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**EVOLUTION OF THE GLOBAL DISTRIBUTION
OF INCOME IN 1970-99**

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SUMMARY

This paper attempts to reconstruct the complex nature of global income distribution during the later part of the 20th century. The primary concern is to demonstrate both the structure of global income distribution and its regional composition and to depict the changing extent of this distribution over time. A new technique for distributional analysis [quasi-exact interpolation] is employed. This allows for an analysis based on the so-called “true” world distribution concept, i.e., taking into consideration both between-country and within-country inequalities, and thus, measuring the inequality between persons across the whole world. The results show that the global distribution has clearly twin peaks: one concentrating around China, India and Africa; and another, around the OECD. Over the 29 year period, 1970-1999, while acute absolute poverty declined from 1.4 bln. to 1.2 bln., global income inequality increased from 0.822 to 0.907 as measured by the Theil index, and from 0.668 to 0.683 as measured by the Gini. Moreover, under a broader definition of poverty, the poor count increased from 2.0 bln. to 2.5 bln. While the inequality grew during 1970-90 as measured by both Gini and Theil indexes, in the 90s its development become more complex, which is reflected in rising Theil and simultaneously declining Gini. This provides evidence for the now widely accepted belief that growth, per se, is not the panacea for poverty reduction. The quality and type of growth matters.

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FIGURES AND TABLES

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1. INTRODUCTION

In the past year, a debate has boiled to the surface over whether global income inequality has been declining or growing, especially since the late 1980s - an era when, following a period of relatively slow growth, many countries and institutions embraced a conservative Reagan-Thatcherite view of economics. The issue goes to the very root of data analysis and touches on important questions concerning the nature of acceptable statistical evidence and how this should be interpreted. The outcome of the controversy has major implications for economic policy. The issue of redistribution is important as much to bring about real economic transformation as it is to improve equality and alleviate social tensions.

This paper describes briefly a number of different approaches that have been applied to determine the underlying pattern of income inequality in the World and explores how observed inequality has changed over time. Special case studies of the derived changes in the income distributions in Africa and the former socialist countries of Central and Eastern Europe (CEE) are also provided.

2. WHAT DRIVES INCOME DISTRIBUTION

The concern with equity has been a central interest of economists from the times of both Smith and Ricardo who similarly viewed economic growth as a means of spreading well-being and enhancing individual welfare. Overall, however, there is a growing body of both statistical and circumstantial evidence that appears to indicate that the distribution of income throughout most countries of the World is getting worse despite, paradoxically, general worldwide economic progress.

The latest information available indicates that, for a number of years, the real gross output of the global economy (World GNP) has been growing faster than the annual increase in the World's population. In addition, over the past decade or so, it is argued that the GDP of the developing countries of World has been growing, on average, somewhat faster than that of the richer industrially developed countries - although the evidence here is mixed and depends on which countries are included in both the beginning and end period comparisons under the term 'developing'. Superficially, therefore, the basic conditions appear to have been established for a potential reduction in overall poverty and for a decline in the number of people who are poor. In theory, if the tenets of a market capitalism now universally embraced are believed to hold, then disparities in income should gradually disappear as powerful economic forces mobilize resources and shift them to the less costly producing areas. The overall situation should tend towards greater equilibrium. According to the dictates of this theory, current differences in well-being should narrow because assets and employment, along with other economic benefits, will begin to trickle down to the majority of people with low incomes.

Unfortunately, despite some progress in poor countries and an evident capacity and political willingness to resolve the most pressing global priority in the development agenda, achievements in the area of poverty reduction and income redistribution have been less than encouraging. From an economic perspective, many poor countries have not yet moved forward, at least in per capita terms. The case of Africa, where recent growth rates have been low or even, in some cases, probably negative, provides a salutary example.

There may be several explanations for this lack of distributional progress in the international economy. The choice of statistics and intractability of the basic data simply may not reveal any progress that could have occurred. More likely, however, is that certain institutional features and constraints and a failure of national policy have hindered distributional progress. To correctly assess income distribution and real poverty, it is not comparative growth rates but, in fact, the absolute numbers that matter. Because there is such a huge gap between the income levels of the rich and the poor, over any meaningful time span, the poor never catch up. When examining real, absolute purchasing power terms, the differential itself only gets wider [see, for example, *Bourguignon and Morrison* (2001)]. Furthermore, even when conditions of impressive international economic growth occur, the position of the poor in many countries still deteriorates, because it all depends on where, in each country, the additional value added is attributed, whether to labour [wages] or to capital [operating surpluses]; and if the income generated accrues to those above the median income level or to those below it. Thus, much of the apparent improvement in economic performance in low income developing countries since the early-1980s has to do with who has derived the most benefit from economic growth. In most poor countries, unfortunately, and especially those in Africa, the providential fall out from economic growth over the past two decades has been deplorable.

Income, as a combination of gross operating surpluses and labor remuneration, is an outward manifestation of the 'initial conditions' of disparity, i.e., the unequal distribution of wealth and the asymmetric ownership of productive capital, which is usually buttressed by [protective] legal arrangements and other sustaining institutional and financial factors [some of which may be tacit]. The world's productive assets remain unequally distributed around the globe by location and ownership. Furthermore, wealth accumulates through a tighter and more dominant control of the market, increasing rather than diminishing income inequality. This process tends to be self-reinforcing, concentrating economic power rather than re-distributing its benefits.

Appealing to growth and assumed fundamentals such as spontaneous market forces to bring about desired changes in the existing pattern of income distribution, which is mainly a reflection of wealth distribution, thus might prove to be of little avail. Indeed, on the basis of extensive empirical analysis, Adelman and Robinson in the 1980s and Fishlow in the 1990s in independent studies have similarly disputed the assumed validity of the relationship between overall income growth and greater income equality. They also questioned how such growth might contribute to reduced poverty. Elsewhere, others [Chenery, et al, 1974] believed it would require direct action to reduce global poverty and have an effective impact, backed up by much stronger international institutional surveillance and broadband intervention across a universal level of resource deprivation.

3. A NEW APPROACH TO ANALYZING INEQUALITY

In an attempt to provide a more substantive information basis for understanding the scope of the problem, this paper employs a new approach to measuring global inequality. In the first place, using partial micro data relating to the incomes and expenditures of households and individuals drawn from selected representative countries, a method to generate a 'quasi-exact' perspective of how the global GNP of all nations is shared between the world's population is provided [see *Annex* for a short discussion of the procedure, and *Y. Dikhanov* (1996) for a broader deliberation]. Thus, 45 of the largest countries were chosen where such distributions were available for more than one reference year [see *Annex* below]. Finally, a global picture was built up by taking the available income distributions from the eight largest countries in each region [for South Asia only five countries are used as the number of countries in the region is small] and filling the gaps [about 1/6 in global

income and population] according to regional patterns. The results reveal a geographical composition of inequality that would be readily predictable to many observers of the development scene. Changes over time, however, depict a general worsening in the pattern of income distribution. It is these apparent changes that are regarded as more controversial. Both results relating to the structure of inequality and to changes in the pattern of inequality over time have important implications for the overall operational support strategies of the major development institutions, donor governments and aid agencies. The importance of this approach was not only to generate a more realistic perspective of global inequality but also to draw attention to the magnitude of the poverty problem. Various poverty measures can be derived from the same methodology as well.

4. ABSOLUTE POVERTY

First, the paper presents some absolute poverty numbers, i.e., poverty below a certain threshold. Two thresholds are chosen: (1) \$700 in 1999 PPP terms, which is approximately equal to the \$1-a-day threshold used in the World Bank when adjusted both for 1985-99 inflation in the denominator country (USA) and for the differences between personal consumption expenditures (PCE) from national accounts and income/expenditure estimates from household surveys; and (2) \$1,400 in 1999 PPP terms.

Table 1 shows that while the global poverty below the \$700 threshold [*acute poverty*] has declined, there is an observed increase in the number of poor below the \$1,400 threshold [*general poverty*]. A striking case is Africa where the acute poverty has increased from 156 mln. to 406 mln.: a result of the combination of a fast growing population [2.25 times in 29 years] and a declining GDP per capita. However, while acute poverty has decreased from 1.4 bln. to 1.2 bln. across the globe, the general poverty has gone up from 2.0 bln. to 2.5 bln., increasing substantially in South Asia [from 638 mln. to 902 mln.]. As a result, the composition of the poor has changed significantly: the share of Africa has been on a rise, while that of East Asia has declined. In 1999, Africa overtakes other regions in terms of acute poverty, whereas in 1970 its share was 5 and 3 times less than those of East Asia and South Asia, respectively.

As a result of their fast economic growth, acute poverty has significantly declined in East Asian countries, even though that economic progress was accompanied by an increase in inequality. In 1970, virtually all the population of China (more than 95%), lived below the \$1,400 threshold whereas, in 1999, that number was less than 57%. China thus exerts a disproportionate influence on the dynamics of both the amount of absolute poverty and the shape and structure of the global income distribution.

The year 1999 witnesses new and unexpected entrants into the poverty counts – the former socialist countries [*CEE* - Central and Eastern Europe, including former republics of the Soviet Union in the Caucasus and Central Asia] which had 16 mln. poor that year, the combined effect of a sharp decline in incomes and growing inequality since 1990.

Table 1. Absolute poverty by region, 1970-99, in mln.

	1970	1980	1990	1999
<i>below \$700 1999 PPP terms *)</i>				
World	1,408.6	1,549.3	1,355.3	1,192.4
<i>of which:</i>				
Latin America	43.2	31.6	43.4	44.0
East Asia	784.2	803.9	529.9	332.8
South Asia	424.6	516.6	494.2	393.9
Africa	155.8	196.8	287.5	405.9
East and Central Europe	0.8	0.3	0.2	15.7
<i>below \$1400 1999 PPP terms</i>				
World	2,024.3	2,366.5	2,548.6	2,520.2
<i>of which:</i>				
Latin America	93.3	82.6	111.1	116.2
East Asia	1,041.7	1,180.4	1,127.7	899.5
South Asia	637.9	795.0	895.9	901.3
Africa	241.9	301.9	407.9	531.1
East and Central Europe	8.8	6.4	5.9	72.0

*) \$700 in 1999 PPP terms approximately corresponds to the \$1-a-day cut-off used by the World bank, when adjusted for 1985-99 inflation and the differences between the Personal Consumption Expenditures (PCE) and incomes/expenditures recorded in household surveys.

5. SHAPE OF THE DISTRIBUTION OF GLOBAL INCOME

Figure 1 below illustrates changes in the shape of the global income distribution [distribution density] during 1970-99. The density functions are plotted on the logarithmic scale to reflect the fact that actual income distributions are approximately lognormal. The integral of the density functions [the area under the curve] for each curve is equal to unity. Such a presentation allows comparing shapes of distributions from different years or countries and provides a common basis for aggregation. It shows clearly the twin-peak nature of the global distribution. However, the fact that the second peak became less prominent in 1999 should not be taken as reassuring: it simply reflects a slower population growth in the OECD countries, and a shift backwards in the CEE region.

The graph illustrates some of the complexity of trying to unravel exactly what is happening to the nature of the underlying distribution and corresponding changes in each percentile component.

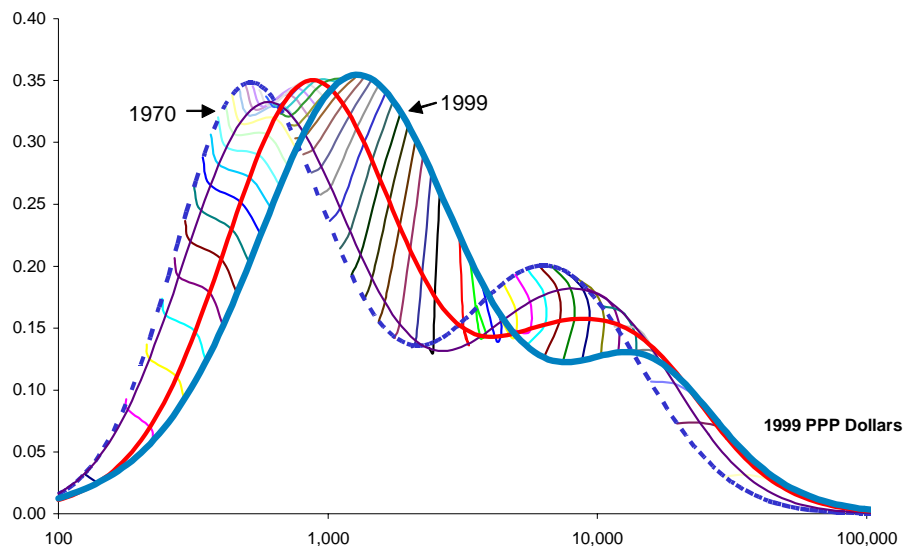


Figure 1. Evolution of Global Income Distribution, 1970-99, trace for each percentile

To illustrate this point, the path of each percentile of the global distribution is shown with trace lines on the graph. The evolution of the global distribution was not uniform [uniform evolution would result in parallel shifts]. Over the three decades some of the percentiles did actually move backwards in terms of income over the three decades. Partly, this phenomenon can be explained by the transformations in the former socialist countries during the 90s. For other years, the explanation is more complex as the percentile growth is a result of both income growth of the individuals from that percentile and of inter-percentile migrations. So, the percentile regional composition does not stay the same.

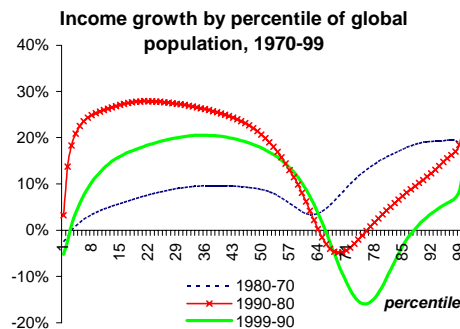


Table 2 elucidates this further by providing information on income levels and growth in individual deciles. Decile 8, for example, shows a decline of 13.2% in 1990-99. A more complete picture, giving changes by each percentile, is provided in the Figure on the right. While the fastest growth occurred in 15-50 percentiles of the global population, as well as in the upper 10%, the first 10 percentiles and the percentiles in the middle grew much slower, and the 67 to 77 percentiles actually declined.

*Table 2. Income Growth and Levels by Decile, 1970-99***INCOME GROWTH BY DECILE, 1970-99***(in 1999 PPP dollars)*

	1970-80	1980-90	1990-99	1970-99 cumulative
Decile 1	2.1%	24.7%	7.6%	37.0%
Decile 2	6.1%	31.2%	17.5%	63.6%
Decile 3	8.7%	31.8%	21.3%	73.8%
Decile 4	10.0%	29.9%	22.6%	75.2%
Decile 5	9.7%	25.9%	21.0%	67.1%
Decile 6	6.5%	15.2%	15.2%	41.3%
Decile 7	5.5%	-1.7%	-0.6%	3.0%
Decile 8	13.7%	-0.1%	-13.2%	-1.4%
Decile 9	19.4%	8.4%	-2.5%	26.1%
Decile 10	20.7%	18.6%	7.9%	54.4%
Mean Income	17.1%	13.2%	4.0%	37.9%
Median Income	9.1%	22.5%	19.2%	59.3%

INCOME LEVELS BY DECILE, 1970-99*(in 1999 PPP dollars)*

	1970	1980	1990	1999
Decile 1	205	209	261	281
Decile 2	343	364	478	561
Decile 3	470	510	673	816
Decile 4	630	694	901	1,105
Decile 5	878	964	1,213	1,468
Decile 6	1,404	1,496	1,723	1,984
Decile 7	2,778	2,929	2,879	2,861
Decile 8	4,999	5,683	5,676	4,927
Decile 9	8,348	9,964	10,800	10,526
Decile 10	18,895	22,808	27,057	29,183
Mean Income	3,895	4,562	5,166	5,371
Median Income	1,061	1,157	1,418	1,690

6. REGIONAL COMPOSITION OF INEQUALITY

Tables 5, 7, 9 and 11 of the *Annex* depict the composition of global deciles by region. The regional structure has undergone major changes during the 1970-99 period. The share of the OECD populations that falls into the 10th global decile, increases from 42.5% to 55.3%. At the same time, the OECD contributed around 8.5%-8.7% to the top global decile, leaving only 1.3%-1.5% to be filled by all other regions.

The biggest changes, however, occurred in East Asia, where the share of the region's population falling into the top three global deciles, has grown from 1.7% to 14.1%, with a corresponding decline, from 53.5% to 30.2%, of its share falling into the bottom three global deciles. This reflects almost entirely the strong economic performance of China over the past two decades (and, to some extent, Indian development as well).

Again, the African continent endured drastic negative changes during this period: in 1999, Africa contributed 50 % to the lowest global decile, whereas in 1970 its share was only 16%. At the same

time, 38.8% of all Africans were found in the lowest global decile in 1999, compared with 17.0% in 1990.

Even more detail is provided in Figure 6 and Figure 7 of the *Annex* where each percentile of the global population is broken down by region. There are some drastic changes in the regional composition that occurred in just 9 years: from 1990 to 1999. In particular, the biggest relative changes occurred among East Asia, CEE and African countries.

7. TYING WORLD POPULATION TO INCOME AND ITS GLOBAL DISTRIBUTION

One more step is necessary to grasp the full picture of global income distribution, i.e., income density. The graphs so far have shown how population is distributed with respect to income levels, but it is equally important to see how income is distributed. The Figure below, and Figure 4 and Figure 5 of the *Annex* show that the *income* distribution from the lower part of the graph [as contrasted with the *population* distribution in the upper part of the graph] is very much a single peak, with most income accruing to the OECD region.

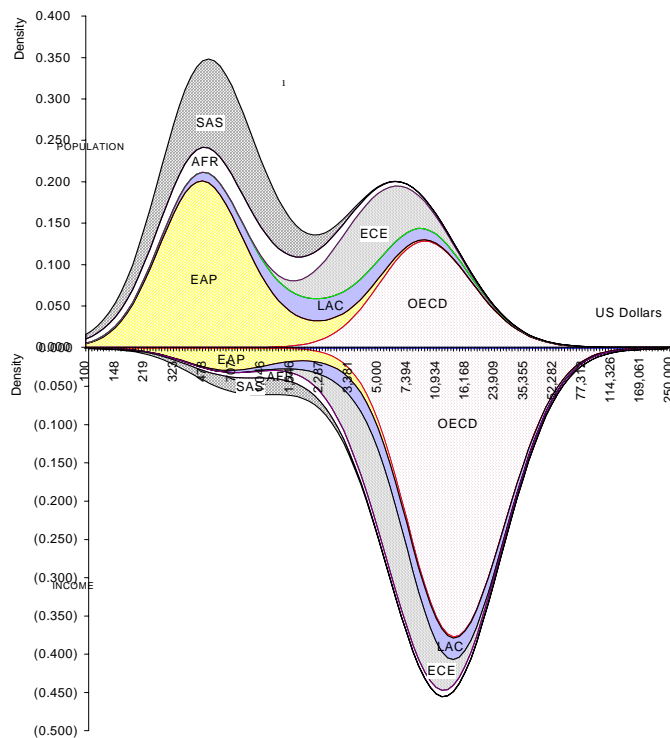


Figure 2. Income Distribution, Decomposition by Region, 1970

Such a presentation follows the same rules as the presentation in Figure 1: i.e., the integral of the density functions [the area under the curve] for each curve is equal to unity. Again, such a technique

allows analysts to compare the changing shapes of distributions from different years or countries. This presentation is decomposable by area, as well as by factors.

Another way of looking into the changes in global inequality is to decompose it into the within-country and between-country parts. It can be inferred from Table 3 that not only was the within-country inequality growing during 1970-99 [from 0.211 to 0.267 in terms of the Theil index], but that between-country inequality grew as well: from 0.610 to 0.640.

During the 90s, the between-country inequality somewhat decreased [from 0.661 to 0.640]. However, that decrease was more than compensated by an increase in the within-country inequality, which rose from 0.230 to 0.267, increasing the overall inequality index from 0.891 to 0.907.

Table 3. Decomposition of the global inequality, Theil index

	1970	1980	1990	1999
Within-country inequality	0.211	0.221	0.230	0.267
	25.7%	25.6%	25.8%	29.5%
Between-country inequality	0.610	0.642	0.661	0.640
	74.3%	74.4%	74.2%	70.5%

At the sub-regional level, the picture of inequality in Africa is particularly skewed. Figure 3 shows a twin-peak population density and a trident shaped income density. The graph permits singling out Sub-Saharan Africa, South Africa, and Northern Africa on the income density scale. On the population density graph, the South African influence is not prominent.

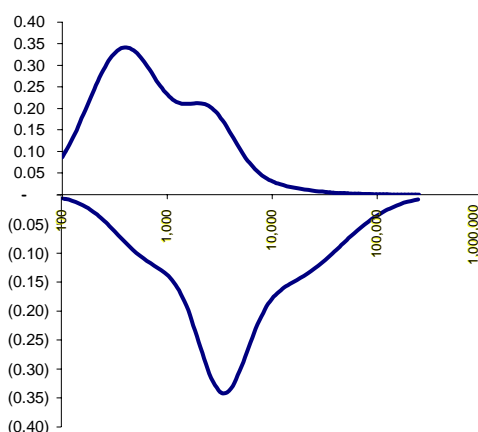


Figure 3. Shape of African income distribution

8. CONCLUSION

The analysis attempted in this paper illustrates that, during the last three decades, the global income distribution became less equal [both between-country and within-country], and the absolute number of the poor increased, even though the global per capita income rose by 38%. The two distinct peaks of the global income distribution stress the fact that there is no “middle class” among the citizens of the world.

Economists still know very little about the underlying dynamics that link equity to output growth, income levels and improved living standards. By concentrating on the economic nature of growth enhancing structural reforms, economists have often overlooked the consequences for inequality, especially where these policy reforms are related to coincident reductions in the scope of public services as less income is channeled via taxation into the provision of non-market goods and services, especially health and education, to the poor. Solutions as to how address this problem rest as much now in the province of political and legislative actions to correct the imbalance rather than in the hands of economists.

ANNEX: NOTES ON CONCEPTS AND PROCEDURES

A. METHODOLOGICAL ISSUES

Attention is drawn to three major statistical concerns:

- i. The overriding relevance and quality of the basic data;
- ii. The choice of methodology for international comparisons;
- iii. The need to distinguish the separate ‘between’ country and ‘within’ country differences affecting inequality.

In the first case, the data are not perfect and there is a continuing conceptual and practical problem of mapping micro household information (not necessarily representative) onto the comprehensive national accounts aggregates. The re-estimation of observed national benchmark numbers by applying official price indices and other indicators to specific measures is required to adjust everything to a common reference year basis. That precipitated recasting means from the household surveys into PCE terms.

As to the second issue, the study uses PPPs rather than currently reported official exchange rates to convert data expressed in national currencies into a common international unit of account (the dollar). While some econometric techniques are required to extend the PPPs reported for 118 benchmark countries to other countries for which such data are not available, the use of PPPs to equalize underlying price level differences obviates the problems caused by the volatility of exchange rates both over time and between countries. This enables the analysis to include the regional composition of inequality.

Third, the ‘within’ country profiles are based on national household surveys while the ‘between’ differences are calculated from PPP converted World Bank GNP per capita estimates.

The preferred methodology utilizes a formalized continuous distribution function, rather than a more disjoint discreet distribution derived from quintile and decile data groups. National level household income distribution data generally relate to consumption rather than income. When drawn from household survey results, the outlay data usually refer to actual expenditures rather than true consumption including that occurring as a result of receipts in kind or imputed income from own account production, specifically from garden plots, for own consumption. These elements are estimated separately. Whichever variable is chosen, this will have a particular impact on the shape of the curve. The use of reported expenditure figures, for example, tends to condense the shape of the actual income distribution curve and compress the apparent range of inequality. But such expenditures, and particularly overall consumption estimates, are closely related to disposable income, particularly at lower income levels, and they tend to have a more relevant bearing on household well-being. The real distribution of individual welfare, however, raises separate issues and has to be considered alongside the public provision of collective amenities and the allocation by governments and non-government organizations of non-market goods and services to households and individuals.

B. THE GLOBAL INCOME: WORLD INEQUALITY ACCOUNTING

At the outset, it is important to define the scope of the current argument. It is about global income inequality. It is not concerned with a more holistic perception of global inequality that would need to incorporate some notional value of non-market goods and services delivered by governments and NGOs to individual recipients across the world. This would require a far more extensive and sophisticated set of impact measures than is currently available in the existing range of collective social indicators.

It is also not about the distribution of wealth and ownership of productive assets which, as the primary sources of economic power, are undoubtedly even more important in explaining the extent of global inequality. The distribution characteristics are drawn primarily from household surveys, where the concept of income used in this analysis refers to disposable income rather than to a national accounts definition of gross personal income that includes unrealized capital gains and taxes, both of which can be significant.

For the purposes of this exercise, global income is taken to be the sum of the reported as well as estimated and imputed Personal Consumption Expenditures (PCE) of all countries as presented in the World Bank databases. Thus, national accounting categories were used in defining national and global incomes instead of averages from household surveys. This has been done for the following reasons: (1) to be consistent with national accounts and to arrive at global income computed using consistent methodology across countries; (2) to attempt to extend national accounts to income groups; and (3) to keep consistency between national GDP/PCE growth rates and incomes used in inequality measurements².

The PCE values in local currencies are converted to “international” dollars using 1999 purchasing power parities (PPPs). These PPPs are in turn derived from the 1993-96 ICP exercise, and in some cases (including such an important case as India) from 1980 and 1985 exercises. In some cases, for example China, a growth rate different from the official one was employed³ [from Maddison (2001)]. Also China-India GDP per capita ratio was kept in line with that publication. In addition, the PPP in Geary-Khamis terms were converted to the EKS to remove the substitution bias present in the former.⁴ As a result, Chinese and Indian GDP per capita levels were somewhat lower than those found in the World Bank database. The PCE shares in GDP were taken from the World Bank databases.

Additionally, World Bank group aggregation and filling procedures were used to obtain global totals for countries where GNP information was missing. These techniques are detailed in the reference notes to *2001 World Development Indicators* and are already fairly well known and recognized.

² For instance, during the 90s, the Indian household sample survey means were growing slower than the PCE, which may indicate a bias in the national household surveys.

³ As it turns out, the extent to which global income inequality has grown over the last decade is significantly influenced by the real economic growth of China. In particular, if the reported official GDP growth rate of China of 10.7% p.a. over the past ten years, 1990-9, is accepted, then there appears to be a marginal improvement in the overall global income distribution during the 90s. On the other hand if, as others [Maddison, Wu, and Keidel] have suggested, the actual GDP growth in China was closer to 8% per annum during that period then global inequality has either remained stable or deteriorated [using the Theil index it increased from 0.908 in 1990 to 0.925 in 1999, whereas the Gini marginally improved from 0.686 to 0.683].

⁴ The extent of the bias (so called Gerschenkron effect) can attain in some cases 50% or more, and, thus, would seriously distort the overall picture of the income distribution [see Dikhanov (1994)].

The imputation procedures apply, for the most part, to only a few small countries. Overall, the 45 countries in the sample were responsible for about 5/6 of the global PCE and population. The remaining 1/6 was distributed at the regional level according to the regional coverage patterns. The primary objective was to envision how 'global PCE' is broadly distributed across various groups by their respective income levels, and to see whether this changes markedly as a result of applying different assumptions.

Thus, with this approach, it is possible to derive various regional (geographical) sub-aggregates of the global distribution and compare these with [a] other regions and [b] the global position. In principle, this can also be done for specific economic "blocks" such as "low income developing countries," "middle income countries," "industrial countries," trading countries, or any other similar grouping.

No adjustment is made to reported GNP/PCE measures for the under-recording of informal and "shadow economy" transactions, although at the country level these can be significant where the authorities exercise only a weak control over policy management and taxation. In many countries, however, the GNP number will usually incorporate some official estimate to account for such missing values.

LIST OF COUNTRIES BY REGION

OECD

Canada
France
Germany
Italy
Japan
Spain
UK
US

Latin America

Argentina
Colombia
Chile
Brazil
Mexico
Venezuela
Peru
Ecuador

East Asia

China
Korea
Taiwan
Indonesia
Malaysia
Philippines
Thailand
Vietnam

South Asia

India
Pakistan
Bangladesh
Myanmar
Sri Lanka

Africa

South Africa
Congo (Zaire)
Ethiopia
Nigeria
Tanzania
Morocco
Egypt
Sudan

Central and Eastern Europe

Russia
Ukraine
Belarus
Romania
Hungary
Poland
Czech Republic
Uzbekistan

QUASI-EXACT RENDERING OF DISTRIBUTIONS

Described below are the general principles of the quasi-exact distribution rendering – the technique used for the current paper to convert national group means or interval data into a continuous functional form⁵. The foundation of the technique is based on a polynomial interpolation.

The essence of the procedure is the following:

Let's assume that we are given only a set $\{F(X_i)\}$ of M elements which describes values that the cumulative distribution function takes at X_i . We need to approximate all other points of the distribution, i.e., to estimate $F(x)$ for $x \in [0, +\infty]$. Within each interval $[X_{i-1}, X_i]$, we will interpolate the distribution function by a polynomial of the order 4 in the form:

$$F_{i,i+1}(x) = \sum_{n=0}^3 \alpha_i^n \left(\frac{x - X_i}{X_{i+1} - X_i} \right)^n$$

At the boundaries the polynomials are exact, and are not interpolations.
i.e., $F_{i,i+1}(X_i) = F_{i-1,i}(X_i) = F(X_i)$.

These polynomials are chosen to be *twice continuously differentiable* across the boundaries. This property allows for differential and integral operations with F and its derivatives in explicit analytical form. For example, the mean of the distribution would be calculated as follows:

$\mu = \int x dF = \sum_{i=0}^M \sum_{n=1}^3 \alpha_i^n \frac{nX_{i+1} + X_i}{n+1}$, where M is the number of intervals. Other characteristics of the distribution function can be derived in a similar way.

PRECISION OF THE PROCEDURE

Estimation errors can be assessed through the following expression:

$$\|F_{i,i+1}(x) - F(x)\| \leq \frac{1}{4!} \left(\frac{X_{i+1} - X_i}{2} \right)^4 \|F^{(4)}(\zeta)\|$$

where $\zeta = \arg \max_{x \in [X_i, X_{i+1}]} \|F^{(4)}(x)\|$

In the case of normal (standard) distribution the above boils down to:

⁵ It should be noted that both tails of the distribution, i.e., the last and first group, were forced to be log-normal for the following reasons: (1) both tails are notoriously badly captured in the surveys, if at all; and (2) if the tails are captured, the biases present are *different* from the rest of the survey. Additionally, attempts were made to utilize household income distributions if personal income distributions were unavailable, using adjustment factor from other years. If distributional characteristics exhibited drastic changes, these data were discarded and a distribution from an adjacent year was used instead. If the restored distribution was found to be drastically non-uniform, the following was attempted: (1) smoothing of the distribution density curve, or (2) merging of the intervals used in the estimate.

$$\|F_{i,i+1}(x) - F(x)\| \leq \frac{1}{384} (X_{i+1} - X_i)^4 \|F^{(1)}(\zeta)(3\zeta - \zeta^3)\|$$

(For details see Y. Dikhanov, 1996, "Decomposition of Inequality Based on Incomplete Information", World Bank).

In the case when the intervals are separated by $\sigma/2$, we obtain that the maximum errors will be in the interval $[0.5\sigma, \sigma]$ (that can be seen from the first order condition for $\|F^{(1)}(\zeta)(3\zeta - \zeta^3)\|$), and the errors in this interval are expressed as follows:

$$\|F_{i,i+1}(x) - F(x)\| \leq \frac{1}{384 \cdot 16} \frac{2}{\sqrt{2\pi}} e^{-\frac{3-\sqrt{6}}{2}} \approx 0.01\%$$

Such a precision in interpolation usually exceeds the precision of survey reporting.

The analytical form is important if we need to carry out serious analysis of distribution, such as calculation of $\int \ln(\mu/x) dF(x)$ (for the Theil index), or of any $\int \Psi(x) dF(x)$ in general (i.e., in integration of the distribution function with other functions). The importance of that can be seen from the following example:

Let's assume that different income groups within a distribution face different price levels $P=x/\xi(x)$. Then the Theil index for real incomes (as opposite to nominal incomes) can be recalculated as:

$$\int \ln(\mu/\xi(x)) F'_\xi \xi'_x dx.$$

Additionally, if we can analytically express distribution function $F(x)$, then we can directly calculate all distribution characteristics, such as mean, median, mode, dispersion, various inequality measures, etc.

FIGURES AND TABLES

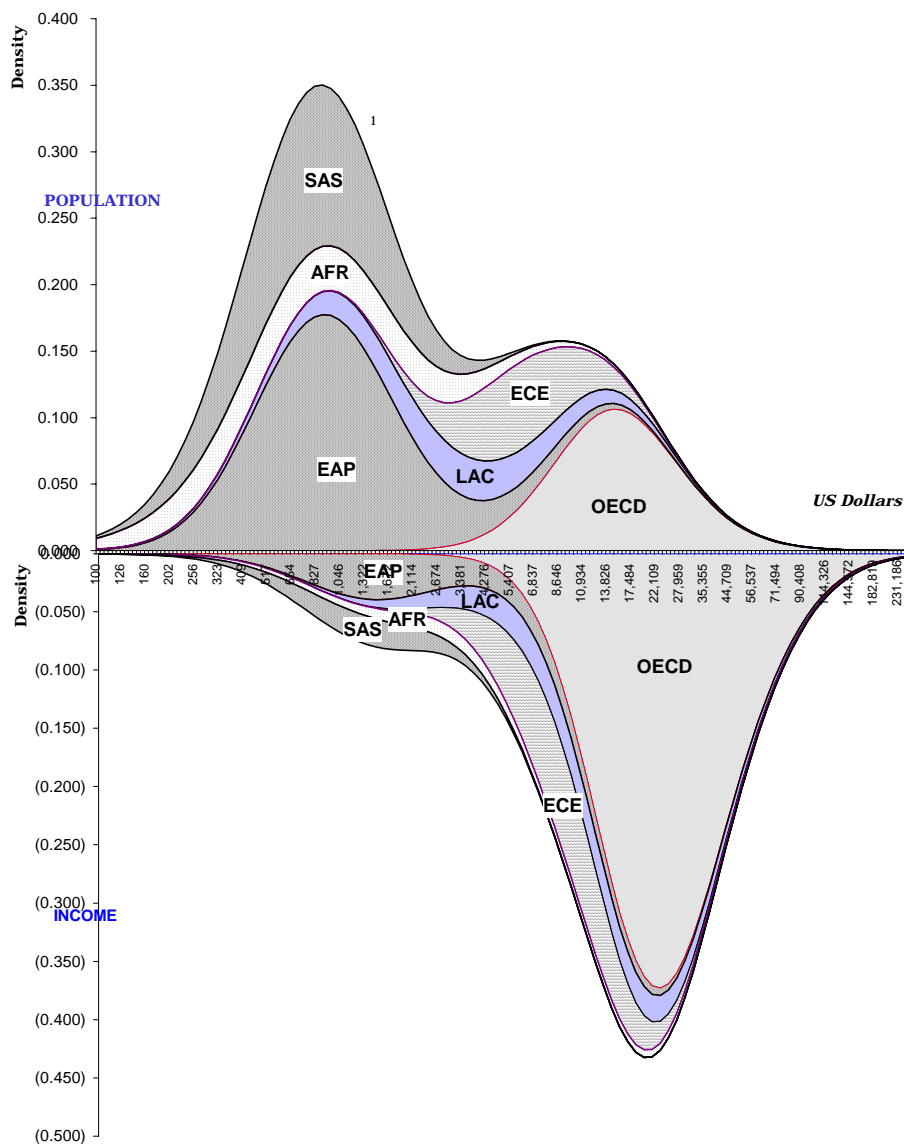


Figure 4. Income Distribution, Decomposition by Region, 1990

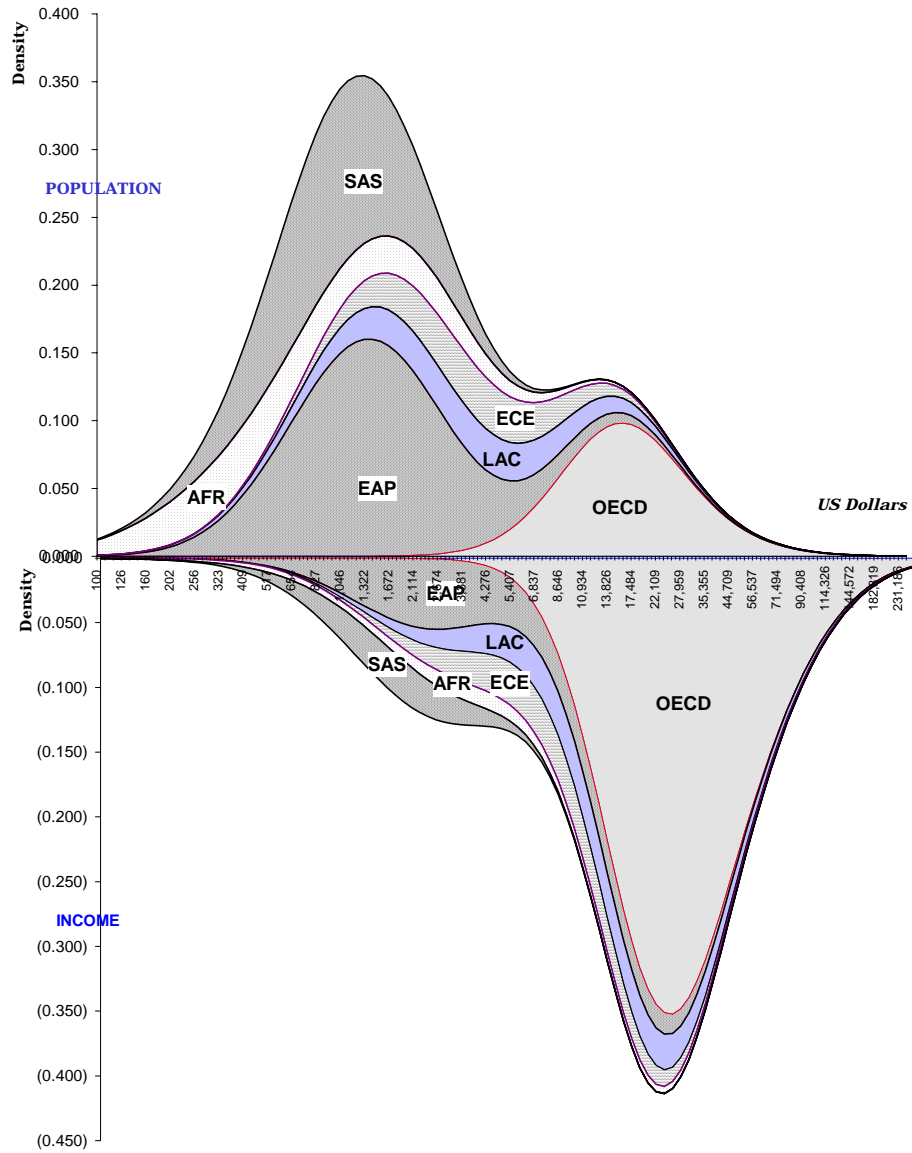


Figure 5. World Income Distribution, Decomposition by Region, 1999

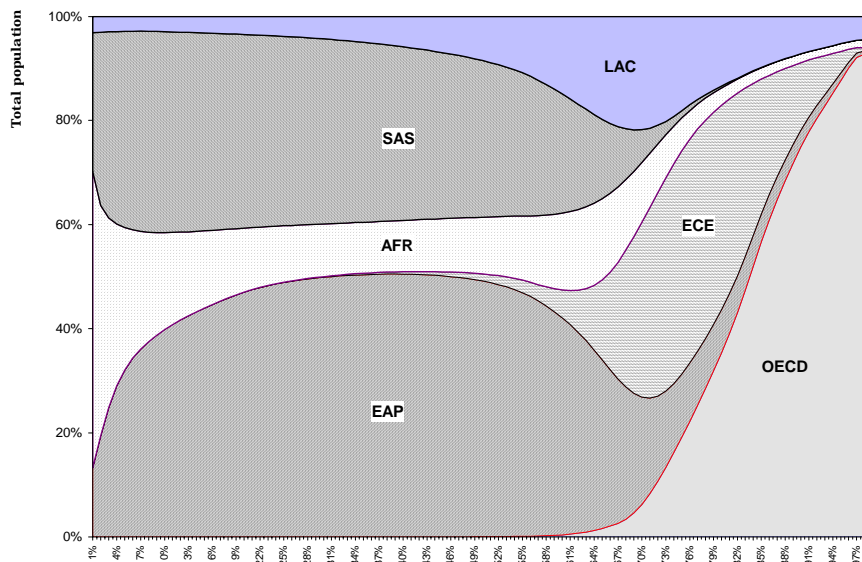


Figure 6. World income distribution, by region, at each percentile of global income distribution, 1990. (population at any particular income = 100)

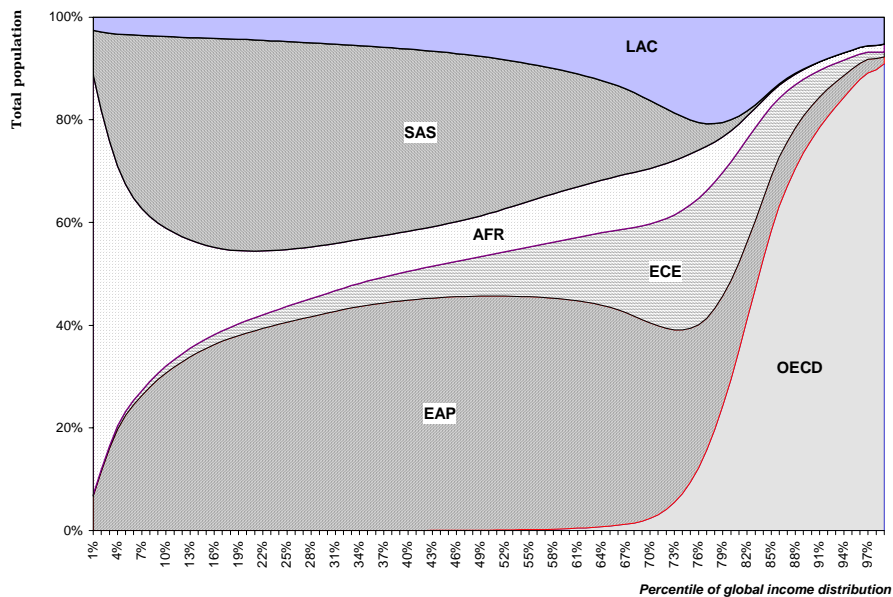


Figure 7. World income distribution, by region, at each percentile of global income distribution, 1999. (population at any particular income = 100)

