Review of Income and Wealth
Series 56, Special Issue 1, June 2010

NEW METHODOLOGICAL DEVELOPMENTS FOR THE INTERNATIONAL COMPARISON PROGRAM

by Erwin Diewert*

University of British Columbia

The paper explains new methodology that was used in the 2005 International Comparison Program (ICP) that compared the relative price levels and GDP levels across 146 countries. In this round of the ICP, the world was divided into six regions: OECD, CIS, Africa, South America, Asia Pacific, and West Asia. What is new in this round compared to previous rounds of the ICP is that each region was allowed to develop its own product list and collect prices on this list for countries in the region. The regions were then linked using another separate product list; 18 countries across the six regions collected prices for products on this list and this information was used to link prices and quantities across the regions. An additional complication was that the final linking of prices and volumes across regions had to respect the regional price and volume measures that were (separately) constructed by the regions. The paper also studies the properties of the Iklé–Dikhanov–Balk multilateral system of index numbers which was used by Africa.

1. Introduction

The final results for the 2005 International Comparison Program (ICP) were released in February; for a tabulation of the results, see World Bank (2008). The program compared the level of prices and the quantities or volumes of GDP (and its components) for 146 countries for the year 2005. International price statisticians developed Structured Product Descriptions (SPDs) for approximately 1,000 products[1] and the individual countries collected price information on these products for the year 2005. The 1,000 products were grouped into 155 Basic Heading (BH) categories. The price information collected in each country was then compared across countries, leading to a matrix of 155 basic heading prices by 146 countries. The precise way in which the individual product prices in each BH category were aggregated into a single country price for each BH heading is the topic which will be investigated in Sections 2 and 3.

Note: This is a revised version of a paper presented at the Joint UNECE/ILO Meeting on Consumer Prices Indices, May 8–9, Palais des Nations, Geneva. The author thanks Bert Balk, Yonas Biru, Yuri Dikhanov, Louis Marc Ducharme, Alan Heston, Peter Hill, Robert Hill, Alice Nakamura, Sergey Sergeev, Fred Vogel, and Kim Zieschang for helpful discussions and comments, and the World Bank for financial support. None of the above are responsible for any opinions expressed by the author. For a less technical version of this paper, see Diewert (2008a), and for a longer version that includes an appendix which looks at the properties of the relatively new Iklé–Dikhanov–Balk multilateral system used by the African region, see Diewert (2008b).

*Correspondence to: Erwin Diewert, Department of Economics, The University of British Columbia, Vancouver V6T 1Z1, Canada (diewert@econ.ubc.ca).

[1]Most of the products referred to are components of individual consumption: "There are about 830 SPDs that cover 100 Basic Headings for individual consumption. Each SPD contains price determining characteristics that will define unique products from any corner of the world" (Trewin, 2008, p. 8). For an overview of the organization and methodology used in the 2005 ICP, see Vogel (2008).

The 2005 ICP differed from previous ICP rounds.[2] In previous rounds, each country attempted to find prices in their country for a common product list. However, it is difficult to find products that are representative for *all* countries in the world, and so the decision was made to break up the world into six regions; price statisticians developed *separate* product lists for each region. The six regions were: (1) Africa with 48 participating countries; (2) South America with 10 countries; (3) Asia Pacific with 23 countries; (4) the Commonwealth of Independent States (CIS) with 10 countries; (5) West Asia with 11 countries; and (6) the OECD and other European countries covered by Eurostat, plus Israel and Russia, adding up to 46 countries in this region. This sums to 148 countries, but Egypt appears in both the African and West Asia regions and Russia appears in both the OECD and CIS regions, so there are 146 participating countries in all.

The fact that the product lists in each region were allowed to be different across regions means that without further information, prices and volumes could not be compared across regions. However, the World Bank, in cooperation with other national and international statistical agencies, developed an additional product list, which was priced out by 18 selected countries across the regions. These 18 countries were called *ring countries*. The prices that were collected by the ring countries using this final product list enabled price comparisons to be made across the six regions. We will indicate how this was done at the Basic Heading level in Section 3, and in Section 5 we will indicate how comparisons at higher levels of aggregation between regions were made.

There was another methodological innovation made in this current ICP round in addition to having regional product lists: the price parities or Purchasing Power Parities (PPPs) and relative volumes for each country were determined using information on prices and GDP expenditure shares that pertained only to countries within the given region; these parities and relative volumes were preserved in the world comparison. Thus each region was independently allowed to determine its country PPPs and volume shares, and the final linking of the regional results into a global world comparison left these regional relative parities undisturbed.[3]

The final results from the 2005 International Comparison Program for the 146 participating countries are available on the World Bank website; see World Bank (2008) for these results and explanations for various difficulties that were encountered. This publication explained the basic framework for the provision of the data as follows:

> The purchasing power parities and the derived indicators in this report are the product of a joint effort by national statistical offices, regional coordinators, and the ICP global office. PPPs cannot be computed in isolation by a single country. However, each country was responsible for submitting official estimates of 2005 gross domestic product and its components, population counts, and average exchange rates. The regional coordinators worked with the national statistical offices to review the national accounts data to ensure that they conformed to the standards of the 1993 System of National Accounts.

[2]For an overview of previous ICP rounds and an assessment of the current round, see Heston and Summers (2008).

[3]Egypt is an exception to this statement as will be explained below.

> Similar reviews were conducted for population and exchange rate data. (World Bank, 2008, p. 2)

The World Bank noted that the data provided by China were not quite complete and that the tables broke China into four separate regions:

> China submitted prices for 11 administrative areas and the urban and rural components. The World Bank and the Asian Development Bank extrapolated these 11 city prices to the national level. The China data do not include Hong Kong, Macao, and Taiwan, China. (World Bank, 2008, p. 2)

The World Bank publication also explained how the ICP dealt with the fact that Egypt appeared in two regions (and priced out the product lists for both regions):

> Egypt participated in both the Africa and West Asia ICP programs by providing prices for the products included in each comparison. Therefore, it was possible to compute PPPs for Egypt separately for Africa and West Asia. Both regions included Egypt results in their regional reports. Egypt appears in the global report in both regions. The results for Egypt from each region were averaged by taking the geometric mean of the PPPs, allowing Egypt to be shown in each region with the same ranking in the world comparison. (World Bank, 2008, p. 2)

Finally, the World Bank explained how the CIS regional results were obtained:

> Russia participated in the price collection for both the CIS and OECD comparisons. As with Egypt, PPPs for Russia were computed separately for the OECD and CIS comparisons. However, the CIS region did not participate in the Ring. Therefore, following past practices the CIS region was linked to Eurostat–OECD using Russia as a link. For comparison purposes, Russia is shown in both regions in the report. (World Bank, 2008, p. 2)

Thus since Russia is the only country that belongs to both the OECD region and the CIS region, linking the two regions at both the Basic Heading level and higher levels of aggregation can be done though Russia. The same linking strategy could have been used to link the Africa and West Asia regions using Egypt as the linking country (or bridge country using ICP parlance) but a decision was made not to do this.[4]

The above material presents a quick overview of the ICP. Our specific task in the present paper is to present some of the methodological details of the methods that were used to:

- link the Basic Heading PPPs across the regions (Sections 2 and 3); and

[4]The problems in the case of Egypt are more complicated than in the case of Russia since there were more than one ring countries in Africa and in West Asia. Hill (2007c, p. 13) listed the 18 ring countries as Brazil, Cameroon, Chile, Egypt, Estonia, Hong Kong, Japan, Jordan, Kenya, Malaysia, Oman, Philippines, Senegal, Slovenia, South Africa, Sri Lanka, United Kingdom, and Zambia. Thus Cameroon, Jordan, Kenya, Oman, Senegal, South Africa, and Zambia join Egypt as ring countries that are present in either the African or West Asian regions.

- link the price levels and volumes for each country within a region across the regions in a way that preserves the regional relative price and volume measures (Sections 4 and 5).

Thus Sections 2 and 3 deal with the problems associated with the aggregation of price information at the lowest level of aggregation where information on expenditures or quantities is not available. Sections 4 and 5 deal with aggregation problems at higher levels of aggregation where expenditure information by category and country is available. It should be noted that the material to be covered in Sections 2–5 overlaps substantially with the material in the *ICP 2003–2006 Handbook*; see Hill (2007a, 2007b, 2007c, 2007d, 2007e). Also the material in Sections 2 and 3 overlaps with Hill (2008) and the material in Sections 3 and 5 overlaps substantially with Diewert (2004).

Section 6 lists some of the methodological problems that require additional research before the next round of the ICP program, which is scheduled to take place in 2011.

Section 7 provides some concluding remarks to the main text.

2. The Comparison of Prices Across Countries Within a Region at the BH Level

Three distinct methods for linking prices across countries within a region at the Basic Heading level were used by the regions in the 2005 ICP:

- The Country Product Dummy (CPD) method (used by the African, Asian Pacific, and West Asian regions).
- The Extended Country Product Dummy (CPRD) method (used by South America).
- The EKS* method used by the OECD/Eurostat and CIS regions.

The most widely used statistical approach to the multilateral aggregation of prices at the first stage of aggregation is the Country Product Dummy (CPD) method, proposed by Summers (1973). This method for making international comparisons of prices can be viewed as a very simple type of hedonic regression model where the only characteristic of the commodity is the commodity itself. The CPD method can also be viewed as an example of the stochastic approach[5] to index numbers. Since an extension of this method was used to link prices across regions, we will outline the algebra behind this approach.

Suppose that we are attempting to make an international comparison of prices between C countries over a reasonably homogeneous group of say N items.[6] In this section, we also assume that no expenditure weights are available for the price comparisons. Let p_{cn} denote the average price of item n[7] in country c for

[5]See Selvanathan and Rao (1994) for examples of the stochastic approach to index number theory. A main advantage of the CPD method for comparing prices across countries over traditional index number methods is that we can obtain *standard errors* for the country price levels. This advantage of the stochastic approach to index number theory was stressed by Summers (1973).

[6]Using the language of the ICP project, we are making a comparison of prices at the basic heading level. In ICP 2005 project, there are 155 basic headings. Thus each region using this method would have to run 155 regressions of the type described here.

[7]In most cases, this item n price in country c was an unweighted arithmetic mean of prices collected over outlets and regions in the country during the reference year.

$c = 1, \ldots, C$; $n = 1, \ldots, N$. Each item n must be measured in the same quantity units across countries but the prices are collected in local currency units. The basic statistical model that is assumed is as follows:

$$p_{cn} = a_c b_n e_{cn}; c = 1, \ldots, C; n = 1, \ldots, N \tag{1}$$

where the a_c and b_n are unknown parameters to be estimated and the e_{cn} are independently distributed error terms with means 1 and constant variances. The parameter a_c is to be interpreted as the *average level of prices* (over all items in this group of items) in country c relative to other countries, and the parameter b_n is to be interpreted as the *average* (over all countries) *multiplicative premium* that item n is worth relative to an average item in this grouping of items. Thus the a_c are the basic heading country price levels that we want to determine while the b_n are item or individual product effects. The basic hypothesis is that the price of item n in country c is equal to a country price level a_c times an item commodity adjustment factor b_n times a random error that fluctuates around 1. Taking logarithms of both sides of (1) leads to the following model:

$$y_{cn} = \alpha_c + \beta_n + \varepsilon_{cn}; c = 1, \ldots, C; n = 1, \ldots, N \tag{2}$$

where $y_{cn} \equiv \ln p_{cn}$, $\alpha_c \equiv \ln a_c$, $\beta_n \equiv \ln b_n$ and $\varepsilon_{cn} \equiv \ln e_{cn}$.

The model defined by (2) is obviously a linear regression model where the independent variables are dummy variables. The least squares estimators for the α_c and β_n can be obtained by solving the following minimization problem:[8]

$$\min_{\alpha's, \beta's} \left\{ \sum_{c=1}^{C} \sum_{n=1}^{N} [y_{cn} - \alpha_c - \beta_n]^2 \right\}. \tag{3}$$

However, it can be seen that the solution for the minimization problem (3) cannot be unique: if α_c^* for $c = 1, \ldots, C$ and β_n^* for $n = 1, \ldots, N$ solve (3), then so does $\alpha_c^* + \gamma$ for $c = 1, \ldots, C$ and $\beta_n^* - \gamma$ for $n = 1, \ldots, N$, for any arbitrary number γ. Thus it will be necessary to impose an additional restriction or normalization on the parameters α_c and β_n in order to obtain a unique solution to the least squares minimization problem (3). The simplest normalization is:

$$\alpha_1 = 0 \text{ or } a_1 = 1. \tag{4}$$

The normalization (4) means that country 1 is chosen as the numeraire country and the parameter a_c for $c = 2, \ldots, C$ is the PPP (Purchasing Power Parity) of country c relative to country 1 for the class of commodity prices that are being compared across the C countries.[9]

Cuthbert and Cuthbert (1988, p. 57) introduced an interesting generalization of the Country Product Dummy method that can be used if information on *representativity* of the prices is collected by the countries in the comparison project

[8]Weighted (by expenditure shares) versions of the CPD model were considered by Rao (1990, 1995, 2001, 2002, 2004), Heston *et al.* (2001), Sergeev (2002, 2003), Diewert (2004, 2005), Hill (2007a, pp. 23–4), and Hill and Timmer (2006).

[9]See Rao (2004) and Hill (2007a) for further analysis of this model. We note that Hill uses a different but equivalent normalization.

along with the prices themselves. Hill (2007a, 2008) explains this method in some detail; he called the method the *extended CPD Method* or *CPRD Method* and justified the method as follows:

> The reason for distinguishing between representative and unrepresentative products is that the relative prices of representative products in a country may be expected to be low compared with relative prices of the same products in countries in which they are not representative. Conversely, of course, the relative prices of unrepresentative products will tend to be high. This will tend to happen as result of normal substitution effects. Products will tend to be purchased in relatively large (small) quantities precisely because their relative prices are low (high). This conclusion is not merely a theoretical deduction, as there is ample empirical evidence of the substitution effect at work in both inter-temporal and inter-national comparisons. (Hill, 2007a, p. 3)
>
> The expected price depends on the interaction of three factors: the country, the product and its representativity. Given that the coefficient of a representative product is fixed at unity, the coefficient of an unrepresentative product may be expected to be greater than unity. The price of product is expected to be higher relatively to the reference product 1 in a country in which it is unrepresentative than in a country in which it is representative. The improvement over the traditional CPD method comes from the partial relaxation of the unrealistic assumption that the pattern of relative prices is the same in all countries. . . . The addition of the new variable, representativity, does not simply add another parameter to be estimated. It adds another dimension to the analysis. As there are three types of explanatory variables in the regression—country, product and representativity—the extended regression will described as the CPRD method to distinguish it from the traditional CPD method. (Hill, 2007a, p. 26)

The basic idea is that representative products in a country should tend to be lower in price (and hence they should be more popular) compared to unrepresentative products; thus representativity becomes a price determining characteristic of the commodity.

The CPD method generalizes the model (2) above as follows. Define $y_{cnu} = \ln p_{cnu}$, where p_{cnu} is the logarithm of the average product n price collected in country c and u is an index that denotes whether the collected price is unrepresentative (in which case $u = 1$) or representative (in which case $u = 2$). The basic (unweighted) statistical model that is assumed is as follows:

$$y_{cnu} = \alpha_c + \beta_n + \delta_u + \varepsilon_{cnu}; c = 1, \ldots, C; n = 1, \ldots, N; u = 1, 2 \tag{5}$$

where the α_c are the log country PPPs, the β_n are the log product price effects, the δ_u are the two log representativity effects, and the ε_{cnu} are independently distributed random variables with mean zero and constant variances. In order to identify the parameters, the following normalizations can be used:

$$\alpha_1 = 0; \delta_1 = 0. \tag{6}$$

Thus the present model is much the same as the basic CPD model except that we have three classifications instead of two. For additional discussion of this model, the reader is referred to Cuthbert and Cuthbert (1988), Cuthbert (2000), Diewert (2004), and Hill (2007a, 2008).

We agree with Hill in endorsing the method in theory. However, in practice, it seems it was at times difficult for national price statisticians to agree on a workable definition of representativity that was uniform across countries and regions. Thus in the end, it appears that only the South American region used CPRD method to construct its 155 by 10 matrix of PPPs by Basic Heading and country. The other regions used the basic CPD method or the EKS* method (which also used the representativity concept).

As mentioned at the beginning of this section, the EKS* method was used to aggregate prices at the lowest level of aggregation in the OECD and CIS regions. This method is explained by Hill as follows:

> Eurostat abandoned EKS 1 in 1982 and replaced it by the method described in the present section, which will be called the asterisk method or EKS*. A detailed exposition of EKS* and its properties is given by Sergey Sergeev (2003). The EKS* method is so called because it makes use of the distinction between representative and unrepresentative products, the representative products being identified in the product lists by an *. The EKS* method recognizes, and exploits, the fact that, as already explained, the prices of representative products are likely to be relatively low, whereas the prices of unrepresentative products are likely to be relatively high. The method proceeds by calculating two separate Jevons indices for each pair of countries. One Jevons index covers products that are representative in the first country, treated here as the base country. The other covers products that are representative in the second country. Of course, some products may be representative in both countries and included in both indices. The two indices may be described as *Jevons 1* and *Jevons 2* respectively. (Hill, 2007a, p. 9)

Thus two bilateral Jevons type indexes are calculated for any two countries. Jevons 1 (2) compares only the price relatives of products that are representative in country 1 (2). The final bilateral index of prices between the two countries under consideration is a geometric mean of the two Jevons indexes.[10] Once all of these bilateral parities have been constructed over each pair of countries in the region, they can be harmonized by using the EKS procedure.[11] For further details of this method, the reader is referred to Hill (2007a).

A majority of the members of the Technical Advisory Group who provided advice to ICP 2005 favored the CPRD method described in the previous section over the EKS* method described in this section for two reasons:

- The CPRD method used all of the available price information, whereas EKS* did not.

[10]Note that prices which are not representative in both countries but are collected in both countries do not appear in the final bilateral index of prices between the two countries. This means that the EKS* procedure is not fully efficient in a statistical sense, whereas the CPRD procedure is fully efficient.

[11]The EKS method is explained in more detail by Balk (1996), Diewert (1999), and Hill (2007a, 2008). The method is due to Gini (1924, 1931) and independently rediscovered by Eltetö and Köves (1964) and Szulc (1964).

- The CPRD method gave straightforward measures of the statistical precision of the estimated parities.

However, it appears that Eurostat price statisticians are locked into the EKS* method by legislation and thus the OECD/Eurostat region stuck by its EKS* method in the current European Comparison Program. More research is required in order to determine how much difference there would be between CPRD and EKS*. But without having this research in hand, I would certainly favor the use of CPRD over EKS*, mainly because the EKS* method throws away valuable information on some prices and this cannot be a statistically efficient procedure.

There is also the issue of choosing between the original CPD method and the enhanced CPRD method, which makes use of representativity information on the item prices. Hill (2007a) explains theoretically why the CPRD method should be preferred over the CPD method. However, in practice, national price collectors in all of the non-OECD regions had great difficulty in deciding on which items were representative and which items were not. Thus when the CPRD regressions were run, the coefficients for the representative dummy variables had more or less random signs instead of the expected signs. This was the case even for the South American region, which used the CPRD method.[12] Thus at this stage of our knowledge of the various methods used to aggregate prices at the basic heading level, I would favor the use of the plain vanilla CPD method.

Having described the methods used to construct PPPs for the 155 basic headings for each country in a region, we now consider how to link these PPPs across regions.

3. The Comparison of Prices Across Regions at the Basic Heading Level

As noted in the introduction, a group of *ring countries* collected prices from a common list and this price information was used to link the regional basic heading prices across the six regions. However, since the CIS region was locked into the OECD/Eurostat region, in practice, there were only five regions to link, with the CIS, OECD, and Eurostat countries forming a single region.

The methodology used to link basic heading prices across regions was developed by Diewert (2004, pp. 36–9) and we review that methodology here.[13] The model is basically an adaptation of the unweighted CPD model presented in Section 2.

In order to set the stage for what was actually done in linking the regions, we first generalize the CPD model presented in Section 2 to allow for a reorganization of the list of C countries into five regions and $C(r)$ ring countries in each region r. Thus $C(r)$ is not the total number of countries in region r; it is only the number of ring countries in each region because only the ring countries collected data on prices from a common international product list. With these changes, the basic model becomes:

[12]Personal communication from Yuri Dikhanov.

[13]The basic methodology is also described in Hill (2007d). However, Hill uses somewhat different normalizations than (11) and (12).

$$p_{rcn} \approx a_r b_{rc} c_n; r = 1, \ldots, 5; c = 1, \ldots, C(r); n = 1, \ldots, N; \tag{7}$$

$$a_1 = 1; \tag{8}$$

$$b_{r1} = 1; r = 1, \ldots, 5. \tag{9}$$

The normalization (8) means that we have to choose a numeraire region. The normalizations (9) mean that within each region, we need to choose a numeraire country in order to identify all of the parameters uniquely. Thus the parameters a_r and b_{rc} replace our initial model parameters a_c. Note that the total number of parameters remains unchanged when we group all of the countries in the comparison into regions and countries within the regions.

Taking logarithms of both sides of (7) and then adding error terms ε_{rcn} (with means 0) leads to the following regression model:

$$\begin{aligned} \ln p_{rcn} &= \ln a_r + \ln b_{rc} + \ln c_n + \varepsilon_{rcn}; r = 1, \ldots, 5; c = 1, \ldots, C(r); n = 1, \ldots, N; \\ &= \alpha_r + \beta_{rc} + \gamma_n + \varepsilon_{rcnk} \end{aligned} \tag{10}$$

where we impose the following normalizations on the parameters in order to uniquely identify them:

$$\alpha_1 = 0; \tag{11}$$

$$\beta_{r1} = 0; r = 1, \ldots, 5 \tag{12}$$

where $\alpha_r \equiv \ln a_r$, $\beta_{rc} \equiv \ln b_{rc}$, $\gamma_n \equiv \ln c_n$.

If all of the data collected for each regional comparison could be pooled and if there are product overlaps between the regions, then there will be 155 regressions of the form (10) to run, one for each basic heading category. In the above model, the interregional log parities (the α_r) are estimated along with the within region country log parities (the β_{rc}) and the product log price premiums (the γ_n). Call this the *first approach* to estimating the regional parities for each basic heading. It uses all of the available information in making comparisons between all of the countries.

However, the above one big regression approach (for each basic heading) is *not consistent* with approaches that used only the regional data to determine the within region parities, the β_{rc} parameters, holding r fixed. But a principle of the current ICP methodology was that regions should be allowed to determine their own parities, independently of other regions. However, the regression model (10) can be modified to deal with this problem. If the regional log parities β_{rc} are known, then the term β_{rc} (which is equal to $\ln b_{rc}$) can be subtracted from both sides of (10), leading to the following regression model:

$$\ln p_{rcn} - \ln b_{rc} = \ln a_r + \ln c_n + \varepsilon_{rcn}; r = 1, \ldots, 5; c = 1, \ldots, C(r); n = 1, \ldots, N; \tag{13}$$

or

$$\ln[p_{rcn}/b_{rc}] = \alpha_r + \gamma_n + \varepsilon_{rcn}; \tag{14}$$

where the normalization (8) still holds. Thus if the within region parities are known, then prices in each region p_{rcn} can be divided by the appropriate regional parity for that country in that region b_{rc}, and these regionally adjusted prices can be used as inputs into the usual CPD model that has now only the regional log parities α_r and the commodity adjustment factors γ_n as unknown parameters to be estimated. Call the model defined by (11) and (14) the *second approach* to estimating the regional parities for each basic heading. This second approach respects the within region parities that have been constructed by the regional price administrators. It is this second approach that was used in ICP 2005.[14]

We now turn our attention to the problems associated with aggregating up the basic heading PPP information (along with country expenditure information) in order to form aggregate country price and volume comparisons within a region.

4. Aggregate Price and Volume Comparisons Across Countries Within a Region

Once the 155 BH price parities for each of the K countries in a region have been constructed, aggregate measures of country prices and relative volumes can be constructed using a wide variety of multilateral comparison methods that have been suggested over the years. These aggregate comparisons assume that in addition to BH price parities for each country, national statisticians have provided country expenditures (in their home currencies) for each of the 155 BH categories for the reference year 2005. Then the 155 by K matrices of Basic Heading price parities and country expenditures are used to form average price levels across all commodities and relative volume shares for each country.

There are a large number of methods that can be used to construct these aggregate Purchasing Power Parities and relative country volumes; Hill (2007b) surveys the main methods that have been used in previous rounds of the ICP and other methods that might be used.[15] Basically, only two multilateral methods have been used in previous rounds:

- The Gini–EKS (GEKS) method based on Fisher (1922) bilateral indexes.
- The Geary (1958) and Khamis (1972) (GK) method, which is an additive method.

In the present ICP round, aggregate PPPs and relative country volumes for countries within each region were constructed for five of the six regions using the Gini–EKS method. However, the African region wanted to use an additive method and so this region used a relatively new additive method, the Iklé–Dikhanov–Balk (IDB) method, for constructing PPPs and relative volumes within the region. These methods will be discussed in more detail below. However, at this point, it may be appropriate to comment briefly on the relative merits of the GEKS, GK, and IDB methods. The GK and IDB methods are additive methods; i.e. the real

[14]Yuri Dikhanov at the World Bank carried out the computations for the global linking.

[15]For additional methods, see Balk (1996), Hill (1997, 1999a, 1999b, 2001, 2004) and Diewert (1999).

output of each country can be expressed as a sum of the country's individual outputs, but each output is weighted by an international price which is constant across countries. This feature of an additive method is tremendously convenient for users and so for many purposes, it is useful to have available a set of additive international comparisons.

4.1. *The Gini EKS Method*

It will be useful to introduce some notation at this point. Let N equal 155 and let K be the number of countries in the regional comparison for the reference year. Denote the regional PPP for country k and commodity category n by $p_n^k > 0$ and the corresponding expenditure (in local currency units) on commodity class n by country k in the reference year by e_n^k for $n = 1, \ldots, N$ and $k = 1, \ldots, K$. Given this information, we can define *implicit quantity levels* y_n^k for each Basic Heading category n and for each country k as the category expenditure deflated by the corresponding commodity PPP for that country:

$$y_n^k \equiv e_n^k / p_n^k ; n = 1, \ldots, N; k = 1, \ldots, K. \tag{15}$$

It will be useful to define *country commodity expenditure shares* s_n^k as follows:

$$s_n^k \equiv e_n^k \Big/ \sum_{i=1}^{N} e_i^k ; n = 1, \ldots, N; k = 1, \ldots, K. \tag{16}$$

Now define *country vectors of BH prices* as $p^k \equiv [p_1^k, \ldots, p_N^k]$, *country vectors of BH quantities* as $y^k \equiv [y_1^k, \ldots, y_N^k]$, *country expenditure vectors* as $e^k \equiv [e_1^k, \ldots, e_N^k]$, and *country expenditure share vectors* as $s^k \equiv [s_1^k, \ldots, s_N^k]$ for $k = 1, \ldots, K$.

In order to define the GEKS parities $P^1, P^2, \ldots, P^K$, we first need to define the *Fisher* (1922) *ideal bilateral price index* P_F between country j relative to k:[16]

$$P_F(p^k, p^j, y^k, y^j) \equiv [p^j \cdot y^j p^j \cdot y^k / p^k \cdot y^j p^k \cdot y^k]^{1/2} ; j = 1, \ldots, K; k = 1, \ldots, K. \tag{17}$$

The *aggregate PPP for country j*, P^j, is defined as follows:

$$P^j \equiv \prod_{k=1}^{K} [P_F(p^k, p^j, y^k, y^j)]^{1/K} ; j = 1, \ldots, K. \tag{18}$$

Once the GEKS P^j's have been defined by (18), the corresponding GEKS *country real outputs or volumes* Y^j can be defined as the country expenditures $p^j \cdot y^j$ in the reference year divided by the corresponding GEKS purchasing power parity P^j:

$$Y^j \equiv p^j \cdot y^j / P^j ; j = 1, \ldots, K. \tag{19}$$

If we divide all of the P^j defined by (18) by a positive number, α say, then we can multiply all of the Y^j defined by (19) by this same α without materially changing the GEKS multilateral method. If country 1 is chosen as the numeraire

[16]Notation: $p \cdot y \equiv \Sigma_{n=1}^{N} p_n y_n$ denotes the inner product between the vectors p and y.

country in the region, then we set α equal to P^1 defined by (18) for $j = 1$ and then the price level P^j is interpreted as the number of units of country j's currency it takes to purchase 1 unit of country 1's currency and get an equivalent amount of utility and the rescaled Y^j is interpreted as the volume of output of country j in the currency units of country 1.

It is also possible to normalize the outputs of each country in common units (the Y^k) by dividing each Y^k by the sum $\Sigma_{j=1}^{K} Y^j$ in order to express each country's real output as a fraction or share of total regional output; i.e., we can define the country k's share of regional output, S^k, as follows:[17]

$$S^k \equiv Y^k \Big/ \sum_{j=1}^{K} Y^j ; k = 1, \ldots, K. \tag{20}$$

Of course, the country shares of regional real output, the S^k, remain unchanged after rescaling the PPPs by the scalar α.

This completes our brief overview of the Gini EKS method for making multilateral comparisons.[18]

4.2. *The Geary–Khamis Method*

The method was suggested by Geary (1958), and Khamis (1972) showed that the equations that define the method have a positive solution under certain conditions.

The GK system of equations involves K country price levels or PPPs, $P^1, \ldots, P^K$, and N international commodity reference prices, $\pi_1, \ldots, \pi_N$. The equations which determine these unknowns (up to a scalar multiple) are as follows:

$$\pi_n = \sum_{k=1}^{K} \left[y_n^k \Big/ \sum_{j=1}^{K} y_n^j \right] \left[p_n^k / P^k \right]; n = 1, \ldots, N; \tag{21}$$

$$P^k = p^k \cdot y^k / \pi \cdot y^k ; k = 1, \ldots, K \tag{22}$$

where $\pi \equiv [\pi_1, \ldots, \pi_N]$ is the vector of GK regional average reference prices. It can be seen that if we have a solution to equations (21) and (22), then if we multiply all of the country parities P^k by a positive scalar, λ say, and divide all of the reference prices π_n by the same λ, then we obtain another solution to (21) and (22). Hence, the π_n and P^k are only determined up to a scalar multiple and we require an additional normalization such as

$$P^1 = 1 \tag{23}$$

in order to uniquely determine the parities. It can also be shown that only $N + K - 1$ of the N equations in (21) and (22) are independent. Once the parities P^k have

[17]There are several additional ways of expressing the GEKS PPPs and relative volumes; see Balk (1996) and Diewert (1999, pp. 34–7).

[18]It should be noted that all of the multilateral methods that are described in this section can be applied to subaggregates of the 155 basic heading categories; i.e., instead of working out aggregate price and volume comparisons across all 155 commodity classifications, we could just choose to include the food categories in our list of N categories and use the multilateral method to compare aggregate food consumption across the countries in the region.

been determined, the real output for country k, Y^k, can be defined as country k's *nominal value of output in domestic currency units*, $p^k \cdot y^k$, divided by its PPP, P^k; i.e., we have

$$(24) \qquad \begin{aligned} Y^k &= p^k \cdot y^k / P^k ; k = 1, \ldots, K \\ &= \pi \cdot y^k \text{ using (22).} \end{aligned}$$

Finally, if we substitute equations (24) into the regional share equations (20), we find that country k's share of regional output is

$$(25) \qquad S^k = \pi \cdot y^k / \pi \cdot y \; k = 1, \ldots, K$$

where the *region's total output vector y* is defined as the sum of the country output vectors; i.e., we have

$$(26) \qquad y \equiv \sum_{j=1}^{K} y^j .$$

Equations (24) show how convenient it is to have an additive multilateral comparison method: when country outputs are valued at the international reference prices, values are additive across both countries and commodities. However, additive multilateral methods are not really consistent with economic comparisons of utility across countries if the number of countries in the comparison is greater than two; see Diewert (1999, pp. 48–50) and the appendix of Diewert (2008b) on this point.[19] In addition, looking at equations (41), it can be seen that large countries will have a larger contribution to the determination of the international prices π_n and thus these international prices will be much more representative for the largest countries in the comparison as compared to the smaller ones.[20] This leads us to the next method for making multilateral comparisons: an additive method that does not suffer from this problem of big countries having undue influence in the comparison.

4.3. *The Iklé–Dikhanov–Balk Method*

Iklé (1972, pp. 202–4) suggested the method in a very indirect way, Dikhanov (1994) (1997) suggested the much clearer system ((27) – (28) below), and Balk

[19]"[T]he Gerschenkron effect [states that] in the consumer theory context, countries whose price vectors are far from the 'international' or world average prices used in an additive method will have quantity shares that are biased upward. . . . It can be seen that these biases are simply quantity index counterparts to the usual substitution biases encountered in the theory of the consumer price index. However, the biases will usually be much larger in the multilateral context than in the intertemporal context since relative prices and quantities will be much more variable in the former context. . . . The bottom line on the discussion presented above is that the quest for an additive multilateral method with good economic properties (i.e., a lack of substitution bias) is a doomed venture: nonlinear preferences and production functions cannot be adequately approximated by linear functions. Put another way, if technology and preferences were always linear, there would be no index number problem and hundreds of papers and monographs on the subject would be superfluous!" (Diewert, 1999, p. 50).

[20]Dikhanov (1994, p. 5) made this point.

(1996, pp. 207–8) provided the first existence proof.[21] Dikhanov's (1994, pp. 9–12) equations that are the counterparts to the GK equations (21) and (22) are as follows:

$$\pi_n = \left[\sum_{k=1}^{K} s_n^k \left[p_n^k / P^k\right]^{-1}\right] \Big/ \left[\sum_{j=1}^{K} s_n^j\right]^{-1}; n = 1, \ldots, N \tag{27}$$

$$P^k = \left[\sum_{n=1}^{N} s_n^k \left[p_n^k / \pi_n\right]^{-1}\right]^{-1} \quad k = 1, \ldots, K. \tag{28}$$

As in the GK method, equations (27) and (28) involve the K country price levels or PPPs, $P^1, \ldots, P^K$, and N international commodity reference prices, $\pi_1, \ldots, \pi_N$. Equation (27) tell us that the n-th *international price*, π_n, is a share weighted harmonic mean of the country k prices for commodity n, p_n^k, deflated by country k's PPP, P^k. The country k share weights for commodity n, s_n^k, do not sum (over countries k) to unity, but when we divide s_n^k by $\Sigma_{j=1}^{K} s_n^j$, the resulting normalized shares do sum (over countries k) to unity. Thus equations (27) are similar to the GK equations (21), except that now a harmonic mean of the deflated commodity n prices, p_n^k / P^k, is used in place of the old arithmetic mean and in the GK equations, country k's share of commodity n in the region, $y_n^k / \Sigma_{j=1}^{K} y_n^j$, was used as a weighting factor (and hence large countries had a large influence in forming these weights), but now the weights involve country expenditure shares and so each country in the region has an equal influence in forming the weighted average. Equation (28) tells us that P^k, the PPP for country k, P^k, is equal to a weighted harmonic mean of the country k commodity prices, p_n^k, deflated by the international price for commodity n, π_n, where we sum over commodities n instead of over countries k as in equation (27). The share weights in the harmonic means defined by (28), the s_n^k, of course sum to one when we sum over n, so there is no need to normalize these weights as was the case for equation (27).

It can be seen that if we have a solution to equations (27) and (28), then if we multiply all of the country parities P^k by a positive scalar, λ say, and divide all of the reference prices π_n by the same λ, then we obtain another solution to (27) and (28). Hence, the π_n and P^k are only determined up to a scalar multiple and we require an additional normalization such as (23).

Although the IDB equations (28) do not appear to be related very closely to the corresponding GK equations (22), it can be shown that these two sets of equation are actually the same system. To see this, note that the country k expenditure share for commodity n, s_n^k, has the following representation:

$$s_n^k = p_n^k y_n^k / p^k \cdot y^k; n = 1, \ldots, N; k = 1, \ldots, K. \tag{29}$$

Now substitute equations (29) into equations (28) to obtain the following equations:

[21] Iklé (1972) and van Ijzeren (1983, p. 42) provided existence proofs for the case of two countries.

$$
\begin{aligned}
P^k &= 1\Big/\sum_{n=1}^{N} s_n^k \left[p_n^k/\pi_n\right]^{-1} \quad k = 1, \ldots, K \\
&= 1\Big/\sum_{n=1}^{N} \left[p_n^k y_n^k / p^k \cdot y^k\right]\left[\pi_n / p_n^k\right] \\
&= p^k \cdot y^k \Big/ \sum_{n=1}^{N} \pi_n y_n^k \\
&= p^k \cdot y^k / \pi \cdot y^k.
\end{aligned} \tag{30}
$$

Thus equations (28) are equivalent to equations (22) and the IDB system is an additive system; i.e., equations (24)–(26) can be applied to the present method just as they were applied to the GK method for making international comparisons.[22]

As mentioned in the introduction, the Iklé–Dikhanov–Balk method was used by the African region in order to construct regional aggregates. Basically, this method appears to be an improvement over the GK method in that large countries no longer have a dominant influence on the determination of the international reference prices π_n, and so if an additive method is required with more democratic reference prices, IDB appears to be "better" than GK. However, again, we caution the reader that additive multilateral methods will not generate very accurate relative volumes (from the viewpoint of the economic approach) if the number of countries is greater than three and there is heterogeneity in relative prices and quantities; see Diewert (1999, p. 50) and the appendix of Diewert (2008b).

We now turn our attention to the problem of linking the regions at higher levels of aggregation.

5. Aggregate Price and Volume Comparisons Across Regions

There are 146 countries in the ICP project and 155 basic headings. At this stage of the aggregation procedure, we assume that we have two 155 by 146 matrices of data: one matrix contains the PPPs for basic heading category n and country k, p_n^k, and the other contains country expenditures in each country's currency, e_n^k, so that the notation is basically the same as in the previous section but now k runs over all 146 countries instead of just the countries in a given region. At this stage, we could use any suitable multilateral method to aggregate up these data into a set of 146 country PPPs and volumes, such as the EKS or IDB methods explained in the previous section. Call this *Approach 1*. However, the problem with this approach is that the multilateral method to be used would not necessarily respect the regional PPPs unless it was restricted in some manner.

Thus we consider *Approach 2*, which will link the regions, while respecting the within-region overall PPPs that the regions deem best for their purposes.[23] The first step is to reorganize the countries into five regions (we regard the OECD/Eurostat/CIS countries as forming one region). Consider region r which has $C(r)$ countries in it. Let p_n^{rc} denote the within-region PPP for basic heading class n and country

[22]In the appendix of Diewert (2008b), different ways of representing the IDB system of parities are obtained and fairly weak conditions for the existence and uniqueness of the IDB parities established. It is also shown how solutions to the equations can be found.

[23]This approach was proposed by Diewert (2004, pp. 45–7). It is further described in much more detail by Hill (2007e).

c in region r,[24] and let e_n^{rc} denote the corresponding expenditure in local currency. The total regional expenditure on commodity group n in currency units of country 1 in each region, E_n^r, is defined as follows:

$$E_n^r \equiv p_n^{r1} \sum_{c=1}^{C(r)} e_n^{rc} / p_n^{rc}; r = 1, \ldots, 5; n = 1, \ldots, 155. \tag{31}$$

The corresponding regional PPPs by region and commodity, P_n^r, are defined to be the world BH parities for the numeraire country in each region:

$$P_n^r \equiv p_n^{r1}; r = 1, \ldots, 5; n = 1, \ldots, 155. \tag{32}$$

Now each region can be treated as if it were a single supercountry, with supercountry expenditures E_n^r and basic heading PPPs P_n^r defined by (31) and (32), respectively, for the five supercountries and any of the linking methods described in the previous section can be used to link the regions. Once the interregional price and volumes have been determined, the regional price and volume aggregates can be used to provide worldwide price and volume comparisons for each individual country. This method necessarily preserves all regional relative parities; see Hill (2007e). The overall procedure does not depend on the choice of the numeraire region, but Sergeev (2009) noted that the method does depend on the choice of the numeraire country within each region.

Approach 2 in conjunction with the EKS method was used to link the regions in the current ICP round; i.e., the EKS method was used to link the five supercountry regions.

Hill (2007e) discusses other possible methods that could be used to link the regions and these various alternative methods should form part of the research agenda for the next round of comparisons. In particular, at higher levels of aggregation, we need to use the results of the present round to evaluate whether regional fixity is a good idea or not. The problem with regional fixity is that countries are not homogeneous within each region. In principle, it makes sense to compare countries whose (relative) price structures are similar and whose (absolute) quantity structures are similar: index number comparisons of price and volumes will work best under these conditions. Thus roughly speaking, it makes sense to compare directly countries who are at the same stage of development and build up a complete set of multilateral comparisons by linking (bilaterally) countries who are most structurally similar.[25] Hill (1997, 1999a, 1999b, 2001, 2004) has developed methodology along these lines; it should be tested out using the detailed data generated by the present round.[26] It may well be that the fixity methodology

[24]The parities p_n^{rc} are the interregionally consistent PPPs that were linked across regions as described in Section 3; i.e., the p_n^{rc} are the estimated parameters $a_r\, b_{rc}\, c_n$ which occur on the right hand side of equations (7). Assuming that country 1 is the numeraire country in each region, then the p_n^{r1} are the parities that link the numeraire countries in each region.

[25]See Diewert (2002) for a discussion on how to measure structural similarity.

[26]Another interesting issue is this: the present fixity imposed procedure is essentially a two stage GEKS procedure. At the first stage, countries are compared using GEKS within each region; at the second stage, the five regions are linked together using another round of GEKS. Question: How does this two stage procedure compare to a single stage GEKS procedure using all 146 countries? The answer will probably be: They generate rather different parities. What then? What is the "truth"? We need criteria to determine "truth." We could look at the axiomatic properties of two stage methods as compared to single stage methods but I do not believe that this would resolve the issues. At this point, I would fall back on the spatial linking methodology: it makes sense to build up a path of linked comparisons where we link together the countries which are most similar in structure.

developed in this round is not the most appropriate methodology for subsequent rounds.

6. Problem Areas and the Future Research Agenda

There are a number of problem areas associated with making international comparisons that require additional research and discussion before the next round of the ICP takes place:

- If a country experiences hyperinflation during the reference year, the average price concept may not be meaningful. A possible solution to this problem is to use within the year inflation rates to "discount" prices collected throughout the year to a single reference week or day.[27]
- The problem of pricing exports and imports.[28] At present, exchange rates are taken as the price of exports and imports. This is a reasonable approximation in some cases, but the question is: Can we do anything better (that is not too costly)?
- The problem of negative expenditure categories. This problem arises with the net export category and the net additions to inventory category. Typically, there is not a problem provided that we do not attempt to provide PPPs for a single category that could be positive or negative across countries.[29] If it is necessary to provide PPPs across countries for such a category, the problems can be avoided by providing separate PPPs for exports and imports or for starting and finishing inventory stocks; users can difference the results.
- Inaccurate expenditure weights can cause grave difficulties. In the next ICP round, it would be very desirable to have more accurate information on expenditures by basic heading available from participating countries.
- Methodological difficulties with hard to measure areas of the accounts. There are particular problems with the treatment of housing,[30] financial services, and non-market production.[31] These are problem areas for regular country accounts as well due to the lack of consensus on an appropriate methodology. Hopefully, international groups and academic economists interested in measurement problems will undertake additional research in these areas before the next ICP round.

[27]See Hill (1996) for a discussion of the accounting problems when there is high inflation.

[28]See Heston and Summers (2008, p. 4) for a discussion of this problem. A first approach to the problem would be to coordinate the calculation of national unit value export and import indexes across countries. This is a separate exercise that should be started well before the next ICP round. O'Connor (2008) mentions that the problems associated with calculating export and import price indexes is getting worse over time due to increasing trade in multinational intermediate goods and the transfer price problem.

[29]Index number theory tends to break down if a value aggregate crosses zero or is equal to zero!

[30]One area that we have not addressed is the impact of different procedures in different regions. For example, Asia and Africa used different methods for making productivity adjustments for government outputs index and they also used a different method for measuring housing output as compared to the CIS and South American regions. These problems need to be addressed well in advance of the next ICP round.

[31]See Heston and Summers (2008), Giovannini (2008), and Bevacqua *et al*. (2008) for a discussion of these problems. The fact that current System of National Accounts conventions do not allow an imputed interest charge for capital that is used in the non-market sector tends to understate the contribution of this sector, and the degree of understatement will not be constant across rich and poor countries.

- There is a very basic problem that makes international comparisons of prices and volumes very difficult; that is the lack of matching of products. The same problem occurs in the time series context due to the introduction of new products and the disappearance of "old" products, but the lack of matching is much worse in the international context due to differences in tastes and big differences in the levels of development across countries, leading to very different consumption patterns. However, Structured Product Descriptions were introduced in the current ICP round and this does open up the possibility for undertaking hedonic regression exercises in the next round in order to improve the matching process. There are many problems to be addressed however,[32] and it would be wise to undertake experimental hedonic studies well in advance of the next round.
- The fact that the ring list of commodities was somewhat different from the regional lists means that there is the possibility of anomalies in the final results; i.e., if different products are priced in the ring list, we cannot be sure the relative ring price levels really match up with the relative prices within the regions. The ring list of commodities was not determined completely independently from the country lists and this is all to the good.[33] But in the next round, this integration of the ring product list with the regional product lists should be intensified with a best case scenario where the ring list becomes unnecessary.[34]
- It would be advisable to undertake some studies on alternative methods of aggregation at the higher levels of aggregation.[35] In particular, the program of making comparisons based on the degree of similarity of the price and quantity data being compared that was initiated by Hill (1999a, 1999b,

[32]See Hill and Timmer (2006) for a discussion of the problem of differing degrees of product overlap across countries.

[33]Yonas Biru, who was responsible for organizing the ring list, describes how this was done as follows: "The Global ring list was developed in close consultation with regional and country experts in an iterative processes. First, a consolidated global draft list was prepared that contained over 6,500 products from the five ICP regions and Eurostat–OECD comparison. Second, the list was then pruned by the Global Office to about 1,500 products, based on the country responses. The next step involved harmonizing product descriptions that originated from different regions and the list was sent back to the regions and a second round regional meetings were organized. A revised list was then created taking the second round comment from ring countries. The Global Office analyzed these second round country responses, basic heading by basic heading, to determine which products should be retained and which should be dropped. Key criteria for determining the final list included the number of regions and also the number of countries within each region where the product could be priced. A workshop was organized in Washington for regional coordinators and representatives of ring countries (one from each region) to go through the list and build consensus on a global list. The workshop modified some products, dropped some and came up with the final list containing about 1200 products. In doing so the Global Office made sure that at least one product was represented from each region for each basic heading." Other World Bank researchers who were involved with the ring project were Yuri Dikhanov, Ramgopal Erabelly, Nada Hamadeh, Farah Hussain, Jinsook Lee, and Amy Lee.

[34]Yonas Biru and Virgina Romand are currently undertaking a study to improve the SPD process. Yonas Biru describes the study as follows: "We are developing coding structures not only for products but also for product characteristics for the next generation SPDs. This would facilitate matching products across regions. This means we will be able to determine ring countries and ring products after data collection based on maximum overlap of products. Both the number and the mix of countries will be determined basic heading by basic heading. Potentially, linking can be done based on different criteria, including by ICP regions, consumption and price similarity indices, etc. The method would also facilitate hedonic type regression, particularly for equipment goods."

[35]Alan Heston is currently undertaking such a study.

2001, 2004) seems to be sensible but users have not embraced it, perhaps due to the instability of the method.[36] In any case, the World Bank now has a considerable dataset based on the current ICP round that could be used to experiment with alternative methods of aggregation.

- Looking ahead into the more distant future, it would be desirable to integrate the ICP with the EU KLEMS project,[37] which is assembling data on the producer side of the economy as opposed to the final demand side, which is the focus of the ICP. Producer data are required in order to calculate relative productivity levels across economies, a topic of great interest to policy makers. Thus in addition to comparing components of final demand across countries, it would be desirable to compare outputs and inputs by industry across countries so that international comparisons of sectoral productivity levels could be undertaken.[38]

7. Conclusion

My overall conclusion is that the 2005 ICP round was a great success. The regions liked the idea that they could define their own list of products for international pricing and this improved the quality of the data. The new methodology to link prices across the regions using ring countries also seems to be a clear improvement over previous rounds. Finally, the use of hand-held computers and the structured product description methodology led to improvements in the production of national price statistics in many cases.[39]

One issue that has not been entirely satisfactorily resolved is the issue of disclosure of the data; i.e., a great deal of effort has gone in to collecting PPPs for 155 categories for 146 countries, but only data on 15 highly aggregated PPPs will be released. Why the reluctance to release the data? Probably because at lower level of aggregation, the results can be quite unreliable. Still, one would think that more than 15 categories could be released.[40]

As indicated in the previous section, some challenges remain, but hopefully these problems will be addressed before the next round takes place.

References

Balk, B. M., "A Comparison of Ten Methods for Multilateral International Price and Volume Comparisons," *Journal of Official Statistics*, 12, 199–222, 1996.

Bevacqua, G., M. Fantin, M. M. M. Quintslr, and F. Ruiz, "International Comparison Program: The South American Experience," *The ICP Bulletin*, 5(1), 23–25, 28, 2008 (http://siteresources.worldbank.org/ICPINT/Resources/270056-1208272795236/ICP_bulletin_03-04_web.pdf).

[36]Robert Hill's methodology for linking countries via a path of bilateral links for countries which have similar price and quantity structures has mainly been applied at higher levels of aggregation. Using a statistical approach, Hill and Timmer (2006) extend this similarity methodology to lower levels of aggregation where only price information is available, and they also take into account situations where the amount of overlap in pricing products differs across countries. This is an important practical problem and their methods need to be studied and tested.

[37]See van Ark *et al*. (2008) on this topic.

[38]See O'Connor (2008) for a similar long run proposal for the direction of the ICP. O'Connor also advocates making wealth comparisons across countries, which is feasible once we generate measures of capital input.

[39]See Trewin (2008) and Fenwick and Whitestone (2008) on the externalities created by the ICP program.

[40]Heston and Summers (2008, p. 5) and O'Connor (2008) discuss this issue.

Cuthbert, J. R., "Theoretical and Practical Issues in Purchasing Power Parities Illustrated with Reference to the 1993 Organization for Economic Cooperation and Development Data," *Journal of the Royal Statistical Society A*, 163, 421–44, 2000.
Cuthbert, J. and M. Cuthbert, "On Aggregation Methods of Purchasing Power Parities," Working Paper No. 56, OECD, Paris, November 1988.
Diewert, W. E., "Axiomatic and Economic Approaches to International Comparisons," in A. Heston and R. E. Lipsey (eds), *International and Interarea Comparisons of Income, Output and Prices*, Studies in Income and Wealth, Volume 61, University of Chicago Press, Chicago, 13–87, 1999.
———, "Similarity and Dissimilarity Indexes: An Axiomatic Approach," Discussion Paper 02-10, Department of Economics, The University of British Columbia, 2002 (http://www.econ.ubc.ca/discpapers/dp0210.pdf).
———, "On the Stochastic Approach to Linking the Regions in the ICP," Discussion Paper 04-16, Department of Economics, The University of British Columbia, 2004.
———, "Weighted Country Product Dummy Variable Regressions and Index Number Formulae," *Review of Income and Wealth*, 51, 561–71, 2005.
———, "New Methodology for Linking Regional PPPs," *ICP Bulletin*, 5(2), 1, 10–22, 45, 2008a.
———, "New Methodological Developments for the International Comparison Program," Discussion Paper 08-08, Department of Economics, The University of British Columbia, 2008b.
Dikhanov, Y., "Sensitivity of PPP-Based Income Estimates to Choice of Aggregation Procedures," Paper presented on behalf of The World Bank at the 23rd General Conference of the International Association for Research in Income and Wealth, St Andrews, Canada, August 21–27, 1994.
———, "Sensitivity of PPP-Based Income Estimates to Choice of Aggregation Procedures," Development Data Group, International Economics Department, The World Bank, Washington DC, January 1997.
Eltetö, O. and P. Köves, "On a Problem of Index Number Computation relating to international comparison," *Statisztikai Szemle*, 42, 507–18, 1964 (http://siteresources.worldbank.org/ICPINT/Resources/icppapertotal.pdf).
Fenwick, D. and B. Whitestone, "Supporting the ICP: Organizational Partnerships," *The ICP Bulletin*, 5(1), 16–20, 2008.
Fisher, I., *The Making of Index Numbers*, Houghton Mifflin, Boston, 1922.
Geary, R. G., "A Note on Comparisons of Exchange Rates and Purchasing Power between Countries," *Journal of the Royal Statistical Society Series A*, 121, 97–9, 1958.
Gini, C., "Quelques considérations au sujet de la construction des nombres indices des prix et des questions analogues," *Metron*, 4(1), 3–162, 1924.
———, "On the Circular Test of Index Numbers," *Metron*, 9(9), 3–24, 1931.
Giovannini, E., "Twenty Five Years of Purchasing Power Parities in the OECD Area," *The ICP Bulletin*, 5(1), 11–13, 2008 (http://siteresources.worldbank.org/ICPINT/Resources/270056-1208272795236/ICP_bulletin_03-04_web.pdf).
Heston, A. and R. Summers, "Interview with Alan Heston and Robert Summers," *The ICP Bulletin* 5:1, 3–6, 2008 (http://siteresources.worldbank.org/ICPINT/Resources/270056-1208272795236/ICP_bulletin_03-04_web.pdf).
Heston, A., R. Summers, and B. Aten, "Some Issues in Using Chaining Methods for International Real Product and Purchasing Power Comparisons," Paper presented at the Joint World Bank and OECD Seminar on Purchasing Power Parities, Washington DC, January 30–February 2, 2001.
Hill, P., *Inflation Accounting*, OECD, Paris, 1996.
———, "Estimation of PPPs for Basic Headings Within Regions," in *ICP 2003–2006 Handbook*, The World Bank, Washington DC, 2007a (http://siteresources.worldbank.org/ICPINT/Resources/Ch11.doc).
———, "Aggregation Methods," in *ICP 2003–2006 Handbook*, The World Bank, Washington DC, 2007b (http://siteresources.worldbank.org/ICPINT/Resources/ch12.doc).
———, "The Ring Program: Linking the Regions," in *ICP 2003–2006 Handbook*, The World Bank, Washington DC, 2007c (http://siteresources.worldbank.org/ICPINT/Resources/Ch13_Ring_Feb07.doc).
———, "Ring Comparison—Linking Within-Region PPPs Using Between Region PPPs," in *ICP 2003–2006 Handbook*, The World Bank, Washington DC, 2007d (http://siteresources.worldbank.org/ICPINT/Resources/ch14_Linking_Apr_06.doc).
———, "Linking PPPs and Real Expenditures for GDP and Lower Level Aggregates," in *ICP 2003–2006 Handbook*, The World Bank, Washington DC, 2007e (http://siteresources.worldbank.org/ICPINT/Resources/Ch15_Linking2Dec2006.doc).
———, "Elementary Indices for Purchasing Power Parities," Paper presented at the Joint UNECE/ILO Meeting on Consumer Prices Indices, Palais des Nations, Geneva, May 8–9, 2008 (http://www.unece.org/stats/documents/ece/ces/ge.22/2008/mtg1/zip.24.e.pdf).

Hill, R. J., "A Taxonomy of Multilateral Methods for Making International Comparisons of Prices and Quantities," *Review of Income and Wealth*, 43, 49–69, 1997.
———, "Comparing Price Levels across Countries Using Minimum Spanning Trees," *Review of Economics and Statistics*, 81, 135– 42, 1999a.
———, "International Comparisons using Spanning Trees," in A. Heston and R. E. Lipsey (eds), *International and Interarea Comparisons of Income, Output and Prices*, Studies in Income and Wealth, Volume 61, NBER, University of Chicago Press, Chicago, 109–20, 1999b.
———, "Measuring Inflation and Growth Using Spanning Trees," *International Economic Review*, 42, 167–85, 2001.
———, "Constructing Price Indexes Across Space and Time: The Case of the European Union," *American Economic Review*, 94, 1379–410, 2004.
Hill, R. J. and M. P. Timmer, "Standard Errors as Weights in Multilateral Price Indexes," *Journal of Business and Economic Statistics*, 24, 366–77, 2006.
Iklé, D. M., "A New Approach to the Index Number Problem," *Quarterly Journal of Economics*, 86, 188–211, 1972.
Khamis, S. H., "A New System of Index Numbers for National and International Purposes," *Journal of the Royal Statistical Society Series A*, 135, 96–121, 1972.
O'Connor, J., "Business Uses of PPPs: Challenges and Opportunities," *ICP Bulletin*, 5(2), 3–7, 9, 2008.
Rao, D. S. Prasada, "A System of Log-Change Index Numbers for Multilateral Comparisons," in J. Salazar-Carillo and D. S. Prasada Rao (eds), *Comparisons of Prices and Real Products in Latin America*, Elsevier Science, New York, 127–39, 1990.
———, "On the Equivalence of the Generalized Country-Product-Dummy (CPD) Method and the Rao System for Multilateral Comparisons," Working Paper No. 5, Centre for International Comparisons, University of Pennsylvania, Philadelphia, 1995.
———, "Weighted EKS and Generalized CPD Methods for Aggregation at the Basic Heading Level and Above Basic Heading Level," Paper presented at the Joint World Bank and OECD Seminar on Purchasing Power Parities, January 30–February 2, Washington DC, 2001.
———, "On the Equivalence of Weighted Country Product Dummy (CPD) Method and the Rao System for Multilateral Price Comparisons," School of Economics, University of New England, Armidale, Australia, March 2002.
———, "The Country-Product-Dummy Method: A Stochastic Approach to the Computation of Purchasing Power parities in the ICP," Paper presented at the SSHRC Conference on Index Numbers and Productivity Measurement, Vancouver, Canada, June 30–July 3, 2004.
Selvanathan, E. A. and D. S. Prasada Rao, *Index Numbers: A Stochastic Approach*, University of Michigan Press, Ann Arbor, 1994.
Sergeev, S., "Calculation of Equi-Characteristic PPPs at the Basic Heading Level (Modification of the Method of 'Asterisks')," Paper presented at the Meeting of the Working Party on Purchasing Power Parities, Eurostat, Luxembourg, June 12–13, 2002.
———, "Recent Methodological Issues: Equi-Representativity and Some Modifications of the EKS Method at the Basic Heading Level," Working Paper No. 8, Statistical Commission and Economic Commission for Europe, Joint Consultation on the European Comparison Programme, Geneva, March 31–April 2, 2003.
———, "The Evaluation of the Approaches Used for the Linking of the Regions in the ICP 2005," Unpublished Paper, Statistics Austria, December, 2009.
Summers, R., "International Comparisons with Incomplete Data," *Review of Income and Wealth*, 29, 1–16, 1973.
Szulc, B., "Indices for Multiregional Comparisons," *Przeglad Statystyczny*, 3, 239–54, 1964.
Trewin, D., "What Have We Learnt from the 2005 ICP Round?" *The ICP Bulletin*, 5(1), 7–10, 2008 (http://siteresources.worldbank.org/ICPINT/Resources/270056-1208272795236/ICP_bulletin_03-04_web.pdf).
van Ark, B., A. Maddison, and M. P. Timmer, "Purchasing Power Parity Measurement for Industry of Origin Analysis," *The ICP Bulletin*, 5(1), 29–34, 2008 (http://siteresources.worldbank.org/ICPINT/Resources/270056-1208272795236/ICP_bulletin_03-04_web.pdf).
van Ijzeren, J., *Index Numbers for Binary and Multilateral Comparison*, Statistical Studies 34, Central Bureau of Statistics, The Hague, 1983.
Vogel, F., "The 2005 ICP has Passed its Final Milestones," *The ICP Bulletin*, 5(1), 13, 2008 (http://siteresources.worldbank.org/ICPINT/Resources/270056-1208272795236/ICP_bulletin_03-04_web.pdf).
World Bank, *2005 International Comparison Program: Tables of Final Results*, preliminary draft, Washington DC, February, 2008 (http://siteresources.worldbank.org/ICPINT/Resources/ICP_final-results.pdf).