

Sources of Variability in Purchasing Power Parities

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A. Overview

Global Purchasing Power Parity (PPPs) for the Gross Domestic Product (GDP) and aggregates are a statistical construct calculated in stages, each with sources of variability. The purpose of this note is to provide an overview of these sources of variability and offer suggestions for additional analysis. The first stage of estimation begins within region at the basic heading level where product prices are compared to estimate basic heading PPPs which are then aggregated to major aggregates and the GDP, still within region. Then, between region basic heading PPPs are estimated using prices from the core list. These between region PPPs are used at the basic heading as linking factors by multiplying them times the within region PPPs to calibrate them to the global level. These global basic heading PPPs are then aggregated to the GDP and then real expenditures are distributed to regions to maintain fixity.

The ICP is a statistical system with data variability present in every computational step. Because price levels and economic structures greatly vary between countries, it can be difficult to identify data problems. The purpose of this analysis is to take a deeper look at the sources of data variability at major levels of estimation to assess the overall quality of the results and identify areas where data quality can be improved. Briefly, the sources of statistical variability are described in Chapters 7 and 9 in “Measuring the Real Size of the World Economy” (World Bank 2013).

B. Variability of Product Prices and within region basic heading PPPs.

A first step is to review the variability of product price ratios (product PPPs) and the PPP adjusted product prices within basic headings. This analysis identifies products and/or prices that are outside the ranges exhibited by other products in the basic heading. These measures also provide an indication of the specificity of the price determining characteristics and whether enough products were priced. This analysis (World Bank 2013-ICP Book page 201) can be applied to the basic heading PPPs derived from the within region comparison, and again to the global core list. Outcomes of this review would be:

- a. Countries/ Products/prices not consistent with other countries and products.
- b. Products identified that provide between region PPPs not consistent with within region PPPs.
- c. Recommendations on the number of products to price by basic heading for the within region basic heading and the between region PPPs

The analysis to follow begins with examining the variability in the basic heading linking factors in each region. The remaining analysis is limited to the Global basic heading PPPs and the global aggregation process. The note concludes with suggestions for additional analysis of the within region results.

C. Variability of Between Region Basic Heading PPPs--Linking Factors

This analysis was based on the 154 Basic Heading between region PPPs (linking factors) for Africa, Asia, Eurostat-OECD, Latin America, and Western Asia with Eurostat-OECD equal 1.00. The CIS region was linked through Russia which participated in both the Eurostat-OECD and CIS comparisons. The basic heading linking factors for the CIS were the Russia basic heading PPPs from the Eurostat-OECD comparison; these multiplied times the CIS basic heading PPPs (Russia = 1.0) calibrated the CIS region to the global comparison. The Caribbean region was calibrated to the global comparison by linking through the Latin American region.

Column (a) in Table 1 shows the 95 confidence intervals for the linking factors by region (and Russia) which provide a measure of the variability of the basic heading linking factors. Columns (b) and (c) show the maximum and minimum linking factors in each region and column (d) their ratio. The maximum values are considerably outside the confidence interval in all regions, thus can be considered to be outliers deserving additional review.

Region	95 % Confidence interval	Maximum BH linking factor	Minimum BH linking factor	Max/Min ratio
	(a)	(b)	(c)	(d)
Africa	0-12.41	28.01 ¹	.70 ⁶	39.81
Asia	0-12.50	22.60 ²	1.67 ⁷	13.50
CIS (Russia)	1-37.0	46.0 ³	3.4 ⁸	14.0
Eurostat/OECD	--	1.00	1.00	1.00
Latin America	0-3.21	4.65 ⁴	.249 ⁹	18.65
Western Asia	.137-.491	2.00 ⁵	.031 ¹⁰	64.16
Basic headings with largest values: 1) Electricity & gas, 2) Gas, 3) Transport by air 4) Jams & Honey' 5). Basic headings with smallest values: Eggs, 6) Passenger transport by railroad, 7) Bicycles, 8) Compensation of employees, 9) Compensation of Employees, 10) Medical services				

Western Asia and Africa show the most variability as measured by the ratio of the maximum to minimum PPPs. The largest PPP in Western Asia was 64 times larger than the minimum value. A more detailed review of the data reveals that electricity and gas basic heading PPPs are problematic in most regions suggesting those specifications be reviewed. The following review will also show that the basic heading—transport by air—is also problematic and is the maximum value coming from the Russia linking factors. Finally, in many cases the maximum and minimum values are outliers with considerable distance between them and the next largest

or smallest numbers. The conclusion is that the between region PPPs need additional validation.

The next step in the estimation process is to calibrate the within region PPPs to a global base country. The between region basic heading PPPs are scalar values applied to the within region PPPs in every country to calibrate them to the US=1.00.

D. Variability of Basic Heading PPPs after Linking

Table 2 shows the variability of the global basic heading PPP after the linking stage. The file for this analysis is the matrix of 154 basic heading PPPs for all countries calibrated to the US as base = 1.00. These global basic heading PPPs are the within region PPPs multiplied by the between region linking factors. This analysis includes the CIS and Caribbean regions which were linked respectively by Russia and Latin America.

For each country, the ratio of the maximum to minimum global basic heading values was computed. Column (a) shows the geo mean of the maximum/minimum ratios across all countries in the region. In Asia, on the average, the smallest and largest basic heading PPPs differ by a factor of 50. Column (b) shows the 95 % confidence interval of the max/min ratios for the region. Column (c) shows the largest max/min ratio within the region and column (d) the country with that value. The Eurostat-OECD region shows the least variability in basic heading PPPs; however, it still has one country that is a significant outlier. These large max/min values are considerably outside the 95 % confidence interval indicating further review of these countries' results is needed.

	Geo Mean Max/min ratios*	95% confidence interval	Largest Max/min ratio	Country with largest max/min ratio	Smallest Max/min ratio	Country with smallest max/min ratio
	(a)	(b)	(c)	(d)	(e)	(f)
Africa	36	2-34	93	Equatorial Guinea	13	Botswana
Asia	50	1-76	141	Indonesia	14	Hong Kong
CIS	50	1-158	258	Tajikistan	14	Russia
Eurostat/OECD	9	1-18	53	Albania	1	US

Latin America**	35	1-126	275	Venezuela	14	Uruguay
Caribbean	27	1-42	101	Grenada	13	Virgin Islands
Western Asia	38	1-58	124	Kuwait	15	United Arab Emirates
*Geo mean of country max/min ratios **Does not include Cuba with Max/min ratio =583						

Table 3 provides a further examination of these and other countries with the greatest variability in basic heading PPPs. Column (a) shows the max/min ratio for each country. Note that the ratio of the largest and smallest basic heading PPPs becomes as large as 275 in Venezuela followed by Tajikistan at 258. Columns (b) and (c) show the basic headings with the largest and smallest PPPs. Note that the basic headings for wine, motor cars, and transport by air had the largest values in more than one country suggesting a further review of those product specifications. A more in-depth review of the maximum values shows that the next largest PPP is many times smaller than the largest value making the maximum values true outliers. The minimum values mainly apply to government services; an interesting outcome given that they have been adjusted for productivity. The large max/min ratio for Venezuela is caused by the minimum value of .06 for fuels and lubricants; not representative of its PPP levels.

Also note that the variability between the basic heading PPPs is much greater than the between region PPPs. The question is whether the maximum and minimum values are plausible and reasonable given the countries in the regions. And were the maximum and minimum values a result of the linking process?

Country	Max/min ratio	Basic Headings with largest PPPs	Basic Headings with smallest PPPs
	(a)	(b)	(c)
Equatorial Guinea	93	Eggs	Out Patient services
Indonesia	141	Wine	Medical services
Lao	113	Wine	Education
Mynmar	118	Wine	Other fuels
Nepal	107	Motor Cars	Medical services
Vietnam	112	Motor Cars	Medical services
Tajikistan	258	Transport by air	Compensation of employees
Albania	53	Transport by air	Education
Venezuela	275	Frozen & preserved fruit	Fuels/lubricants

Grenada	101	Tools & Equipment	Education
Kuwait	124	Other services	Electricity

A concluding point, however, is how does the variability of the basic heading linking factors affect the variability between global basic heading PPPs? Does the distribution of the linking factors increase or decrease the variability in the global basic heading PPPs? And, should some countries be excluded from the initial estimation phase as being too different from the rest of the countries?

E. Variation at the Aggregation Stages

A major change for ICP 2011 was how basic heading PPPs were aggregated to the GDP and major aggregates. In 2005, each level of aggregation was at the within region level, and the between region linking factors were also aggregated to each level to calibrate them to the US =1.00.

The aggregation to the GDP in 2011 was done in stages starting with the 148 countries in Africa, Asia, Eurostat-OECD, Latin America, and Western Asia. The remaining countries were brought in so that their results did not impact the first 148 countries.

A direct aggregation was made across the 148 countries following the within region process of first computing the Fisher matrix, then using the GEKS method to make the PPPs transitive and base country invariant.

This begins with the matrix of bilateral basic heading PPPs for each country with the 147 other countries. For each pair of countries (a and b), there is the set of basic heading PPPs and basic heading expenditures for country a and for country b. The basic heading PPPs are first averaged to the GDP and major aggregates using country a's weights (Laspeyres index), then using country b's weights (Paasche index). The geo mean is taken of the Laspeyres and Paasche indexes. The outcome is the Fisher index of aggregated PPPs between every pair of countries which in 2011 included 148 countries.

The ratios of the Laspeyres and Paasche indexes provide a measure of variability. If the basic heading price levels and their distribution across the basic headings are similar, then the ratio will approach 1.0. If the economies differ in price levels and structure, then the ratios become larger. It also may mean the data need additional review and validation.

Table 4 shows the countries with the largest L/P ratios on the average, their maximum value and the country pair with that value. For example, the Fisher matrix contains the bilateral PPP between Burundi and each of the other 147 countries. The geo mean of these ratios for Burundi was 1.51 meaning on the average the L/P ratio was 1.5. Of the 147 L/P ratios for Burundi with all other countries, the largest was 3.03 for the Burundi-Venezuela bilateral PPP. Note that Venezuela is the bilateral country associated with the largest L/P ratio in 4 additional countries shown.

Table 4. Countries with largest L/P ratios			
Country	Geomean of L/p	Max L/p	Country pair with max
Burundi	1.51	3.03	Venezuela
Comoros	1.57	3.45	Bahrain
Gambia	1.45	3.01	Venezuela
Madagascar	1.32	3.01	Venezuela
Rwanda	1.73	3.69	Venezuela
Uganda	1.42	3.05	Venezuela
Cambodia	1.39	2.76	Bahrain
Japan	1.39	2.63	Comoros
Venezuela	1.91	3.69	Rwanda
Bahrain	1.70	3.45	Comoros
Data—Matrix of 148x148 binary Fishers, Laspeyres and Paasche PPPs, and L/P Ratios across all countries			

Recall from above that Venezuela had the most variability of its PPPs across the basic headings. A brief review of Venezuela expenditures also shows, for example, that expenditures for actual and imputed housing are only a third of expenditures for catering services suggesting those be reviewed again.

The next step in the aggregation is to compute the multilateral PPPs for each country to the base US = 1.00. The matrix of 148 countries has for each country a column containing the direct PPP to the US and 146 columns of indirect PPPs of each country to the US through each of the other countries. The GEKS multilateral PPP for each country is the geo mean of the its direct PPP to the base and to the indirect PPP through each of the n-2 other countries; in this case 146 countries. This means that the PPP of China to the US is determined not only by the direct comparison, but by the indirect PPPs of China to every other country in the comparison.

Table 5 shows the variability of the direct and indirect PPPs based on the ratios of the maximum to minimum values. For each country, the ratio of the largest indirect PPP to the smallest indirect PPP (max/min ratio) was computed. For each region, the geo mean of the country max/min ratios and the standard deviations are shown in columns (a) and (b).

Table 5. Variability in direct and indirect bilateral PPPs—148 countries—measured by ratio of maximum PPP to minimum PPP for each country.					
Region	Geomean of max/min PPPs in region	Standard deviation of max/min PPPs in region	Country in each region with largest Max/min ratio	Country largest indirect PPP with country in column (c)	Country with smallest indirect PPP with (c)

	(a)	(b)	(c)		(e)	(f)
Africa	1.61	.10	Burundi	1.87	Lithuania	Liberia
Asia	1.43	.11	Nepal	1.68	Luxembourg	Sierra Leone
Eurostat/OECD	1.32	.08	Albania	1.48	Kuwait	Liberia
Latin America	1.37	.08	Nicaragua	1.51	Venezuela	Liberia
Western Asia	1.45	1.47	Yemen	1.54	Mauritania	Liberia

Column (c) shows the country in region with the largest max/min ratio and the respective countries with which it has the largest and smallest indirect PPPs.

Note that the variability at this stage is considerably less than that in the previous stages. However, it does raise the question whether some countries have price levels and economic structures so different that they should be excluded from the first aggregation; or is it a data quality issue suggesting more validation be done. The countries shown as outliers do have price and economic structures different than the norm. Should the PPP of Nepal to the US be affected by the indirect PPPs of Nepal to Luxembourg and Nepal to Sierra Leone?

Table 6 provides a summary view of the sources of variability. Column (a) shows the final ICP PPPs for selected countries. Columns (b) and (c) show the variability in 155 basic heading and 20+ published aggregated PPPs. The maximum PPPs are generally for machinery and equipment and the minimum for health and education. The point is the user needs to consider the use to be made of the data and choose the appropriate PPPs for the analysis instead of only using PPPs at the GDP level. Section D above contains a brief description of the Fisher index which is the direct PPP between countries before applying the multilateral methods. Column (d) shows the Laspeyres/Paasche ratio, which is a measure of the difference in the aggregated PPPs based on which country's weights were used. As economies become more diverse in their price and economic structure, the ratio increases. As described above, the geo mean of the two aggregated PPPs becomes the bilateral Fisher index which is not affected by indirect comparisons with other countries. Note that the smaller Fisher PPPs, column (e), compared to the final ICP PPPs imply larger real expenditures for those countries.

Table 6. ICP PPPs, variability of global basic heading and aggregate PPPs, the Laspeyres/Paasche ratio, and Fisher, GEKS with no fixity, and IKLE PPPs.

	ICP PPPs CAR	Basic Heading CVs ¹	Aggregate CVs ²	L/P Ratio	Fisher PPPs ³	GEKS PPPs, no fixity ⁴	IDBM ⁵
	(a)	(b)	c	d	e	f	g
US	1.00	1.00	1.00	1.00	1.00	1.00	1.00
China	3.51	.75	.42	1.17	3.42	3.46	3.50
India	15.11	1.00	.62	1.39	14.93	14.83	14.97
Russia	17.35	.49	.48	1.03	16.84	16.50	16.32
Brazil	1.47	.52	.47	1.29	1.47	1.45	1.49
S. Africa	4.77	.68	.34	1.19	4.79	4.76	4.93

- 1) Standard deviation of basic heading PPPs/geomean of basic heading PPPs
- 2) Standard deviation of aggregated PPPs/ geomean of PPPs
- 3) Direct PPP between the US and selected countries before applying GEKS
- 4) GEKS before applying CAR to preserve within region fixity.
- 5) Real expenditures are additive

Column (f) provides PPPs resulting if the fixity requirement was removed. Note the smaller PPPs compared to the final ICP numbers imply larger real expenditures without the fixity requirement. Finally, column (g) shows PPPs from the IKLE method, which provides additive results. It is noteworthy that the Gerschenkron impact would be small for these countries.

F. Conclusions and Recommendations

There are significant outliers (countries and basic headings) for linking factors and global basic heading PPPs. Some countries are also outliers as measured by the Laspeyres/Paasche ratios from the aggregation to the bilateral Fisher PPPs. The GEKS stage results are more robust, but with variability in the indirect PPPs.

Several recommendations follow.

- Basic Heading linking factors: Review basic headings with greatest deviations from the averages
- Global Basic Heading PPPs: Review outliers. Also do same analysis of within region PPPs to determine if the variation in global PPPs comes from the regions or the linking factors or some combination.
- Aggregation to the Fisher Index—do same analysis within each to compare variation in the the L/P ratios between the within region and global results. Also, review distribution of expenditure weights for outliers.
- GEKS—do analysis of indirect PPPs within each region.

The questions remaining are about the role of the linking PPPs in the estimation of global PPPs. Do weak links need to be identified and removed, or is it a data quality issue? The suggestion is that it first be addressed as a data quality issue.

References:

World Bank 2013. *Measuring the real Size of the World Economy: The Framework, Methodology, and Results of the International Comparison Program*. Washington, DC: World Bank

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