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Aggregation of Economic Indicators Across Countries: Exchange Rate versus PPP Based GDP Weights

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Abstract

Relative GDP shares are frequently used as weights in aggregations. In order to ensure that these weights reflect countries' shares in real output, GDP data in national currencies should be converted into a common numeraire currency at purchasing power parity (PPP) rates. A review of the empirical evidence on the relationship between exchange rates and prices suggests that market (or official) exchange rates are generally poor proxies for PPP rates. The paper examines the PPP-based GDP data generated by the International Comparison Program and compares aggregations with PPP- and exchange rate-based GDP weights.

JEL Classification Numbers:
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Summary

Aggregation of economic indicators across countries frequently involves the calculation of weighted averages. A widely employed approach is to define countries' weights as their shares in total GDP of the group considered. In order to ensure that these weights reflect shares in real output and not differences in price levels across countries, conversion factors based on purchasing power parities (PPPs) should be used to convert data in national currencies into a common numeraire currency. Nonetheless, for practical reasons, market or official exchange rates are widely used to convert real GDPs.

The paper examines GDP weights based on exchange rates and on PPPs and discusses the implications of alternative weighting schemes for the derived aggregate economic indicators. A brief review of the literature on the relationship between exchange rates and prices suggests that market exchange rates are poor proxies for PPPs as conversion factors. The results from time-series analyses indicate frequent and prolonged deviations from PPP in the postwar period, and cross country comparisons have revealed a systematic bias in GDP data converted at market or official exchange rates. Moreover, weighting systems based on exchange rates often involve a rather arbitrary choice of the base year and--as in the weighting system currently used in the World Economic Outlook--frequent ad hoc adjustments to account for large discrete changes in official exchange rates or changes in the exchange rate regime. The paper shows that these relatively arbitrary decisions can have a significant impact on the weights and, hence, on the derived aggregates.

The estimates of PPP-based GDP produced by the International Comparison Program (ICP) for a significant number of countries and several benchmark years are a possible alternative to conventional exchange rate based GDP weights. The paper summarizes the methodology underlying these estimates and discusses problems relating to the extrapolation to non-benchmark years and nonbenchmark countries. Aggregates of real GDP growth based on PPP weights are compared with the corresponding aggregates based on the current WEO weighting system in order to illustrate the implications of using PPPs as conversion factors. The main conclusion of the paper is that GDP weights derived from the available estimates of PPPs, while not perfect and in some cases subject to substantial errors, are a closer approximation of real output shares than weights based on exchange rates.

I. Introduction

Global economic analyses generally involve the aggregation of economic indicators across countries. In many instances, aggregates are defined as weighted averages of indicators for individual countries, with the weights reflecting the relative size of countries. 1/ A widely employed approach is to define countries' weights as their shares in total GDP of the group considered. 2/ In order to ensure that GDP weights reflect each country's share in real output, differences in price levels across countries need to be taken into account. Data expressed in national currencies should thus be converted into a common numeraire currency using conversion factors that reflect each currency's purchasing power relative to the numeraire currency. 3/

For practical reasons, GDP data expressed in national currencies are usually converted at market exchange rates. The use of market exchange rates for conversion purposes may be an acceptable approach as long as differences between market rates and purchasing power parities (PPPs) are likely to be small and transitory. However, if market exchange rates diverge substantially and for extended periods from purchasing power parities, conversion at market exchange rates may yield biased GDP weights and hence biased indicators of aggregate economic activity in groups of countries.

This paper compares GDP weights based on market (or official) exchange rates with weights based on available estimates of PPPs. The comparison focusses on conversion factors and does not bear on issues relating to equilibrium exchange rates. The paper reviews alternative weighting schemes and examines their impact on indicators of aggregate real GDP growth. Section II deals with exchange rate based GDP weights. It provides a brief summary of the empirical evidence on the relationship between exchange rates and PPPs and discusses the implications of aggregating growth rates of real GDP with different sets of exchange rate based GDP weights. Section III examines an alternative weighting scheme derived from PPP-based GDP data generated by the International Comparison Program (ICP). The section briefly summarizes problems of PPP index construction and the main features

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1/ Indicators that are additive and expressed in a common unit of account, such as current account balances, can readily be aggregated by summing up individual country data.

2/ There are, of course, other weights that can be used to aggregate economic indicators. Weights based on population shares, for example, are discussed in World Bank, Global Economic Prospects and the Developing Countries (1991), Appendix B. The choice among alternative weighting schemes depends ultimately on the focus of the analysis.

3/ Comparisons and aggregation of economic data across countries are, of course, also complicated by other problems, such as differences in definition and coverage.

of the ICP approach. 1/ It discusses issues relating to the intertemporal extension of PPP-based GDP data that are available only for individual benchmark years, and issues relating to the estimation of PPPs for non-benchmark countries. The section then compares aggregate growth rates of real GDP derived from PPP-based GDP weights with aggregates derived from exchange rate based GDP weights. Section IV summarizes the main conclusions of the paper.

II. GDP Weights Based on Exchange Rates

1. Exchange rates and purchasing power parities

Comparison and aggregation of real GDPs across countries would pose less of a problem if market (or official) exchange rates were equal to the ratios of the weighted averages of prices (at the level of GDP) in the respective countries relative to a base country. 2/ In this case price levels, defined as the weighted average of prices (at the level of GDP) expressed in a common unit of account, would be the same in all countries. Converting GDPs in terms of current domestic prices and national currencies at market (or official) exchange rates into a common unit of account would then yield GDP data that reflect cross country differences in real output rather than price differences. Over time, changes in the weighted average of prices in any given country relative to the numeraire country would be offset by changes in the exchange rate and would not affect the country's GDP relative to the numeraire country or any other country.

The relationship between prices and exchange rates has been the subject of numerous theoretical and empirical studies. 3/ PPP theories of exchange rate determination describe an equilibrium relationship between prices and exchange rates without specifying the mechanisms that bring about this relationship. 4/ They are based on the notion that in the absence of transportation cost and trade barriers, the law of one price ensures that the prices of homogeneous goods are equalized across countries:

$$p_i = sp_i^* \qquad (1)$$

1/ A detailed review of methodological problems encountered in the construction of PPP indices is beyond the scope of this paper. See United Nations Statistical Office (1991), Kravis, Kenessy, Heston and Summers (1975), and Kravis, Heston and Summers (1982) for a discussion of these issues.

2/ Issues relating to the determination of the appropriate weights are discussed in Section III.1.

3/ See, for example, Officer (1976), Dornbusch (1985), Isard (1988), Levich (1988), and Mussa (1990) for surveys of the literature.

4/ This point is emphasized in Frenkel (1981).

with

p_i = the price of good i;
s = the market exchange rate defined as units of domestic currency per unit of foreign currency.

Variables relating to the foreign country are marked with an "*".

If all goods are tradable, the PPP rate can be defined as

$$s_{PPP} \equiv \frac{\prod_{i=1}^{m} p_i^{a_i}}{\prod_{i=1}^{m} p_i^{*a_i^*}} = \frac{s \prod_{i=1}^{m} p_i^{*a_i}}{\prod_{i=1}^{m} p_i^{*a_i^*}} \qquad (2)$$

assuming that the arbitrage condition described by equation (1) holds. According to equation (2), the market exchange rate s is equal to the PPP rate, s_{PPP}, if $a_i = a_i^*$, i.e., if the weights are the same in both countries.

In the presence of nontradables, assuming that the law of one price holds for all tradable goods, the PPP rate can be defined as

$$s_{PPP} \equiv \frac{P_N^{\alpha} P_T^{(1-\alpha)}}{P_N^{*\alpha^*} P_T^{*(1-\alpha^*)}} = \frac{s(P_N/P_T)^{\alpha}}{(P_N^*/P_T^*)^{\alpha^*}} \qquad (3)$$

with

$$P_N = \prod_{d=1}^{h} p_{Nd}^{b_d}$$

$$P_T = \prod_{i=1}^{m} p_{Ti}^{a_i}$$

and similarly for P_N^* and P_T^*. The share of nontradables in total output is represented by α. If some goods are nontradable, the market exchange rate s is only equal to the PPP rate, s_{PPP}, if $(P_N/P_T)^{\alpha} = (P_N^*/P_T^*)^{\alpha^*}$, i. e., if the

relative prices and shares of nontradables are the same in both countries. 1/

Not all PPP theories of exchange rate determination refer to the concept of PPP described by equation (3). The theories differ in the definition of the price level and the time horizon for which the equilibrium relationship between prices and exchange rates is expected to hold. Also, PPP theories can be formulated in absolute form as in equation (3), relating the level of the exchange rate to relative price levels, or in relative form, relating changes in exchange rates to changes in relative price levels. 2/ Empirical tests of these various forms of PPP provide useful information about the relationship between prices and exchange rates. However, market (or official) exchange rates would only be appropriate conversion factors for GDPs if there was evidence that PPP holds for broadly defined price indices and in the absolute form described by equation (3).

A number of empirical and theoretical studies suggest that the conditions for $s=s_{ppp}$ are likely to be violated frequently. 3/ While the law of one price is believed to hold for a subset of internationally traded goods such as primary commodities, Isard (1977) concludes that it is "flagrantly and systematically violated" for manufactured goods. 4/ Moreover, there is evidence that the ratio of the price levels of traded and nontraded goods differs systematically across countries and changes over time. 5/

A well known explanation for differences in the relative prices of tradables and nontradables across countries is the "productivity difference model," which dates back to Ricardo and was developed mainly by Balassa. 6/ This model assumes that international productivity differences tend to be larger in the tradables than in the nontradables sector and that prices for tradables are determined in international markets. 7/ With marginal cost pricing, intercountry differences in

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1/ McKinnon (1979) discusses the conditions that have to be met for PPP to hold for the overall price level.

2/ See Officer (1976) for a discussion of various forms of PPP theories.

3/ See, for example, Samuelson (1964) for a theoretical discussion of the necessary conditions for $s=s_{ppp}$ to hold.

4/ See Isard (1977), p.942. Isard's conclusion is based on an empirical analysis at a disaggregated level of the dollar prices of German goods relative to their U.S. equivalents.

5/ Officer (1976a) and Kravis and Lipsey (1983) survey the most important studies in this area.

6/ See Balassa (1964). For a discussion of the historical origins of the model, including a statement of the theory by Harrod, see Kravis and Lipsey (1983), and Marris (1984).

7/ Balassa (1964) discusses some indirect empirical evidence on international productivity differences in tradables and nontradables sectors.

factor prices reflect productivity differences in the tradables sector, while unrestricted factor mobility within each country ensures equalization of factor prices across sectors. Under these conditions, relatively high productivity in the tradables sector translates into relatively high wages and prices in the nontradables sector. 1/ The market exchange rate of a country with higher productivity than the numeraire country is thus likely to be more appreciated than the PPP rate, unless the differences in the relative prices of tradables and nontradables are fully offset by differences in their respective weights in total output. 2/

Direct empirical tests of PPP are generally based on time series data, with prices in each country expressed in the form of intertemporal indices, rather than ratios of weighted averages of prices as in equation (3). Unless the market exchange rate is known to be equal to the PPP rate in the base period, such tests cannot ascertain whether $s=s_{PPP}$; they only test whether there is a one-to-one relationship between the index of s and the ratio of the corresponding price indices over time (absolute PPP), or between the changes in the index of s and the changes in the corresponding price indices (relative PPP). The evidence from these tests is mixed. 3/ There is evidence of significant short-run deviations from PPP, which are generally attributed to differences in the degree of price flexibility in goods and asset markets. 4/ Moreover, while several empirical studies confirm the validity of absolute PPP in the long run for major currencies during the 1920s, 5/ there is evidence of long-run PPP only in its relative form for major currencies during the 1970s and 1980s. 6/

1/ Bhagwati (1984) has proposed an alternative (or supplementary) explanation for international differences in prices for nontradables in the vein of the standard factor proportions model of international trade. The argument is based on the observation that nontradables, notably services, are relatively labor intensive in all countries. Since labor is highly productive and expensive in countries with a relative abundance of capital, prices of labor intensive services tend to be relatively high in such countries. The reverse argument can be made for countries with a relative abundance of labor. It should be noted that Bhagwati's argument presupposes that the countries compared do not lie in the same cone of diversification so that factor price equalization across countries fails.

2/ According to equation (3), the market exchange rate tends to be more appreciated than the PPP rate in countries where the ratio of the prices of nontradables to the prices of tradables is higher than in the numeraire country.

3/ See Officer (1976), Dornbusch (1985), and Isard (1988) for surveys of empirical tests of PPP theory.

4/ See Frenkel (1981) for a discussion of these factors in the context of an analysis of deviations from PPP during the 1970s.

5/ See, for example, Frenkel (1978), and Taylor (1990).

6/ See Mecagni and Pauly (1987).

To sum up, the direct empirical evidence on PPP theory indicates that market exchange rates differ frequently and for extended periods from PPP rates. Moreover, there is indirect evidence suggesting that the conditions for PPP to hold in its strong, absolute form for broadly defined price indices are generally violated. In these circumstances, market exchange rates are unlikely to be good proxies for the conversion factors that are required to offset international differences in price levels and derive real GDP data that are comparable across countries.

2. Aggregation with exchange rate based GDP weights

Notwithstanding their shortcomings, market exchange rates are widely used in comparisons and aggregations of GDPs and related economic data. The weighting system used to aggregate time series such as GDP growth rates, investment ratios, and consumer price inflation in the World Economic Outlook is based on three year moving averages of nominal GDPs converted into U.S. dollars at market or official exchange rates, which are adjusted on a case by case basis to account for apparent anomalies in levels or changes such as large discrete changes in official exchange rates or large spreads between official and secondary market rates. In the World Bank's Global Economic Prospects and the Developing Countries 1/, growth rates of real GDP are aggregated on the basis of constant 1987 GDP weights, with GDPs in national currencies converted into U.S. dollars at the period average market exchange rate of the base year. Constant GDP weights based on market exchange rates are, in principle, also used to aggregate time series of consumer price inflation and money growth in International Financial Statistics (IFS), but weights for a given base year are applied to sub-periods of about 5 years, which are spliced to create a continuous time series. 2/

There are no well established criteria for choosing between alternative forms of exchange rate based weights; choices of base years or certain averaging procedures are thus generally based on pragmatic considerations. 3/ These largely arbitrary choices can have a significant impact on the weighting system and thus on the derived aggregates.

1/ See World Bank, Global Economic Prospects and the Developing Countries, Washington May 1991.

2/ See International Financial Statistics, September 1991, p.15 for a description of the weighting scheme.

3/ The choice between fixed and moving weights, however, depends on the specific focus of the analysis. Aggregation of GDP growth rates with fixed weights, for example, yields a weighted average of growth in individual countries, while moving weights yield an aggregate growth rate that reflects developments in total output of the group considered. Specifically, aggregating growth rates of real GDP with real GDP weights that are lagged one period is equivalent to calculating the growth rate of the sum of the GDPs considered.

Table 1 illustrates how alternative exchange rate based weighting systems affect aggregate real GDP growth rates for major country groups during 1982-91. The table shows mean deviations and mean absolute deviations between the aggregates published in the World Economic Outlook of October 1991 and aggregate growth rates based on the same set of country data but alternative weighting schemes. While the differences between the aggregate growth rates at the world level and for the industrial countries are relatively small, there are considerable discrepancies between the aggregate growth rates for the developing countries as a group and, in particular, the growth rates for certain developing regions, such as the Middle East, Africa, and the Western Hemisphere. For example, the aggregate growth rate for the developing countries based on real GDP weights with 1987 as base year differs, on average, by almost one half of a percentage point from the corresponding aggregate published in the World Economic Outlook of October 1991; for the developing countries in the Middle East, these two weighting systems produce aggregate growth rates that differ on average by more than 2 percentage points. Nominal GDP weights, which are conceptually the same as current WEO weights but do not include the averaging and the case by case adjustments of the latter, yield aggregate growth rates that are significantly different from the WEO aggregates, particularly for Africa and the Middle East. With the exception of the aggregates for the Middle East, there is little evidence of systematic deviations in one direction, with most discrepancies canceling out over time. The comparison suggests, however, that the choice among alternative exchange rate based weighting systems can have significant implications for the interpretation of developments in output growth in a number of groups of developing countries.

III. GDP Weights Based on Purchasing Power Parities

1. Problems of PPP index construction

a. The international comparison program

Widespread interest in international comparisons of national incomes and the recognition that conversion factors based on market exchange rates are poor substitutes for PPPs led to the creation of the International Comparison Project, later renamed International Comparison Program (ICP), whose task was to estimate PPPs on the basis of price surveys for certain benchmark years. ICP started in the late 1960s as a joint venture of the United Nations and the International Comparison Unit of the University of Pennsylvania, with initial support from the Ford Foundation and the World Bank. 1/ Phases I and II of ICP focused on methodological issues and produced PPP-based comparisons of national incomes for a small number of industrial and developing countries for the reference years 1967, 1970,

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1/ Antecedents of ICP include comparisons within the OECD and among CMEA countries in the 1950s. For a brief history of ICP, see "Handbook on the International Comparison Program," mimeographed, United Nations Statistical Office, February 1991.

Table 1. Effects of Alternative Exchange Rate Based Weighting Schemes on Aggregate Real GDP Growth
(In percentage points)

	Average annual growth of real GDP 1982-91, WEO October 1991	Mean deviations from WEO aggregates, 1982-91 1/							
		Nominal GDP weights 2/	Variable real GDP weights with base years 3/			Constant real GDP weights with base years 4/			IFS weights 6/
			1980	1985	1987	1980	1985	1987 5/	
World	3.1								
Mean deviation		0.03	0.02	0.07	0.04	0.17	0.05	--	0.08
Mean of absolute deviations		0.06	0.13	0.15	0.13	0.02	0.19	0.15	0.14
Industrial countries	3.2								
Mean deviation		-0.01	0.10	0.07	0.01	0.11	0.07	--	0.05
Mean of absolute deviations		0.03	0.12	0.14	0.05	0.12	0.15	0.04	0.09
Developing countries	2.8								
Mean deviation		0.10	-0.22	-0.01	0.09	0.23	-0.06	-0.06	0.12
Mean of absolute deviations		0.19	0.25	0.24	0.41	0.31	0.36	0.52	0.24
Africa	2.1								
Mean deviation		0.26	-0.04	-0.09	-0.01	-0.05	-0.17	-0.14	-0.06
Mean of absolute deviations		0.44	0.16	0.16	0.70	0.14	0.21	0.82	0.16
Asia	7.0								
Mean deviation		--	-0.15	0.09	0.18	0.03	0.02	--	0.04
Mean of absolute deviations		0.08	0.24	0.17	0.20	0.13	0.09	0.14	0.07
Europe	0.7								
Mean deviation		-0.09	-0.07	-0.03	-0.02	--	-0.01	-0.02	--
Mean of absolute deviations		0.20	0.17	0.19	0.25	0.17	0.19	0.25	0.19
Middle East	0.4								
Mean deviation		-0.82	-0.33	-0.55	-1.28	0.04	-0.97	-1.44	-0.31
Mean of absolute deviations		1.08	0.69	0.85	2.05	0.78	1.09	1.85	0.63
Western Hemisphere	1.4								
Mean deviation		0.16	-0.07	-0.16	-0.08	-0.07	-0.22	-0.15	-0.23
Mean of absolute		0.24	0.53	0.50	0.30	0.59	0.50	0.32	0.47

1/ Difference between aggregate growth rates of real GDP from World Economic Outlook, October 1991, and aggregates based on the same data set and the weights indicated in the table. Mean deviations in the table refer to the arithmetic average of the deviations for the period 1982-91; means of absolute deviations refer to the arithmetic averages of the absolute deviations. The weights used in the World Economic Outlook are 3-year moving averages of U.S. dollar GDPs derived from nominal GDPs converted at market exchange rates, adjusted on an ad hoc basis, and lagged one period.

2/ Nominal GDPs in national currencies converted into U.S. dollars at period average market exchange rates, lagged one period.

3/ Real GDPs in national currency converted into U.S. dollars at the period average exchange rate of the base year, lagged one period.

4/ Real GDPs of the base year converted into U.S. dollars at the average market exchange rate of the base year.

5/ Aggregate growth rates in the World Bank's Global Economic Prospects and the Developing Countries, May 1991 are based on constant 1987 GDP weights.

6/ IFS aggregates of changes in consumer prices are based on constant GDP weights for subperiods (1980 weights for the period 1978-83, and average 1984-86 weights for the period 1983 onward), which are spliced at overlapping years. See, for example, International Financial Statistics, September 1991, p. 15 for a description of this weighting system.

and 1973. Beginning with phase III, ICP became a regular exercise which has generated benchmark estimates of PPPs in five-year intervals for an increasing number of countries. Interest in intra-regional comparisons led to a growing regionalization of ICP during the 1980s, with regional organizations assuming a central role in ICP-related statistical work. ICP has now entered phase VI, which is to produce estimates for the reference year 1990. Current work on PPP estimation in various regional centers, including the OECD and the Statistical Office of the European Communities, is based on the methodological foundations developed in the context of ICP.

b. Desired properties of a PPP index

A PPP index is essentially a type of international price index with a particular set of desired properties. 1/ At the disaggregated level, PPP for a given pair of countries j, k refers to the ratio of prices for a well defined item i:

$$PPP_{ijk} = \frac{p_{ij}}{p_{ik}} \tag{4}$$

In order to determine the overall purchasing power of country j's currency relative to that of country k, a large number of prices for individual items have to be aggregated to yield a ratio of weighted averages of prices. PPP at the level of GDP is thus a function of prices and weights:

$$PPP_{jk} = f\ (P,\ W). \tag{5}$$

Evidently, the resulting PPP depends on the composition of P and W, as well as on the functional form of (5). For example, if PPP is derived from weighted arithmetic averages of prices in countries j and k, weights based on quantities in country j (which would correspond to a Paasche formula) will normally yield a lower PPP_{jk} than weights based on quantities in country k (corresponding to a Laspeyres formula). This is due to substitution effects, which typically result in widely observed negative correlations between prices and quantities, and is a well-known problem in the literature on index numbers. 2/

1/ Conversely, a price index can be regarded as a conversion factor that is used to convert income or output valued at the prices of different time periods (intertemporal price index) or the prices of different countries (international or PPP index) into income or output valued at the prices of a certain base period or a certain base country.

2/ See, for example, Allen (1975) and Marris (1984).

The core problem in constructing a PPP index is to choose the appropriate sets of prices and weights and to determine the precise form of f (P, W). In order to evaluate solutions to this problem, it is useful to consider the desired properties of a PPP index. 1/ In general, a PPP index should meet the following requirements:

-- Base country invariance. All countries included in a comparison should be treated in such a way that the resulting PPPs will be independent of the country that is chosen as the base (or numeraire) country. 2/

-- Transitivity. In a multilateral comparative study involving (at least) three countries (j, k, m), an index PPP_{jm} multiplied by another index PPP_{mk} should equal the index PPP_{jk}, if this one had been calculated directly.

-- Additive (matrix) consistency. Derived quantities (in value terms) for subaggregates should be stated in such a way as to allow for comparisons across subaggregates (within one country) and across countries (within any subaggregate).

-- Characteristicity. The quantity weights used for PPP index construction should be characteristic in the sense that they should reflect the actual quantities consumed in the countries involved.

Unfortunately, it is not possible to construct a single index that satisfies all requirements simultaneously. In practice, for example, there is a tradeoff between transitivity and characteristicity. 3/ If PPPs are estimated to derive internationally comparable real GDP data, base country invariance and transitivity seem to be important properties because they ensure a unique ordering of countries according to their PPP-based GDPs. 4/ Characteristic weights are very desirable, but in worldwide comparisons characteristicity is constrained by the transitivity requirement.

1/ These properties are discussed in Kravis, Kenessy, Heston and Summers (1975), Drechsler (1973), and Allen (1975).

2/ It should be noted that in a demand-theoretic context, imposing base country invariance is equivalent to requiring that the consumer utility function assumed for all countries is homothetic.

3/ In a multilateral framework, "characteristicity" requires that each bilateral comparison ignore the outside world, focusing only on weights that are characteristic of the countries compared. This leads to a different set of weights for each bilateral comparison and thus indices that are not transitive.

4/ If PPPs are calculated for a different purpose, the preferred ordering of desired properties may well be different.

In principle, a multilateral system of PPP indices can be derived from individual bilateral comparisons. To fulfill the transitivity requirement, all bilateral comparisons must be calculated using the same weights from a given base country. This approach, which has been termed the "star country method," will result in indices that are not invariant to the choice of the base country. As a general rule, base country invariance and transitivity can only be achieved if each bilateral comparison in a multicountry framework uses information on prices and weights for all countries included in the comparison.

c. The methodology of the International Comparison Program

The approach to multilateral PPP index construction chosen by the ICP is the Geary-Khamis (GK) method 1/ which is conveniently summarized in the following sets of simultaneous equations:

$$\pi_i = \sum_{j=1}^{n} \frac{p_{ij}}{PPP_j} \left[\frac{q_{ij}}{\sum_{j=1}^{n} q_{ij}} \right] \qquad i = 1, \ldots, m \tag{6}$$

$$PPP_j = \frac{\sum_{i=1}^{m} p_{ij}\, q_{ij}}{\sum_{i=1}^{m} \pi_i\, q_{ij}} \qquad j = 1, \ldots, n \tag{7}$$

where i denotes each of m categories of goods and j each of n countries included in the comparison, p_{ij} the price of good i in country j, q_{ij} the quantity of good i in country j, π_i the international price of good i and PPP_j the PPP of country j.

The basic idea of the GK approach is to express PPP for a given country j as the ratio of total expenditure valued at country j's own prices p_{ij} to total expenditure valued at international prices π_i. These international prices are in turn a weighted average of the domestic prices of all countries included in the comparison, with domestic prices converted into the currency of the numeraire country at the country's PPP, and the weights

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1/ This method was originally suggested by Geary (1958) and amplified by Khamis (1972); see Kravis, Kenessy, Heston and Summers (1975) and Kravis, Heston and Summers (1982).

reflecting the share of each country in the total quantity of each good. 1/ PPPs and πs can be derived simultaneously from the above system of m + n equations, using prices and quantities in individual countries as inputs. Only m + n - 1 equations of the system described by (6) and (7) are independent, and PPP for the numeraire country is set equal to 1.

In order to keep the system manageable, the number of prices included in the calculation of the PPPs needs to be limited. The ICP solution to this problem was to divide the main sub-aggregates of GDP into approximately 150 detailed categories of goods and services, 2/ and to derive prices for these categories as simple geometric averages of the prices of several well

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1/ This method of calculating international prices implies that the resulting structure of international average prices is closer to the price structure of the large and/or rich countries than to the price structure of the small and/or poor countries. As a result, the GK method tends to underestimate the PPPs and to overestimate the PPP based GDPs of small/poor countries relative to those of large/rich countries in comparisons that are dominated by the latter. In comparisons that include a number of large and poor countries as well as small and rich countries, the net effects on the calculated international prices and hence on the derived PPP based GDPs are more ambiguous. Kravis and Lipsey (1990) have reaggregated Phase III (1975) ICP data using international prices based on equal weights for rich and poor countries. Their results suggest that the impact of this change in the structure of international prices on the estimates of PPP based GDP is relatively modest, ranging from 9 to 13 percent for the eight poorest countries in the sample where the potential upward bias of the GK method is expected to be the largest.

2/ These include approximately 110 detailed categories for consumption, 35 for investment, and 5 for government.

defined items. 1/ The approach may be illustrated by a matrix (M) of prices of items representing a given category: 2/

		Item (γ)	Country (j) 1	2	...	n
(4)	M :	1	p_{11}	p_{12}	...	p_{1n}
		2	p_{21}	p_{22}	...	p_{2n}
		•	•	•		•
		•	•	•		•
		•	•	•		•
		g	p_{g1}	p_{g2}	...	p_{gn}

The main problem with the derivation of a transitive system of category prices is that they should be based on the same set of items in each country, i.e., the matrix M should have no empty cells. One possible solution is to exclude all items that cannot be priced in all countries.

1/ ICP surveys prices for between 400 and 700 particular items in the participating countries. The determination of these prices is a formidable task as quality differences, price differences between different types of outlets, regional price differences within one country, and seasonal price differences during the year have to be taken into account. In many instances it is not possible to derive perfectly matching national average annual prices on the basis of survey data alone, and adjustments have to be made to account for quality and other differences that influence prices. Problems of quality differences are particularly serious for certain categories such as housing and cars. In a number of cases ICP experts have used hedonic regression methods to estimate prices that allow for a variety of factors affecting quality. For a detailed discussion of problems relating to international price comparisons see United Nations Statistical Office (1991), *Kravis, Kenessy, Heston and Summers* (1975), Kravis, Heston and Summers (1982), and United Nations Statistical Commission and Economic Commission for Europe (1988).

2/ It should be noted that the prices used are final product prices which include explicit or implicit taxes and subsidies. The derived international prices thus reflect the average of such price distortions across countries. Valuing expenditures for a given country at these international prices, which is achieved by dividing expenditures in terms of national prices and currency by the PPP index, therefore eliminates the impact on real GDP of a price structure which is more distorted than price structures in the rest of the world.

However, this would greatly reduce the number of items considered in each category and would unduly limit the characteristicity of the results. To overcome this difficulty, the ICP developed the Country-Product-Dummy (CPD) method, which is a regression procedure for estimating the missing observations from the available price data. 1/

For certain service categories, such as general government services and education, direct price comparisons are generally not possible because market prices are not observed. In these cases, ICP has employed indirect estimation methods based on input cost, or, in some instances, on output related quantity information that has been used to derive implicit price comparisons. These methods are clearly less reliable than direct price comparisons but it is worth noting that they are also used in intertemporal comparisons where similar problems with "comparison resistant services" are encountered. 2/

1/ This method was developed by Summers and is described in detail in Summers (1973) and in Kravis, Kenessy, Heston and Summers (1975). Since countries with many price observations have a larger influence on the estimated category prices than countries with only a few observations, price observations for each country were weighted by the reciprocal of the number of prices available for that country. The CPD approach is a genuinely multilateral method that makes optimal use of the basic price information available. Its main drawback is that it requires specification of items that can be priced in a relatively large number of (albeit not necessarily all) countries. This requirement can limit the characteristicity of the items chosen if the comparison covers a large set of very diverse countries. An alternative approach to the calculation of PPPs at the basic category level is the Elteto-Koves-Szulc (EKS) method. (See Kravis, Heston, and Summers (1982), p. 76 for a description of the method.) This method is a multilateralized bilateral approach that derives category PPPs from a large set of bilateral PPPs for all countries included in a comparison. By building on bilateral comparisons, the EKS method can incorporate prices of items that are generally more characteristic of the countries compared than the multilateral CPD method. However, the EKS method is likely to be more resource intensive, as it requires a large number of bilateral pricing exercises, and has been applied mainly in comparisons among EC and OECD countries.

2/ Even for services with observed market prices, comparisons tend to be less reliable than for goods, because output and quality differences of the former are more difficult to measure. However, calculations by Kravis, Heston and Summers (1982, p. 140) suggest that estimates of real GDP are relatively insensitive to varying assumptions about productivity in comparison resistant services.

With category prices and derived "notional quantities" as inputs, 1/ the GK method described by equations (6) and (7) above can be used to derive PPPs. 2/ These PPPs are expressed in terms of the numeraire country's currency, which is usually the US dollar, but they are invariant to the choice of the base country. In addition, they fulfill the requirements of transitivity and matrix consistency. 3/ Dividing the sum of all expenditure categories valued at national prices and in national currencies by these PPPs yields expenditure valued at constant international prices (in terms of US dollars).

As noted above, beginning with the 1980 benchmark study, ICP became increasingly regionalized. 4/ While the emphasis on intra-regional comparisons (covering the European Community and the OECD area in particular) helped to enhance the characteristicity of the comparisons within a given group of countries, it was, inevitably, achieved at the cost of the quality of inter-regional comparisons. As the international prices used for the estimation of PPPs in regional comparisons are only based on prices of countries in a particular region, GDP for a given country valued at international prices can vary considerably depending on the specific region for which the analysis is carried out. 5/ In order to avoid the

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1/ "Notional quantities" are category quantities valued at corresponding U.S. prices, derived by dividing category expenditures by category price parities.

2/ In practice, ICP has used a modified form of equations (6) and (7). All prices are expressed relative to prices in the United States, i.e., as category price parities relative to the United States, which serves as the numeraire country. The resulting international price for a category i is thus π_i/p_{ius}. This modification does not affect the PPPs. It should be noted that the procedure outlined here does not apply to certain special components of GDP, such as changes in stocks, and net exports of goods and services. The treatment of these components is described in Kravis, Kenessy, Heston and Summers (1975).

3/ The GK approach has been criticized by a number of ICP experts because of its potential bias in comparisons involving countries that are very diverse in price structures and at the same time very diverse in relative size. (See, for example, Drechsler (1988).) However, as noted above, this bias is likely to be relatively small compared with the differences between exchange rates and PPPs. Moreover, alternative methods, such as the EKS approach, lack the property of matrix consistency. The "Handbook on the International Comparison Program" issued in draft form by the Statistical Office of the United Nations in February 1991 leaves open the question of possible future changes in the ICP methodology.

4/ This development, which is related to the shift in funding for the project, is discussed in Drechsler (1988).

5/ In principle, this problem arises also in worldwide comparisons if the sample of countries considered is not representative of all countries. The ICP dealt with this problem by weighting individual sample countries according to their degree of representativeness in the world.

proliferation of conflicting results, ICP has accepted the principle of "fixity" which states that a result published for a regional comparison must remain unchanged in any other comparison including a larger set of countries. 1/ However, fixity cannot be achieved without cost. The methods developed to ensure fixity either produce the desired result only at the aggregate GDP level or result in subaggregates which meet the fixity requirement but are non-additive in the sense that the components of GDP may not add up to total GDP.

2. Intertemporal extension of benchmark data

In view of the considerable cost of benchmark studies, which require collection and processing of a large amount of price and expenditure data, it is generally not feasible to produce benchmark data on an annual basis. Time series of PPP-based real GDP thus have to be derived from extrapolated benchmark data.

GDP at constant international prices can, in principle, be extrapolated using growth rates of real GDP in national currency. However, since these growth rates represent domestic rather than international price weights, they may lead to distortions in the time series for GDP at constant international prices. In order to minimize such distortions, Summers and Heston (1988) have suggested a method that extrapolates the principal components of GDP at constant international prices on the basis of the corresponding real growth rates from national sources; these components are then aggregated to GDP at constant international prices.

A special problem arises in the case of countries for which multiple benchmark studies are available. In theory, the rate of change of GDP at constant international prices derived from two benchmark studies should be equal to the rate of change over the same period derived from the corresponding national accounts series in constant prices. In practice, this is frequently not the case, even when allowance is made for differences in methodology between individual benchmark studies. 2/ As international comparisons and national accounts data are both subject to error, Summers and Heston argue that there is no a priori reason for considering one system to be more reliable than the other. Instead of discarding information from multiple benchmark studies in favor of national accounts growth rates, they therefore applied a special procedure that ensures the consistency of the data from both sources. This procedure is based on a general errors in variables model that produces adjustment factors for national accounts growth rates as well as for benchmark data. 3/

1/ See Drechsler (1988) for a detailed discussion of the fixity issue.

2/ In order to overcome the problem of differences in methodology, Summers and Heston (1988) re-estimated benchmark values for the years 1970, 1975 and 1980 on the basis of a common methodology and the same vintage of national accounts data.

3/ See Summers and Heston (1988) for a description of the approach.

3. Estimation of PPPs for non-benchmark countries

Cost constraints have not only precluded benchmark studies on an annual basis, they have also limited the sample of countries for which benchmark comparisons have been undertaken. Extension of the scope of PPP-based GDP data to a global system thus depends on the quality of possible "short-cut" methods for estimating PPPs for those countries that have not yet been included in benchmark studies.

One approach to generating PPPs for non-benchmark countries is to estimate a simple model of the relationship between PPPs and exchange rates for those countries for which benchmark data on PPPs are available and to use this "bridging equation" to predict PPPs for non-benchmark countries. The theoretical arguments outlined in section II.1 suggest that structural characteristics, such as relative productivity levels, may play an important role in explaining differences in the ratio of PPP to the exchange rate (real price level) across countries. In the empirical literature, real per capita GDP has been widely used as a proxy for productivity levels and indeed much of the empirical research has focused on the relationship between real per capita GDPs and real price levels. 1/ In order to use these price level equations as bridging equations, PPP-based per capita GDP has to be replaced by exchange rate based per capita GDP as the explanatory variable. Alternatively, bridging equations that include real PPP-based per capita GDP as the dependent variable and exchange rate based per capita GDP as the explanatory variable can be estimated directly. This approach was adopted in several studies by the ICP team. 2/ Estimation results for both types of bridging equations are reported in the Appendix.

1/ See, for example, Balassa (1964), Clague and Tanzi (1972), Officer (1976), Lipsey and Kravis (1983), and Clague (1988). Some authors have examined the role of alternative indicators of relative productivity levels such as relative quantities or prices of skilled labor (Clague and Tanzi (1972)). Several other structural characteristics, including the relative abundance of natural resources (Clague (1988)), and openness (Kravis and Lipsey (1983)) have also been considered. However, besides posing problems of interpretation, data on most of these variables are generally not readily available for developing countries.

2/ See, for example, Kravis, Heston and Summers (1978a) and (1980), and Heston and Summers (1988).

In order to improve the quality of PPP estimates for non-benchmark countries, Summers and Heston have developed an approach using price data from post-adjustment surveys. 1/ While post-adjustment indices, which are based on price surveys for a special consumer basket (expatriates) in special areas (usually capital cities), are not a perfect substitute for PPPs, they are probably more closely correlated with "true" PPPs than market exchange rates. Summers and Heston estimated PPP-based GDPs for non-benchmark countries on the basis of bridging equations that include PPP-based domestic absorption as the dependent variable and absorption based on the conversion factors implicit in the post-adjustment data as explanatory variables. 2/

Table 2 examines the out-of-sample prediction properties of alternative bridging equations. For a set of countries that were included in the 1985 but not in the 1980 benchmark study, benchmark values of PPP-based per capita GDP for 1985 are compared with predictions from alternative bridging equations that were estimated for the sample of 1980 benchmark countries. 3/ Mean deviations between exchange rate based per capita GDPs and the ICP benchmark values are included for comparison. In addition, the table shows the results from an evaluation by Kravis and Lipsey (1990) of the prediction properties of bridging equations that include as explanatory variables exchange rate based data and data based on post-adjustment indices.

Three main conclusions emerge from Table 2. First, while predictions from bridging equations are subject to substantial errors, these errors are considerably smaller than the errors resulting from approximating PPPs by exchange rates. Second, while per capita GDPs converted at market exchange rates entail a marked downward bias, there is no strong bias in the predictions derived from the bridging equations with PPP-based per capita GDP as the dependent variable. Third, the information incorporated in the post-adjustment data improves the prediction properties of the bridging equations.

1/ See Summers and Heston (1988) and (1991). Their estimations are based on the International Civil Service Commission (ICSC) index, published in the Monthly Bulletin of Statistics by the United Nations Statistical Office, as well as an index published by Employment Conditions Abroad (ECA), a London based organization. In addition, Summers and Heston (1991) incorporate information from the U.S. State Department on cross country differences in housing cost, as other post adjustment indices tend to be weak in this area.

2/ Domestic absorption was chosen instead of GDP because the real expenditure shares required for the intertemporal extension of PPPs relate to domestic absorption rather than GDP. See Summers and Heston (1984) and (1988).

3/ See footnotes to Table 2 for details of the methodology.

Table 2. Prediction Properties of Alternative Bridging Equations

	Percentage deviations between predicted and actual benchmark values of PPP based per capita GDP 1/	
	Mean deviation	Mean absolute deviation
1985 benchmark values of PPP-based per capita GDP derived from bridging equation for (dependent variable, sample):		
Price level, all countries in 1980 benchmark study 2/	29.83	33.79
Price level, developing countries in 1980 benchmark study 3/	26.74	28.81
PPP based per capita GDP, all countries in 1980 benchmark study 4/	-2.25	27.94
PPP based per capita GDP, developing countries in 1980 benchmark study 5/	-1.79	34.65
Memorandum:		
1985 benchmark values predicted by per capita GDP converted at market exchange rates	-61.22	61.22
1980 benchmark values predicted from bridging equation with exchange rate based domestic absorption as explanatory variable 6/	---	15.30
1980 benchmark values predicted from bridging equation with domestic absorption based on U.N. post-adjustment data as the explanatory variable 6/	---	12.30

1/ Percentage deviations were calcuated as: ((predicted-actual)/actual)*100. Means refer to arithmetic averages for a sample of 13 developing countries that were included in the 1985 benchmark study but not in the 1980 benchmark study. The bridging equations yield predictions for 1980 PPP-based per capita GDP which were extrapolated to 1985 using the growth rates of real per capita GDP from Summers and Heston (1991).

2/ Based on equation 1, Table 6 in the Appendix. The price level is defined as the ratio of the PPP rate to the market exchange rate. Predicted values for the price level were used to derive PPPs which then were used to convert per capita GDP in national currency.

3/ Based on equation 6, Table 6 in the Appendix.

4/ Based on equation 1, Table 7 in the Appendix.

5/ Based on equation 5, Table 7 in the Appendix.

6/ The mean absolute deviations reported here are taken from Kravis and Lipsey (1990), Table 3, who specified alternative bridging equations with PPP-based domestic absorption as the dependent variable. These bridging equations were estimated for two subsets of the 1980 (Phase IV) benchmark countries and the results were used to predict PPP-based domestic absorption for the other subset. GDP was derived by adding the foreign balance (converted at the market exchange rate) to domestic absorption.

4. Aggregation with PPP-based GDP weights

With 5 benchmark studies completed to date, ICP has produced estimates of PPP-based GDP for 80 countries for at least one, and in most cases several, benchmark years. Extended over time and to non-benchmark countries according to the methods described above, these data represent a possible alternative to exchange rate based GDP weights.

As a result of the regionalization of ICP, worldwide comparisons have unfortunately lagged behind. In 1986, the UN Statistical Office and the EC published an international comparison based on linked regional comparisons of the 1980 benchmark study. 1/ There is, to date, no similar comparison based on the 1985 benchmark results. However, Summers and Heston have produced a worldwide comparison based on ICP's detailed price and expenditure composition data. 2/ They have extrapolated the benchmark values according to the procedures described in section III.2 using growth from national accounts sources. In addition, they have estimated PPPs for non-benchmark countries on the basis of information on post-adjustment indices. These data are included in the Penn World Tables (PWT), the most recent of which is the Penn World Table Mark 5 (PWT5). PWT5 contains data on GDPs at constant international prices (PPP-based GDP) for 138 industrial and developing countries, with data for 80 countries based on ICP benchmark studies, including in some cases the 1985 benchmark data.

Estimates of GDP in terms of U.S. dollars, or any other common foreign currency, are particularly difficult to obtain for the formerly centrally planned economies. These countries typically used a large variety of exchange rates and special conversion factors, which made the conversion of national data into foreign currency virtually impossible. 3/ Given the difficulties of choosing among a large number of conversion factors, which bear no resemblance to market exchange rates, most attempts to derive GDPs in terms of a common foreign currency for the formerly centrally planned economies have relied on some approximation of PPPs. 4/

ICP benchmark data are available only for Hungary, Poland, and Yugoslavia for 1980. In addition, there are data for Romania from the 1975 ICP benchmark study. For Bulgaria, the Czech and Slovak Federal Republic

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1/ See United Nations and EUROSTAT (1986) and (1987).

2/ See Summers and Heston (1988) and (1991).

3/ In addition, national statistics in these countries were historically based on the net material product (NMP) concept, which covers only value added in the "material" sectors and thus excludes most services. However, while the problem of adjusting NMP data to a GDP concept can be solved in a relatively satisfactory manner, there is no generally accepted solution to the conversion problem. See Marer (1985) for a detailed discussion of this issue.

4/ See, for example, Alton (1989), Central Intelligence Agency (1990), and Planecon (1990).

(Czechoslovakia), and the former U.S.S.R., estimates of U.S. dollar GDP are available from a study published in 1980 by the United Nation's Economic Commission for Europe, which is based on the physical indicators global (PIG) method. 1/ The estimates of U.S. dollar GDP for the Eastern European countries and the former U.S.S.R. in PWT5 2/ are derived from these sources, and are thus broadly similar to other published estimates for these countries, which are based on the same sources. 3/

PWT5 does not provide data for all countries but relatively few and mainly small countries are excluded. For these countries, PPP-based GDPs were estimated on the basis of equation 1, Table 7 in the Appendix. All time series on PPP-based GDPs were extended using growth rates of real GDP from the WEO data base. 4/

The resulting set of PPP-based GDP weights is complete but not perfect. Estimates derived from ICP benchmark studies cover between three quarters (PPP-based GDPs) and 90 percent (exchange rate based GDPs) of world output, but only the estimates for the industrial countries are likely to be very reliable. The estimates for the developing countries are probably subject to much larger errors, reflecting the paucity of the data in many countries,

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1/ See Economic Commission for Europe (1980) as well as Fink and Havlik (1989) for a description of the PIG method. PIG estimates are usually adjusted to levels that are comparable to PPP-based estimates. This adjustment procedure is described in Alton (1989).

2/ In PWT5, data for Hungary, Poland and Yugoslavia are based on Phase V (1980) ICP benchmark estimates. For Bulgaria, Czechoslovakia, Romania, and the U.S.S.R., Summers and Heston provide only estimates of 1985 per capita GDP as a percentage of per capita GDP in the United States. For Bulgaria and Czechoslovakia, these estimates are derived from Economic Commission for Europe (1980); for the U.S.S.R. the figure is based on Edwards, Hughes and Noran (1979); the estimate for Romania is derived from the 1975 ICP benchmark study. (See Summers and Heston (1991), Appendix B for a more detailed description of the methodology.)

3/ See Alton (1989), Central Intelligence Agency (1990), and Planecon (1990). Discrepancies reflect differences in the growth rates that were used to extrapolate the data as well as differences in the adjustment of PPP and PIG method estimates. The estimates for the former U.S.S.R. by the Central Intelligence Agency are however derived independently and differ significantly from the other sources.

4/ These growth rates are not fully compatible with benchmark data because they incorporate expenditure weights based on national rather than international prices. However, the results from ICP benchmark studies suggest that the differences between the two sets of growth rates are usually not very large, and that differences tend to be significant only in those countries where the spread between growth rates derived from base and current period weights tends to be large. In the latter case, growth rates based on national price weights are also difficult to interpret. See Summers and Heston (1991) for a more detailed discussion.

and possibly also the effects of a potential bias in the structure of the estimated international prices toward the prices of large and/or rich countries. Errors are likely to be even larger for those countries whose PPP-based GDPs are derived from relatively simple bridging equations. 1/ However, while the errors for individual countries can be substantial, there is no indication that the estimates are systematically biased. Moreover, it appears that the available estimates for the developing countries are much closer to the "true" PPP-based GDPs than data converted at market (or official) exchange rates.

Table 3 compares, for illustrative purposes, the shares in world GDP based on PPP and WEO weights for major country groups in the World Economic Outlook. The most striking difference between the two weighting schemes is that PPP-based GDPs imply a substantial increase in the weight for the developing countries. In interpreting this result it is helpful to recall the "productivity difference model" discussed briefly in Section II.1, which suggests that GDP data converted at market exchange rates generally understate the position of countries with relatively low productivity and hence low per capita income, because the market (or official) exchange rates in these countries tend to be more depreciated than the PPP rates that would eliminate differences in price levels across countries. The difference between PPP-based GDP weights and WEO weights is particularly pronounced for the developing countries in Asia, whose share in world GDP in 1990 based on PPPs is more than three times larger than in the WEO weighting system. 2/ Between 1982 and 1990, the share of the developing countries in Asia in world GDP based on PPPs increased by 6 percentage points, reflecting the fact that real GDP growth during that time was well above the world average in many countries in East and Southeast Asia. By contrast, WEO weights, which are strongly influenced by movements in real exchange rates, suggest that the share in world GDP of the developing countries in Asia actually

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1/ While benchmark studies are available for most large developing countries, the estimate for China is based on a partial price survey in 1975 (see Kravis (1981)) and is subject to a much larger error margin than the estimates for other developing countries with benchmark studies. Moreover, given the large changes in relative prices in China in the 1980s, growth rates derived from national statistics are probably not very reliable.

2/ For Africa, the differences between PPP-based GDP weights and WEO weights are relatively small, and for the Middle East, the WEO weights are in some instances larger than the PPP-based weights, suggesting that in many countries in these regions, exchange rates have been more appreciated relative to the respective PPP rates than in other developing regions. This is also borne out by the results of the cross section estimations of price level equations discussed in the Appendix.

Table 3. Comparison of PPP-Based GDP Weights and WEO Weights
(In percent of world GDP)

	1982		1985		1990	
	PPP Weights	WEO Weights	PPP Weights	WEO Weights	PPP Weights	WEO Weights
WORLD	100.0	100.0	100.0	100.0	100.0	100.0
Industrial countries	53.5	71.5	52.9	70.8	51.1	76.3
Seven major industrial countries	46.0	60.4	45.6	61.4	44.1	65.8
Other industrial countries	7.6	11.0	7.3	9.3	6.9	10.5
European countries	21.0	30.9	20.2	25.6	19.2	29.6
European Community	18.8	27.2	18.1	22.4	17.2	25.9
Developing countries	46.5	28.5	47.1	29.2	48.9	23.7
By region						
Africa	3.7	3.1	3.4	3.0	3.2	2.2
Asia	17.3	7.4	19.5	7.9	23.3	7.2
Europe	12.2	7.8	12.1	7.5	11.4	6.0
Middle East	3.7	4.1	3.6	4.2	3.2	2.6
Western Hemisphere	9.5	6.2	8.5	6.7	7.8	5.7
By predominant export						
Fuel	8.9	7.4	8.1	7.7	7.4	4.8
Manufactures	20.4	10.9	22.2	11.2	25.5	10.8
Primary products	3.8	2.7	3.6	2.7	3.3	2.2
Services and private transfers	1.8	0.9	1.9	0.9	2.1	0.6
Diversified export base	11.4	6.7	11.2	6.7	10.6	5.3
By financial criteria						
Net creditor countries	2.7	3.5	2.6	3.5	2.3	2.4
Net debtor countries	43.8	25.1	44.5	25.7	46.7	21.4
Miscellaneous groups						
Sub-Saharan Africa	1.4	1.0	1.3	0.9	1.2	0.8
Four newly industrializing Asian economies	1.6	1.3	1.8	1.4	2.2	1.9
Small low-income economies	2.6	1.3	2.7	1.3	2.7	1.1
Fifteen heavily indebted countries	11.2	7.6	9.9	7.8	9.2	6.5
Eastern Europe	3.0	2.3	2.9	2.1	2.5	1.6
Eastern Europe and the USSR	11.3	7.2	11.2	7.0	10.4	5.6

declined during 1982-90. 1/ To illustrate the impact of PPP-based weights on aggregate real GDP growth for major country groups in the World Economic Outlook, the country data underlying the World Economic Outlook of October 1991 were re-aggregated using the set of PPP-based GDP weights described above. The results from this aggregation are summarized in Table 4. Table 5 presents the differences between these aggregates and the aggregate growth rates that were published in the World Economic Outlook of October 1991. For the years 1989-91, there is almost no difference between world real GDP growth derived from PPP-based weights and the growth rates based on current WEO weights. However, for the years 1982-88, PPP-based GDP weights yield world GDP growth rates that are generally higher than the growth rates derived from current WEO weights, with deviations averaging one half of one percentage point over the whole period 1982-91. This increase in average world GDP growth is due to the larger PPP-based GDP weight for the developing countries and the fact that these countries grew more rapidly than the industrial countries during 1982-88. In 1989-91, the growth differential between the industrial and the developing countries disappeared, and the impact of different weighting schemes on world GDP growth became negligible.

For the industrial countries as a group, the impact of PPP-based GDP weights on aggregate real GDP growth is marginal, with the exception of 1990-91. In these years, average GDP 2/ growth in the G7 countries derived from PPP-based weights is almost one half of one percentage point lower than the aggregate growth rates derived from current WEO weights, reflecting mainly differences in the relative weights of the United States and Japan. While the relative shares of both countries in total industrial country GDP are relatively stable over time when PPPs are used as conversion factors, there are large shifts in the corresponding shares in the current WEO weighting system, which is based on exchange rate conversion. In the WEO weighting system, the share of the United States in industrial country GDP declines by nearly 10 percentage points between 1986 and 1991, while the corresponding share of Japan increases by 5 percentage points. As a result, the current WEO weighting scheme implies a larger weight for Japan in 1990-91 and a lower weight for the United States than PPP-based GDP weights. As growth slowed significantly in the United States and remained strong in Japan in 1990-91, PPP-based GDP weights result in lower aggregate growth

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1/ The problem of fluctuating weights due to real exchange rate movements could be overcome by adopting exchange rate based weights with a fixed base year. However, as shown in Section II.2, movements in real exchange rates would then be reflected in large shifts in the weights each time the base year is changed.

2/ The WEO data base contains GNP data for the United States, Japan, and Germany and GDP data for all other industrial countries.

Table 4. Aggregate Real GDP Growth Rates Based on PPP Weights[1]
(Annual changes, in percent)

	Average [1982-91]	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
WORLD	3.5	1.1	3.0	5.0	4.1	3.8	4.3	5.1	3.3	2.2	1.0
Industrial countries	3.1	-0.4	2.6	4.7	3.4	2.7	3.4	4.5	3.2	2.2	1.0
Seven major industrial countries	3.1	-0.6	2.8	4.9	3.4	2.8	3.4	4.6	3.1	2.2	0.9
Other industrial count ries	2.7	0.6	1.4	3.3	3.1	2.5	3.0	3.4	3.8	2.4	1.4
European countries	2.6	0.8	1.7	2.4	2.5	2.8	2.8	3.9	3.4	2.6	1.2
European Community	2.6	0.8	1.6	2.3	2.4	2.8	2.9	4.0	3.5	2.7	1.3
Developing countries	4.0	2.8	3.3	5.4	5.0	4.9	5.3	5.8	3.4	2.1	1.0
By region											
Africa	2.2	1.9	-0.8	1.2	3.5	1.9	1.3	4.3	3.1	2.1	3.2
Asia	7.5	6.0	8.2	9.7	8.6	7.2	8.8	9.5	4.8	5.3	5.4
Europe	0.9	2.1	3.0	2.5	1.6	3.6	3.0	4.4	2.1	-2.3	-9.1
Middle East	1.1	1.0	1.2	1.3	2.1	0.5	2.1	1.1	4.1	-0.0	-2.1
Western Hemisphere	1.7	-0.9	-3.1	3.8	3.5	4.4	2.3	0.6	1.4	0.2	2.1
By predominant export											
Fuel	2.0	0.1	-1.3	2.4	2.5	1.5	1.0	2.2	3.8	3.1	2.9
Manufactures	6.3	4.8	6.2	9.2	8.8	7.2	8.0	7.9	3.7	3.0	3.1
Primary products	2.0	-1.4	0.1	2.9	1.3	4.7	3.2	0.5	0.5	1.8	3.3
Services and private transfer	4.2	4.6	3.6	4.9	4.0	4.9	6.5	4.6	4.2	3.0	2.5
Diversified export base	1.3	2.6	2.7	1.5	0.7	2.8	2.6	5.7	3.3	-0.6	-6.5
By financial criteria											
Net creditor countries	2.5	-0.3	2.8	1.4	1.5	0.2	0.8	1.8	4.4	4.8	4.8
Net debtor countries	4.1	3.0	3.4	5.7	5.2	5.2	5.5	6.0	3.4	2.0	0.8
Miscellaneous groups											
Sub-Saharan Africa	2.1	2.4	-0.1	0.8	2.9	3.5	2.7	2.8	2.4	1.9	2.4
Four newly industrializing Asian economies	8.4	5.5	9.7	9.6	4.5	11.3	12.2	9.7	6.1	6.8	6.0
Small low-income economies	3.6	4.1	2.7	3.6	3.8	4.2	3.5	3.5	3.7	3.7	3.4
Fifteen heavily indebted countries	1.5	-0.3	-3.0	2.5	3.4	4.3	1.9	1.6	1.8	0.1	1.3
Eastern Europe	-0.6	-0.0	2.2	4.4	2.7	3.2	1.7	1.4	-0.4	-7.9	-11.8
Eastern Europe and the USSR	0.5	1.8	2.9	2.3	1.3	3.3	2.6	4.4	2.2	-3.3	-10.4

[1] Weights based on GDPs in terms of constant international prices.

Table 5. Differences Between Aggregate Real GDP Growth Rates Based on PPP Weights and on WEO Weights
(In percentage points)

	Average [1982-91]	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
WORLD	0.5	0.7	0.5	0.6	0.7	0.7	0.8	0.8	0.0	-0.0	0.2
Industrial countries	-0.1	-0.2	0.0	-0.0	-0.0	0.0	0.0	-0.1	-0.1	-0.3	-0.3
Seven major industrial countries	-0.1	-0.2	0.0	-0.0	-0.0	0.0	-0.0	-0.1	-0.2	-0.4	-0.4
Other industrial countries	0.0	0.0	-0.1	-0.2	-0.1	0.0	0.1	0.1	0.1	0.0	0.1
European countries	-0.0	0.0	-0.1	-0.1	0.0	0.0	0.1	0.1	-0.0	-0.1	-0.1
European Community	-0.0	0.0	-0.0	-0.0	0.0	0.0	0.1	0.1	-0.0	-0.1	-0.1
Developing countries	1.3	0.8	1.2	1.5	1.4	0.9	1.4	1.9	0.2	1.1	1.6
By region											
Africa	0.0	0.2	0.1	0.4	-0.5	0.4	0.3	0.2	-0.4	-0.0	0.0
Asia	0.5	0.4	0.2	1.3	1.7	0.4	0.7	0.5	-0.6	-0.2	0.4
Europe	0.1	0.0	0.1	-0.1	-0.0	0.1	0.1	0.1	0.2	0.4	0.4
Middle East	0.8	0.3	1.1	0.9	0.7	0.7	0.5	2.2	-0.5	-0.8	1.9
Western Hemisphere	0.2	0.3	-0.3	0.0	0.2	-0.3	-0.1	0.5	-0.0	1.1	0.9
By predominant export											
Fuel	0.8	-0.4	0.1	1.2	0.2	0.8	0.3	1.5	-0.2	0.6	2.6
Manufactures	1.5	1.0	1.4	1.7	1.7	0.4	1.6	2.3	0.1	1.9	2.1
Primary products	0.3	0.9	-0.0	0.1	0.9	-0.0	0.2	0.5	0.7	0.4	-0.2
Services and private transfer	0.5	0.2	0.6	1.1	0.9	-0.1	0.5	0.3	0.6	0.5	-0.2
Diversified export base	0.1	0.1	0.2	-0.2	0.1	0.2	-0.0	0.0	0.1	0.2	0.2
By financial criteria											
Net creditor countries	0.5	-0.5	0.6	0.9	0.3	1.0	0.9	1.5	-0.2	-0.7	0.3
Net debtor countries	1.2	0.7	1.3	1.3	1.3	0.6	1.2	1.7	0.3	1.5	2.0
Miscellaneous groups											
Sub-Saharan Africa	-0.1	0.3	-0.4	-0.3	-0.7	0.2	0.4	0.2	-0.4	-0.1	0.1
Four newly industrializing Asian economies	0.0	-0.0	0.1	-0.0	0.0	0.2	0.1	0.2	-0.3	0.1	-0.2
Small low-income economies	0.4	0.5	0.6	0.6	0.3	0.2	0.3	-0.0	0.4	0.5	0.2
Fifteen heavily indebted countries	0.2	0.2	-0.1	0.2	-0.2	-0.2	-0.0	0.4	0.0	1.0	0.7
Eastern Europe	0.1	-0.3	0.1	-0.1	0.0	-0.1	0.1	0.1	0.3	0.0	0.2
Eastern Europe and the USSR	0.1	0.0	0.1	-0.2	-0.1	-0.0	0.0	0.1	0.2	0.3	0.1

rates for both years for the G7 countries and, consequently, for the industrial countries as a group. 1/

For the developing countries as a group, PPP-based GDP weights result in substantial increases in aggregate GDP growth rates, averaging well over one percentage point in 1982-91. These increases reflect mainly a larger weight for the developing countries in Asia, many of which have been growing at considerably faster rates than the countries in other developing regions during 1982-91. Even though PPP-based GDP weights imply larger shares in world GDP for all developing regions, they only imply a larger share in total developing country GDP for Asia. For all other developing regions, the corresponding shares in total developing country GDP are smaller than in the current WEO weighting system.

IV. Conclusions

The available evidence on the relationship between exchange rates and PPPs suggests that exchange rates are poor proxies for the PPPs that are required to derive internationally comparable national income data. Even so, exchange rate based GDP weights in a variety of forms are widely used in aggregations of output growth and related economic data. The choice among these various sets of exchange rate based GDP weights is largely arbitrary, but it can have a significant impact on aggregate indicators of economic activity.

Estimates of PPP-based GDPs are a valuable alternative to conventional exchange rate based weighting systems and have been used for several years by institutions such as the EC Commission and the OECD, albeit only for industrial countries where relatively reliable PPP estimates have been available for some time. PPP estimates for many developing countries are no doubt considerably weaker, and deviations from "true" PPPs are likely to be even larger for the countries where benchmark studies are not available. However, notwithstanding these shortcomings, the PPP-based GDP weights considered in this paper are probably a better measure of real output shares than exchange rate based GDPs, which are likely to be biased due to systematic discrepancies between PPPs and exchange rates.

The PPP estimates discussed in this paper are conversion factors for GDP and related economic data. As such they are broadly defined for a whole range of prices of tradables and nontradables. They are unrelated to and should not be confused with the concept of equilibrium exchange rates. Also, PPPs are not necessarily the right conversion factors for all purposes. Conversion and aggregation of international transactions valued at current market prices, such as current account and capital flows, require conversion factors that reflect the actual price at which one currency is

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1/ It should be noted that real GDP weights based on market exchange rates with 1985 as the base year generate aggregate GDP growth rates for the G7 countries that are similar to those derived from PPP-based weights.

exchanged against another currency in foreign exchange markets, i.e. market exchange rates.

Bridging Equations for Non-Benchmark Countries

This appendix summarizes the results from cross section estimations of equations that relate the price level, defined as the ratio of PPP to the market (or official) exchange rate, and PPP-based per capita GDP to a few readily observable explanatory variables. These equations can be used as "bridging equations" to derive PPPs or PPP-based GDPs for countries that were not included in ICP benchmark studies. The selection of explanatory variables is based on the theoretical arguments and the empirical research summarized in section III.3. The following variables were included:

-- Real per capita GDP, which is frequently used as a proxy for the productivity level, the main variable explaining cross country differences in price levels according to the productivity difference model. 1/ Its coefficient is expected to be positive.

-- Openness, which is defined as the ratio of exports and imports of goods and services to GDP. This variable has been found significant in explaining price levels in several studies by members of the ICP team. 2/ Kravis and Lipsey (1983) argue that, ceteris paribus, a high degree of openness tends to raise the price of the abundant factor and thus implies higher prices for non-tradables in relatively labor-abundant countries and lower prices for non-tradables in capital-abundant countries. As countries' price levels are generally expressed relative to the price level of the United States, one of the most capital-abundant countries, the effect of the degree of openness on the price level is expected to be positive. 3/

-- Money growth, which can be relatively easily identified among the various transitory factors influencing price levels. 4/ In the context of models of exchange rate overshooting, relatively high money growth is expected to lower the ratio of PPP to the exchange rate due to a depreciation of the nominal exchange rate which is not immediately matched by a corresponding change in prices. 5/

1/ While PPP-based per capita GDP is a more appropriate proxy for the productivity level, GDP converted at market (or official) exchange rates is included in bridging equations that are used to predict PPPs for non-benchmark countries.

2/ See Kravis, Heston and Summers (1978a), Kravis and Lipsey (1983), and Summers and Heston (1984).

3/ Clague (1988) has pointed out that the degree of openness itself is an endogenous variable and that the relationship between the price level and the degree of openness ultimately depends on the factors that determine the degree of openness of an economy.

4/ Money growth is expressed in terms of deviations from trend growth, with the latter defined as a three year moving average of the rate of change of broad money.

5/ See Dornbusch (1976).

In order to allow for the possibility of different intercepts for the industrial and the developing countries, a dummy variable for the developing countries was included in the equation that were estimated for the full sample of industrial and developing countries. Moreover, results from earlier empirical studies suggest that price levels are on average higher--and spreads between PPP-and exchange rate-based GDPs consequently smaller--in Africa than in other developing regions. Ideally, this phenomenon should be explained by the bridging equations, and attempts were made to incorporate variables representing factors such as exchange regimes and structural characteristics of the external sector. 1/ However, possibly due to the paucity of the data, these variables contributed much less to the overall explanatory power of the equations than a simple dummy variable for Africa.

Estimation results for the price level equations are summarized in Table 6. The equations were estimated for the two samples of countries covered by the 1980 and 1985 ICP benchmark studies, and for two samples that include only the developing countries in each benchmark study. The estimated equations explain more than two thirds of the cross country variation in price levels, somewhat less if only developing countries are considered. The coefficients of per capita GDP are significant and have the expected sign in all equations. They are also relatively stable for the majority of the equations. 2/ By contrast, the intercept is generally smaller in the equations that were estimated for the sample of developing countries only--an effect that is not fully captured by the dummy variable in the equations for the full sample. The coefficients of the variable representing openness are significant but negative, while differences in money growth do not appear to contribute to the explanation of cross country variation in price levels. 3/ The results confirm the finding of earlier studies that African countries tend to have relatively high price levels given their per capita GDPs.

1/ More elaborate models were not feasible because of data limitations, particularly for those countries whose PPPs have to be predicted by the bridging equations.

2/ It should be noted that the coefficient of the per capita GDP variable may be biased upward because using exchange rate based GDP instead of PPP-based GDP as the explanatory variable is likely to result in measurement errors that are positively correlated with the dependent variable.

3/ The negative coefficient of the openness variable may be due to a bias resulting from measurement errors that are negatively correlated with the dependent variable. With openness defined as the ratio of exports and imports to GDP converted at market (or official) exchange rates, and the price level defined as the ratio of PPP to the exchange rate, an overvalued exchange rate would be reflected in a relatively low degree of openness and a relatively high price level.

Table 6. Bridging Equations for the Price Level

(Dependent variable: ln (PL))

Equation No.	Constant	ln (GDPPC)	ln (OP)	M2	DD	DA	R^2	S.E.E.
			Sample: 1980 benchmark study--all countries (57 observations)					
1.	2.19	0.29	--	--	-0.19	0.40	0.72	0.217
	(5.53)	(6.57)			(1.89)	(4.52)		
2.	1.96	0.31	-0.07	-0.0046	-0.16	0.43	0.74	0.211
	(4.82)	(7.01)	(1.15)	(1.73)	(1.57)	(4.86)		
			Sample: 1985 benchmark study--all countries (47 observations)					
3.	1.94	0.27	--	--	-0.13	0.18	0.70	0.256
	(6.80)	(7.93)			(1.24)	(1.83)		
4.	1.42	0.32	-0.21	--	--	0.17	0.77	0.226
	(6.53)	(11.67)	(3.73)			(2.02)		
5.	1.42	0.31	-0.21	0.0024	--	0.16	0.76	0.228
	(6.49	(11.48)	(3.73)	(0.52)		(1.90)		
			Sample: 1980 benchmark study--developing countries (41 observations)					
6.	1.33	0.36	-0.23	--	--	0.52	0.54	0.212
	(3.34)	(7.03)	(3.00)			(5.41)		
7.	1.31	0.37	-0.21	-0.0041	--	0.52	0.56	0.208
	(3.37)	(7.24)	(2.77)	(1.55)		(5.49)		
			Sample: 1985 benchmark study--developing countries (36 observations)					
8.	0.72	0.39	-0.37	--	--	0.34	0.67	0.211
	(2.06)	(8.49)	(5.36)			(3.99)		
9.	0.71	0.39	-0.37	-0.0003	--	0.34	0.66	0.214
	(1.86)	(7.64)	(5.24)	(0.06)		(3.75)		

Notes: T-values are indicated in parentheses below the coefficients. The variables are defined as follows:

PL: Price level, defined as the PPP rate divided by the market exchange rate (national currency per U.S. dollar), multiplied by 100.
GDPPC: Per capita GDP in terms of U.S. dollars, derived by converting GDP in national currency at the market (or official) exchange rate.
OP: Openness, defined as the ratio of exports and imports of goods and nonfactor services to GDP.
M2: Annual rate of change of M2 (in percent) minus trend growth of M2, where the latter is a three-year moving average of annual rates of change of M2.
DD: Dummy variable for developing countries.
DA: Dummy variable for African Countries.

Data sources: Price level data from Summers and Heston (1991); all other data from WEO data bank.

APPENDIX

Table 7 summarizes estimation results for a set of equations that include PPP-based per capita GDP directly as the dependent variable. The results suggest a close relationship between exchange rate based and PPP-based per capita GDPs, but a 10 percent difference in the former would only correspond to a 6-7 percent difference in the latter, confirming earlier findings that cross country differences in per capita GDPs tend to be smaller when PPPs are used to convert GDPs into a common unit of account. The coefficient of the openness variable is only significant in the equations that were estimated for the samples of 1985 benchmark countries; its positive sign is consistent with the negative sign in the price level equations. The dummy variable for Africa is again significant in most equations. A comparison of equations with similar specifications across samples (for example, equations 2 and 6, and equations 1 and 3) suggests that the coefficients of the main explanatory variable do not vary significantly.

Table 7. Bridging Equations for PPP Based per Capita GDP

(Dependent variable: ln (RGDPPC))

Equation No.	Constant	ln (GDPPC)	ln (OP)	DD	DA	$\bar{R}^2$	S.E.E.
		Sample: 1980 benchmark study--all countries (57 observations)					
1.	2.99	0.69	--	--	-0.19	0.94	0.234
	(11.52)	(21.27)			(2.10)		
2.	2.71	0.73	0.057	0.12	-0.19	0.94	0.233
	(6.03)	(14.82)	(0.84)	(1.10)	(1.91)		
		Sample: 1985 benchmark study--all countries (47 observations)					
3.	2.57	0.74	--	-0.17	-0.15	0.94	0.269
	(8.57)	(20.47)		(1.53)	(1.44)		
4.	2.97	0.71	0.19	--	--	0.95	0.250
	(14.83)	(26.87)	(3.14)				
		Sample: 1980 benchmark study--developing countries (41 observations)					
5.	2.14	0.81	--	--	--	0.89	0.263
	(6.90)	(17.95)					
6.	2.68	0.75	0.077	--	-0.16	0.89	0.263
	(5.43)	(11.69)	(0.82)		(1.36)		
		Sample: 1985 benchmark study--developing countries (36 observations)					
7.	2.50	0.76	--	--	--	0.86	0.307
	(7.47)	(14.81)					
8.	3.97	0.60	0.37	--	-0.34	0.92	0.230
	(10.43)	(12.01)	(4.98)		(3.66)		

Notes: T-values are indicated in parentheses below the coefficients. RGDPPC is PPP-based per capita GDP from Summers and Heston (1991), defined as per capita GDP valued at constant 1985 international prices. For definitions and sources of all other variables see notes to Table 6.

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