Measuring Global Poverty: why PPP Methods Matter

Robert Ackland, Steve Dowrick and Benoit Freyens*

Australian National University

June 17, 2004

Draft Paper prepared for the 2004 Conference of the International Association for Research in Income and Wealth, to be presented on Thursday August 26.

ABSTRACT

We present theory and evidence to suggest that, in the context of analysing global poverty, the EKS approach to estimating purchasing power parities yields more appropriate international comparison of real incomes than the Geary-Khamis approach. Our analysis of the 1996 International Comparison Project data confirms that the Geary-Khamis approach leads to substantial overstatement of the relative incomes of the world's poorest nations and to misleading comparisons of poverty rates across regions. Similar bias is found in the Penn World Table which uses a modified version of the Geary-Khamis approach. The EKS index of real income is much closer to being a true index of economic welfare and is therefore to be preferred for assessment of global poverty.

* Author contact: Steve.Dowrick@anu.edu.au

Introduction

Global estimates of the numbers of people living in poverty depend crucially on the purchasing power parities that are used to translate a common poverty line into local currencies. This paper draws on insights from index number theory and welfare economics to highlight the fact, little appreciated in most of the debate on global poverty measurement, that the concept of 'purchasing power parity' is slippery and that the implications of choosing one method over another can have a substantial impact not only on estimates the number of poor people but also on their distribution across countries and regions. In particular, we draw attention to the significant differences that arise from using the EKS index method rather than the Geary-Khamis[1] (GK) index on which the Penn World Table is based.

According to Ravallion (2003, pages 2-3), since 1990 the World Bank was using the Penn World Table as the 'main source' of PPP rates for their estimates of global consumption poverty; however, "the latest estimates" use PPPs based on the Fisher index. We interpret this to mean that the Bank has recently changed to using the EKS method, since the EKS index is a multilateral extension of the bilateral Fisher index. We suspect that this change in the Bank's method of converting a common poverty line into national currencies has received little attention because of a failure to understand that changes in apparently arcane index number methods can have a major impact on international comparisons. For example, a recent study of global inequality and poverty by Sala-i-Martin (2002) investigates various measurement problems in great detail, but fails to question the use of the GK method in the Penn World Table data that he uses.

In this paper we demonstrate and explain the importance of the choice between alternative methods of calculating purchasing power parities. We find that the GK method understates the number of the world's poor by more than one third relative to the EKS method. Our analysis suggests that the EKS method produces purchasing power parities which are closer to economic-based comparisons of welfare.

Various other aspects of World Bank measurement of global poverty have been criticised. Reddy and Pogge (2003) emphasises the Bank's 'failure' to identify the

[1] These indexes are based on the work of Elteto and Koves (1964) and Sculc (1964), and Geary (1958) and Khamis (1972) respectively.

minimum basket of goods and services that is required to avoid poverty; and to convert the cost of a minimum basket consistently and accurately across countries and across time. Associated with these criticisms are claims that the original "one dollar per person per day" (at 1985 purchasing power parity) was grossly inadequate and that its revaluation to $1.08 at 1993 purchasing power parity understated the fall in the purchasing power of the US dollar on which the purchasing power parities are normalised. Reddy and Pogge's analysis suggest that the Bank's methodology may have not only underestimated the extent of poverty by a substantial margin, but may also have led to a mistaken inferences that poverty has been falling. Related criticisms focus on the fact that the purchasing power parities used by the Bank are based on the costs of average national consumption rather than on the consumption patterns of the poor and that a focus on measured consumption ignores the wide differences in standards of living and capabilities that arise from the uneven distribution of public services and public capital, such as public health and medical facilities and access to water and education.

Whilst we do not discount these criticisms of the Bank's approach, they are not the focus of this paper. Our focus is on identification of the most appropriate PPP methodology. It is important to note that we do not attempt to provide a definitive count of the world's poor. We restrict our empirical analysis to the countries that participated in the 1996 ICP survey, we estimate within-country income distributions, we ignore differences between the consumption bundles of the poor and the average consumption bundles of each nation, and we ignore differences between 'consumption poverty' based on income and other definitions of poverty based on concepts such as capabilities. Our analysis is intended to quantify the order of magnitude involved, rather than precise numbers, in getting the purchasing power parity concept and method right.

In Section 1 of this paper we explain the difference between the GK and the EKS methods of calculating purchasing power parities, using a simple trade model to illustrate the reason why the GK method may exaggerate the purchasing power of poor country currencies and to explore the properties of the EKS measures. We also introduce the notion of 'true income comparisons' based on the economic theory of index numbers that has been developed by Sydney Afriat (1967 & 1984) and Hal Varian (1983).

In our second section, we apply the two PPP methodologies to the latest International Comparison Project (ICP) data set covering 115 countries, enabling us to quantify the direction and magnitude of bias imparted by the two methods.

In Section 3 we discuss approaches to measuring world poverty. In Section 4 we estimate the cumulative income distribution function for 95 of the ICP countries using published data on quintile shares (since we do not have access to expenditure surveys for each country). We are then able to demonstrate, in Section 5, the order of magnitude of the impact of changing from GK to EKS measures of purchasing power parity.

1. An explanation of the different purchasing power parity methods.

It is well established that international currency markets tend to undervalue the domestic purchasing power of currencies of low productivity / low income countries. Real wages are low in countries with low labour productivity, so non-traded labour-intensive services are cheap relative to traded goods in poorer countries. Market exchange rates tend to equate the prices of tradables rather the than the prices of non-tradables. This trade-sector bias causes the foreign exchange market to undervalue the domestic purchasing power of the currencies of poor countries, hence to understate their real incomes relative to income levels in rich countries.

Alternatives to exchange-rate comparisons of income rely on the estimation of purchasing power parities. A massive research effort, based on detailed price surveys in many countries under the auspices of the International Comparison Program (ICP), has resulted in the publication of the Penn World Table (see Heston et al., 2002) which provides ready access to measures of *real* GDP per capita at constant international prices for over one hundred countries since 1950. These data are commonly referred to as PPP (purchasing power parity) measures of real income.

Many users of the PWT data are unaware, however, that attempts to measure purchasing power are problematic. The PWT estimates of average real incomes (GDP *per capita*) are based on a modification of the Geary-Khamis method of constructing 'average international prices'. The GDP of each country is evaluated at these fixed prices. Fixed price valuations, however, introduce systematic bias by ignoring consumer substitution towards goods and services that are locally cheap.

The authors of the Penn World Table describe the problem of substitution bias thus:

> *"The issue arises out of a familiar problem in price and quantity index number construction. …Valuation at other than own prices tends to inflate the aggregate value of the bundle of goods because no allowance is made for the substitutions in quantities toward the goods that are relatively cheap. … The practical importance of this issue … may loom large in comparisons between countries that have widely divergent price and quantity structures."* Kravis, Heston and Summers (1982), p.7.

Use of the PWT estimates of real national incomes, whilst avoiding the traded sector bias in the FX income data, introduces substitution bias in its place. An alternative way of comparing real incomes across countries is the EKS method, which extends the bilateral Fisher index to multilateral comparisons of real incomes. The OECD now prefer this method.

Whilst this literature focuses on international comparisons of income, it is important to note that for every 'real income' index there is an implicit PPP index. The relationship is defined by the requirement that the product of the quantity index and the implicit price index should equal total expenditure in the national currency. PPP indexes are often normalised to unity for the USA, though that choice is arbitrary. For example, data on real GDP *per capita* for country i which have been produced using method m ($RGDP^{m}_{i}$) imply a purchasing power parity index (PPP^{m}_{i}) in terms of units of domestic currency relative to the US dollar which can be recovered using the formula:

$$(RGDP_i^m \text{ x } PPP_i^m) / (RGDP_{US}^m) = NCGDP_i \ / \ NCGDP_{US} \tag{1}$$

where NCGDP represents GDP per capita expressed in national currency, and the method m might be any index number method, such as EKS or GK, which satisfies transitivity. Methodological differences which result in different real income ratios yield equal but opposite differences in purchasing power parities.

In order to better understand sources of bias in PPP methods, we analyse a general equilibrium model of two trading economies. Each produces a non-traded labour-intensive service, S. Country 1 has comparative advantage in producing an intermediate good, A, which we might think of as an unprocessed agricultural or mineral product. Both countries manufacture a final tradable good, M, using labour and the intermediate good. The production technologies exhibit constant returns to scale and are identical across countries, except that country-specific private knowledge affects labour productivity in manufacturing. We define country 2 as the high-productivity country.

To keep the model simple we assume Cobb-Douglas production functions in manufacturing, we treat labour as the only factor of production, we disregard transport costs for trading the intermediate and manufactured goods and we assume competitive pricing behaviour in product and labour markets, including free trade. We assume that all goods and services must be produced, traded and consumed within the one time period. The production side of the economy in country i can be summarised as follows:

$$S^i = L_s^i; \qquad A^1 = L_a^1; \qquad M^i = \left(\lambda^i L_m^i\right)^{\alpha} . \left(A_m^i\right)^{1-\alpha} \qquad (1)$$

where Z = (S, A, M) represent the domestic output of services, intermediate product and manufactured product respectively; L_z^i represents the amount of labour employed in each sector; A_m^i is the amount of intermediate input used in manufacturing; and λ^i is the productivity of labour in country i's manufacturing sector.

Comparative advantage dictates that country 1 will export the intermediate good and import manufactures. We assume that the productivity differential and relative population size are such that it is feasible for country 1 to produce all of the intermediate good demanded in both countries.

Given the assumptions of constant returns to scale and competitive pricing, we can solve for the domestic price of the manufactured good in country i, P^i_M in terms of the input prices for labour and the intermediate good, w^i and P^i_A:

$$P^{iM} = \mu\left(\frac{w^i}{\lambda^i}\right)^{\alpha} \left(P_A^i\right)^{1-\alpha}; \ where \ \mu = \alpha^{-\alpha}(1-\alpha)^{\alpha-1} \qquad (2)$$

We normalise prices and productivity by setting the wage and productivity level in country 1 to unity. We can then use λ (>1) without a superscript to represent manufacturing labour productivity in country 2. The price vector for country 1 is:

$$\mathbf{P}^1 \equiv (P_S^1, P_A^1, P_M^1) = (1, 1, \mu) \tag{3}$$

The exchange rate is E units of currency 2 per unit of currency 1. The local currency price of the imported intermediate good in country 2 is E. This determines the price of the manufactured good, using (2), as:

$$\mathrm{P}_{\mathrm{M}}^2 = \mu \left(\frac{\mathrm{w}^2}{\lambda} \right)^{\alpha} \mathrm{E}^{1-\alpha} \tag{4}$$

Trade in the manufactured good equalises prices, requiring $P^2{}_M = E.P^1{}_M = \mu E$. These conditions fully determine the wage in country 2. Setting the right hand side of (4) equal to μE yields:

$$w^2 = \lambda E \tag{5}$$

That is to say, productivity-adjusted factor-prices are equalised across the traded sectors.

By assumption, there are no differences across countries in the productivity of labour in the production of non-traded services. The price of services is simply the wage. It follows that services are relatively expensive in the high-productivity, high-wage country. The price vector in country 2's currency is:

$$\mathbf{P}^2 \equiv E(\lambda, 1, \mu) \tag{6}$$

We analyse demand and welfare by assuming common Cobb-Douglas preferences for the representative consumer-producer who is supplying a unit of labour inelastically:

$$U^i(s^i, m^i) = (s^i)^{\beta} (m^i)^{1-\beta} \tag{7}$$

where s and m refer to *per capita* consumption of services and manufactured goods.

The budget share of services is β in each country. Given that *per capita* income in each country equals the wage, the *per capita* consumption bundles are:

$$\boldsymbol{q}^1 \equiv \left[s^1, m^1\right] = \left[\beta,\ \frac{1-\beta}{\mu}\right]; \qquad \boldsymbol{q}^2 \equiv \left[s^2, m^2\right] = \left[\beta,\ \frac{\lambda(1-\beta)}{\mu}\right] \qquad (8)$$

Per capita consumption of services is identical in the two countries, despite the fact that services are more expensive in country 2, because the income effect of higher manufacturing productivity, leading to higher wages, offsets the price effect. This exact offsetting is an artefact of the Cobb-Douglas production and utility functions, but it is not crucial to our results. There is higher *per capita* consumption of manufactures in the higher productivity country. Thus we can refer unambiguously to the higher productivity country as the high income or richer country.

Evaluating the common utility function (7) at $\mathbf{q}^1$ and $\mathbf{q}^2$ gives the welfare ranking $U^2>U^1$. In general the utility ratio, U^2/U^1, is greater than unity but otherwise indeterminate because the utility function is ordinal rather than cardinal. Cardinality is achieved by the Allen welfare index which compares the minimum expenditures required to achieve utilities U^2 and U^1 at some reference price vector. In our model, where preferences are homothetic, the Allen index is independent of the reference price vector. The true *per capita* income ratio between country 2 and country 1 is the unique value:

$$A^{2:1} = \frac{e[U(\boldsymbol{q}^2)]}{e[U(\boldsymbol{q}^1)]} = \lambda^{1-\beta} > 1 \qquad (9)$$

With free trade in intermediate and manufactured goods and competitive pricing, we find that the country with higher productivity in manufacturing exhibits the following features:

i) a higher level of real income *per capita*; and

ii) a higher price for non-traded labour-intensive services relative to traded goods.

GK Purchasing Power Parity comparisons

We examine the measurement of the income ratio across the two countries by the Geary-Khamis method.

This method values each country's GDP at 'international prices'. The international price of manufactures, relative to services, is constructed as a weighted average of the relative prices of all the countries in the GK system. For the purposes of our model we have considered only two countries, but we can allow for other countries with a range of productivity levels in the GK system.

We represent the GK price vector for services and manufactures as:

$$\boldsymbol{P}^{GK}(g) \equiv \left[P^{GK,S}, P^{GK,M}\right] = [g, \mu] \tag{10}$$

Referring back to equation (6), we see that the price of services relative to manufactures, g/μ, corresponds to the relative price in a country where the manufacturing productivity parameter is g.

The Geary-Khamis measure of real GDP *per capita* for country i is the *per capita* consumption bundle evaluated at international prices: $\mathbf{q}^{i} \bullet \mathbf{P}^{GK}$. Evaluating the consumption bundles given in (8) at prices [g, μ], the GK income ratio between countries 2 and 1 is:

$$GK^{2:1}(g) \quad \equiv \quad \frac{GK^{2}(g)}{GK^{1}(g)} \quad = \quad \frac{\beta g \;+\; (1-\beta)\lambda}{\beta g \;+\; (1-\beta)} \tag{11}$$

Whether this under or over-states the true income ratio depends on the value of g. We summarise the relationship, following Dowrick and Akmal (2003), as follows.

PROPOSITION 1: Substitution bias in Geary-Khamis comparisons

i) A bilateral international comparison of *per capita* income which values expenditure at constant prices will understate the true income differential if the constant price vector corresponds to that of the high productivity country, or the prices of an even richer country.

ii) A constant price comparison will overstate the true income differential if the constant price vector corresponds to that of the low productivity country, or the prices of an even poorer country.

iii) The bias is greater, the less similar is the reference price vector with respect to the comparison country prices.

iv) Where i) or ii) holds, the magnitude of the bias is an increasing function of the underlying productivity differential between the two comparison countries.

Proof: The ratio of the constant price (GK) income ratio to the true income ratio is $B^{GK}(g)$:

$$B^{GK}(g) \equiv \frac{GK^{2:1}(g)}{A_r^{2:1}} = \frac{\beta g + (1-\beta)\lambda}{\left[\beta g + (1-\beta)\right]\lambda^{1-\beta}} \qquad (12)$$

$B^{GK}(g)$ measures the proportional bias in the GK index, with $B^{GK}=1$ representing no bias. Evaluating (12) gives $B^{GK}(1) > 1$ and $B^{GK}(\lambda) < 1$ (given that $\lambda > 1$ and $0 < \beta < 1$). Differentiating (12) yields $\partial B^{GK}/\partial g < 0$. Hence i) and ii).

B^{GK} is less than 1 for all $g>\lambda$. As g rises above λ (i.e. as the reference price vector becomes less similar to prices in countries 1 and 2) B^{GK} falls.

B^{GK} is greater than 1 for all $g<1$. As g falls below unity (i.e. as the reference price vector becomes less similar to prices in countries 1 and 2), B^{GK} rises. Hence iii).

B^{GK} is decreasing / increasing in the productivity differential, λ, as $\lambda<g$ or $\lambda>g$. Hence iv).
***

We can use Proposition 1 to clarify the impact of substitution bias on GK PPPs. To the extent that the GK international price vector is representative of rich country prices, it will tend to over-estimate the incomes of the poor countries not only in relation to the rich countries but also in relation to the middle-income countries.

EKS Purchasing Power Parity comparisons

We illustrate the construction of the EKS index by constructing the Valuation matrix, which values the consumption bundle of each country first at country 1 prices and then at country 2 prices, as shown in Table 1. The matrix is highlighted in the lower right-hand corner of the Table. We refer to the elements of this matrix as V_{ij}.

Table 1: Calculating The Valuation Matrix

	Country 1	Country 2
composition of *per capita* consumption bundle	$\beta\ ,\ \frac{1-\beta}{\mu}$	$\beta\ ,\ \lambda\frac{1-\beta}{\mu}$
consumption price vector	$1\ ,\ \mu$	$E(\lambda\ ,\ \mu)$
consumption valued at prices of country 1	1	$\beta + \lambda(1-\beta)$
consumption valued at prices of country 2	$E[\lambda\beta + (1-\beta)]$	$E\lambda$

The EKS approach to valuing the rich country's consumption bundle relative to the poor country's bundle proceeds as follows. The Laspeyres index, valuing the ratio at poor country prices, is $V_{12} / V_{11} = \beta + \lambda(1-\beta)$ which exceeds λ; i.e. it overstates the true income ratio, $\lambda^{1-\beta}$. The Paasche index, valuing consumption at country 2 prices, is $V_{22} / V_{21} = [\lambda\beta + (1-\beta)]/\lambda$ which is less than unity; i.e. it understates the true income ratio.

In this two country example, the EKS index, $EKS^{2:1}$, is the same as the Fisher index, the geometric mean of the Laspeyres and Paasche indices[2]:

$$EKS^{2:1} = \sqrt{\frac{\lambda\beta + \lambda^2(1-\beta)}{\lambda\beta + (1-\beta)}} \qquad (13)$$

We define the degree of bias in the EKS index, relative to the true income ratio, as follows:

$$B^{EKS} \equiv \frac{EKS^{2:1}}{A^{2:1}} = \sqrt{\frac{\lambda^{2\beta-1}\beta + \lambda^{2\beta}(1-\beta)}{\lambda\beta + (1-\beta)}} \qquad (14)$$

When productivity is the same in each country, $\lambda=1$, we find that BEKS = 1, there is no bias.. Nor is there any bias when the share of non-tradables, β, equals ½. More

[2] With n countries, $EKS^{2:1}$ is the geometric mean of all the Fisher indices involving either country 1 or country 2.

generally, however, the bias may be positive (B>1) or negative (B<1), as the positive bias in the Laspeyres exceeds the negative bias in the Paasche index, or *vice versa*.

In the upper panel of Table 2 we show the value of B^{EKS} for various values of the preference and productivity parameters, β and λ. We notice that the bias is negative when the share of non-tradables in consumption is less than one half, and positive when the share is greater than one half. The magnitude of the bias rises with the magnitude of the productivity differential, reflecting an increase in the dissimilarity of prices between the countries.

Table 2: Predicted Index Number Bias Relative to the True Welfare Index

	Share of non-tradables in consumption (β)				
Productivity differential (λ)	*0.3*	*0.4*	*0.5*	*0.6*	*0.7*
Bias in EKS relative to true index					
1	1.00	1.00	1.00	1.00	1.00
2	1.00	1.00	1.00	1.00	1.00
5	0.95	0.97	1.00	1.03	1.05
10	0.89	0.94	1.00	1.07	1.13
Bias in GK relative to true index[1]					
1	1.00	1.00	1.00	1.00	1.00
2	0.73	0.75	0.77	0.81	0.85
5	0.57	0.58	0.61	0.66	0.72
10	0.54	0.55	0.57	0.62	0.69

1. The GK bias is calculated using the formula (12) and assuming that the parameter g equals 10. A value of 1 indicates no bias.

The second panel of Table 2 shows the bias in the GK index for the same combinations of parameters, using equation (12) and choosing a value of 10 for the GK system parameter, g. We find, as indicated by Proposition 1, that the GK bias is negative and its magnitude is increasing in the productivity parameter. In every case the EKS index is closer than the GK index to the true income ratio.

Whilst these results are derived from particular parameterisations of a simple two-country model, they do suggest that PPPs estimated using the EKS method are likely to be closer to true (utility-consistent) PPPs than those derived from the GK method. Indeed, if the underlying preference function is linear quadratic rather than Cobb-Douglas, the EKS index is exact. To the extent that the GK price vector corresponds to the prices of relatively rich countries, the GK method is likely to substantially overstate the purchasing power of currencies in poorer countries. This bias is likely to be particularly important in the assessment of global poverty because the greatest numbers of the world's poor are living in the poorest countries. In the following sections we test these conjectures using data from the 1996 ICP survey.

2. Calculating GK, EKS and True PPPs for 115 countries in 1996

In this section we report our analysis of the most recent survey data from the International Comparison Project (ICP). The data consist of prices and *per capita* expenditures in local currency on 31 items which sum to GDP per capita, based on the familiar national accounting identity: Y = C + I + G + NX. From these data we can calculate the real *per capita* quantities of each item in each of the 115 countries surveyed. Given prices and quantities, we can calculate both the GK and EKS measures of real GDP *per capita*. Each measure of real GDP implies a corresponding purchasing power parity (PPP) given the definition that local currency GDP divided by the PPP equals real GDP.

In Table 3, we give summary statistics for population and real GDP (PWT definition) for the ICP sample and the larger sample in the Penn World Table version 6.1, which covers 168 countries. We see that the ICP sample contains 52% of the PWT population and 79% of the aggregate real GDP.

Table 3: Comparison of PWT6.1 and ICP Samples for 1996

		Total	Average	Standard Deviation
168 PWT countries				
Population	millions	5,588	33	122
Total Real GDP (PWT$)	billions	37,065	221	742
115 ICP Countries				
Population	millions	2,911	25	43
Total Real GDP (PWT$)	billions	29,460	256	812
ICP as proportion of PWT sample				
Population		52%	76%	35%
Total Real GDP (PWT$)		79%	116%	109%

The 1996 ICP did not include either China or India, omitting a third of the world's total population and a substantial proportion of the world's poor. Accordingly we are unable to directly calculate the sensitivity of global poverty estimates to the choice of PPP method. The ICP sample of countries is, however, sufficiently representative that we consider it likely to give a good idea of the order of magnitude of the differences between the poverty estimates based on the GK and EKS methods. We can also examine differences with respect to the PWT measures which are based on a different implementation of the Geary-Khamis system.

The Geary-Khamis method

GK measures of real GDP are based on a vector of notional international prices, π, the components of which are the weighted average of national prices, p^{ik}, deflated by the purchasing power parity for each country, e^i, where i indexes countries and k indexes commodities. The weights are that country's share in total real expenditure on commodity k. Each country's GDP bundle valued at international prices is equal to its local currency GDP deflated by e^i. These relationships define a set of simultaneous equations. Given data on prices and quantities for each country, and normalising an element of the international price vector to unity, there is a unique solution to the system comprising the international price vector, π, the dimension of which is the number of commodities, and the PPP vector, $\mathbf{e}$, the dimension of which is the number of countries. For convenience we normalise the parities so that $e^{USA}=1$, giving a vector of national purchasing power parities, $\mathbf{E}^{GK}$, and a vector of real GDP *per capita*, $\mathbf{y}^{GK}$, where the value of real GDP for the USA equals its local currency value.

The PWT v6.1 uses a 'super-country' weighting system which inflates the populations of ICP countries, classed in seven income groups, to the world population in each income group. This is intended to make the calculated GK international prices more representative of average world prices. We suspect that this amendment to the standard GK system may well reduce the degree of substitution bias in comparing real income levels between rich and poor countries, since the ICP sample is relatively under-representative of the world's poorer nations – particularly because it excludes China and India. We will test this hypothesis.

The EKS method

The EKS method does not involve direct calculation of purchasing power parities. Rather it is a method for calculating a multilateral *per capita* quantity index from disaggregated price and quantity data. The index value for each country, EKS^i, is the unweighted geometric mean of the Fisher bilateral quantity indexes between country i and every other country in the system.

We explain a method of calculating the EKS index which will prove useful later when we come to compare it with the ideal Afriat index. We construct a matrix **L**, calculating element L_{ab} as the logarithm of the Laspeyres index for country B relative to country A – i.e. the ratio of country B's GDP *per capita* to country A's GDP *per capita* with both bundles valued at country A's prices. Row a of **L** is the vector of log Laspeyres indexes with A as the base country, and column a is the vector of negative log Paasche indexes with respect to country A. The diagonal of **L** consists of zeros. $(L_{ab} – L_{ba})$ is the log of the Fisher index between countries A and B. We subtract the vector of column averages from the vector of row averages to generate the log EKS index. By construction, the mean of this index is zero. Exponentiation of each term gives the EKS index with a geometric mean of unity. We normalise this to the index $\mathbf{y}^{EKS}$, where the value for the USA equals its local currency GDP.

Comparison of GK, EKS and PWT measures of real GDP

In the Appendix we discuss some apparent errors in the ICP price data and we explain the assumptions we adopted to rectify these errors. Lacking access to accurate ICP data, our results must be treated with some caution. However, our corrections are associated with items that comprise only a very small part of expenditure on GDP. We are primarily concerned with differences between the EKS and GK measures which we construct from the same data, so we expect our results to be robust.

In Figure 1 we present a scatter plot with the log of the GK measure on the horizontal axis and the log of the EKS measure of GDP on the vertical axis. The OLS regression equation and regression line are displayed.

$$\ln y_i^{GK} = \underset{(s.e. = 0.077)}{0.679} + \underset{(0.009)}{0.940} \ln y_i^{EKS} \quad ; \; R^2 = 0.990, \; n = 115 \tag{15}$$

We see that the two measures of log GDP are very highly correlated, with an R^2 value of 0.99. The slope coefficient of 0.94 is, however, significantly less than unity, implying that the GK measure compresses the distribution of income across countries relative to the EKS measure. The incomes of poor countries, relative to those of richer countries, tend to be less when measured by the EKS method than when measured by the GK method. For a poor country with real income one twentieth that of the USA, for example, the regression coefficient implies that the GK method tends to overstate the real income ratio by 20% relative to the EKS method.[3]

Figure 2 displays the log difference between the GK and EKS measures on the vertical axis, plotted against the log of the EKS index on the horizontal axis. The two measures have been defined to be identical for the USA, so the values on the vertical axis can be interpreted as the extent to which the GK income ratio, relative to the US, exceeds the EKS income ratio. For all but one country, New Zealand, the GK ratio exceeds the EKS ratio. The degree of discrepancy tends to be significantly higher for the poorer countries, averaging 28% for the dozen poorest countries. We also find that income relativities amongst the poor countries vary considerably depending on which method of measuring GDP is used. In Figure 2 we can see that the income ratio between Tanzania and Malawi, to take an extreme example, differs by around 50%.

We suspect that the PWT measure of real GDP *per capita* may be closer to the EKS index than is the GK measure, because the PWT's use of super-country weights may lower the influence of rich-country prices in the construction of the international price vector. Figure 3 plots the logarithm of the PWT6.1 estimates against the log EKS index. The regression line indicates a very similar level of substitution bias to that

[3] Calculated as exp [-(1-0.940) x ln(1/20)].

which we found for the GK index, with a slope coefficient of 0.935 – compare with Figure 1. Although the PWT measures differ slightly from the GK index (also displayed in Figure 3), they appear to display the same direction and magnitude of substitution bias.

Evaluating Bias in the GK and EKS Indexes

Evidence that the GK and EKS income ratios differ substantially suggests that the choice of method is likely to have a significant influence on estimates of the level of global poverty and its distribution across countries. This begs the question of which is the preferred method of measuring purchasing power parity: are the GK income ratios biased upwards or are the EKS measures biased downwards? As previous authors have argued, and as illustrated by the model in our previous section, fixed price indexes such as Geary-Khamis are subject to substitution bias. There are reasons to suspect that the EKS index is relatively free from such bias because it is based on bilateral Fisher indexes. The Fisher index is the geometric mean of the Laspeyres and Paasche indexes, and we expect the substitution bias inherent in the Laspeyres to be offset by the opposite bias in the Paasche index. It is not clear, however, whether the biases in the Paasche and Laspeyres indexes cancel out exactly.

To address these questions we make use of the theory of consumer behaviour which underlies the economic approach to welfare indexes. In the context of national income or GDP we suppose the existence of a representative national household with preferences over the inter-temporal consumption bundle, leading to rational choices over current consumption and investment. In order to make meaningful international comparisons we further suppose that representative households have common preferences. If this assumption is valid, we can use the money-metric Allen welfare index which compares the minimum expenditures required to achieve utilities U^2 and U^1 at some reference price vector, $\mathbf{p}^r$

$$A_r^{2:1} \equiv \frac{e[U(\boldsymbol{q}^2), \boldsymbol{p}^r]}{e[U(\boldsymbol{q}^1), \boldsymbol{p}^r]} \tag{16}$$

The Allen index is, in general, highly dependent on the choice of reference price vector – except in the case where preferences are homothetic. If a set of price and quantity data can be shown to be consistent with common homothetic preferences, we can use theorems from Afriat (1968, 1984) to determine tight bounds on the Allen index, which we refer to as the True Afriat index. We can then define bias as the extent to which either the GK or EKS indexes violate the true bounds.

Typically, studies of purchasing power parity do not test the hypothesis of common preferences, nor do they know the form of the preference relationship. Here we report on tests for common preferences and on tests for homothetic preferences, noting that linear quadratic functions, for which the EKS index is exact, comprise a subset of the more general homothetic set. We follow Dowrick and Quiggin (1994) in using revealed preference relationships to test for common preferences. The hypothesis of common preferences is rejected for countries A and B if we observe that the Laspeyres index is strictly less than one and the Paasche index is strictly greater than one – i.e. A could have afforded B's commodity bundle and B could have afforded A's bundle. Applying these tests to the 6,555 bilateral comparisons amongst the 115 ICP countries, we find only one pair where common preferences are rejected: Armenia and Uzbekistan.

The test for common homothetic preferences is much stricter. Afriat has shown that the test requires that there exist a true multilateral index, **a,** such that the ratio a_i / a_j, lies between the Paasche and Laspeyres indexes for every pair of countries i and j. We use Varian's (1983) minimum path algorithm to identify a set of 80 countries that satisfy the test. The fact that nearly one third of the ICP countries do not satisfy the test is a major weakness in applying the Afriat approach to constructing a comprehensive multilateral index. Nevertheless, we can use the Afriat results to assess the degree of bias in the GK and Afriat indexes within the homothetic set of countries.

Satisfying the Afriat test does not imply a unique Afriat index. Rather, there are well-defined bounds. Within these bounds there is an irreducible indeterminacy resulting from the fact that we do not observe utility. We make use of results from Dowrick and Quiggin (1997) to assess the extent to which the EKS and GK measures violate the bounds, $a_i^- \le a_i / \overline{a} \le a_i^+$, where $\overline{a}$ is the geometric mean of the index. and $\mathbf{a}^-$ and $\mathbf{a}^+$ are multilateral indexes derived from the minimum path matrix which is derived from the Laspeyres matrix, **L**.

The results are illustrated in Figure 4 where the solid lines represent the upper and lower Afriat bounds, $\mathbf{a}^-$ and $\mathbf{a}^+$, and the GK and EKS indexes are displayed as open and closed circles respectively. Both indexes are in logs and have been normalised to a zero mean. The countries are ordered from the poorest, Tanzania, to the richest, USA, along the horizontal axis. Two thirds of the GK observations lie outside the bounds. The average absolute value of the 51 deviations from the bounds is 11%, with a maximum deviation of 60%. It is noticeable that the GK index tends to understate the true income level of the richest countries and to overstate the true income of the poorest countries, consistent with our model of substitution bias with the GK price vector being representative of the rich countries. On the other hand, 80% of the EKS observations lie within the bounds. The 16 deviations from the bounds are small, averaging only 5% with a maximum deviation of 15%, and there is no tendency for the EKS to systematically under- or over-estimate the true GDP of the relatively rich or relatively poor. This finding is consistent with our model which predicts no systematic bias in the EKS.

In Figure 5 we turn to a comparison of the GK and PWT indexes. To enable closer inspection we display each index in terms of its deviation from the mid-point of the Afriat bounds. We find that the PWT index violates the bounds in 54 cases, which is similar to the number of GK violations, with a similar mean absolute deviation of 11%, though the size of the PWT deviations amongst the poorest countries is less than the GK deviations. Although we expected the different weighting system of the PWT to reduce the magnitude of substitution bias, such a reduction in bias is evident only for the group of very poor countries, and the bias is still substantial.

Given the absence of systematic bias in the EKS index relative to the true Afriat bounds and the evidence of substantial and systematic bias in both the GK and PWT indexes for our sub-sample of 80 countries, we regard the EKS index as a suitable benchmark for measuring bias in the full sample of 115 countries. In Appendix Table A1 we list the EKS, GK and PWT estimates of real GDP for the 115 1996 ICP countries, along with the percentage bias in the latter two indexes relative to the EKS.

The bias in the GK and PWT indexes arises because the international price vector, which is used to value the GDP bundles of each country, is closer to the rich country price-structures than it is to poor-country price structures. International prices are calculated as the weighted average of national prices, the weights being each country's share of the total expenditure of all the countries in the system. We examine the GDP shares of the 115 countries in the 1996 ICP, dividing them into three income groups where the richest 30 countries have *per capita* incomes above $13,500 and the poorest 30 countries have incomes below $3,200. It turns out that the rich group contains only slightly more people than the poor group. Their weightings in the GK system are very different, however, because average income in the rich group is more than fourteen times the average income in the group of poor countries. We see in Table 4 that the weight accorded to rich country prices in the standard GK system is 69%, compared with only 4% for the prices of the poorest countries. Moreover, more than one quarter of the weight is accorded to the USA.

Table 4: Relative Weights in the Geary-Khamis System applied to the 115 countries in the 1996 IPC

	30 poorest countries	middle 55 countries	richest 30 countries	rich relative to poor	*USA*
Standard GK System					
Population Share	27%	43%	30%	1.1	*9.1%*
average real GDP *per capita* ($I)[1]	1658	6156	23365	14.1	*29194*
GDP Share	4%	26%	69%	15.9	*26.3%*
PWT Super-country Weighting					
Population Share[2]	38%	47%	16%	0.4	4.6%
average real GDP *per capita* ($I)	1901	5286	23149	12.2	*29194*
GDP Share	11%	36%	53%	5.1	19.9%

1. GDP figures from PWT v6.1.

2. The population of each country has been multiplied by the Supercountry Weight from PWT6 Technical Documentation, Table 1. [http://pwt.econ.upenn.edu/Documentation/Doc-tech.pdf]

When we apply the 'supercountry' weights used to construct the Penn World Table, the GDP share of the 30 poorest countries rises from 4% to 11%. The GDP share of the 30 richest countries falls from 69% to 53%, with the GDP share of the USA falling from 26% to 20% - see the lower panel of Table 4. These adjustments are designed to reflect the actual shares of rich and poor countries in world GDP. Nevertheless, the fact remains that rich countries still dominate the GK system. The increased weight accorded to the poor countries by the PWT weighting system explains why there is some reduction in bias compared with the basic GK system, but the continued dominance of rich country GDP explains why a substantial degree of substitution bias remains in the PWT index.

3. Approaches for estimating world poverty

In this section, we present a brief summary of two approaches that have been used for estimating global poverty. First, we look at the World Bank's (WB) global poverty estimates based on its "$1/day" poverty line. The WB's $1/day global poverty estimates have been important for monitoring international progress in poverty alleviation and mobilising support for anti-poverty policies and they are key elements of the Millennium Development Goals.

However, the WB's approach has been challenged on several methodological grounds, and we also present a summary of an alternative approach recently used by Sala-i-Martin (2002). While Sala-i-Martin (2002) takes the WB's $1/day and $2/day poverty lines as given, he estimates world poverty rates using data on 125 countries by integrating individual income distributions (estimated using kernel density estimation techniques) below these poverty lines. One of the key contributions of this approach is that it enables the construction of global poverty estimates without the need for access to household-level income or consumption data for each country (in contrast, the WB uses household-level data in its global poverty work). In Sections 4 and 5 below, we employ the approach of Sala-i-Martin (2002) to evaluate the impact of different PPP methods on global poverty estimates.

World Bank approach

The World Bank approach to global poverty measurement proceeds in three steps. (1). The definition of an international poverty line (IPL) in absolute poverty terms (i.e. as the inability to attain a minimal standard of living, proxied by expenditure or income per capita). (2). The conversion of the IPL into local currencies using PPP$ exchange rates, coupled to the use of Consumer Price Indexes (CPI) for survey year equivalence, which yields a National Poverty Line (NPL) for each country. (3). The comparison of each NPL with domestic household expenditure or income survey data to measure the world's absolute poor count and depth. The main difficulty with this approach is the first step; the definition of the criteria upon which the IPL is to be generated, and the problematic issue of making sure the result yields a consensual view of what it means to be absolutely poor in poor countries.

This result is the well-known $1/day International Poverty Line defined by the World Bank, which is the yardstick by which most global poverty comparisons are produced today.[4] Since we make use of the $1/day and $2/day IPL to generate GK and EKS based poverty rates it is important to clarify what these notions represent and to briefly document the foundations upon which they have been built.

The World Bank's World Development Report (WDR) 1990 officially introduced the $1/day IPL. To set its international benchmark for absolute poverty assessment, the World Bank collected a sample of 34 country-specific poverty lines[5] (CSPL), which were then converted in constant 1985 PPP$/capita[6] and plotted against mean per capita consumption. On the pure analysis of this graph, the World Bank set two IPLs: the extreme poverty IPL of $275/yr and the well known "$1/day" IPL of $370/yr. The former is merely India's CSPL (which is very close to the CSPL of the poorest country in their data set – Somalia) expressed in PPP terms. The latter was established from "a cluster of CSPLs for 6 poor countries"[7] with a mean consumption ranging from PPP$ 300 to PPP$ 1100 (hence significantly differing from each other in consumption terms).

The $2/day IPL was simply taken as double the $1/day IPL and therefore doesn't seem to stem from any statistical discovery other than the aforementioned original cluster. The motivation behind the $2/day IPL arose from the need to reveal a poverty picture in "middle income" countries where the $1/day IPL did not permit such analysis.

In its World Development Report 2000, the World Bank presents a new, updated IPL. It used current CSPLs to readjust the $1/day IPL with a more recent and comprehensive PPP dataset (the new 1993 PPP$ developed by the International Comparison Program[8]), thus yielding the $1.08/day IPL, deemed to reflect similar purchasing power in 2000 as the earlier $1/day IPL in 1990 (and therefore terminologically still referred to as

---

[4] See for instance Chen and Ravallion (2000), Bhalla (2000), Deaton (2001), Sala-I-Martin (2002). See also Atkinson and Bourguignon (1999) for a discussion.

[5] Note the difference between CSPL and NPL. The CSPL is a local poverty line unilaterally defined by the respective country or by research institutions, international bodies etc. The NPL is just a local currency translation of the IPL and therefore is defined solely by the WB.

[6] The original 1985 PPP index is a GK index produced by the Penn World Tables.

[7] Indonesia, Bangladesh, Nepal, Kenya, Tanzania, Morocco.

[8] As mentioned previously, the new 1993 PPP is understood to be an EKS index.

"$1/day"). This time however the WDR 2000 redefines the IPL as "the median of the 10 lowest $PPP CSPLs".[9]

As readily admitted by the World Bank, the choice of an IPL is somewhat arbitrary. The argument that "the most typical CSPL among low-income countries was chosen" is tested by regressing CSPLs on countries mean consumption (Ravallion et al. 1991). The results show that CSPLs are indeed "sticky" at low consumption levels. This result was later reproduced for a larger set of poor countries CSPLs in Ravallion (1998). Interestingly, it also seems that the notion of $1/day as the WB's global poverty benchmark dates well further back in time than the cluster of PPP adjusted CSPLs found in 1990 (on this, see Yotopoulos 1989). These arguments go a long way to vindicating the choice of the 1$/day IPL, however, as mentioned earlier, other arguments have been put forward challenging this approach. We do not pursue this issue any further and use the $1/day and $2/day IPL as the best-recognised instruments currently available to appraise the sensitivity of global poverty rates.

Approach using estimates of individual income distributions

Sala-i-Martin (2002) produces estimates of the evolution of world poverty and inequality between 1970 and 1998 using data on 125 countries covering close to 90 percent of the world's population. While Sala-i-Martin found that global estimates of poverty declined substantially over the past 30 years, there were marked differences across regions, with Asia being identified as the best performing region in terms of poverty reduction and Africa, in contrast, experiencing substantial increases in poverty. Sala-i-Martin (2002) does not enter into the debate regarding the construction of the IPL, taking the World Bank's $1/day and $2/day poverty lines as given. However he takes a major methodological departure from the WB's approach by using kernel density estimates of individual income distributions for each country; in contrast, the World Bank's approach involves the use of household-level expenditure data for each of the countries in the study.

[9] This issue as well as the change of PPP methods and structure is at the source of an intense debate, which is beyond the scope and interest of this paper. A sense of the debate can be found in Deaton (2001) and Pogge and Reddy (2003).

Following Sala-i-Martin (2002), and omitting time subscripts, let s_{ik} represent the income share for quintile k for country i, and let N_i and y_i represent country i's population and per capita income, respectively. To each fifth of the population in country i, $N_i/5$, we assign the income level $5s_{ik}\, y_i$. A limitation here is that each individual within a quintile is assumed to have the same level of income; to overcome this, Sala-i-Martin constructs a continuous income distribution for country i by computing kernel density estimates of the true density function $f(y_i)$. The advantage of this approach is that one does not need to assume a particular functional form for the income distribution.[10] However, an assumption needs to be made regarding the type of kernel density function (Sala-i-Martin uses the gaussian kernel, but also experimented with the Epanechnikov kernel and found no qualitative difference in the results) and the bandwidth of the kernel, which is similar to the inverse of the number of bins in a histogram (and hence smaller widths produce more detail). While it is conventional to use bandwidth of w = 0.9*sd*n-0.2, where n is the number of observations and sd is the standard deviation of (log) income, Sala-i-Martin's focus was on comparing poverty and inequality across countries and the evolution of these measures over time, and he thus selected a common bandwidth of 0.35 for all countries.

For each country, Sala-i-Martin evaluated the density function at 100 different points, and then applied a normalisation so that the total area under it equals the population of the country. Thus, he calculated the number of people estimated to be associated with each of the 100 income groups. The poverty rate for a particular country and a particular poverty line is then calculated as the quotient of the sum of the density data points for income categories below the poverty line and the total population (or more generally, the quotient of the integral of the density function between 0 and the log of the poverty line, and the integral between 0 and infinity).

[10] For other examples of using kernel densities to estimate world income distributions, see Quah (1996, 1997), Jones (1997) and Kremer, Onatski and Stock (2001).

4. Estimating the income distribution for ICP countries (plus China and India)

In this section, we use the approach of Sala-i-Martin (2002) to construct kernel density estimates of income distributions for the countries represented in the 1996 ICP data set. Unfortunately, India and China are not represented in the 1996 ICP data set and since it is problematic to construct estimates of global poverty without including these two countries in the analysis, we impute EKS and GK real income for these countries. In Section 5, we present estimates of regional and global poverty, constructed using our estimated income distributions.

There are three main data inputs used in the Sala-i-Martin approach to estimating individual-county income distributions: per capita real GDP, population numbers and income shares for each quintile group. Sala-i-Martin uses PPP-adjusted GDP data from PWT6.1, which, as discussed above, is constructed using the Geary-Khamis approach. It appears that the population figures used by Sala-i-Martin also come from the PWT. Sala-i-Martin's data on income shares for quintiles is based on national-level income and expenditure surveys and is taken from Deininger and Squire (1996) (updated using the World Development Indicators, 2003 CD-ROM).

Since the purpose of the present paper is to assess the impact of different PPP approaches on poverty estimates using Sala-i-Martin's approach to estimating poverty, we have attempted to construct data that is comparable to that used by Sala-i-Martin, and hence where possible have used the same sources. However, there are several key differences that need to be mentioned. First, Sala-i-Martin did not produce poverty estimates for 1996 (the year of focus in our study) – the closest year covered in his study was 1998 – and hence our population data, and in some cases quintile share data, will differ to the 1998 data used by Sala-i-Martin. Second, we do not use the PWT real GDP series and instead use the ICP-GK and ICP-EKS real GDP estimates discussed earlier. As noted above, the PWT-GK series has been constructed differently to our own GK series, and 'shortcut' estimation methods have been used to estimate real GDP for countries that were not in the 1996 ICP survey.

Finally, there are marked differences in the coverage of countries between our study and that of Sala-i-Martin. While we started out with a total of 117 countries - 115 ICP countries plus China and India - we had to drop 14 of the ICP countries because we could not obtain quintile share data for them from either Deininger and Squire (1996) or the WDI. We also decided to drop six other ICP countries because the quintile information was either too old or considered unreliable by the source (see data annex for more details). The combined population of the 20 countries dropped from our data is 72 million and our final data set of 97 countries accounts for a total population of 5 billion (or 87 percent of the 1996 world population of 5.8 billion).[11] Sala-i-Martin's dataset of 125 countries accounted for 5.2 billion, or 88 percent of the 1998 world population of 5.9 billion. It is also notable that Sala-i-Martin did not include countries from the former Soviet Union (as they did not exist until the early 1990s and he required time series data for each country dating back to the 1970s).

Imputing EKS and GK real GDP for China and India

In order to provide meaningful estimates of world poverty, China and India must be included in the analysis since these two countries are home to many of the world's poor. Unfortunately, China and India were not included in the 1996 ICP, and it has been necessary to impute EKS and GK real GDP for these countries. EKS real GDP for China and India were imputed using the 1996 PWT-GK real GDP estimates and the coefficients from the regression of the (log) PWT-GK index on the (log) ICP-EKS index presented in Figure 3. The PWT-GK 1996 per capita real GDP estimate for China (India) was $2969 ($2118), and the imputed ICP-EKS per capita real GDP estimate was $2646 ($1856).

While the PWT real GDP is constructed using the GK approach, the PWT uses "super-country" weights and hence the PWT-GK real GDP numbers are not directly comparable to the ICP-GK numbers that we have constructed here. A regression of (log) ICP-GK real GDP on (log) PWT-GK real GDP produces the following results:

$$\ln y_i(\text{ICP-GK}) = 0.118 + 0.996 \ln y_i(\text{PWT-GK}); \qquad R2 = 0.995 \qquad (17)$$

The imputed ICP-GK per capita real GDP values for China and India are $3230 and $2308, respectively. Note that the ICP-GK real GDP is systematically higher than the PWT-GK real GDP, and this has implications for our poverty estimates and, in particular, the comparability with poverty estimates of Sala-i-Martin.

[11] Our full data set of 117 countries covers a combined population of 5.1 billion (88 percent of world population).

Kernel density estimates for 117 countries

In Figure 6 we present estimated income PDFs for the nine most-populous non-high income countries in our data set, and also the USA. The figures are arranged in order of population size, most populous first. The logarithm of the $1/day and $2/day poverty lines are also shown as straight lines. The figures show the PDFs constructed under both the EKS and GK approach and it is apparent that a switch of index methodology causes a horizontal shift in the PDF. Our estimated PDFs have the same shape as those presented by Sala-i-Martin (2002). In Figure 7 we present the implied income CDFs for the same 10 countries. The poverty rate for a given poverty line and index number method can be read off the vertical axis as the point where the poverty line intersects the CDF.

5. Global poverty analysis

For our poverty analysis, we use the poverty lines of Sala-i-Martin (2002), which were updates of the $1/day and $2/day absolute poverty lines originally used by the WB. Sala-i-Martin calculates the $1/day poverty line at $532 per year in 1996 dollars, while the $2/day line equates to $1064 per year.

It is apparent that choice of PPP index has a marked impact on estimates of world poverty. Under the $1/day poverty line we estimate world poverty to be 3 percent using the ICP-GK real GDP series and this estimate rises to 4.7 percent when we use the ICP-EKS real GDP series [see Table 5]. It should be noted that the denominator used in our estimates of the world poverty rate is our sample of world population (for 97 countries) of 5 billion, not the actual world population of 5.8 billion. Using the EKS real income series leads to an estimate of 236 million people in poverty – an increase of nearly 60 percent over the 149 million people found to be poor under the GK approach to real income measurement. Sala-i-Martin found a world poverty rate of 6.7 percent for 1998 using the $1/day poverty line. This is higher than either of our estimates, however as argued above we cannot make comparisons with Sala-i-Martin because of major differences in the real GDP series and the coverage of the data sets.

Table 5: Global poverty estimates - $1/day poverty line

	Pop. (bill.)	Comp.(%)	*Geary-Khamis real GDP* Poverty rate (%)	No. poor (bill.)	Comp. (%)	*EKS real GDP* Poverty rate (%)	No. poor (bill.)	Comp. (%)
Africa - Sub Saharan	278	0.056	0.365	101	0.680	0.430	120	0.506
East Asia & Pacific	1,619	0.324	0.009	15	0.099	0.025	41	0.172
Eastern Europe & Central Asia	461	0.092	0.004	2	0.014	0.009	4	0.019
Latin America and Carribean	344	0.069	0.012	4	0.029	0.024	8	0.035
Middle East & North Africa	175	0.035	0.031	5	0.036	0.049	9	0.037
South Asia	1,233	0.247	0.017	21	0.142	0.044	55	0.231
High-income	890	0.178	0.000	0	0.000	0.000	0	0.000
World (n=97)	5,000	1.000	0.030	149	1.000	0.047	236	1.000

Under the $2/day poverty line, we estimate a world poverty rate of 14.7 percent using ICP-GK real GDP and 20.3 percent using the ICP-EKS index [Table 6].[12] There are 278 million more people found to be poor (at the $2/day poverty line) when the EKS rather than GK index is used to derive the income distribution.

Table 6: Global poverty estimates - $2/day poverty line

	Pop. (bill.)	Comp.(%)	*Geary-Khamis real GDP* Poverty rate (%)	No. poor (bill.)	Comp. (%)	*EKS real GDP* Poverty rate (%)	No. poor (bill.)	Comp. (%)
Africa - Sub Saharan	278	0.056	0.621	173	0.235	0.685	190	0.188
East Asia & Pacific	1,619	0.324	0.138	223	0.304	0.194	315	0.311
Eastern Europe & Central Asia	461	0.092	0.030	14	0.019	0.053	25	0.024
Latin America and Carribean	344	0.069	0.123	42	0.058	0.145	50	0.049
Middle East & North Africa	175	0.035	0.080	14	0.019	0.114	20	0.020
South Asia	1,233	0.247	0.218	269	0.366	0.335	413	0.408
High-income	890	0.178	0.000	0	0.000	0.000	0	0.000
World (n=97)	5,000	1.000	0.147	735	1.000	0.203	1,013	1.000

[12] Sala-i-Martin calculated a world poverty rate of 18.6 percent, using the $2/day poverty line.

Regional analysis

It is of interest to see whether the choice of real income series leads to markedly different conclusions regarding the risk of poverty in different regions (i.e. regional poverty rates) and where the poor live (i.e. the distribution of poverty). In general, the impact of the two different PPP approaches on measured poverty for a particular country will depend on three factors:

The first difference is between the GK and EKS estimates of average real income for the country. As shown earlier, the GK index tends to overestimate the real income of poorer countries. The estimated real income density functions constructed under the two PPP approaches are direct horizontal translations of one another, with the proportional horizontal translation equal to the proportional difference between the two income estimates. A larger horizontal left shift will result in a larger relative increase in the poverty rate. We refer to this as the index number effect on poverty estimates.

The second difference is related to where the IPL intersects the estimated income density function. For a given leftward translation in the income density function, the relative increase in the poverty rate will be greater for a country where the IPL intersects the density function further to the left (i.e. a richer country). We refer to this as the distribution mean effect on poverty estimates.

The third difference is related to the shape of the income density function. For a given horizontal translation of the density function, the relative increase in the poverty rate will be greater if the density function is concave in the area above the poverty line (i.e. if many people are "bunched" around the poverty line), compared with if it is convex over this range. We refer to this as the distribution shape effect on poverty estimates.

For our regional analysis, we have identified six regions that broadly coincide with the regional groupings used by the World Bank: Sub-Saharan Africa (SSA), East Asia & Pacific (EAP), Eastern Europe & Central Asia (ECA), Latin America & Caribbean (LAC), Middle East & North Africa (MENA), South Asia (SA). For completeness and interpretation we also include as a separate grouping the high-income countries (HIC) from our data set. See the Data Annex for a complete listing of all countries and their regional classification.

With the $1/day poverty line, Africa has a poverty rate of 36.5 percent under the GK approach, compared with 43 percent under the EKS approach. Africa experiences the biggest absolute change in its poverty rate – its poverty rate is 6.5 percentage points higher under EKS approach, compared with the GK approach. In contrast, South Asia experiences a 2.7 percentage point increase in its measured poverty rate (from 1.7 point under the GK approach to 4.4 percent under the EKS approach), while the other regions experience increases in the poverty rate of less than 2 percentage points. However, in relative terms, the shift from GK to EKS indexes has a larger impact on the poverty experience of Asia, compared with Africa. The number of poor in Africa increases by 20 percent, compared with an almost threefold increase in the number of poor in Asia. The reason for this is of course that there are so many poor people in Africa that the choice of index number approach does not have a large relative impact (the distribution mean effect referred to above is "swamping" the index number effect).

The choice of real income series has a large impact on the composition of world poverty. With a $1/day poverty line and the GK measure of real income, nearly 70 percent of the world's poor live in Africa, and Asia is home to approximately a quarter of the poor. However switching to the EKS approach, although the estimated number of poor people rises in every region, the percentage of the poor living in Africa falls to approximately 50 percent, and Asia now accounts for over 40 percent of the poor. A shift from the EKS to the GK index number approach results in a marked redistribution of measured poverty away from Africa and towards Asia. In other words, a disproportionately large section of the population of Asia are just above the poverty line when the GK method, which overstates their real incomes, is used. The main point of this is not that we should be any less concerned about poverty in Africa, but rather that estimates of the regional composition of world poverty are highly sensitive to the choice of index number approach for constructing real income.

Under the $2/day poverty line we find that index number method has a smaller, but still significant impact on the regional poverty rates and the distribution of the poor. A shift from GK to EKS real GDP results in a 6.4 percentage point increase in the poverty rate in Africa, compared with a 5.6 point increase in East Asia & Pacific, and a 11.7 point increase in South Asia. Under the GK approach, 67 percent of the world's poor live in Asia while Africa accounts for 24 percent of the poor. With the EKS approach, Africa's share of the poor decreases by 5 percentage points with South Asia's share increasing by approximately 4 points and East Asia's share by 1 percentage point.

6. Conclusions

The well-known phenomenon of substitution bias in fixed-price index numbers implies that purchasing power parity measures that rely on the Geary-Khamis method are not appropriate for measurement of global poverty. Because the GK method values incomes at prices corresponding to those found in relatively rich countries, it tends to overstate real incomes in the poorest countries relative to the US by an order of magnitude around thirty percent. On the other hand, whilst the EKS method does not in general produce a true index, it exhibits no systematic bias and appears to be appropriate for assessing the extent and distribution of poverty.

Switching to the EKS method from the more commonly used GK method raises the estimated number of the very poor by more than fifty percent, giving a much more realistic impression of the magnitude of extreme poverty. We find that Asia is home to two-thirds of the people who are mis-classified as living just above the poverty line when the GK method is used.

We intend to carry out further research to reconcile the non-index-number differences between our approach and that of Sala-i-Martin's recent study which relies on the PWT estimates of purchasing power parities. We also intend to examine the implications of the World Bank's approach which starts with poverty rates in a sample of poor countries and uses PPPs to estimate poverty rates in other (mostly poor) countries. The "US$1-a-day" is just an intermediate calculation in their approach, possibly mitigating the problem of index number bias in PPPs relative to the US. But the World Bank approach still depends on estimates of PPPs between poor countries, and we have shown that these can be highly sensitive to the index number approach.

Given the substantial and variable degree of substitution bias that we have documented in both the standard GK methodology and the supercountry-weights variation used in constructing the Penn World Table 6.1, our general conclusion appears robust. The index number approach matters to global poverty measurement, and it matters a lot.

References

Afriat, Sydney N. (1967), 'The Construction of Utility Functions from Expenditure Data', *International Economic Review* 8 (1): 67-77.

Afriat, Sydney N. (1984) 'The True Index', in A.E. Ingham and A.M.E. Ulph (ed.), *Demand, Equilibrium, and Trade: Essays in Honor of Ivor F. Pearce* 37-56*,* New York: St. Martin's Press.

Atkinson, Anthony B. and Francois Bourguignon (1999): "Poverty and inclusion from a world perspective". Paper prepared for the ABCDE Europe Conference, June 1999

Bhalla, Surjit (2000): "Trends in world poverty: ideology and research", paper presented at the IMF, 28 june 2000.

Chen, S. and M. Ravallion (2000). "How Did the World's Poorest Fare in the 1990s?," Working Papers -- Poverty. Income distribution, safety nets, micro-credit. 2409, World Bank

Deaton, Angus. (2001): "Counting the World's Poor: Problems and Possible Solutions" World Bank Research Observer, 16, 125-47.

Deininger, Klaus and Lyn Squire (1996), 'A New Data Set Measuring Income Inequality', *World Bank Economic Review* 10 (3): 565-591.

Dowrick, Steve and Muhammad Akmal (2003), 'Explaining Contradictory Trends in Global Income Inequality: A Tale of Two Biases', *Draft paper for World Institute for Development Economics Research on 'Inequality, Poverty and Human Well-being', http://ecocomm.anu.edu.au/people/info.asp?Surname=Dowrick&Firstname=Steve*

Heston, Alan, Robert Summers and Bettina Aten (2002), 'Penn World Table Version 6.1', Center for International Comparisons at the University of Pennsylvania (CICUP), October.

Jones, Charles I. (1997): "On the Evolution of World Income Distribution", *Journal of Economic Perspectives*, 11(3), Summer 1997, (19 - 36)

Kravis, Irving B., Alan Heston and Robert Summers (1982), *World Product and Income: International Comparisons of Real Gross Products*, Baltimore: The Johns Hopkins University Press.

Kremer, M., A. Onaski, and J. Stock, (2001), "Searching for Prosperity", Carnegie-Rochester Conference Series on Public Policy, vol 55, December

Quah, Danny T. (1996), Twin Peaks: growth and convergence in models of distribution dynamics. *Economic Journal*, 106, July, 1045-1055

Quah, D. (1997), "Empirics for Growth and Distribution: Stratification, Polarization, and Convergence Clubs," *Journal of Economic Growth*, 2, 27-60

Reddy, Sanjay G. and Thomas W. Pogge (2003), "How not to Count the Poor", www.socialanalysis.org

Ravallion, M., G. Datt, and D. Van De Walle (1991), "Quantifying Absolute Poverty in the Developing World" *Review of Income and Wealth*, 37, 345-61.

Ravallion, M. (1998), "Poverty Lines in Theory and Practice" *LSMS Working Paper* 133, World Bank, Washington DC.

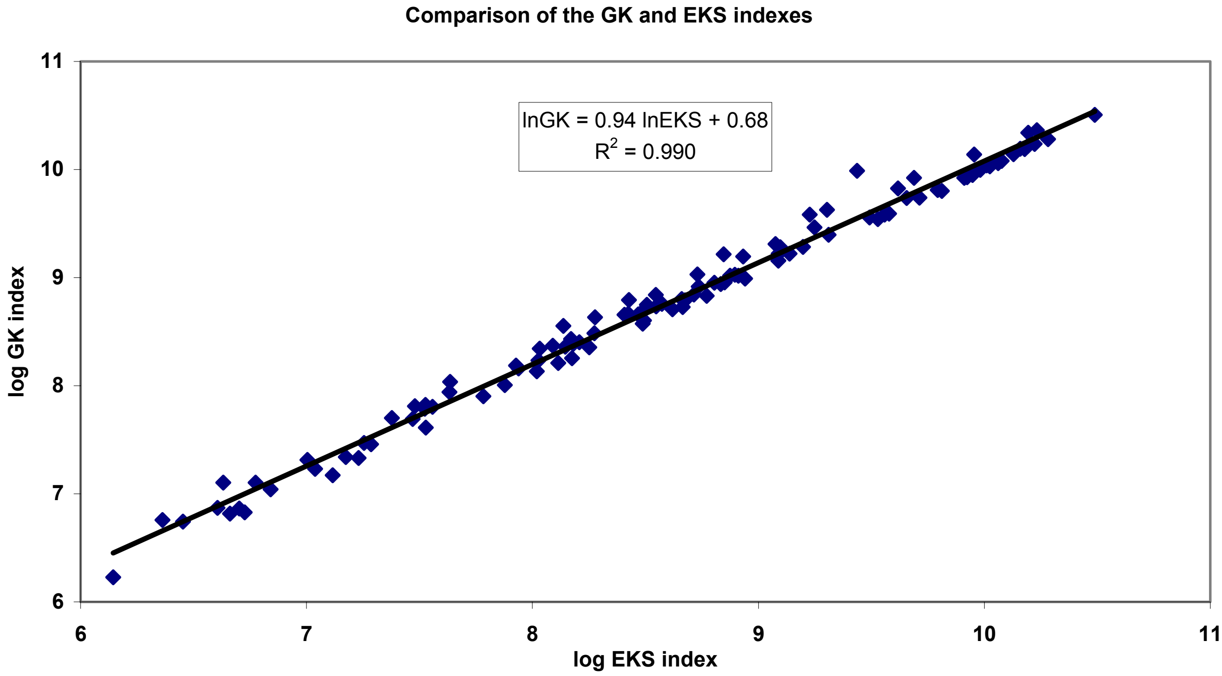
Ravallion, M. (2003), 'How *Not* to Count the Poor? A Reply to Reddy and Pogge', mimeo, World Bank, Washington.

Sala-i-Martin, Xavier (2002), 'The World Distribution of Income (Estimated from Individual Country Distributions), *NBER Working Paper* 8933 (May): 1-65.

Varian, Hal R. (1983), 'Non-Parametric Tests of Consumer Behaviour', *Review of Economic Studies* 50 (1): 99-110.

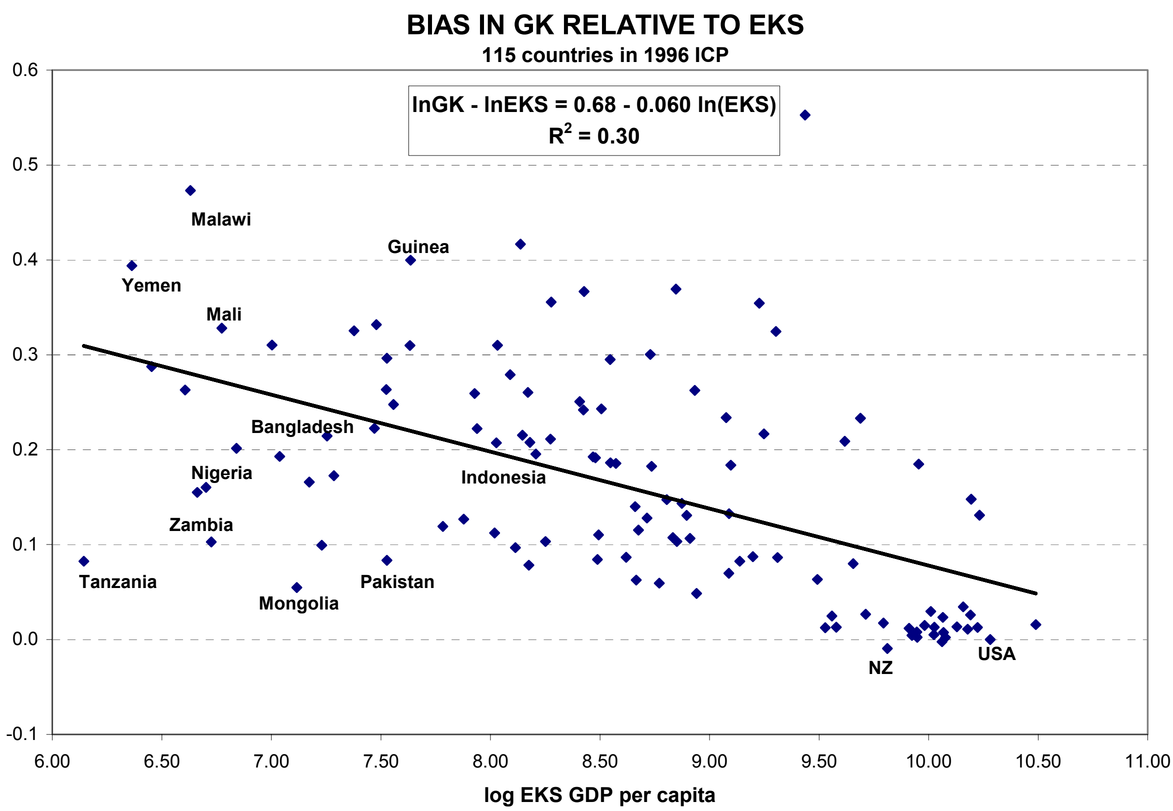
Yotopoulos, P. A. (1989), "Distributions of Real Income: Within Countries and by World Income Classes" Review of Income and Wealth, 35, 357-76.

Figure 1



note:

Figure 2



note

Figure 3

note:

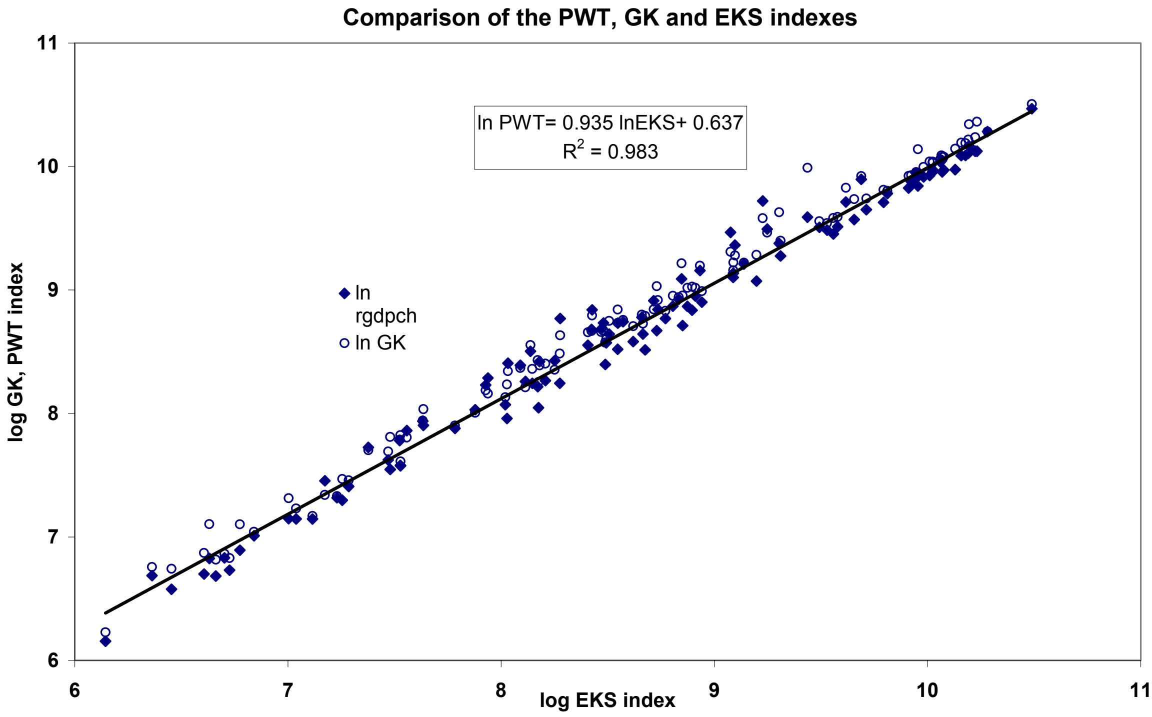
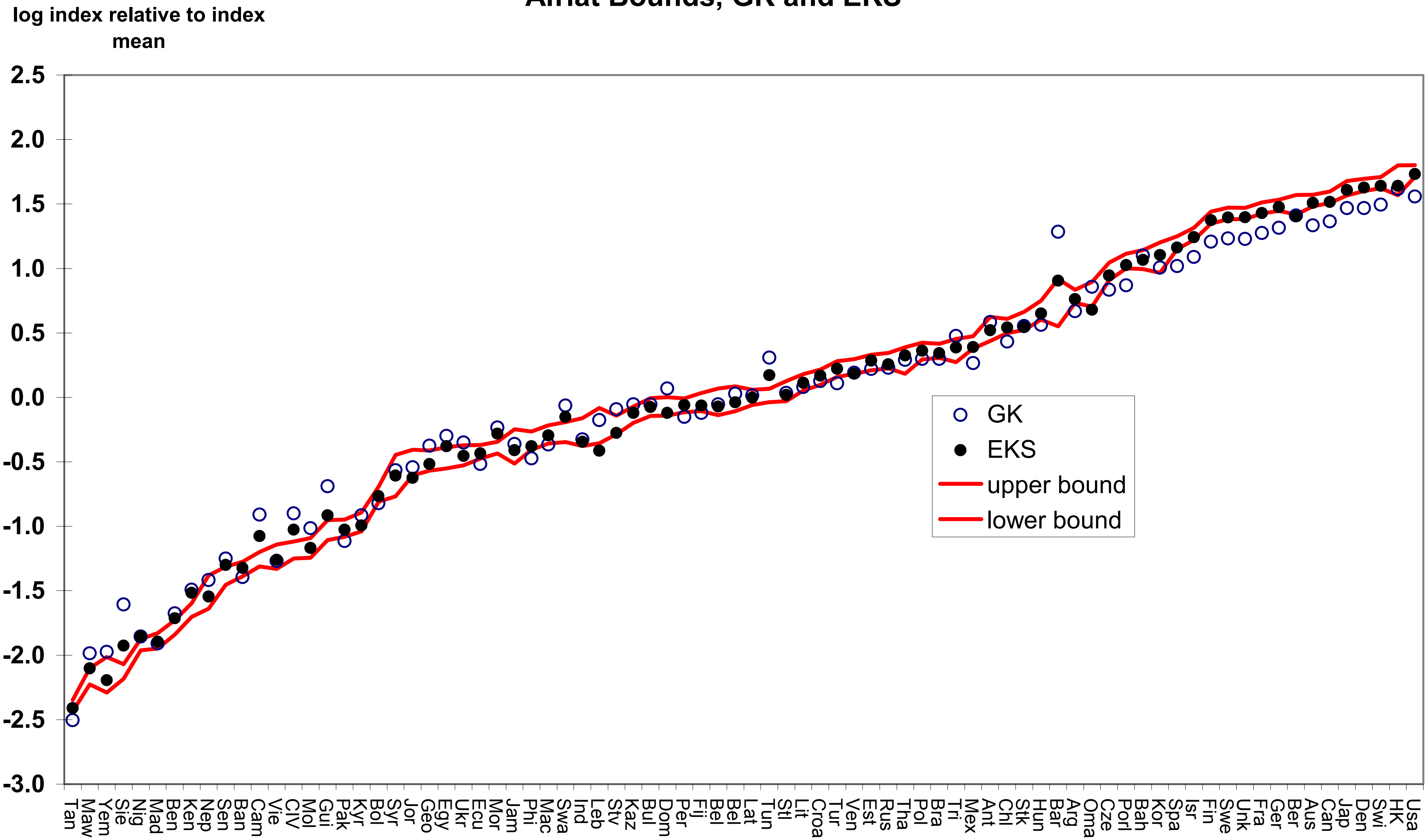


Figure 4

Afriat Bounds, GK and EKS



Notes:

Figure 5

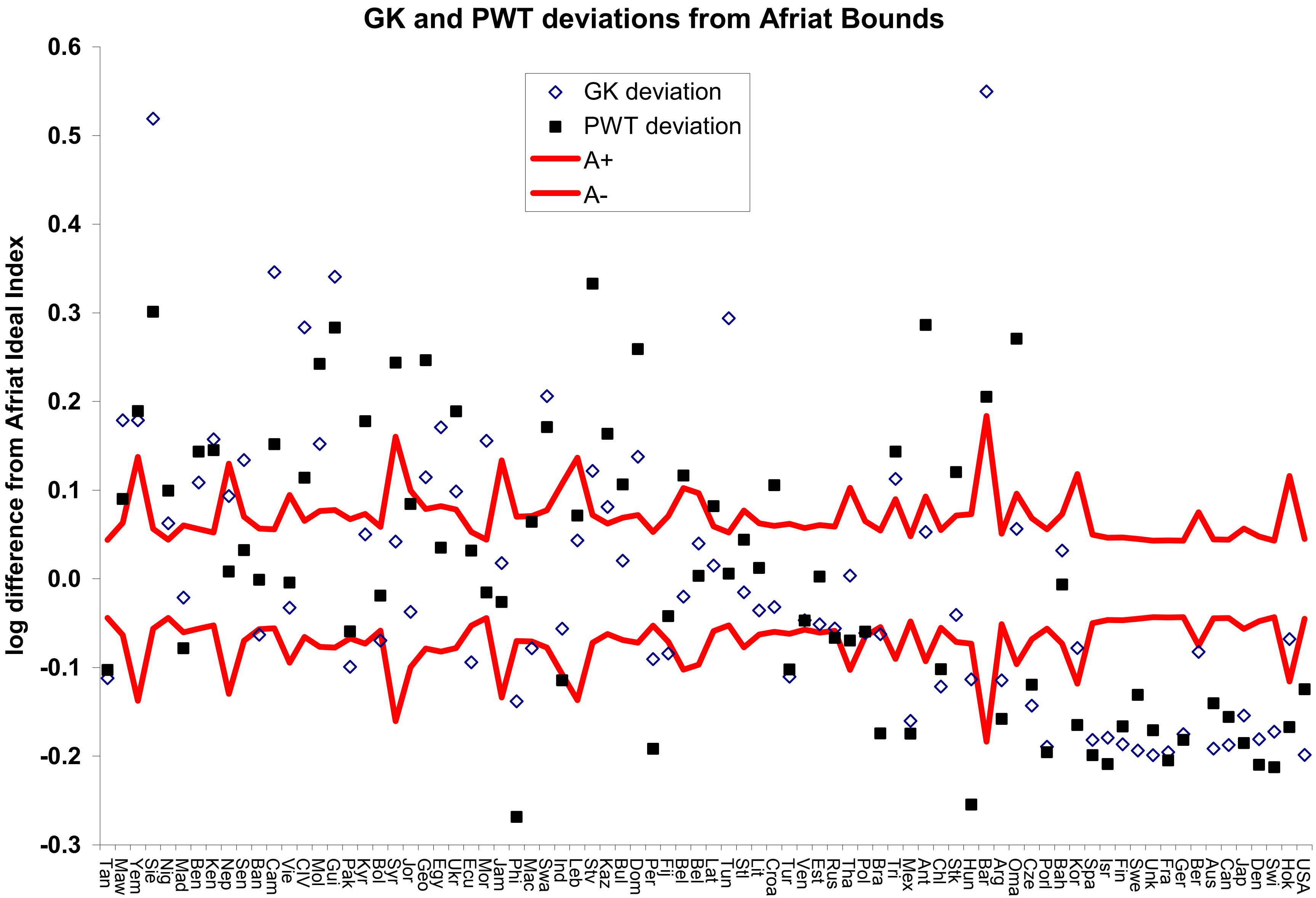

GK and PWT deviations from Afriat Bounds
log difference from Afriat Ideal Index
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
GK deviation
PWT deviation
A+
A-
Tan Maw Yem Sie Nig Mad Ben Ken Nep Sen Ban Cam Vie CIV Mol Gui Pak Kyr Bol Syr Jor Geo Egy Ukr Ecu Mor Jam Phi Mac Swa Ind Leb Stv Kaz Bul Dom Per Fij Bel Bel Lat Tun Stl Lit Croa Tur Ven Est Rus Tha Pol Bra Tri Mex Ant Chl Stk Hun Bar Arg Oma Cze Porl Bah Kor Spa Isr Fin Swe Unk Fra Ger Ber Aus Can Jap Den Swi Hok USA

Figure 6a: Estimated income PDF, China

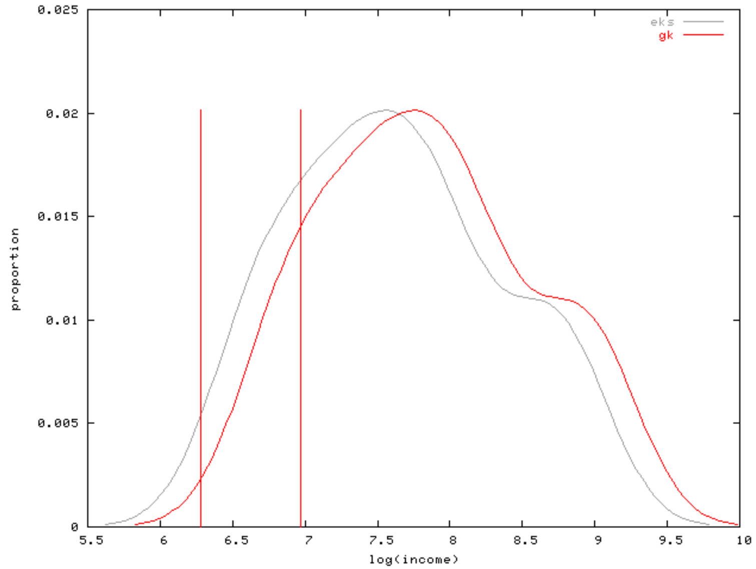


Figure 6b: Estimated income PDF, India

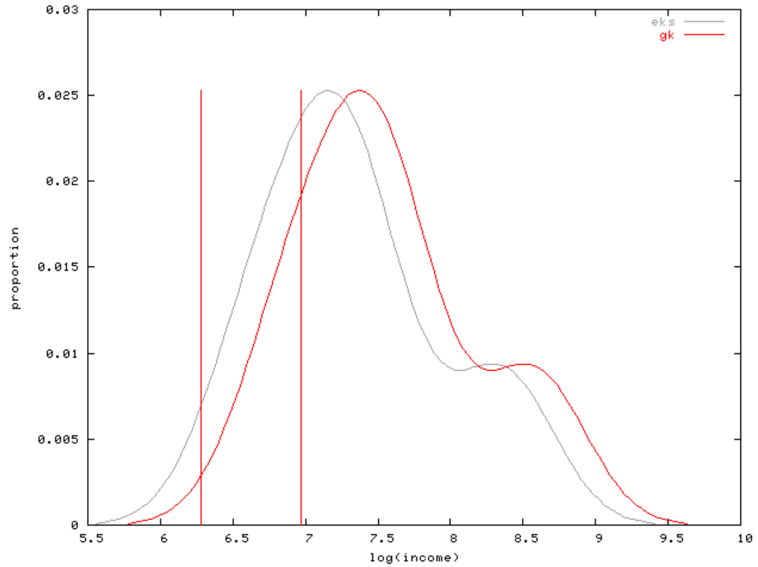


Figure 6c: Estimated income PDF, USA

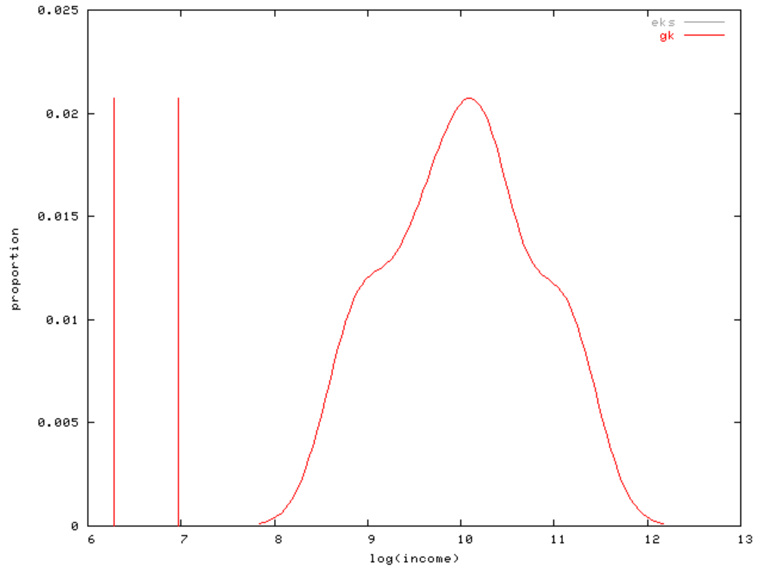


Figure 6d: Estimated income PDF, Indonesia

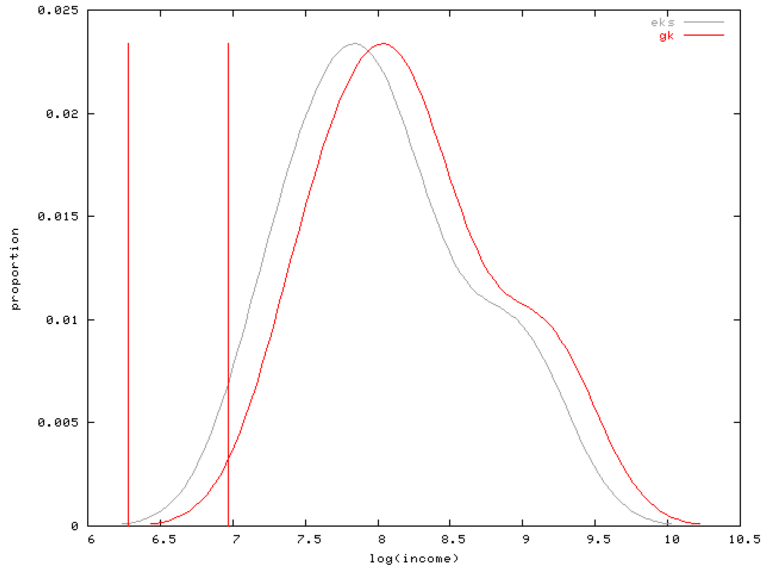


Figure 6e: Estimated income PDF, Brazil

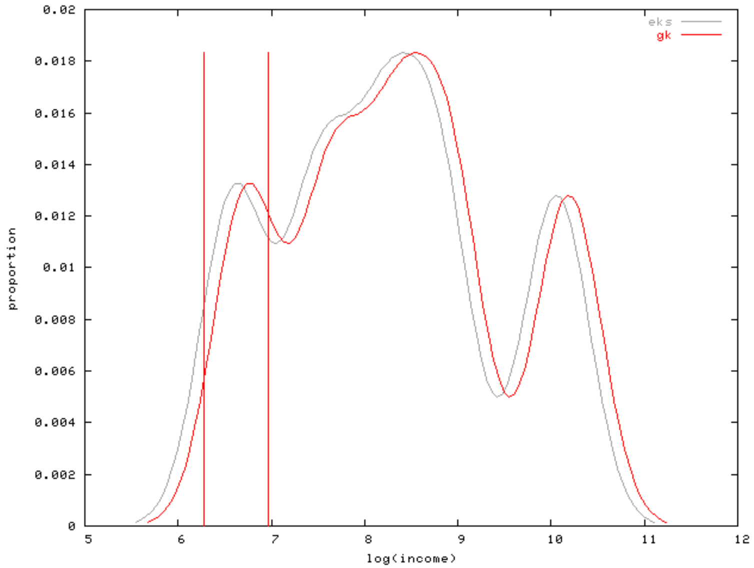


Figure 6f: Estimated income PDF, Russia

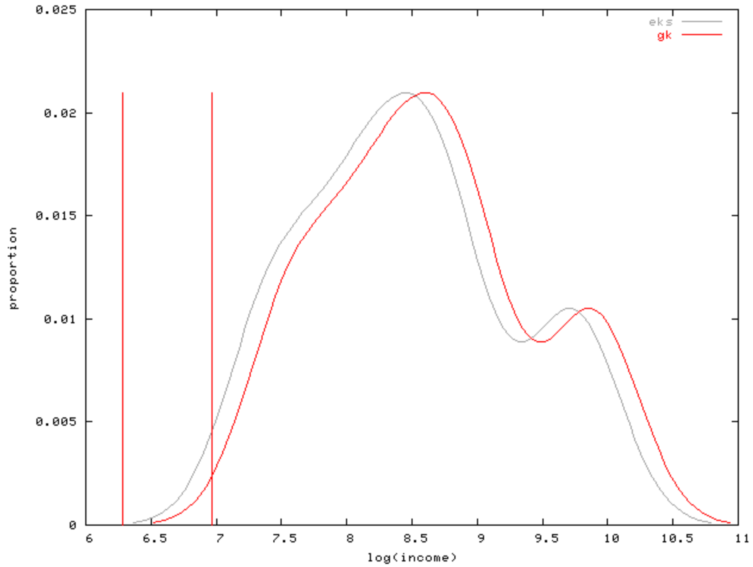


Figure 6g: Estimated income PDF, Pakistan

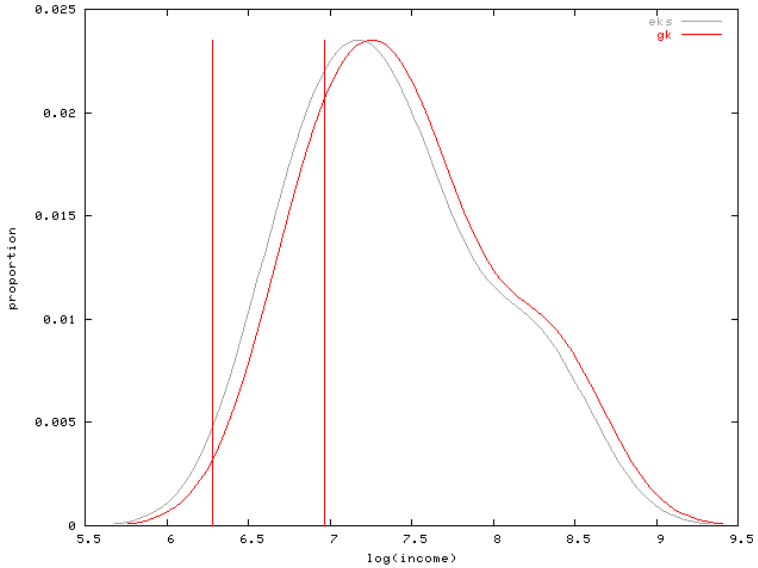


Figure 6h: Estimated income PDF, Bangladesh

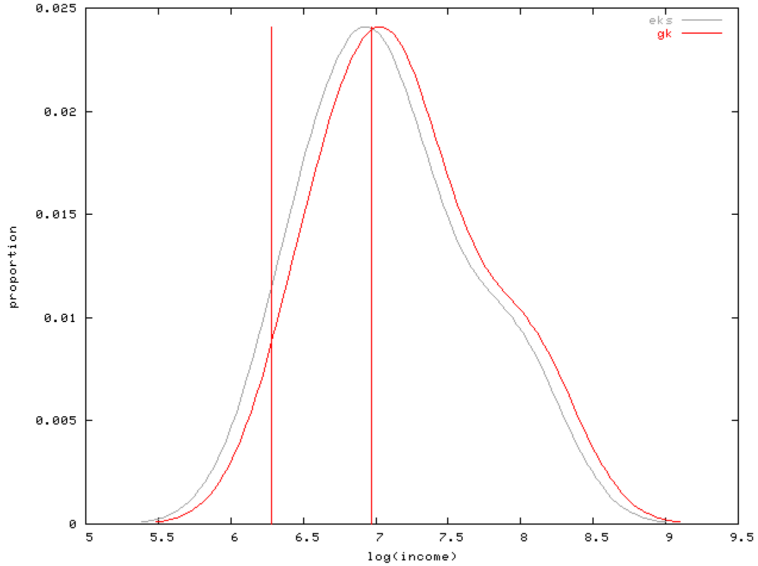


Figure 6i: Estimated income PDF, Nigeria

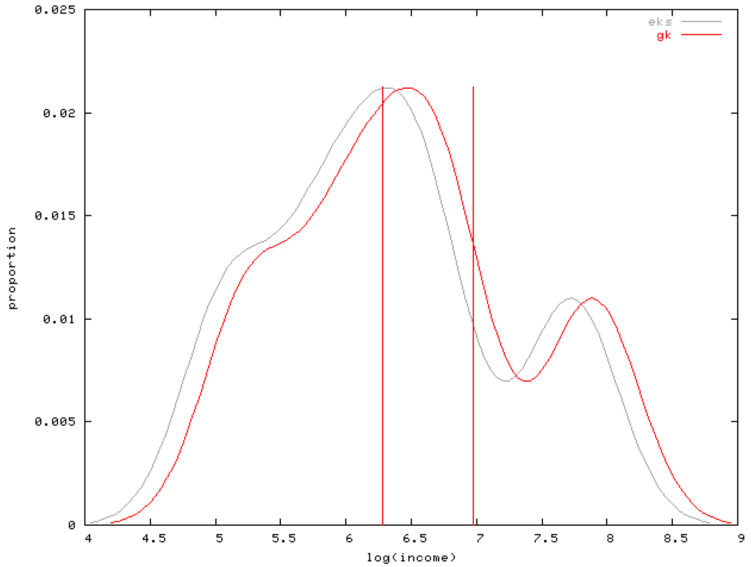


Figure 6j: Estimated income PDF, Mexico

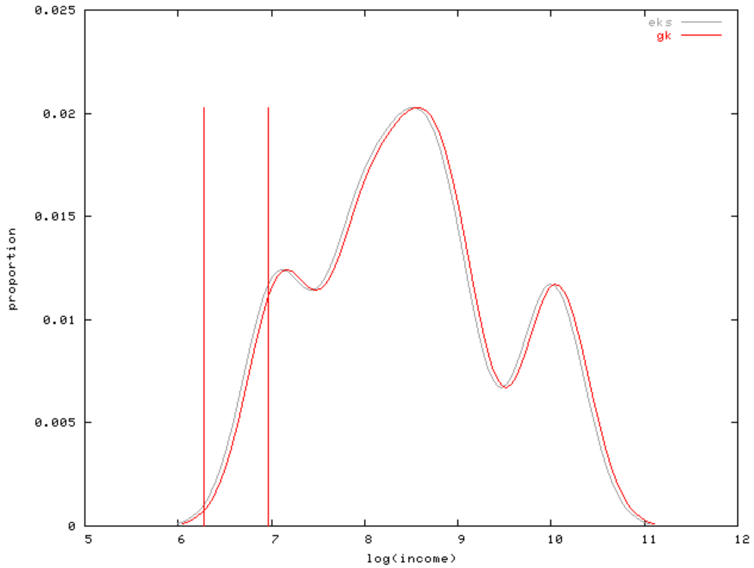


Figure 7a: Estimated income CDF, China

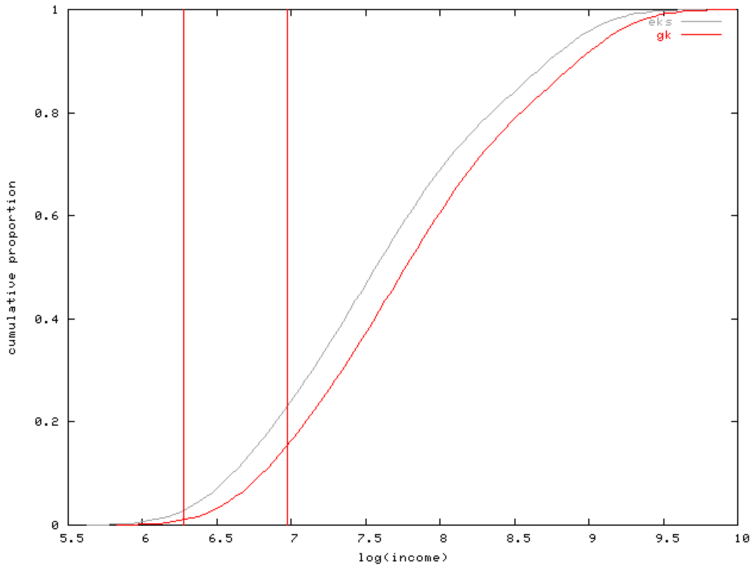


Figure 7b: Estimated income CDF, India

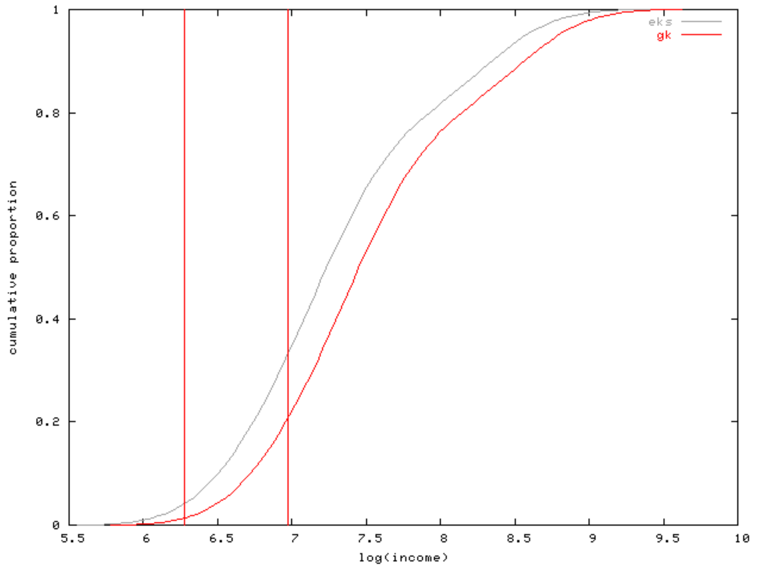


Figure 7c: Estimated income CDF, USA

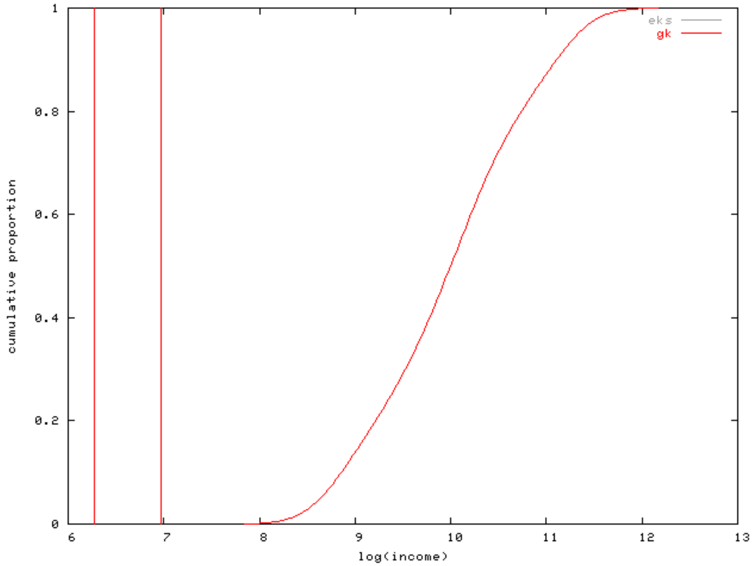


Figure 7d: Estimated income CDF, Indonesia

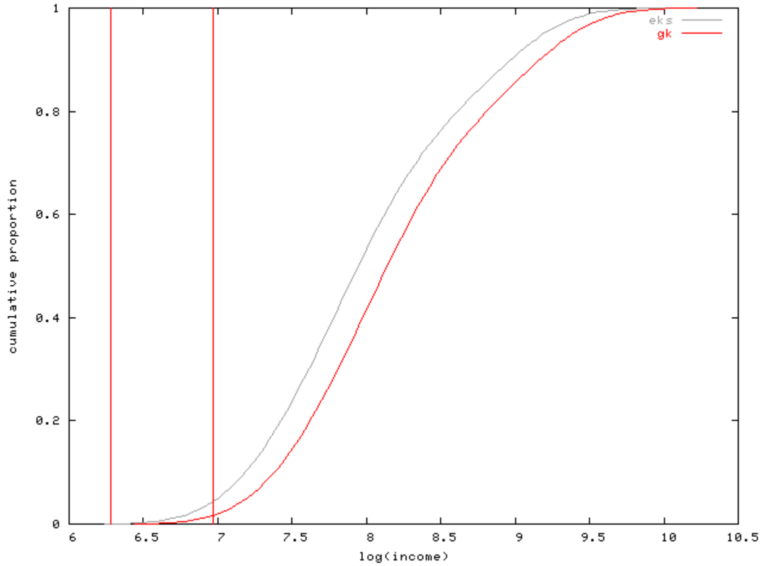


Figure 7e: Estimated income CDF, Brazil

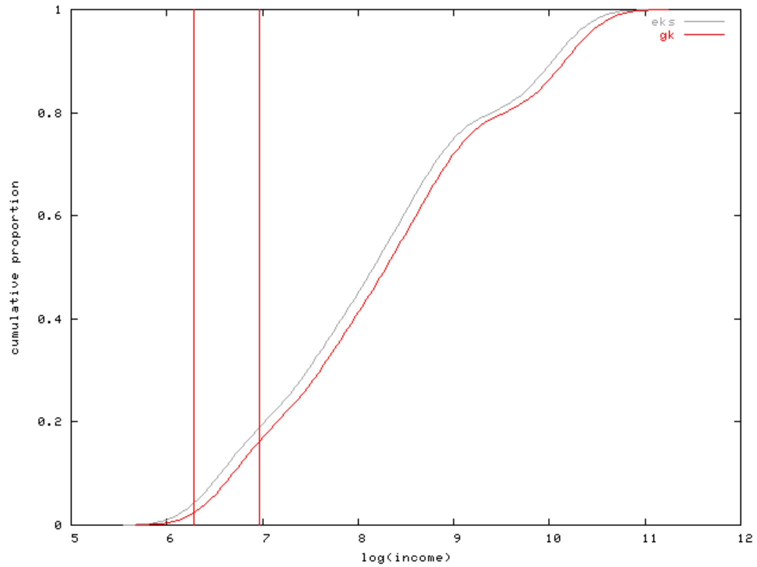


Figure 7f: Estimated income CDF, Russia

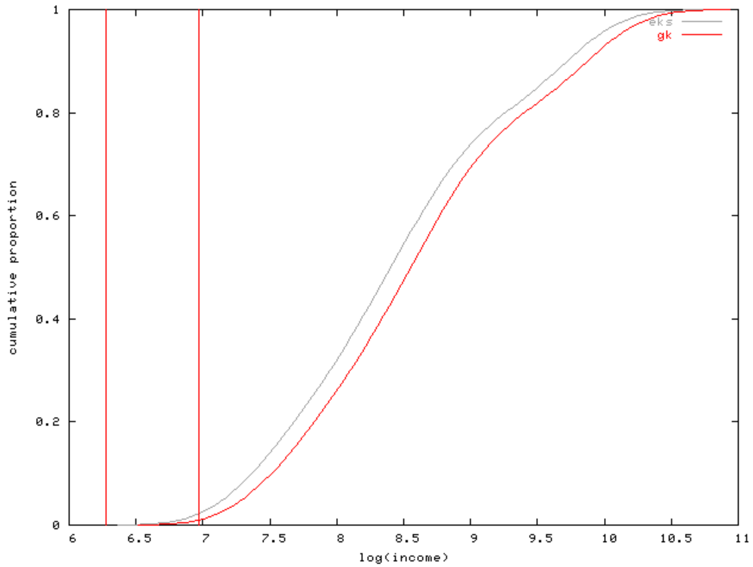


Figure 7g: Estimated income CDF, Pakistan

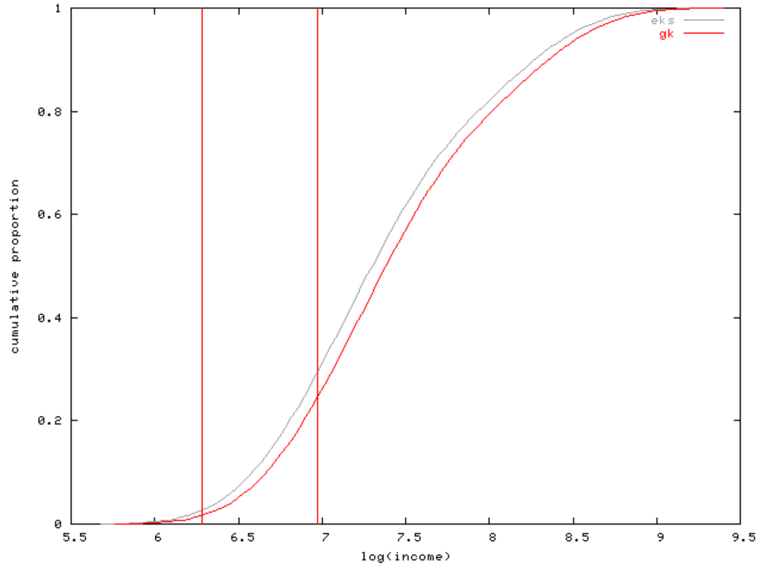


Figure 7h: Estimated income CDF, Bangladesh

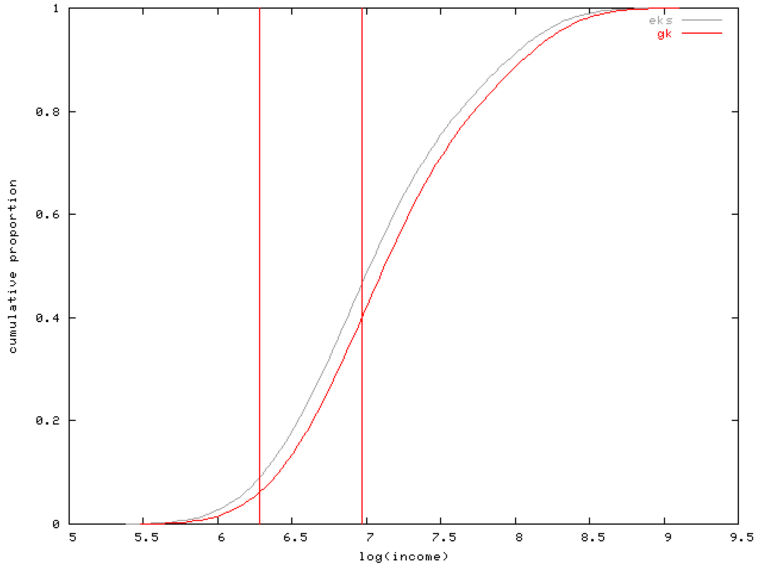


Figure 7i: Estimated income CDF, Nigeria

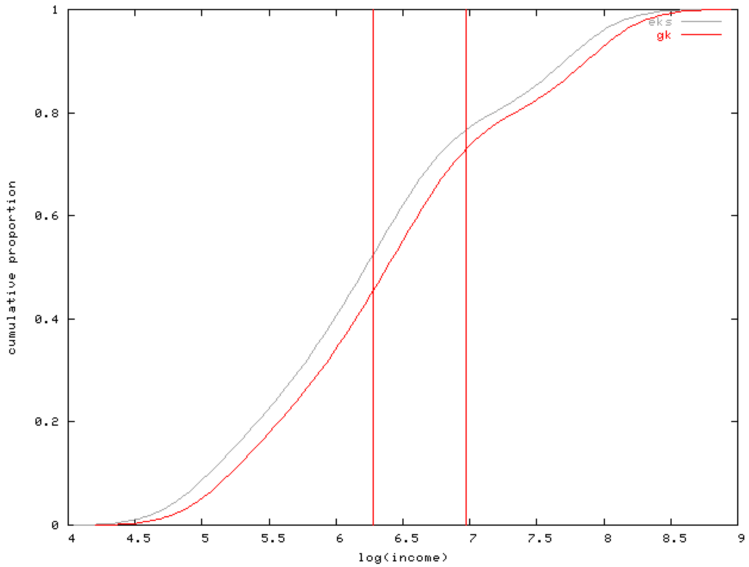
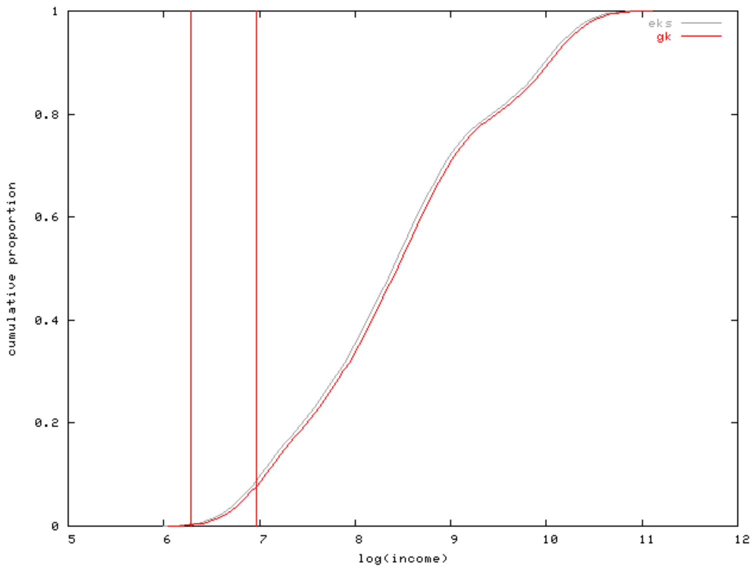


Figure 7j: Estimated income CDF, Mexico



APPENDIX

Table A1: Estimates of Real GDP *per capita* and Bias relative to the EKS index

	EKS[1]	GK[1]	PWT	GK Bias	PWT Bias
Tanzania	466	506	471	9%	1%
Yemen	580	860	802	48%	38%
Malawi	635	847	718	33%	13%
Mali	740	962	812	30%	10%
Sierra Leone	758	1217	921	61%	21%
Madagascar	782	913	799	17%	2%
Nigeria	814	956	926	17%	14%
Zambia	834	924	838	11%	1%
Tajikistan	875	1215	986	39%	13%
Benin	935	1144	1107	22%	18%
Nepal	1100	1501	1272	36%	16%
Kenya	1139	1381	1269	21%	11%
Mongolia	1231	1300	1268	6%	3%
Congo, Republic of	1304	1540	1729	18%	33%
Bangladesh	1381	1525	1506	10%	9%
Senegal	1415	1753	1478	24%	4%
Vietnam	1459	1734	1652	19%	13%
Moldova	1599	2214	2264	38%	42%
Azerbaijan	1755	2193	2047	25%	17%
Cameroon	1771	2468	1895	39%	7%
Armenia	1852	2410	2393	30%	29%
Cote d'Ivoire	1858	2499	1959	35%	5%
Pakistan	1859	2021	1952	9%	5%
Kyrgyzstan	1915	2453	2596	28%	36%
Uzbekistan	2064	2813	2804	36%	36%
Guinea	2071	3088	2708	49%	31%
Bolivia	2399	2704	2642	13%	10%
Albania	2639	2996	3071	14%	16%
Jordan	2773	3594	3748	30%	35%
Syria	2803	3501	3971	25%	42%
Sri Lanka	3039	3401	3201	12%	5%
Zimbabwe	3062	3768	2860	23%	-7%
Georgia	3078	4197	4479	36%	46%
Ukraine	3261	4310	4403	32%	35%
Ecuador	3341	3681	3863	10%	16%
Lebanon	3420	5187	4927	52%	44%
Jamaica	3449	4278	3804	24%	10%
Egypt	3538	4591	3700	30%	5%
Philippines	3551	3841	3122	8%	-12%
Turkmenistan	3571	4395	4533	23%	27%
Indonesia	3668	4461	3891	22%	6%
Macedonia	3834	4251	4571	11%	19%
Morocco	3923	4846	3808	24%	-3%
St.Vincent & Grenadines	3934	5614	6432	43%	63%
Swaziland	4479	5756	5175	28%	16%
Kazakhstan	4557	5804	5882	27%	29%
Dominica	4570	6594	6904	44%	51%

Bulgaria	4763	5774	5893	21%	24%
Belize	4817	5834	6199	21%	29%
Peru	4859	5287	4434	9%	-9%
Fiji	4883	5452	5282	12%	8%
Belarus	4947	6308	5667	28%	15%
Grenada	5148	6914	5016	34%	-3%
Latvia	5154	6208	6194	20%	20%
St. Lucia	5283	6360	6268	20%	19%
Iran	5538	6039	5333	9%	-4%
Lithuania	5771	6637	6495	15%	13%
Panama	5799	6174	5671	6%	-2%
Romania	5857	6572	4984	12%	-15%
Croatia	6094	6926	7428	14%	22%
Tunisia	6185	8351	5830	35%	-6%
Venezuela	6221	7467	6916	20%	11%
Turkey	6443	6837	6424	6%	0%
Russia	6669	7729	7107	16%	7%
Estonia	6856	7635	7510	11%	10%
Gabon	6951	10056	8860	45%	27%
Botswana	6981	7741	6071	11%	-13%
Thailand	7144	8247	7094	15%	-1%
Brazil	7301	8320	6881	14%	-6%
Poland	7411	8245	7713	11%	4%
Trinidad &Tobago	7578	9853	9482	30%	25%
Mexico	7640	8020	7344	5%	-4%
Antigua	8744	11049	12923	26%	48%
Chile	8849	9489	8972	7%	1%
Uruguay	8859	10116	9285	14%	5%
St. Kitts & Nevis	8926	10725	11662	20%	31%
Slovak Republic	9307	10109	9993	9%	7%
Hungary	9877	10778	8708	9%	-12%
Oman	10168	14493	16668	43%	64%
Bahrain	10387	12900	13261	24%	28%
Mauritius	10978	15190	11808	38%	8%
Argentina	11053	12052	10672	9%	-3%
Barbados	12543	21798	14608	74%	16%
Czech Republic	13261	14129	13458	7%	1%
Slovenia	13747	13920	13152	1%	-4%
Greece	14166	14522	12751	3%	-10%
Portugal	14451	14641	13523	1%	-6%
Bahamas	15023	18512	16527	23%	10%
Korea, Republic of	15616	16915	14320	8%	-8%
Qatar	16142	20380	19844	26%	23%
Spain	16532	16977	15535	3%	-6%
Israel	17927	18241	16464	2%	-8%
New Zealand	18252	18080	17707	-1%	-3%
Ireland	20159	20397	18494	1%	-8%
Finland	20416	20508	19489	0%	-5%
Sweden	20873	21039	20865	1%	0%
United Kingdom	20916	20966	20066	0%	-4%
Bermuda	21066	25345	18793	20%	-11%
France	21627	21950	20228	1%	-6%
Italy	22244	22910	20475	3%	-8%
Netherlands	22569	22685	21431	1%	-5%

Germany	22599	22897	21119	1%	-7%
Australia	23402	23348	22835	0%	-2%
Canada	23508	24062	23091	2%	-2%
Belgium	23589	23764	21101	1%	-11%
Austria	23787	23836	21399	0%	-10%
Iceland	25070	25411	21476	1%	-14%
Japan	25808	26710	24047	3%	-7%
Denmark	26331	26619	24087	1%	-9%
Switzerland	26661	27359	24460	3%	-8%
Hong Kong	26739	30998	25994	16%	-3%
Norway	27537	27890	24937	1%	-9%
Singapore	27774	31660	24939	14%	-10%
USA	29194	29194	29194	0%	0%
Luxembourg	35926	36501	35144	2%	-2%

1. Both the GK and the EKS indexes have been normalise to give the same value of GDP *per capita* as the PWT.

A.1. Estimates of Real GDP:

Sources and Notes:

The population 1996 data has been drawn from the World Penn Tables 6.1. The source for the real GDP calculated using EKS and GK methods is the ICP 1996 data set. The real income analysis was conducted on a set of 117 countries (ICP countries + imputed values for China and India).

A certain number of irregularities were detected in the ICP data when constructing real GDP data. Most of these issues had to do with zero ICP PPP data for some countries and aggregate consumption positions. Zero PPPs do not allow the derivation of real quantities as that implies a division by zero. Adjustments had therefore to be designed in order to generate our index numbers with the ICP price and quantity data (occasionally, an adjustment becomes redundant as the country concerned was later excluded from our analysis for lack of distribution data). All irregularities and adjustments are documented below. Adjustments were made to the raw ICP data and therefore carry out for both GK and EKS real GDPs. Any adjustment in raw ICP prices was followed by an adjustment in raw ICP quantities such that expenditure data remain the same (except when such raw quantities were found to be zero as documented below).

(i) Consumption PPPs:

1. We found negative PPPs for the Consumption item “Restaurants, Cafes and Hotels” for Egypt and Morocco. Negative PPPs make no sense. We therefore assigned a positive sign to the original ICP PPPs (implicitly assuming the negative sign was an error term of some sort). In general, the PPPs for “Restaurants, Cafes and Hotels” display a peculiar pattern. All Caribbean countries exhibit PPPs close to zero, yielding extravagantly high real quantities. The same problem is found for some Middle East, African and FSU countries (albeit, to a lesser extent). We decided to proxy this irregular data with the PPP for the position ”Other Goods and Services” and readjust raw quantities.

2. PPPs for the item “Alcoholic beverages” were found to be zero for the following 10 countries: Egypt, Lebanon, Yemen, Syria, Qatar, Jordan, Oman, Pakistan, Bahrain, Iran. These PPPs were proxied by the PPPs for the item “Other Food”, which appears to behave in a more similar way to “Alcoholic beverages” than “Non-Alcoholic Beverages”. The same 10 countries also exhibit infinitesimally small quantity data. Although one would expect

low numbers for such countries, the close proximity of the quantities to the absolute zero was deemed suspicious. The quantity data was thus aligned to zero for these 10 countries. Hence no raw quantity adjustment was made (except the alignment).

3. PPPs for the item "Communication" were found to be zero for the following 4 countries: Antigua & Barbuda, Grenada, St. Kitts & Nevis, St.Vincent & Grenadines. In principle, since the price ratio of "Communications" to GDP varies around 1, nominal GDP PPP could be used as a proxy. Since raw quantities for the same position and countries was also found to be zero, no quantity adjustment was made

4. PPPs for positions "Personal Transport", "Operation of Transportation Equipment" and "Machinery and Equipment" were found to be zero for Mongolia. They were replaced by the PPPs for positions "Purchased Transport Services" and "Construction", respectively. Since raw quantities were also found to be zero, no quantity adjustment was made.

(ii). Investment PPPs

PPPs for the item "Changes in Stocks" were found to be zero for the following 6 countries: Cameroon, Gabon, Madagascar, Mali, Senegal, Sierra Leone. They were replaced by the PPPs for the item "Machinery and Equipment". Since raw quantities were also found to be zero, no quantity adjustment was made. (Gabon was later excluded from the analysis for insufficient distribution data).

(iii). Nominal GDP Expenditures:

As noted in the Handbook of the ICP (2003)[1], the quantities for some GDP expenditure items such as "Net Foreign Balance" often take a negative value. This poses a problem for the production of Geary-Khamis index numbers. Since the GK system of equations assumes positive quantities, the solution of the system can only be computed over the positive orthant. We resolve this issue by removing the "Net Foreign Balance" data and apportioning the NFB quantity data over the other expenditures categories of GDP using relative budget share of other expenditure items as a weight (ie. adjusting all other expenditure categories by a fixed proportion so that GDP remains the same).

A.2. Income Distribution data:

Sources and Notes:

The income distribution data has been taken from the Deininger-Squire 1996 (DS) income inequality database and updated where possible by the income quintiles published by the World Bank in the World Development Indicators 2003 (WDI). Since the reference year in the study is 1996 (the most recent year for which ICP data is available), the quintile data was selected to be as close to 1996 as possible. For instance, for Bulgaria, the 1993 DS data was preferred to the 2001 WDI data. Starting from the original 115 ICP countries plus India and China; 14 countries (Congo, Antigua & Barbuda, Belize, Bermuda, Dominica, Grenada, St.Kitts & Nevis, St.Vincent & Grenadines, Bahrein, Oman, Qatar, Syria, Iceland and Albania) had to be dropped out of the analysis because no quintile information was provided in either data set. 6 more countries (Benin, Gabon, Fiji, Barbados, Argentina and Lebanon) had to be dropped as their quintile information was considered either too old (Gabon 1977, Barbados 1979) to be a reasonable proxy for 1996 distribution or because the data was marked as unreliable in the DS database

[1] "Some Loose Ends", Handbook of the International Comparison Program, Annex II: "Methods of Aggregation", United Nations, 2003. http://unstats.un.org/unsd/methods/icp/icp7_htm.htm

(Argentina: estimate based on surveys of less than full national coverage, Benin, Fiji and Lebanon: unclear sources) or both. Hence the poverty analysis was conducted on a set of 97 countries. The WDI data usually provides a better 1996 proxy for most of the 97 countries. The countries not covered by WDI data (and hence covered by DS data) are: Mauritius, Tanzania, Bahamas, Bulgaria, Moldova, Estonia, Lithuania, Georgia, Kazakhstan and the Kyrgyz Republic. Estonia, Mauritius and Tanzania data refers to expenditure instead of income.

Table A.2. Income Distribution data:

Country	Year	Q1	Q2	Q3	Q4	Q5
Botswana	1993	0.02	0.05	0.08	0.14	0.70
Cameroon	1996	0.05	0.08	0.13	0.21	0.53
Cote_dIvoire	1995	0.07	0.11	0.16	0.22	0.44
Egypt	1999	0.09	0.12	0.15	0.20	0.44
Guinea	1994	0.06	0.10	0.15	0.21	0.47
Kenya	1997	0.06	0.09	0.14	0.20	0.51
Madagascar	1999	0.06	0.11	0.15	0.23	0.45
Malawi	1997	0.05	0.08	0.12	0.18	0.56
Mali	1994	0.05	0.08	0.12	0.19	0.56
Mauritius	1991	0.07	0.12	0.16	0.23	0.43
Morocco	1999	0.07	0.11	0.15	0.21	0.47
Nigeria	1997	0.04	0.08	0.13	0.19	0.56
Senegal	1995	0.06	0.10	0.14	0.21	0.48
Sierra_Leone	1989	0.01	0.02	0.10	0.24	0.63
Swaziland	1994	0.03	0.06	0.10	0.17	0.64
Tanzania	1993	0.07	0.11	0.15	0.22	0.45
Tunisia	1995	0.06	0.10	0.15	0.22	0.48
Zambia	1998	0.03	0.08	0.13	0.20	0.57
Zimbabwe	1995	0.05	0.08	0.12	0.19	0.56
Bangladesh	2000	0.09	0.13	0.16	0.21	0.41
China	1998	0.06	0.10	0.15	0.22	0.47
Hong_Kong	1996	0.05	0.09	0.14	0.21	0.51
India	1997	0.08	0.12	0.15	0.19	0.46
Indonesia	2000	0.08	0.12	0.15	0.21	0.43
Iran	1998	0.05	0.09	0.14	0.21	0.50
Korea	1998	0.08	0.14	0.18	0.23	0.37
Nepal	1996	0.08	0.12	0.15	0.21	0.45
Pakistan	1999	0.09	0.12	0.16	0.21	0.42
Philippines	2000	0.05	0.09	0.13	0.20	0.52
Singapore	1998	0.05	0.09	0.15	0.22	0.49
Sri_Lanka	1995	0.08	0.12	0.16	0.22	0.43
Thailand	2000	0.06	0.09	0.14	0.21	0.50
Vietnam	1998	0.08	0.11	0.15	0.21	0.45
Bahamas	1993	0.04	0.08	0.18	0.24	0.47
Jamaica	2000	0.07	0.11	0.15	0.22	0.46
St.Lucia	1995	0.05	0.10	0.15	0.22	0.48
Trin&Tobago	1992	0.06	0.10	0.16	0.23	0.46
Bolivia	1999	0.04	0.09	0.15	0.23	0.49
Brazil	1998	0.02	0.05	0.10	0.18	0.64
Chile	1998	0.03	0.07	0.11	0.18	0.61
Ecuador	1995	0.05	0.09	0.14	0.21	0.50
Panama	1997	0.04	0.08	0.14	0.22	0.53
Peru	1996	0.04	0.09	0.14	0.21	0.51
Uruguay	1998	0.04	0.09	0.14	0.22	0.50
Venezuela	1998	0.03	0.08	0.14	0.22	0.53
Jordan	1997	0.08	0.11	0.15	0.21	0.44
Yemen	1998	0.07	0.12	0.17	0.23	0.41
Austria	1995	0.07	0.13	0.18	0.24	0.38
Belgium	1996	0.08	0.14	0.18	0.23	0.37

Country	Year	Q1	Q2	Q3	Q4	Q5
Denmark	1997	0.08	0.15	0.18	0.23	0.36
France	1995	0.07	0.13	0.17	0.23	0.40
Finland	1995	0.10	0.15	0.18	0.22	0.35
Germany	1998	0.06	0.10	0.16	0.23	0.45
Greece	1998	0.07	0.11	0.16	0.22	0.44
Ireland	1987	0.07	0.12	0.16	0.22	0.43
Italy	1998	0.06	0.12	0.17	0.23	0.43
Luxembourg	1998	0.08	0.13	0.17	0.23	0.40
Netherlands	1994	0.07	0.13	0.17	0.23	0.40
Portugal	1997	0.06	0.11	0.15	0.22	0.46
Spain	1990	0.08	0.13	0.17	0.23	0.40
Sweden	1995	0.09	0.14	0.18	0.23	0.35
UK	1991	0.06	0.12	0.16	0.23	0.43
Norway	1995	0.10	0.14	0.18	0.22	0.36
Poland	1998	0.08	0.13	0.17	0.23	0.40
Switzerland	1992	0.07	0.13	0.17	0.23	0.40
Czech_Rep	1996	0.10	0.14	0.18	0.22	0.36
Hungary	1998	0.10	0.15	0.18	0.23	0.34
Turkey	2000	0.06	0.11	0.15	0.22	0.47
Australia	1994	0.06	0.12	0.17	0.24	0.41
New_Zealand	1997	0.06	0.11	0.16	0.23	0.44
Japan	1993	0.11	0.14	0.18	0.22	0.36
Canada	1997	0.07	0.13	0.17	0.23	0.39
Mexico	1998	0.03	0.07	0.12	0.19	0.58
USA	1997	0.05	0.10	0.16	0.22	0.46
Israel	1997	0.07	0.11	0.16	0.23	0.44
Slovak_Rep.	1996	0.09	0.15	0.19	0.23	0.35
Russian_Fed	2000	0.05	0.09	0.14	0.20	0.51
Romania	2000	0.08	0.13	0.17	0.23	0.38
Belarus	2000	0.08	0.13	0.17	0.23	0.39
Bulgaria	1993	0.07	0.12	0.17	0.22	0.42
Croatia	2001	0.08	0.13	0.17	0.23	0.40
Slovenia	1998	0.09	0.13	0.17	0.22	0.38
Ukraine	1999	0.09	0.13	0.17	0.23	0.38
Moldova	1992	0.07	0.12	0.17	0.23	0.42
Estonia	1995	0.07	0.11	0.16	0.22	0.44
Latvia	1998	0.08	0.13	0.17	0.22	0.40
Lithuania	1993	0.08	0.12	0.16	0.21	0.42
Macedonia	1998	0.08	0.14	0.18	0.23	0.37
Armenia	1998	0.07	0.11	0.15	0.22	0.45
Azerbaijan	2001	0.07	0.12	0.15	0.21	0.45
Georgia	2000	0.06	0.11	0.16	0.22	0.45
Kazakhstan	1993	0.07	0.12	0.17	0.23	0.40
Kyrgyz_Rep.	1993	0.07	0.12	0.16	0.23	0.42
Mongolia	1998	0.06	0.10	0.14	0.19	0.51
Tajikistan	1998	0.08	0.13	0.17	0.22	0.40
Turkimenistan	1998	0.06	0.10	0.15	0.22	0.47
Uzbekistan	2000	0.09	0.14	0.18	0.23	0.36

Table A3. Regional Classification and Population data

Country	ISO-3	Region	pop 96	Country	ISO-3	Region	pop 96
Benin	BEN	SSA	5629	Jordan	JOR	MENA	4314
Botswana	BWA	SSA	1496	Lebanon	LBN	MENA	4077
Cameroon	CMR	SSA	13549	Oman	OMN	MENA	2173
Congo	COG	SSA	2634	Qatar	QAT	MENA	693
Cote_dIvoire	CIV	SSA	13889	Syria	SYR	MENA	14506
Egypt	EGY	MENA	59272	Yemen	YEM	MENA	15692
Gabon	GAB	SSA	1125	Austria	AUT	HIC	8059
Guinea	GIN	SSA	6756	Belgium	BEL	HIC	10155
Kenya	KEN	SSA	27918	Denmark	DNK	HIC	5256
Madagascar	MDG	SSA	13718	France	FRA	HIC	59533
Malawi	MWI	SSA	10016	Finland	FIN	HIC	5125
Mali	MLI	SSA	9993	Germany	GER	HIC	81896
Mauritius	MUS	SSA	1134	Greece	GRC	HIC	10476
Morocco	MAR	MENA	26848	Ireland	IRL	HIC	3626
Nigeria	NGA	SSA	114496	Italy	ITA	HIC	57397
Senegal	SEN	SSA	8557	Luxembourg	LUX	HIC	418
Sierra_Leone	SLE	SSA	4630	Netherlands	NLD	HIC	15526
Swaziland	SWZ	SSA	929	Portugal	PRT	HIC	9927
Tanzania	TZA	SSA	30488	Spain	ESP	HIC	39279
Tunisia	TUN	MENA	9089	Sweden	SWE	HIC	8841
Zambia	ZMB	SSA	9214	UK	GBR	HIC	58807
Zimbabwe	ZWE	SSA	11242	Iceland	ISL	HIC	269
Bangladesh	BGD	SA	121679	Norway	NOR	HIC	4381
China	CHN	EAP	1215414	Poland	POL	ECA	38618
Fiji	FJI	EAP	776	Switzerland	CHE	HIC	7072
Hong_Kong	HKG	HIC	6311	Czech_Rep	CZE	ECA	10315
India	IND	SA	945612	Hungary	HUN	ECA	10193
Indonesia	IDN	EAP	197156	Turkey	TUR	ECA	62695
Iran	IRN	MENA	59925	Australia	AUS	HIC	18311
Korea	KOR	HIC	45545	New_Zealand	NZL	HIC	3714
Nepal	NPL	SA	21795	Japan	JPN	HIC	125864
Pakistan	PAK	SA	125410	Canada	CAN	HIC	29672
Philippines	PHL	EAP	71899	Mexico	MEX	LAC	92450
Singapore	SGP	HIC	3670	USA	USA	HIC	265504
Sri_Lanka	LKA	SA	18300	Israel	ISR	HIC	5692
Thailand	THA	EAP	60003	Slovak_Rep.	SVK	ECA	5374
Vietnam	VNM	EAP	74300	Russian_Fed	RUS	ECA	147739
Antigua & B.	ATG	LAC	67	Romania	ROM	ECA	22608
Bahamas	BHS	LAC	284	Belarus	BLR	ECA	10298
Barbados	BRB	LAC	264	Bulgaria	BGR	ECA	8356
Belize	BLZ	LAC	222	Croatia	HRV	ECA	4494
Bermuda	BMU	LAC	62	Slovenia	SVN	ECA	1991
Dominica	DMA	LAC	73	Ukraine	UKR	ECA	51114
Grenada	GRD	LAC	95	Moldova	MDA	ECA	4325
Jamaica	JAM	LAC	2538	Estonia	EST	ECA	1469
St.Kitts & N.	KNA	LAC	41	Latvia	LVA	ECA	2491
St.Lucia	LCA	LAC	147	Lithuania	LTU	ECA	3709
St.Vincent&G.	VCT	LAC	112	Albania	ALB	ECA	3266
Trinidad&Tob	TTO	LAC	1270	Macedonia	MKD	ECA	1980
Argentina	ARG	LAC	35220	Armenia	ARM	ECA	3774
Bolivia	BOL	LAC	7588	Azerbaijan	AZE	ECA	7763
Brazil	BRA	LAC	161513	Georgia	GEO	ECA	5420
Chile	CHL	LAC	14419	Kazakhstan	KAZ	ECA	15921
Ecuador	ECU	LAC	11698	Kyrgyz_Rep.	KGZ	ECA	4576
Panama	PAN	LAC	2674	Mongolia	MNG	ECA	2498
Peru	PER	LAC	23947	Tajikistan	TJK	ECA	5927
Uruguay	URY	LAC	3242	Turkimenistan	TKM	ECA	4598
Venezuela	VEN	LAC	22311	Uzbekistan	UZB	ECA	23225
Bahrain	BHR	MENA	599				

Appendix

SSA (Sub-Saharan Africa), EAP (East-Asia Pacific), ECA (Eastern Europe and Central Asia), LAC (Latin America and Caribbean), MENA (Middle-East and North Africa), SA (South Asia), HIC (High Income Countries).