		-0.012	
		(0.003)		(0.003)	
Constant	1.184	1.181	1.149	1.216	1.685
	(0.131)	(0.066)	(0.032)	(0.068)	(0.186)
Number of observations	6,173	65,987	5,083	65,987	6,173
R-squared	0.69	0.65	0.49	0.95	0.69

Table 2: **Regression results, robust least squares estimation.** The table reports five sets of estimates (standard errors are in parentheses). Sample weights and population weights are used. The first column reports the estimates for equation (4), which is estimated for households with two children and two adults, i.e., the main model, whereas the other columns display estimates from the robustness analysis. The second column reports the estimates for equation (4) using all households and the OECD's adult equivalence scaling. The third column reports the estimates for equation (1) on the subsample of the richer countries. The fourth column reports the estimates for equation (4) when replacing country dummies with regional dummies. The country dummies of this column are weighted means of the regional dummies. The fifth column reports the estimates of (12).

	Y^{PWT}	Y^{EC}	Y^{EX}
China	1277.5	337.6	246.1
Nicaragua	1448.0	353.5	443.7
Côte D'Ivoire	1452.9	501.7	571.1
Azerbaijan	1542.1	575.0	274.5
Hungary	5651.4	5149.0	2839.0
Italy	13696.0	5933.2	13359.7
France	13274.2	10186.5	16458.8
United Kingdom	14291.0	16048.5	14656.2
United States	19007.6	19007.6	19007.6

Table 3: **Three different income measures.** The table shows the income measured by the PWT, EC incomes, and EX incomes for the nine countries in the main analysis.

	Gini PWT	Gini EC	Gini EX
Benchmark countries	0.45	0.57	0.54
Pop w, benchmark countries	0.58	0.72	0.71
Extended model	0.30	0.43	0.39
Pop w, extended model	0.29	0.42	0.36

Table 4: **Gini indices.** The table shows the Gini index for the PWT incomes, the EC incomes, and the EX incomes. The first row presents the unweighted Gini index, i.e., the index that gives equal weight to each country irrespective of its size. The second row presents the population weighted Gini index, which weights each country proportionally to its population size. The third and fourth rows present the unweighted and weighted Gini indices, respectively, from the extended model.

	Azerbaijan	China	USA	Nicaragua	Côte D'Ivoire	Hungary	France	UK	Italy
Slope	-0.09	-0.10	-0.08	-0.10	-0.10	-0.13	-0.08	-0.08	-0.12

Table 5: **Slopes of country-specific semiparametric Engel curves.** The table gives mean slopes of the kernels from the semi-parametric analysis of the different countries.

Country	Y^{EC}	E		Standard error of E
Botswana	121.2	20.11		3.41
Belarus	317.3	8.99		2.34
Iran	378.5	8.17		1.66
Estonia	387.4	10.52		1.95
Dominican Republic	388.6	6.72		0.95
South Africa	441.7	10.43		1.66
Latvia	485.0	7.03		1.22
Colombia	770.5	4.91		0.73
Mexico	1485.3	3.58		0.44
Hungary	2993.2	1.91	(1.10*)	0.22
Israel	4969.2	1.85		0.15
Japan	5179.4	2.70		0.24
Portugal	6000.7	1.56		0.11
Spain	6318.3	1.90		0.13
Greece	6456.6	1.50		0.10
Italy	6744.6	2.03	(2.31)	0.13
New Zealand	7861.8	1.47		0.09
Ireland	8070.9	1.36		0.07
Hong Kong	8171.3	2.05		0.09
France	11680.5	1.14	(1.30)	0.05
Norway	12243.2	1.12		0.05
Belgium	12526.2	0.90		0.03
Australia	13221.8	1.15		0.03
Luxembourg	13511.8	1.48		0.05
Finland	13816.0	0.86		0.04
Austria	14238.5	0.10		0.03
Canada	14343.5	0.91		0.02
Switzerland	15863.7	0.89		0.02
Denmark	17384.3	0.88		0.03
Germany	17625.1	0.80		0.02
United Kingdom	18280.3	0.78	(0.89)	0.02
Sweden	18559.1	0.74		0.03
United States	19007.8	1.00	(1.00)	0.00

Table 6: **EC income, PPP bias and standard error of bias.**The table displays the EC incomes, PPP bias, and standard error of the PPP bias for the 33 countries included in the extended model for the year 1995. The measured bias for the benchmark model is given in parentheses for the five countries for which we have such measures. *The PPP bias estimate for Hungary in the benchmark analysis is for 1996.

	Dep var: E	p-value	R-squared	N*
Log of EC income	-0.746	0.000	0.759	32
Constant	7.086	0.000		

Table 7: **Estimated relationship between PPP bias and the logarithm of EC income.** The table shows estimation results from regressing the PPP bias against the logarithm of EC income. Weights equal to the inverse of the variance of the PPP bias are used. *As all biases are measured relative to the United States, there are 32 independent observations in this regression.

	Benchmark countries			Extended model		
	All countries	OECD	Non-OECD	All countries	OECD	Non-OECD
Mean bias PWT	1.89	0.52	3.61	2.48	0.49	7.06
Mean bias EX	0.64	0.64	0.64	1.89	0.58	1.96

Table 8: **Mean bias for the PWT and EX incomes.** The table displays the mean of the absolute value of the bias for the benchmark countries and the countries in the extended analysis. The OECD countries in the benchmark model consist of France, Hungary*, Italy, the United Kingdom, and the United States, whereas the non-OECD countries consist of Azerbaijan, China, Côte d'Ivoire, and Nicaragua. The OECD countries in the extended model consist of Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hong Kong, Ireland, Italy, Japan, Luxembourg, Mexico, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States, whereas the non-OECD countries consist of Belarus, Botswana, Colombia, the Dominican Republic, Estonia, Hungary*, Iran, Israel, Latvia, and South Africa. *Hungary was included in the OECD in 1996, and hence it is an OECD country in the benchmark dataset because we have micro data for Hungary from 1996, whereas it is a non-OECD country in the extended model with data from 1995.