

# Price Structures, the Quality Factor, and Chaining

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## Introduction

1. It will come as no surprise that at a meeting discussing the first phase of the ICP at the World Bank almost 30 years ago, there were discussions of methods of producing PPPs and international comparisons of real product. At that session Phase I results were presented using many alternative methods: Walsh, EKS, own country weighted binaries, Fishers expressed relative to the United States, Van Yzeren, our beloved G-K method, and the then the still much loved (by others!) exchange rates (KKHS, 1975, p. 75). There was much heated discussion, little of which is memorable except for one remark of Nancy Ruggles that has remained with us. She said that the important thing was not the difference between the various non-exchange rate methods, but that the comparisons get done. That was good enough then, but what about now?
2. This paper looks at alternative approaches to multilateral comparisons based on spatial chains. The ground covered includes a review of the multiple-benchmark problem and a discussion of what might give rise to it. While much of our recent work has been with respect to the Penn World Table (PWT), most of this paper will be concerned with benchmark comparisons. In particular we argue that serious consideration be given to spatial chaining as a method of multilateral comparison, but there still remain major problems to solve. The case we make is as much empirical as it is methodological. Our application is to the 115 country 1996 reduced benchmark data. For this data set, we examine spatial linking based upon the spanning tree approach of Robert Hill, but using both price similarity as well as the Paasche-Laspeyres spread as criteria. We go on to describe how we might extend this benchmark over time and space along the lines of PWT.
3. Part A of this paper discusses the problems posed by multiple benchmark comparisons. In Part B we focus on spatial chaining based on the work and conversations with Robert Hill, Erwin Diewert, Michael Ward, none of whom is implicated in what follows. Part C provides an empirical implementation of a chaining scheme based upon the recent benchmark work for 1996. Part D then looks at the problem of extending this across time and space.

## A. Problems Posed by Multiple Benchmark Comparisons

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<sup>1</sup> The University of Pennsylvania and Bridgewater State College. Support of the National Science Foundation (SES99-11377) for this work is gratefully acknowledged. An earlier version of this paper was presented at the Joint World Bank-OECD Seminar on Purchasing Power Parities, Washington D.C., January 30 – February 2, 2001.

4. This section takes up several problems that have emerged with the availability of benchmark comparisons over a number of years. The issues examined include the reconciliation of national growth rates with the growth rates implied by successive benchmark comparisons; the question of using the latest benchmark as the base for extrapolations; and the relationship of the number of countries included in a benchmark to the resulting estimates.
5. If per capita GDP in India relative to Korea is 40% in a 1970 benchmark and 35% in a 1975 benchmark, then one inference is that the growth rate per capita in Korea must have been about 5% more than India between 1970 and 1975. Often such an implied result is not consistent with the national growth rates in the two countries, posing a problem to users. Of course, the two estimates of growth rates should not be identical, but it is still disconcerting to producers and users of the data when the differences are as large as they have been in the ICP thus far.
6. The differences in growth rates arising from the difference in concepts are only part of the explanation for the observed differences. When countries have participated in several benchmark comparisons, there will be the inevitable stochastic differences in the item samples and weights used in the various benchmark purchasing power estimates. This underlies the motivation for the EU system of annual comparisons and for other OECD countries to move towards annual comparisons. However, the experience of the recent OECD comparisons in 1993 and 1996 as well as that of other multiple benchmark pathologies suggests that harmonization of items in the temporal and benchmark price comparisons may be only part of the problem.
7. Consider the differences in the standings of countries relative to the United States that emerge from the 1993 and 1996 benchmark studies. One of the puzzles of the 1996 OECD comparison is that 16 of 23 countries have higher GDPs per capita relative to the U.S. than in the 1993 benchmark. However, the economies of many OECD countries like Austria and Canada were experiencing low growth between 1993 and 1996 while the U.S. was enjoying respectable growth.<sup>2</sup> It is paradoxical that Canada, for example, moved relative to the U.S. from 77.2 to 79.5 (US = 100) between the 1993 and 1996 benchmarks, both based on the EKS method.<sup>3</sup> This implies that Canada's relative growth rate over the 3 years was 2.9 per cent greater than that of the U.S. However, its national accounts growth rate was 2.7 percent less than that of the U.S.'s national accounts per capita GDP growth. This is a combined difference of over 5.5%. For many of the other OECD countries, the combined differences erred in the same direction: 2.4% for Japan, 1.0% for Belgium, 3.5% for Australia, and 2.7% for Austria.

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<sup>2</sup> From 1993 to 1996 per capita GDP growth in the U.S. was 8.1% before the revised national accounts numbers for 2000 were released, where the growth is put at 6.4%. It is not clear which should be used for the illustrations above. We have opted for 7.2% as a compromise.

<sup>3</sup> EKS refers to the method of Eltető, Köves and Szulc, that in turn was developed by Gini. Several of the comments related to OECD benchmarks have been informed by Scarpetta, Bassanini, Pilat, and Schreyer [ECO/WKC/(2000)21].

8. Several questions flow from this:
- i. When there are differences between benchmarks that do not seem consistent with other information, does it make sense to base results on only the latest benchmark?
  - ii. Does the focus on the U.S. as the numeraire for many comparisons in any way affect our understanding of changes over time?

### **Use of the Latest Benchmark**

9. As to the first question, it has often been official practice to use only the latest benchmark as the basis for current, past and future projection comparisons until the next benchmark becomes available.<sup>4</sup> Use of the latest benchmark is simple and understandable, virtues that should not be taken lightly. Further, those producing the benchmarks try to improve the quality of the data each round so there is a basis for believing the latest benchmark is better than its predecessors. Since most users are likely to use the results to analyze countries' most recent economic experience, it may appear more sensible to base results on the most recent benchmark. To our knowledge there have not been tests to see whether the quality of comparisons has improved from benchmark to benchmark for the OECD. However, we accept these as reasonable positions to defend.
10. But there are at least two counterarguments. And here we refer only to using the latest benchmark for purposes of forward extrapolations until the next one becomes available. One argument turns on the number of countries in each benchmark, an issue taken up below. The second relates to an implicit assumption involved in opting for the latest benchmark, namely that countries are in international macro-equilibrium from one benchmark to another, something we certainly do not believe has been the case for the United States over the past 25 years. (Heston and Summers, 1993). What we mean by not being in international macro-equilibrium is that movements of the real exchange rate of a country significantly depart from PPP movements from benchmark to benchmark.
11. Table 1 presents data designed to illustrate our point. Column (1) presents an index of the price level of the US expressed relative to the 4 largest EU countries with 1990 equal to 100.<sup>5</sup> If there is a correspondence between movements in exchange rates and

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<sup>4</sup> The OECD has moved away from this practice since 1993 in that backward extrapolations between two benchmark years take into consideration both sets of results, while forward extrapolations take into account only the latest year benchmark. For example estimates for 1994 and 1995 would take into account both the 1993 and 1996 benchmarks, while estimates after 1996 will be based only on the 1996 benchmark until the 1999 benchmark is completed.

<sup>5</sup> When the U.S. is used as numeraire the price level is taken as 100 and variation from benchmark to benchmark shows up in other countries. To take this into account in Table 1 we first express the price level of the U.S. relative to the four largest countries in the European Union that have participated in all of the benchmark comparisons, namely France, Germany, Italy and the U.K. In this method of presentation, the US price level can vary from benchmark to benchmark; and a glance at Column (1) of Table 1 shows that it most certainly does vary.

relative inflation rates in the U.S. and these countries the index in column (1) of Table 1 would remain around 100. This is clearly not the case. Basically price level fluctuations can occur when relative inflation rates differ, while exchange rates remain the same; or when exchange rates change and relative inflation rates are similar; or some combination of the two.

- The other two columns in Table 1 provide measures of the US exchange rate and suggest that the price level movements of the United States are primarily related to exchange rate movements. Column 2 is the real effective exchange rate of the US\$ as estimated by IMF, which is a measure of changes in the dollar prices at exchange rates of goods that the United States buys and sells, weighted by country specific exports and imports. When the effective exchange rate rises, it means the relative costs of importing goods has fallen and the cost of exporting has risen. Column 3 is the nominal rate of the US\$ to the Special Drawing Rights (SDR) of the IMF. These relationships are also represented in Figures 1 and 2.

**Figure 1: Relation of US Price Level To Real Exchange Rate**

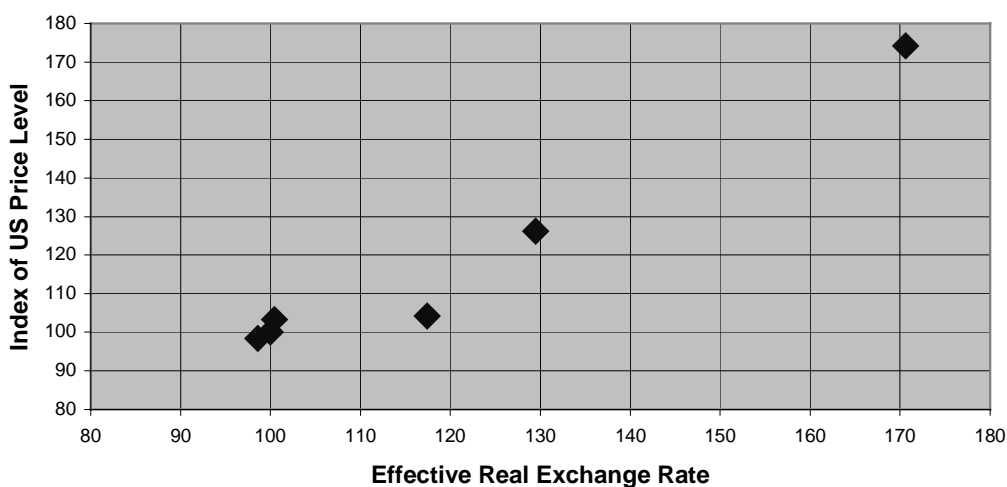
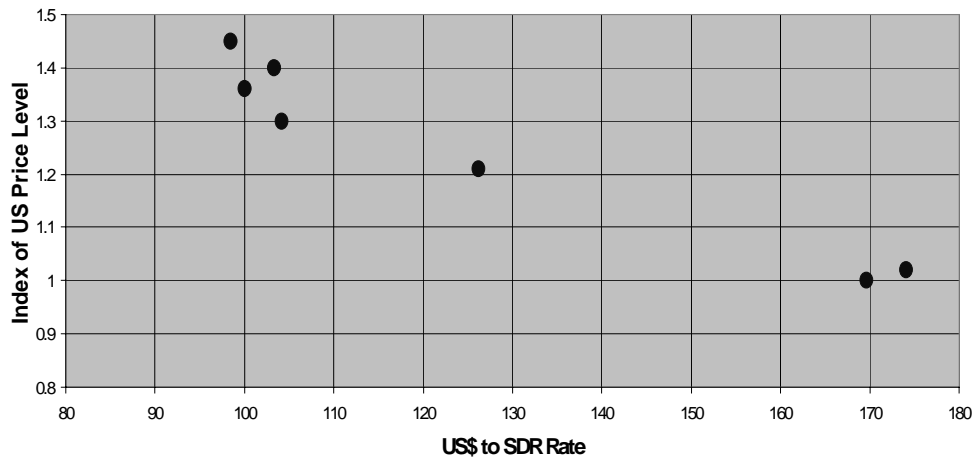


Figure 2: Relation of US Price Level to US\$ per SDR Rate



13. In both Figures 1 and 2 the index of the US price level relative to the four EU countries is on the vertical axis. In Figure 1, the real exchange rate beginning with the 1975 benchmarks, is on the horizontal axis, and there is a strong positive relationship ( $r = .98$ ). In Figure 2, the exchange rate or the US\$ to the SDR is on the horizontal axis, and we find that there is a strong negative relationship ( $r = -.97$ ) with the index of the U.S. price level. So not only is the index of the US price level not flat across benchmarks, but it is driven by movements in exchange rates.

Table 1: Movements of the US Price Level and Measures of the US Exchange Rate

Benchmark Year	Index of US Price Level to EU4 (1990=100) (1)	Effective Real Rate of Exchange (1990 = 100) (2)	\$ Rate to SDR (3)
1970	169.6	Not available	1.00
1975	126.2	129.5	1.21
1980	104.2	117.4	1.30
1985	174.1	170.6	1.02
1990	100.0	100.0	1.36
1993	103.3	100.5	1.40
1996	98.4	98.6	1.45

14. This divergence from a flat relationship is what we mean by a country not being in macro-international equilibrium. The most striking instance of course is 1985 when Fed policies supported a very strong dollar. Many would say this was at the cost of a world recession and the creation of a rust belt in the Midwest.<sup>6</sup> The bottom line is that

<sup>6</sup> This is strikingly revealed in a research report of the OECD that shows the maximum and minimum values of the price levels observed in various benchmarks relative to the US. What this report shows is that for the benchmarks from 1980-1996, the maximum PPP values to the US\$

there are major movements in the principal measures of the nominal and real value of the dollar that in timing are associated with significant discrepancies between the U.S. price levels in different benchmarks. Why this occurs we leave to others or to other papers.<sup>7</sup> For now we simply note that if a country as central to comparisons as the U.S. can have significant departures in its price level from that which has been the normal expectation in ICP work, then it does raise questions about using only the latest benchmark.

15. In our own work we have used a reconciliation approach that went by the much maligned term, consistentization. This disparagement notwithstanding, consistentization did reconcile national growth rates with implied growth rates of multiple benchmarks in a sensible way. It made use of information of past benchmarks as well as current benchmarks, which seems a reasonable thing to do. In practice though, this proved difficult to implement.<sup>8</sup>

### **Number of Countries**

16. Clearly a major issue over the years has been that the number of countries has typically increased from benchmark to benchmark in the EU and OECD comparisons. But this is an element that is likely to remain a characteristic of the EU and OECD benchmarks for some years down the line. And of course it is the basis for the “fixity” convention of the EU and OECD. This convention calls for the results for subgroups like the EU to retain their intercountry relationships when they are included in a larger entity like the OECD.
17. To our knowledge the various aggregation methods are not notably robust with respect to changes in the number of countries. For EKS as usually carried out, the weight of indirect comparisons rises with each country added; or put another way the importance of direct comparisons declines from 100% for two countries to 20% if there are ten countries, to 10% if there are 20 countries, and so forth. In the way we

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for the 22 OECD countries that participated in the 1985 benchmark are all observed for 1985. Though it is not shown here, this would also be true if the 1975 and 1970 benchmark comparisons were considered. However, as indicated in Table 1, the index of the US price level in 1970 was very near the 1985 level; for what it is worth, 1970 was still the quasi-fixed exchange rate era.

<sup>7</sup> A line of explanation runs as follows. Fluctuations in the price level index are larger in amplitude than in the exchange rate measures, perhaps because the former covers all of GDP, not just traded goods. Looking at the 1980, 1985 and 1990 benchmarks, we believe something like the following was occurring. The large appreciation of the dollar between 1980 and 1985 had the effect of reducing the prices of tradables relative to non-tradables in the U.S., a Dutch disease type of disequilibrium. In the literature the relative downward movement in the prices of tradables is termed a beachhead effect of the dollar appreciation. Thus 1985 was not an equilibrium year, with the U.S. enjoying a temporary increase in income through a terms of trade effect, that reversed itself by the end of the 1980s. For more, see Heston and Summers (1993, pp.366-67).

<sup>8</sup> It was also hard to sell the idea of modifying country growth rates to countries, international organizations, and to men or women of affairs. Therefore in our recent uses of consistentization we have not modified country growth rates, but only the different benchmark estimates.

have used G-K in world comparisons we attempted to allow for the increase in the number of countries by using so-called supercountry weights. This was a procedure in which an extra weight was assigned to each participating country that reflected the weight of similar non-participating countries. It still seems the right thing to do in principle, but in practice, there may remain substantial differences between the price structures of new countries and those of the countries that previously represented them in earlier benchmarks.

### **Data Quality and Other Comparison Difficulties**

18. Related to the increase in the number of countries is the fact that the benchmark data for new countries in a group are usually of lower quality both initially, and often later too. One reason is that the first countries undertaking purchasing power comparisons joined or were chosen because of the higher quality of their statistical systems. Other factors affecting the quality of data and its comparability across countries in all benchmarks is the fact that the number of products and services and their quality are changing more rapidly than in the past. As is discussed in Heravi, Heston and Silver (2001) this has typically been handled by choosing items for comparisons that are of somewhat dated technology because they will be the common denominator across the countries. This is not obviously the appropriate choice.
19. A related quality problem concerns comparing like with like. To the extent possible one would like to compare goods and services from comparable outlets. In Beijing one may get a haircut in a hotel, an exclusive shop, a stall, and in the summer on the street. Clearly one does not want the average price of a haircut in China to compare the average price in Finland, but rather to hold the outlet constant, and aggregate the ratios in some appropriate way. This is a common problem in services, like the transport and medical areas, but it is also very important in commodities too.<sup>9</sup> In fact the “new good” problem so common in time-to-time indexes has its direct counterpart in spatial comparisons. There are many instances where items are common in some countries and not others, usually because markets are income sensitive, or factor price differences lead to the prevalence of lower-tech items being common in poorer countries for the same purposes that higher-tech items are used in more affluent countries. Despite rapid globalization, differences in income and size of markets mean that new or technologically more sophisticated products will be common in some countries and not common typically in others. If it is an item that is a passing fad, a case can be made for not trying to use it for spatial comparisons.
20. But often there are items much more or much less available or of much different quality in poorer countries compared to more affluent countries. This will show up in both consumer goods and services and also producers durables. If one is to carry out

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<sup>9</sup> A well known growth economist looked at our medical price parities for the 1980 benchmark and made the following comment. He said that based on those parities, he would have his neurosurgery done in Kenya. While we did not take that as a wholly friendly comment, it does point up well the new or income-sensitive product, or service problem in the spatial context.

strict matching, it is necessary to use common denominator items.<sup>10</sup> Austria has given a great deal of thought to the kinds of quality adjustments in the comparisons for the Group 2 countries in Europe as one way to deal with this problem. Services may be the least well covered in national statistics in time-to-time indexes, and they are an increasing share of consumption. The problems of comparing non-priced services over time or across space are even more problematic.

21. These problems are in the nature of the data collected. Couldn't one improve comparisons by collecting better service price data or to try harder to add new goods to existing price collection lists? The answer of course is "Yes" if the resources are available and this exercise has a priority in the statistical programs of the countries involved. But consider the problem of comparing priced-services, which provides a possible bridge on how to compare non-priced services. In fact, as poor as comparisons of service prices are in high income countries, they are still much better than those in low income countries, where very few service prices are collected for either temporal or spatial indexes. We do not see this situation improving in the near future.

### **The Bottom Line of This Section**

22. These remarks suggest that new benchmark comparisons are put together with (i) different and usually larger groups of countries than in the past; and (ii) with price inputs that may be quite weak in some countries and in some expenditure headings. Further, in addition to new goods issues, there are systematic problems of quality differences in goods and services across countries as well. Current methods of aggregation probably amplify the effects of data errors, quality differences and new countries, rather than compensate for them. The combined effect is to make it difficult to make good benchmark comparisons and hard to reconcile multiple benchmark comparisons. What to do? We do not have all the answers, but we will argue in the next section why chaining may be a helpful approach to some of these questions.

## **B. Spatial Chaining**

23. In this section we discuss one method of spatial chaining proposed by Robert Hill. We explore some reasons why this kind of approach may help overcome some problems of quality control that have been difficult in spatial comparisons. We also propose an alternative version of Hill's spanning tree namely use of price similarity indexes (SIM) which we believe provides a better basis for a spatial chain than Paasche-Laspeyre Spreads (PLS).

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<sup>10</sup> In Heravi, Heston and Silver (2001) we have raised the question of using virtual prices in this case. While this may sound like using a pile driver to pound a pin, there are some approaches to the use of virtual prices to obtain parities that may be surprisingly manageable and even reasonable and transparent.

24. The spanning tree approach to chaining that Robert Hill (1999a and 1999b) has explored involves several dimensions. First, it provides a path by which to chain over space that involves the minimum number of binary comparisons to link all countries in a comparison. The particular path Hill has chosen in his work minimizes the sum of the Paasche-Laspeyres Spread (PLS). In this way each country is linked to at least one other country and some countries may be linked to several countries.
25. In the Hill version one country may become a star for several other countries. However, there is an important difference between this type of star country and those familiar from past practice, such as the role of Austria in the Group 2 comparisons in Europe. In the spanning tree version there is a similarity in economic structure of the countries linked to a star country, whereas that has not been the characteristic of links in the ICP in the past. For example, Japan is not a very good link in terms of economic similarity between ESCAP and OECD countries.
26. Also note that if one were adopting the Hill approach and there were political reasons for country groups, these might be accommodated. For example, suppose that the EU wished only to use binaries involving its countries. There would be no problem in accommodating such a constraint within the spanning tree approach. It would simply mean in Hill's framework that the spatial chain did not minimize the PLS across all countries, but it might still be a perfectly plausible chain.
27. What does one do with a binary chain when one has it? The chain simply provides an order for binaries. The next step is translate the binaries into a common real measure like the US\$ building up through the established chain. Hill has shown the results one would get if one performed the indicated binary comparisons, which would of course be transitive at the GDP level. We carry out the same exercise in the empirical section and discuss alternatives in the concluding section.
28. The result of this chain binary might in our view be a more reasonable approach than Gini-EKS as typically applied. Why? In addition to EKS being anything but transparent in its operation, there is a much more fundamental point. If there are systematic differences in quality across countries that extend to many commodity groups and to both priced and non-priced services, then many direct binaries are flawed. If they are included in EKS, they influence the final result similarly to less flawed binaries. If there are poor quality data for some of the countries, then following the spanning tree approach reported in this paper, they might also influence the resulting tree, a question we take up later in the paper.
29. One could modify EKS to recognize the likely systematic differences in data quality or item qualities across countries. To a limited extent that is what the OECD has done in building up its 1996 comparison from four groups of countries.<sup>11</sup> A way to

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<sup>11</sup> The OECD has retained fixity for various subgroups of countries. While this was originally done to maintain only one set of EU comparisons, it has the effect of eliminating the effect of a number of indirect binary comparisons in an EKS for a larger group of countries.

use EKS that would meet some of the systematic data problems is to give very little weight to doubtful binaries. In fact one can think of the spanning tree method, if you like, as an extreme pruning of binaries based on the economic proximity of countries.<sup>12</sup>

30. Also, Hill has suggested that the spanning tree could be implemented as a resource-saving device since one could reduce the multilateral character of the price collection. However, as Hill and others have noted, the spanning tree will not necessarily be stable over time, so the resource savings may not be great. However, this temporal instability in the spanning tree is not really a major drawback to its use, except as a precise guide to what binary comparisons to emphasize in some future benchmark. However, as a guide to similarity of economies, the spanning tree approach seems to have considerable merit, including one feature not yet discussed. Before developing that feature, namely spatial chaining and quality of goods, we want to discuss another candidate criteria for spanning trees, namely price similarity.

### **Paasche-Laspeyere Spread (PLS) and Price Similarity (SIM) Indexes**

31. As a way of summarizing how closely countries resemble each other in price structure, we have in previous work used similarity indexes. These are the raw correlation coefficient between the vector of price parities across the basic headings of each possible pair of countries weighted by the importance of the basic heading. The similarity of prices is given by:

$$S_p = \frac{\sum_{i=1}^m w_i pp_{ij} pp_{ik}}{\sqrt{\sum_{i=1}^m w_i pp_{ij}^2 \sum_{i=1}^m w_i pp_{ik}^2}}$$

32.  $S_p$  is the price similarity index between country j and k, and  $pp_{ij}$  is the price-parity in price level form for the i'th heading in country j, expressed as a deviation from the average value for the heading.<sup>13</sup> This version is termed SIM-NORM below to

<sup>12</sup> Unfortunately, the actual spanning tree method can not make claims that it uses only the binaries to countries closest to it in the PLS sense. For example Barbados may be the most closely linked by PLS to Jamaica, and less so to Belize. However, if Jamaica is closer to Brazil than to Barbados, and Brazil is a star to other countries, then Barbados may be only directly linked to Belize and not be directly linked to Jamaica, even though Jamaica is the country with which its PLS is least. Hill (1999) sets out why links beginning with any particular country like Barbados, that would involve a direct link to Jamaica, are only one of a set of spanning trees.

<sup>13</sup> We are indebted to Erwin Diewert and Jim Cuthbert for pointing out that in an earlier version of this paper, the definition of the similarity index was not base-country invariant. In that version, the parity for each heading was expressed as the national currency units per US dollar, with the entry for the US for each heading being 1.0. and we have also presented those results below. However, because changing base country does affect the spanning tree path and the resulting multilateral comparisons, we felt it important to go with a definition of the similarity index that was base country invariant. In the present version each country's price level for a heading is

distinguish it from SIM, that depends on the base country chosen. The weight for each of the  $m$  headings,  $w_i$ , is defined as:

$$w_i = \frac{(\text{exp}_{ij} + \text{exp}_{ik})}{2}$$

33. where  $\text{exp}$  is a country's heading expenditure share.<sup>14</sup> For each pair of countries, the average of their expenditure shares is used as the heading weight.
34. The price similarity index, a raw correlation coefficient, will range between 0 and 1. It will be close to 1 for pairs of countries whose relative prices across headings are close together, and will be less for pairs of countries with quite different price structures. It will not necessarily bear a close negative relationship to the PLS because relative quantities enter into the PLS while the similarity index reflects only prices. Our reasons for also using the price similarity index is that we believe it contains more relevant information for spatial chaining than the PLS. This is because we believe that many of the errors entering into the generation of heading parities are correlated and that this will show up in the similarity indexes. This argument is developed below.

### **Spatial Chaining and Data Quality**

35. There are three factors that systematically affect the heading parities across different groups of countries. First, the quality of many priced services is hard to hold constant across countries, while there is no satisfactory way to measure non-priced services. It is generally thought that this tends to produce parities for these headings that are too low and real expenditure shares that are too high for lower income countries.
36. Second, where it is difficult to match like with like across countries, it is felt that the quality of commodities in poorer countries tend to be lower than the corresponding quality in richer countries. For example, bulk rice sold in supermarkets in richer countries is likely to be more uniform and contain less foreign matter than bulk rice in a rural or urban market in a poorer country.

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expressed relative to that of the simple average of all the countries. As discussed below in the text, there are alternative measures of price, and or price and quantity similarity that might be used as criteria for spanning trees. This is clearly an area for further research.

<sup>14</sup> . This definition of the weight is different from the one used in KHS (1982). Previously we had used the world average expenditure real share for each heading that came from total world expenditures from a G-K aggregation. We believe now that the average shares of each pair of countries at their national prices is a more appropriate weight. Also in KHS (1982) we did not use the heading parities, but rather the heading parities divided by the overall parity of the country so that it was a relative price that depended upon an overall PPP. We did this to provide an easy way for the US, the numeraire, to also have a similarity index with each country. And each country would have a similarity index with the world average, or Earthea, as we termed the world price structure. This was not done in the present paper, however. As noted in the previous footnote, some earlier versions of our similarity index were not base-country invariant.

37. Third, we believe that the usual practice of matching across quite different economies often produces inappropriate comparisons that may err in either direction. For example, suppose beer prices are compared with Heineken in the can as a common denominator specification. For low income countries where import duties or restrictions often push up the price compared to what would be the case without restrictions, then using Heineken prices will raise the heading parities of such countries. We believe that more commonly errors run in the other direction, namely that in order to obtain matches it is necessary to choose common denominator items that tend to understate parities in lower income countries. It is also likely that the patterns will be similar across basic headings. That is, if parities for alcoholic beverages are overstated and those for electrical machinery understated, this will occur for the same groups of countries.
38. One further point should be made. The PLS will be affected for those headings in low-income countries where the parities are understated or overstated. If the Heineken effect dominates alcoholic beverages, then the true quantity consumed is larger than obtained by dividing expenditure ratios by price ratios for that heading. And for a heading like electrical machinery, the true quantity is less than appropriate for the heading. Whatever the merits of the PLS as a criterion on an analytical level, it seems to us that the similarity index is more likely to pick up these systematic variations in heading parities than the PLS.

### **C. An Empirical Application**

39. The empirical application relates to 1996 where 32 heading parities and expenditure shares were put together for 115 countries from various regional comparisons by the World Bank. The underlying data set combined the benchmark comparisons of the EU, OECD, and other European and former Soviet Union countries for 1996, a total of 52 countries; The World Bank then updated the 1993 benchmark ICP comparisons for 14 ESCAP countries, 22 African countries, 12 Caribbean countries and 8 ECWA countries to 1996 and combined these with the results for 9 South American countries for 1996. (The total of 117 double counts Japan in the OECD and ESCAP and Egypt in Africa and ECWA). The data then combine ICP benchmark comparisons in different regions for either 1993 or 1996, with the former being brought forward to 1996. The linking of the various regions was done in different ways, usually with a link country like Japan for ESCAP, and the United States for Africa, and the Western Hemisphere.
40. For this data set, six multilateral results are reported, each an index of per capita Domestic Absorption as a percent of the United States. These are (1) Fisher indexes with the U.S. as the only node or star country; (2) EKS; (3) supercountry-weighted G-K; (4) a binary chain based on the Paasche-Laspeyres Spread (PLS); and two binary chains based upon the price similarity indexes, (5) with the United States as base country (SIM-US) and (6) with row-normalized price parities (SIM-NORM). In

order to make estimates for the three spatial chain approaches it is necessary to first obtain the minimum spanning trees.

41. There are 6555 ( $115 \times 114 / 2$ ) possible links for each chain, that is, half the matrix of possible binaries. The first 114 links to join all countries without creating a closed loop form the minimum spanning tree or chain for the PLS and SIM-US and SIM-NORM indexes. Before reporting these results we would like to provide some representation of the chains that make up the spanning trees, not a transparent task. To facilitate the reader in using Table 3 and Figures 3-5 where only ISO country codes are used, Table 2 provides the ISO country codes and country names alphabetically.

### **The Character of the Chains**

42. Table 3 in the Appendix shows the pairs of countries that make up the spanning trees based upon PLS and Similarity (SIM-US) with the US as base, and the base country invariant version, SIM-NORM. Each pair of countries represents a link in the spanning tree chain. For readability, the countries in the table are sorted alphabetically by their three-letter ISO codes with each of the 114 pairs repeated with the second country first. Thus, there are  $114 \times 2 = 228$  links in Table 3 for the 115 countries. For example, if Belgium and France form a link, the BEL-FRA pair is listed before the FRA-BEL link. This makes it easier to find all the links to any one particular country. The total number of links for each country are given to the left of the country code. Figures 3-5 in the Appendix are graphical representations of the three spanning trees.
43. In the PLS tree, the pair with the lowest Paasche-Laysperes spread is Peru and Ecuador, while the highest spread is between Georgia and Barbados. In the SIM-US tree, the highest similarity index is between France and Belgium, with the lowest between Turkmenistan and Belarus. For the final graph, SIM-NORM, the highest and lowest pairs in the tree are Spain and Greece and Belize and the Bahamas. Note that this rank does not correspond exactly to the spread or similarity index rank, since pairs of countries with a high index are excluded if they form a closed loop in the chain. The PLS tree required going to the 2114<sup>th</sup> ranked pair (out of the 6555 possible pairs), the SIM-US tree to the 2291<sup>st</sup> pair and the standardized SIM-NORM to the 2208<sup>th</sup> pair.
44. Looking at the number of links in Table 3 for the PLS, there is some good news and bad news. The good news about Albania is that its links are all geographically close; the bad news is that it has four links so, like Uzbekistan with five links, it is numerically important in the chain in Europe and the former Soviet Union, when it is unlikely that the quality of its statistical base is as strong as countries like Hungary, which only has two links. The same problem exists in other world areas. Spain in the EU has the most links: five, but data quality in Spain and Greece, with four links, is probably lower than the Netherlands, which has only one link. Similar anomalies exist in Africa, where Tanzania has six links, the most of any country in Table 3, and chains the region to Asia and the Middle East. Is the situation any better with the

chaining using price similarity indexes? The answer is probably no. Chile and Spain both have seven links, while Bolivia, Ecuador, Peru and Ukraine each have five links for the SIM-NORM spanning tree. And with the exception of Ukraine, the links are widely spread across the world regions.

45. The fact that countries with weaker statistical systems may play an important role in spatial chaining is clearly a limitation on the using spanning trees based on mechanical rules such as those applied in generating Table 3. This is clearly an area where more research needs to be carried out, including investigation of alternative criteria for generating spatial chains. One direction would be to use other definitions of similarity such as those suggested by Allen and Diewert (1981), Theil (1967), and Cuthbert (2000) to generate spatial chains. Constraints might also be introduced into the spanning tree approach so as reduce the possibility that countries with weaker statistics enter into say, more than 2 comparisons. However, for present purposes we will concentrate on how good a multilateral comparison can be generated from the three spatial chains in Table 3.

### **The Results**

46. Once the links in the trees are determined, we must work backwards to obtain the corresponding binaries for those 114 pairs of countries relative to the United States. For example, in the SIM-US tree we take the Germany relative to the US Fisher binary (1.357) as the SIM tree binary since this is the only US link. But Germany is linked to Luxembourg, so the SIM binary for Luxembourg relative to the U.S. (1.297) is obtained by multiplying the LUX-GER Fisher (0.955) by the GER-USA Fisher. The Netherlands and Switzerland are also linked to Germany in the SIM-US tree, so their SIM-US binary relative to the U.S. would be obtained in the same manner. A more 'distant' country, such as Morocco, requires traversing more links in order to obtain the Morocco-USA binary for the SIM-US tree. In this way binary comparisons for Domestic Absorption may then be compared for the 3 spanning trees and US based Fisher binary estimates and the EKS and G-K multilateral results.
47. These results are presented in Table 4 in the Appendix. The direct Fisher binaries were applied to nominal per capita Domestic Absorption in 1996 dollars, and are ranked in decreasing magnitude relative to the United States (column 1). The EKS, G-K and the binaries from the three chain indexes are shown in columns 2-6. All are indexed with the United States equal to 100.
48. The only exploration of Table 4 that we attempt here is to examine the relationship between price levels from the various methods with per capita domestic absorption. We first take as the income measure the per capita domestic absorption based on the direct Fisher binaries with the United States, on the grounds that these are transparent and should not obviously privilege one of the other methods in a regression explaining its price level. Using a semi-log form, we regress the price levels of Fisher, EKS, SIM, SIM Norm, PLS and GK on the log of income relative to the US

from the Fisher binaries with the US. For each method, the intercept, slope, adjusted correlation and standard error are provided in Table 5.

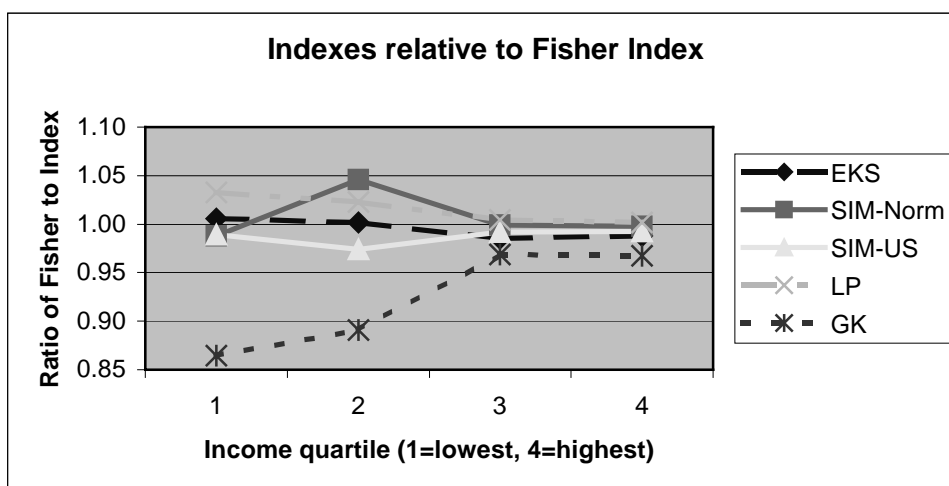
**Table 5: Regression of Price Levels on per capita DA**

	Intercept (std. error)	Log <sub>e</sub> of per capita DA (std. error)	RMSE	Adj R <sup>2</sup>
Fisher	-1.421 (0.234)**	0.243 (0.027)**	0.300	0.412
EKS	-1.388 (0.227)**	0.239 (0.026)**	0.291	0.419
SIM-Norm	-1.522 (0.225)**	0.255 (0.026)**	0.289	0.455
SIM-US	-1.454 (0.221)**	0.245 (0.026)**	0.283	0.445
LP-Spread	-1.401 (0.232)**	0.242 (0.027)**	0.298	0.412
GK	-1.522 (0.216)**	0.248 (0.025)**	0.278	0.461

Model df = 113

\*\* Pr > |t| < 0.0001

**Figure 6: Mean Ratio of Fisher Indexes to Other Methods**



49. The variance of the dependent variable is different for each equation reported in Table 5, so we have taken the residual error as a criterion with which to examine the results. At first glance, the SIM-US and SIM-NORM chain performs slightly better than either the PLS chain or other methods. However, the margins are small and the criterion is one of several that might be used to judge alternative methods. In Table 4

we are basically looking at how tight the relationship is between per capita domestic absorption and the price level across countries.

50. This positive relationship has been consistent in all benchmarks, and is probably the single most important finding of the ICP. But at least since 1975, this relationship has been marked by a fair amount of variance. So the fact that the similarity chains have marginally better fits with the price level we take as encouraging but that is all. The PLS chain also performs nearly as well, so the results in Table 5 reinforce our main conclusion that the spanning tree chains show promise as multilateral methods.
51. Figure 6 summarizes the quantitative results reported in Table 4. The ratio of the per capita income of each country from the various methods to the US based Fisher has been averaged by quartiles. The results in Figure 6 indicate that the G-K has a systematic relation with higher income estimates in the first two quartiles compared to other methods. There is a slight downward drift in the PLS chain, and fairly flat relationships for the EKS and SIM-US. The SIM-NORM has a spike in the 2<sup>nd</sup> quartile but is otherwise similar to all the other indexes except the G-K.

## **D. Conclusion**

52. In this section we will briefly summarize the results thus far and sketch how we would apply the technique proposed here in the Penn World Table (PWT) exercise that extends benchmark estimates over time and space.

### ***Estimates at the Component Level***

53. The empirical results showed few differences between the EKS and the PLS and SIM chains. We argued that the similarity chains a marginally better performance over the other indexes in the income-price level relationship. We would not make much of this.
54. There is one aspect of the chains that seem to us a major advantage over EKS, namely disaggregation. The weakness of the present build-up of aggregates by the EU is that the way in which the aggregates relate to each other is unclear. With the spatial chain, one can certainly do at least as well as EKS with respect to the components.
55. Suppose we have a PLS or SIM chain. Then just as we have generated at the GDP level a set of transitive measures across the countries, we can do the same for components. This has not been carried out here but it certainly can be done. What then? One would be faced with the usual question of how to build up GDP, by adding up the components, or by applying the component shares to the GDP total. However, note that it makes perfectly good economic sense to add up components obtained in this way. And our first thought is that this would be the way to go. It would then provide a transitive matrix of real values that was additive.

56. However, we acknowledge that adding up the components would not preserve fixity for a subgroup of countries, even if that subgroup had built up its comparison based on only binaries within the subgroup. But if we accept the GDP total from such a chain and apply the shares built up from the binary, we do preserve fixity at the GDP level. Further the shares in this case will not correspond to national price shares and will in fact have some analytic meaning. So if fixity is a strong consideration for a group, this way of handling components would preserve it.

### **Extensions over time and space**

57. If we applied the chains at the component level, we would have a set of inputs comparable to those that have been used to build up PWT in the past. Extension to non-benchmark countries, while not without substantial error, would be straightforward. What about extensions over time?

58. Clearly there would be no problem carrying out extrapolations at the GDP level. In PWT we have made extensions over time for the components of C, I and G, in both current and constant prices. Without going into detail, the constant price procedure that we have used could be applied straightforwardly to the components generated from a PLS or SIM chain.

59. With respect to current price extensions over time, we also believe the present procedures could be applied. In PWT we have made current price comparisons in non-benchmark years by extrapolating heading parities back and forth over time.<sup>15</sup> This could be readily carried out with either the PLS or SIM chains. In any given year the binary Fisher matrix could be calculated at an aggregated level, and a set of current price comparisons produced. It would also be possible to re-do the spanning tree each year, but right now that sounds excessive.

### **Some Caveats**

60. This paper offers support for spatial chaining as a basis for multilateral comparisons that at first examination appears comparable to alternative aggregation methods. However, this is hardly the last word on how to do multilateral comparisons.<sup>16</sup> Rather

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<sup>15</sup> The extrapolation of heading parities requires deflators of the given and numeraire country at the appropriate component level. In practice, this has only been done in PWT at the level of C, I, and G because of the lack of more detailed deflators for a large number of countries.

<sup>16</sup> The following anecdote suggests why the discussion of methods of aggregation will not go away quickly. One of the consultants seconded to us in Phase III of the ICP by the then U.K. Ministry of Overseas Development was Harry (Angus) Fell who did work in Sri Lanka. Some years later I (AH) met Angus, then long retired, in Hong Kong where he was consulting on national accounts. He asked me if we were still using the Genghis Khan method, and after a double-take, I realized he meant the G-K method. I then asked him if when I was long retired I would still be worrying about index number problems. He just smiled.

along with the work of others on similarity indexes and spatial chaining, we regard this as a beginning in this area of research. Some of the issues that need to be explored further are below.

61. Our comparisons of spatial chains were based on PLS and on price similarity measures. Other price similarity measures should also be investigated, as well as quantity similarity indexes. Paasche-Laspeyeres spreads are one way of combining price and quantity structures and Cuthbert (2001) has offered an alternative that also warrants investigation.
62. Other problems connecting with the spanning tree approach require further research. What is troublesome in the procedure, which Hill has also mentioned, is that often countries can take a pivotal position in the estimation, even when it is known that their database is not strong. In his work for 1996 OECD countries for example, Hill (2001, p.14) found using the PLS that several countries had three links but that the country with the most links, six, was Greece. On many criteria including overlap of items with other countries, Greece is not obviously the country to play a central role.
63. However, the logic of the minimum spanning tree approach is such that the links between large groups of countries may be any country, regardless of other characteristics that might or might not make them suitable for that role. Can one introduce other constraints into the derivation of the spanning tree that will lead to more plausible spatial chains? This is clearly a priority area of research that needs to be carried out before we can use spatial chaining as a multilateral approach to replace existing methods

## References

Allen, R.C. and W.E. Diewert (1981), "Direct versus Implicit Superlative Index Numbers", *The Review of Economics and Statistics* 63:3, 430-435.

Cuthbert, Jim (2000), "Theoretical and practical issues in purchasing power parities illustrated with reference to the 1993 Organization for Economic Co-operation and Development Data," Journal of the Royal Statistical Society, 163, Part 3, pp. 421-44.

\_\_\_\_\_, (2001), "Using Price and Quantity Indicators to Explore Data Structure," Joint World Bank-OECD Seminar on Purchasing Power Applications, Washington D.C., [www.oecd.org/std/ppp/MTG2001/index.htm](http://www.oecd.org/std/ppp/MTG2001/index.htm), January 30-February 2<sup>nd</sup>.

Heravi, Saeed, A. Heston, and M. Silver, "Using Scanner Data to Estimate Country Price Parities: An Exploratory Study,"

---

Heston, A., and R. Summers (1993) "What Can We Learn from Successive ICP Benchmark Estimates?," in A. Szirmai and D. Pilat ed., Explaining Economic Growth; Essays in Honour of Angus Maddison, North Holland, Amsterdam.

Heston, A., with R. Summers and D. Nuxoll "Comparative Country Performance at Own-Prices or Common International Prices," 1994) in Economics, Econometrics and the Link Essays in Honor of Lawrence R Klein, ed, Jan Dutta, et al. Elsevier, New York.

Hill, Robert (1999a), "Comparing Price Levels Across Countries Using Minimum Spanning Trees," Review of Economics and Statistics, 81, No. 1.

\_\_\_\_\_ (1999b), "International Comparisons Using Spanning Trees," in International and Interarea Comparisons of Income, Output, and Prices, ed. A. Heston and R. Lipsey, Studies in Income and Wealth, vol 61, NBER, Univ of Chicago Press.

\_\_\_\_\_ (2001), "Linking Countries and Regions using Chaining Methods and Spanning Trees, Joint World Bank-OECD Seminar on Purchasing Power Applications, Washington D.C., [www.oecd.org/std/ppp/MTG2001/index.htm](http://www.oecd.org/std/ppp/MTG2001/index.htm), January 30-February 2<sup>nd</sup>.

Kravis, I. B., Z. Kenessey, A. Heston and R. Summers (1975), A System of International Comparisons of Gross Product and Purchasing Power Baltimore: Johns Hopkins University Press, May 1975.

Scarpatta, Stefano, Andrea Bassanini, Dirk Pilat and Paul Schreyer, (2000) "Economic Growth in the OECD Area: Recent Trends at the Aggregate and Sectoral Level," Economic Department Working Papers No. 248 OECD, 26-June.

Theil, H. (1967), *Economics and Information Theory*, Amsterdam: North-Holland.

## APPENDIX

**Table 2. Countries and ISO (International Organization for Standardization) codes**

Country	ISO code	Country	ISO code	Country	ISO code
Albania	ALB	United Kingdom	GBR	Netherlands	NLD
Argentina	ARG	Georgia	GEO	Norway	NOR
Armenia	ARM	Guinea	GIN	Nepal	NPL
Antigua & Barbuda	ATG	Greece	GRC	New	NZL
Australia	AUS	Grenada	GRD	Oman	OMN
Austria	AUT	Hong Kong	HKG	Pakistan	PAK
Azerbaijan	AZE	Croatia	HRV	Panama	PAN
Belgium	BEL	Hungary	HUN	Peru	PER
Benin	BEN	Indonesia	IDN	Philippines	PHL
Bangladesh	BGD	Ireland	IRL	Poland	POL
Bulgaria	BGR	Iran	IRN	Portugal	PRT
Bahrain	BHR	Iceland	ISL	Qatar	QAT
Bahamas	BHS	Israel	ISR	Romania	ROM
Belarus	BLR	Italy	ITA	Russia	RUS
Belize	BLZ	Jamaica	JAM	Senegal	SEN
Bermuda	BMU	Jordan	JOR	Singapore	SGP
Bolivia	BOL	Japan	JPN	Sierra Leone	SLE
Brazil	BRA	Kazakhstan	KAZ	Slovakia	SVK
Barbados	BRB	Kenya	KEN	Slovenia	SVN
Botswana	BWA	Kyrgyzstan	KGZ	Sweden	SWE
Canada	CAN	St. Kitts & Nevis	KNA	Swaziland	SWZ
Switzerland	CHE	Korea	KOR	Syria	SYR
Chile	CHL	Lebanon	LBN	Thailand	THA
Cote d'Ivoire	CIV	St. Lucia	LCA	Tajikistan	TJK
Cameroon	CMR	Sri Lanka	LKA	Turkmenistan	TKM
Congo	COG	Lithuania	LTU	Trinidad & Tobago	TTO
Czech Republic	CZE	Luxembourg	LUX	Tunisia	TUN
Germany	DEU	Latvia	LVA	Turkey	TUR
Dominica	DMA	Morocco	MAR	Tanzania	TZA
Denmark	DNK	Moldova	MDA	Ukraine	UKR
Ecuador	ECU	Madagascar	MDG	Uruguay	URY
Egypt Africa	EGY	Mexico	MEX	Unite States	USA
Spain	ESP	Macedonia	MKD	Uzbekistan	UZB
Estonia	EST	Mali	MLI	St.Vincent & Grenadines	VCT
Finland	FIN	Mongolia	MNG	Venezuela	VEN
Fiji	FJI	Mauritius	MUS	Vietnam	VNM
France	FRA	Malawi	MWI	Yemen	YEM
Gabon	GAB	Nigeria	NGA	Zambia	ZMB
				Zimbabwe	ZWE

**Table 3. : Spanning Tree Links**

	LP Spread		Similarities (US)		Similarities (NORM)					
1	4	ALB	HRV	1	ALB	KAZ				
2		ALB	LTU	4	ARG	BRA				
3		ALB	LVA		ARG	ECU				
4		ALB	POL		ARG	HRV				
5	1	ARG	MEX		URY	2	ARM	IDN		
6	2	ARM	MDA	2	ARM	GEO		ARM	LTU	
7		ARM	UKR		ARM	LVA		1	ATG	KNA
8	1	ATG	KNA	2	ATG	JAM		1	AUS	NZL
9	1	AUS	ESP		ATG	KNA		4	AUT	BEL
10	2	AUT	BEL	3	AUS	GBR			AUT	FRA
11		AUT	CHE		AUS	MEX			AUT	ITA
12	4	AZE	BGR		AUS	NZL			AUT	NLD
13		AZE	KAZ	1	AUT	BEL		1	AZE	UKR
14		AZE	LVA	1	AZE	KAZ		4	BEL	AUT
15		AZE	RUS	4	BEL	AUT			BEL	GER
16	2	BEL	AUT		BEL	ESP			BEL	SGP
17		BEL	NZL		BEL	FRA			BEL	SWE
18	2	BEN	EGY		BEL	GER		1	BEN	GAB
19		BEN	TZA	2	BEN	BWA		1	BGD	PAN
20	3	BGD	LKA		BEN	CIV		3	BGR	ROM
21		BGD	PAK	2	BGD	CHI			BGR	UZB
22		BGD	PAN		BGD	PAK			BGR	VNS
23	1	BGR	AZE	2	BGR	UKR		1	BHR	QAT
24	2	BHR	MDG		BGR	VNS		2	BHS	BLZ
25		BHR	SGP	1	BHR	LBN			BHS	BMU
26	3	BHS	BLZ	1	BHS	KNA		1	BLR	VEN
27		BHS	BMU	2	BLR	MDA		2	BLZ	BHS
28		BHS	LCA		BLR	TKM			BLZ	TTO
29	1	BLR	UZB	1	BLZ	GRD		1	BMU	BHS
30	2	BLZ	BHS	1	BMU	OMN		5	BOL	KAZ
31		BLZ	JAM	1	BOL	MEX			BOL	PER
32	1	BMU	BHS	2	BRA	ARG			BOL	SYR
33	1	BOL	PAN		BRA	VEN			BOL	TJK
34	2	BRA	URY	1	BRB	GRD			BOL	YEM
35		BRA	VEN	1	BWA	BEN		3	BRA	ARG
36	1	BRB	GEO	1	CAN	NZL			BRA	MEX
37	4	BWA	MAR	1	CHE	GER			BRA	PRT
38		BWA	SEN	3	CHI	ARG		1	BRB	TTO
39		BWA	TZA		CHI	BGD		1	BWA	ESP
40		BWA	ZWE		CHI	PAN		2	CAN	CHI
41	1	CAN	IRE	3	CIV	BEN			CAN	USA
42	2	CHE	AUT		CIV	GIN		2	CHE	ESP
43		CHE	GER		CIV	SEN			CHE	LUX
44	1	CHI	MEX	1	CMR	ZWE		7	CHI	CAN
45	1	CIV	GAB	5	COG	GAB			CHI	CMR
46	1	CMR	GAB		COG	SEN			CHI	CZE
47	5	COG	MLI		COG	SVK			CHI	MAR
48		COG	NGA		COG	SYR			CHI	MNG
49		COG	SLE		COG	YEM			CHI	NZL
50		COG	TUN	2	CZE	HUN			CHI	TKM

LP Spread		Similarities (US)		Similarities (NORM)	
51	COG ZWE	CZE	SVK	3 CIV	COG
52	2 CZE GRC	1 DMA	VCT	CIV	GAB
53	CZE HUN	1 DNK	GBR	CIV	SLE
54	2 DMA GRD	4 ECU	ARG	3 CMR	CHI
55	DMA TTO	ECU	MEX	CMR	PAN
56	1 DNK SWE	ECU	PER	CMR	TZA
57	2 ECU PER	ECU	THA	3 COG	CIV
58	ECU URY	1 EGY	GAB	COG	PHL
59	1 EGY BEN	3 ESP	BEL	COG	ROM
60	5 ESP AUS	ESP	GRC	2 CZE	CHI
61	ESP GBR	ESP	ITA	CZE	SVK
62	ESP PRT	3 EST	LTU	1 DMA	GRD
63	ESP SWE	EST	LVA	1 DNK	SWE
64	ESP USA	EST	RUS	5 ECU	ARG
65	1 EST RUS	4 FIN	GBR	ECU	PER
66	2 FIN GRC	FIN	ISR	ECU	THA
67	FIN IRE	FIN	NOR	ECU	TUR
68	3 FJI KNA	FIN	SWE	ECU	VEN
69	FJI PAK	1 FJI	POL	1 EGY	GAB
70	FJI VNS	1 FRA	BEL	7 ESP	BWA
71	2 FRA GBR	2 GAB	COG	ESP	CHE
72	FRA JPN	GAB	EGY	ESP	GRC
73	3 GAB CIV	4 GBR	AUS	ESP	JOR
74	GAB CMR	GBR	DNK	ESP	JPN
75	GAB SLE	GBR	FIN	ESP	POL
76	5 GBR ESP	GBR	IRE	ESP	SVN
77	GBR FRA	1 GEO	ARM	2 EST	LTU
78	GBR GER	5 GER	BEL	EST	LVA
79	GBR ITA	GER	CHE	2 FIN	IRE
80	GBR NLD	GER	LUX	FIN	SWE
81	2 GEO BRB	GER	NLD	1 FJI	GRC
82	GEO UZB	GER	USA	3 FRA	AUT
83	3 GER CHE	1 GIN	CIV	FRA	ISL
84	GER GBR	2 GRC	ESP	FRA	LUX
85	GER LUX	GRC	SVN	3 GAB	BEN
86	1 GIN MWI	3 GRD	BLZ	GAB	CIV
87	4 GRC CZE	GRD	BRB	GAB	EGY
88	GRC FIN	GRD	KNA	3 GBR	HKG
89	GRC SVN	3 HKG	KOR	GBR	IRE
90	GRC TZA	HKG	QAT	GBR	NOR
91	2 GRD DMA	HKG	SGP	1 GEO	UKR
92	GRD VCT	3 HRV	LVA	1 GER	BEL
93	1 HKG SGP	HRV	MKD	1 GIN	VEN
94	2 HRV ALB	HRV	SVN	3 GRC	ESP
95	HRV TUR	2 HUN	CZE	GRC	FJI
96	2 HUN CZE	HUN	MKD	GRC	SWZ
97	HUN SVK	1 IDN	VEN	3 GRD	DMA
98	1 IDN LKA	1 IRE	GBR	GRD	KNA
99	4 IRE CAN	1 IRN	KGZ	GRD	VCT
100	IRE FIN	1 ISL	NOR	1 HKG	GBR
101	IRE ISR	1 ISR	FIN	1 HRV	ARG
102	IRE SWE	1 ITA	ESP	1 HUN	PRT
103	4 IRN ROM	1 JAM	ATG	3 IDN	ARM
104	IRN RUS	1 JOR	QAT	IDN	KOR

	LP Spread		Similarities (US)		Similarities (NORM)	
105	IRN	SYR	2 JPN	KOR	IDN	QAT
106	IRN	TKM	JPN	SWE	2 IRE	FIN
107	1 ISL	SWE	5 KAZ	AZE	IRE	GBR
108	1 ISR	IRE	KAZ	KGZ	1 IRN	VNS
109	1 ITA	GBR	KAZ	MNG	2 ISL	FRA
110	1 JAM	BLZ	KAZ	RUS	ISL	ISR
111	1 JOR	QAT	KAZ	TJK	1 ISR	ISL
112	2 JPN	FRA	2 KEN	SEN	2 ITA	AUT
113	JPN	KOR	KEN	TZA	ITA	MUS
114	1 KAZ	AZE	3 KGZ	IRN	2 JAM	LCA
115	1 KEN	SEN	KGZ	KAZ	JAM	TTO
116	1 KGZ	UZB	KGZ	MDA	1 JOR	ESP
117	3 KNA	ATG	7 KNA	ATG	1 JPN	ESP
118	KNA	FJI	KNA	BHS	KAZ	ALB
119	KNA	LCA	KNA	GRD	2 KAZ	BOL
120	1 KOR	JPN	KNA	LCA	1 KEN	LKA
121	1 LBN	OMN	KNA	TTO	1 KGZ	ROM
122	3 LCA	BHS	KNA	VCT	3 KNA	ATG
123	LCA	KNA	KNA	YEM	KNA	GRD
124	LCA	VCT	2 KOR	HKG	KNA	YEM
125	2 LKA	BGD	KOR	JPN	2 KOR	IDN
126	LKA	IDN	2 LBN	BHR	KOR	LBN
127	1 LTU	ALB	LBN	OMN	1 LBN	KOR
128	1 LUX	GER	1 LCA	KNA	2 LCA	JAM
129	3 LVA	ALB	1 LKA	PAK	LCA	VCT
130	LVA	AZE	1 LTU	EST	3 LKA	KEN
131	LVA	UZB	1 LUX	GER	LKA	MDG
132	1 MAR	BWA	4 LVA	ARM	LKA	TUN
133	1 MDA	ARM	LVA	EST	3 LTU	ARM
134	2 MDG	BHR	LVA	HRV	LTU	EST
135	MDG	MLI	LVA	POL	LTU	RUS
136	3 MEX	ARG	1 MAR	TUN	2 LUX	CHE
137	MEX	CHI	5 MDA	ALB	LUX	FRA
138	MEX	URY	MDA	BLR	2 LVA	EST
139	1 MKD	ROM	MDA	KGZ	LVA	SVN
140	2 MLI	COG	MDA	ROM	1 MAR	CHI
141	MLI	MDG	MDA	UKR	1 MDA	UKR
142	2 MNG	POL	2 MDG	MLI	1 MDG	LKA
143	MNG	URY	MDG	TZA	4 MEX	BRA
144	1 MUS	SLE	3 MEX	AUS	MEX	MLI
145	2 MWI	GIN	MEX	BOL	MEX	MWI
146	MWI	TZA	MEX	ECU	MEX	URY
147	1 NGA	COG	2 MKD	HRV	1 MKD	SVN
148	1 NLD	GBR	MKD	HUN	1 MLI	MEX
149	1 NOR	SWE	1 MLI	MDG	1 MNG	CHI
150	1 NPL	PER	1 MNG	KAZ	1 MUS	ITA
151	1 NZL	BEL	1 MUS	ZWE	1 MWI	MEX
152	2 OMN	LBN	1 MWI	TZA	1 NGA	SLE
153	OMN	QAT	2 NGA	SLE	1 NLD	AUT
154	2 PAK	BGD	NGA	ZWE	1 NOR	GBR
155	PAK	FJI	2 NLD	GER	1 NPL	UKR
156	3 PAN	BGD	NLD	SWE	2 NZL	AUS
157	PAN	BOL	2 NOR	FIN	NZL	CHI
158	PAN	URY	NOR	ISL	1 OMN	QAT

	LP Spread		Similarities (US)		Similarities (NORM)	
159	3	PER ECU	1	NPL PER	1	PAK PER
160		PER NPL	2	NZL AUS	2	PAN BGD
161		PER THA		NZL CAN		PAN CMR
162	1	PHL TZA	3	OMN BMU	5	PER BOL
163	3	POL ALB		OMN LBN		PER ECU
164		POL MNG		OMN QAT		PER PAK
165		POL SVK	2	PAK BGD		PER SEN
166	1	PRT ESP		PAK LKA		PER ZWE
167	3	QAT JOR	1	PAN CHI	1	PHL COG
168		QAT OMN	2	PER ECU	1	POL ESP
169		QAT TZA		PER NPL	2	PRT BRA
170	2	ROM IRN	1	PHL PRT		PRT HUN
171		ROM MKD	2	POL FJI	3	QAT BHR
172	3	RUS AZE		POL LVA		QAT IDN
173		RUS EST	2	PRT PHL		QAT OMN
174		RUS IRN		PRT SVN	3	ROM BGR
175	2	SEN BWA	3	QAT HKG		ROM COG
176		SEN KEN		QAT JOR		ROM KGZ
177	2	SGP BHR		QAT OMN	1	RUS LTU
178		SGP HKG	1	ROM MDA	1	SEN PER
179	3	SLE COG	2	RUS EST	1	SGP BEL
180		SLE GAB		RUS KAZ	3	SLE CIV
181		SLE MUS	3	SEN CIV		SLE NGA
182	3	SVK HUN		SEN COG		SLE URY
183		SVK POL		SEN KEN	2	SVK CZE
184		SVN GRC	1	SGP HKG		SVK URY
185	5	SWE DNK	3	SLE NGA	4	SVN ESP
186		SWE ESP		SLE SWZ		SVN LVA
187		SWE IRE		SLE TZA		SVN MKD
188		SWE ISL	2	SVK COG		SVN TUR
189		SWE NOR		SVK CZE	3	SWE BEL
190	1	SWZ ZMB	4	SVN GRC		SWE DNK
191	2	SYR IRN		SVN HRV		SWE FIN
192		SYR YEM		SVN PRT	1	SWZ GRC
193	1	THA PER		SVN TUR	1	SYR BOL
194	1	TJK UKR	3	SWE FIN	1	THA ECU
195	1	TKM IRN		SWE JPN	2	TJK BOL
196	1	TTO DMA		SWE NLD		TJK UKR
197	1	TUN COG	1	SWZ SLE	1	TKM CHI
198	1	TUR HRV	1	SYR COG	3	TTO BLZ
199	6	TZA BEN	1	THA ECU		TTO BRB
200		TZA BWA	1	TJK KAZ		TTO JAM
201		TZA GRC	1	TKM BLR		TUN LKA
202		TZA MWI	1	TTO KNA	2	TUN TZA
203		TZA PHL	2	TUN MAR	2	TUR ECU
204		TZA QAT		TUN ZWE		TUR SVN
205	3	UKR ARM	1	TUR SVN	2	TZA CMR
206		UKR TJK	5	TZA KEN		TZA TUN
207		UKR UZB		TZA MDG	5	UKR AZE
208	5	URY BRA		TZA MWI		UKR GEO
209		URY ECU		TZA SLE		UKR MDA
210		URY MEX		TZA ZMB		UKR NPL
211		URY MNG	3	UKR BGR		UKR TJK
212		URY PAN		UKR MDA	3	URY MEX

	LP Spread	Similarities (US)			Similarities (NORM)		
213	1 USA	ESP	UKR	UZB	URY	SLE	
214	5 UZB	BLR	1 URY	ARG	URY	SVK	
215	UZB	GEO	1 USA	GER	1 USA	CAN	
216	UZB	KGZ	1 UZB	UKR	1 UZB	BGR	
217	UZB	LVA	2 VCT	DMA	2 VCT	GRD	
218	UZB	UKR	VCT	KNA	VCT	LCA	
219	2 VCT	GRD	2 VEN	BRA	3 VEN	BLR	
220	VCT	LCA	VEN	IDN	VEN	ECU	
221	1 VEN	BRA	1 VNS	BGR	VEN	GIN	
222	1 VNS	FJI	2 YEM	COG	2 VNS	BGR	
223	1 YEM	SYR	YEM	KNA	VNS	IRN	
224	2 ZMB	SWZ	1 ZMB	TZA	2 YEM	BOL	
225	ZMB	ZWE	4 ZWE	CMR	YEM	KNA	
226	3 ZWE	BWA	ZWE	MUS	1 ZMB	ZWE	
227	ZWE	COG	ZWE	NGA	2 ZWE	PER	
228	ZWE	ZMB	ZWE	TUN	ZWE	ZMB	
Total links	228		228		228		

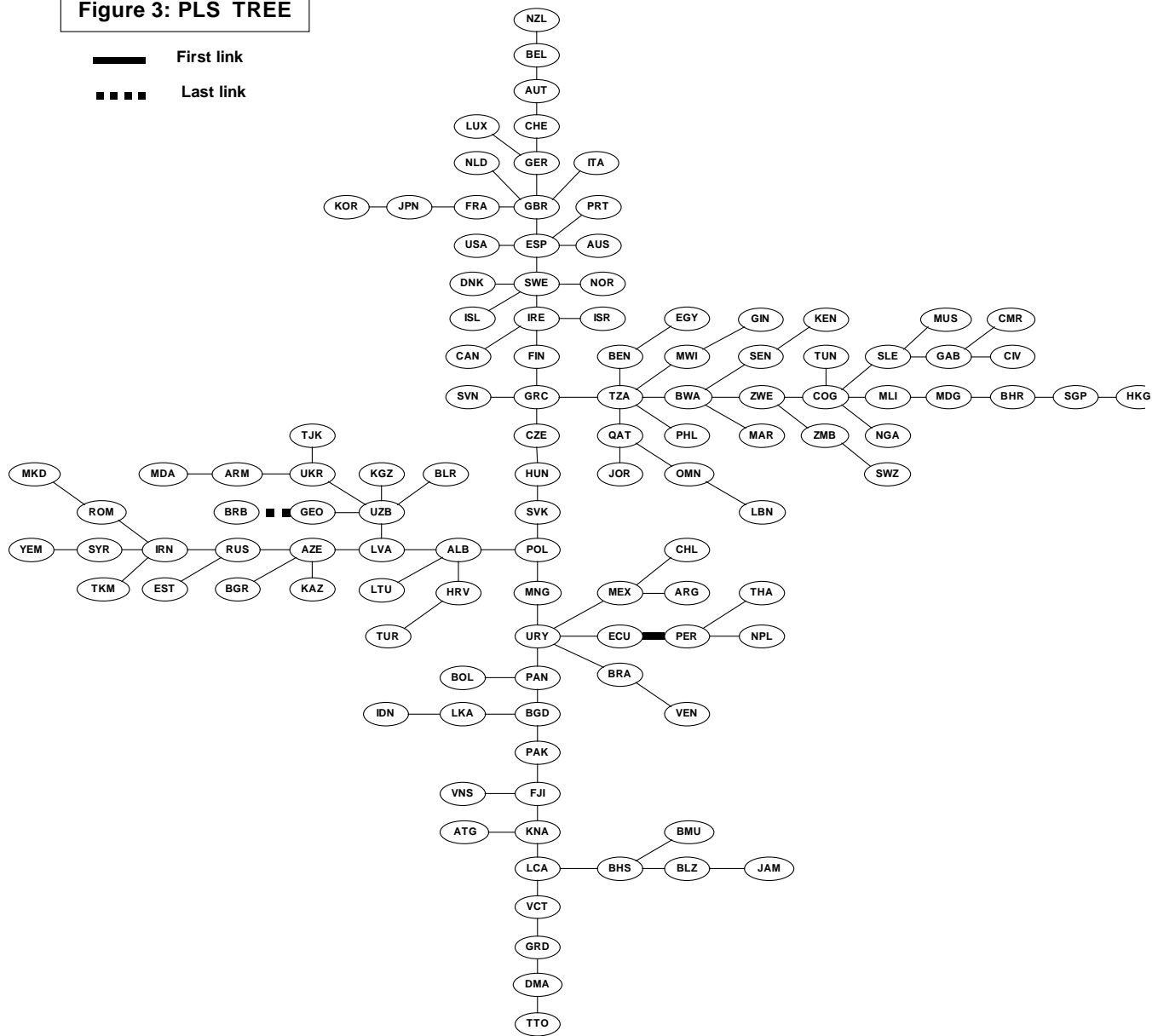
**Table 4: Per capita DA (Domestic Absorption) relative to United States**

ISO code	Fisher (1)	Eks (2)	Sim Norm (3)	Sim us (4)	Lp Spread (5)	Gk (6)	Country name
LUX	102.7	106.8	102.7	104.2	99.9	108.3	Luxembourg
USA	100.0	100.0	100.0	100.0	100.0	100.0	USA
JPN	85.3	84.4	84.5	83.3	79.6	87.6	Japan
CHE	83.5	83.9	83.5	84.2	80.7	86.2	Switzerland
HKG	83.1	87.6	83.0	85.6	114.4	101.2	Hong Kong
DNK	80.6	82.2	80.8	82.4	78.1	82.8	Denmark
NOR	79.9	81.9	79.6	80.0	77.0	82.6	Norway
ISL	79.7	79.5	79.5	80.2	77.6	79.3	Iceland
CAN	77.8	75.8	77.8	78.1	76.0	77.5	Canada
AUT	77.7	79.5	77.5	78.6	75.8	79.3	Austria
AUS	77.5	78.4	80.6	78.0	76.3	77.4	Australia
BEL	72.4	72.6	72.1	73.0	70.5	71.9	Belgium
GER	72.1	72.8	71.2	72.1	69.1	73.7	Germany
FRA	70.9	70.1	70.4	70.9	67.8	70.1	France
SGP	70.0	78.5	67.5	70.6	94.3	91.7	Singapore
ITA	69.0	69.0	68.5	68.9	67.0	69.5	Italy
GBR	68.7	69.0	69.2	70.0	66.2	68.0	United Kingdom
NLD	68.6	69.0	67.2	68.1	65.4	69.0	Netherlands
ISR	65.3	64.6	63.7	64.2	62.0	64.9	Israel
SWE	64.2	63.6	63.2	63.8	61.1	63.5	Sweden
BMU	61.8	64.6	65.5	64.4	68.1	76.3	Bermuda
NZL	60.8	61.7	63.5	61.5	59.3	61.0	New
FIN	60.6	61.1	60.3	60.9	58.6	60.8	Finland
IRL	55.2	55.9	55.6	56.3	54.1	55.3	Ireland

ISO code	Fisher (1)	Eks (2)	Sim Norm (3)	Sim us (4)	Lp Spread (5)	Gk (6)	Country name
ESP	52.9	54.2	54.9	54.5	52.9	53.4	Spain
PRT	51.9	53.2	48.3	52.9	51.7	52.8	Portugal
GRC	49.8	50.5	50.6	50.3	49.5	50.1	Greece
KOR	49.6	52.9	48.8	50.6	48.3	58.3	Korea
CZE	48.4	48.0	45.9	48.8	47.5	50.2	Czech Republic
QAT	48.2	47.7	44.8	50.8	56.4	56.7	Qatar
BHS	48.2	47.2	45.5	58.7	47.4	56.4	Bahamas
SVN	46.4	46.7	46.8	46.2	45.4	46.2	Slovenia
BRB	42.0	40.1	39.3	50.0	29.4	67.0	Barbados
MUS	38.3	37.1	37.9	32.7	32.6	46.8	Mauritius
ARG	34.9	36.6	35.9	34.3	38.7	39.3	Argentina
KNA	34.9	33.2	33.3	44.5	36.0	37.8	St. Kitts & Nevis
HUN	34.6	33.9	30.5	34.2	33.3	35.8	Hungary
SVK	34.0	34.2	31.8	33.7	33.3	36.5	Slovakia
URY	30.6	29.3	28.3	27.3	30.8	31.9	Uruguay
OMN	30.1	31.8	26.9	30.4	33.8	43.7	Oman
ATG	29.9	29.0	27.7	37.0	29.9	34.8	Antigua & Barbuda
CHL	28.5	29.7	29.8	27.4	31.4	31.1	Chile
EST	27.6	27.1	26.9	27.1	24.3	29.1	Estonia
BHR	25.1	26.1	28.0	26.8	36.7	31.9	Bahrain
BRA	24.7	24.5	23.8	22.7	25.9	26.9	Brazil
POL	24.6	24.8	23.8	24.7	23.5	26.9	Poland
MEX	24.6	25.0	24.6	23.8	26.8	25.2	Mexico
THA	23.3	25.0	23.7	22.6	25.8	28.9	Thailand
HRV	22.8	21.8	21.8	21.5	19.2	23.8	Croatia
TTO	22.5	22.4	21.7	27.7	21.8	27.4	Trinidad & Tobago
TUR	22.0	23.1	22.5	22.2	20.5	24.1	Turkey
TUN	21.9	21.2	23.3	19.0	19.8	26.2	Tunisia
RUS	21.8	20.9	21.5	21.8	19.6	23.2	Russia
LTU	21.1	20.7	20.7	20.9	18.5	23.0	Lithuania
GRD	20.6	20.1	18.8	25.1	19.8	25.8	Grenada
ROM	20.3	21.1	26.3	23.0	20.4	22.9	Romania
GAB	19.6	17.9	20.4	15.9	16.2	23.0	Gabon
BWA	19.3	19.2	19.9	21.1	18.7	19.9	Botswana
LCA	19.1	18.7	18.7	24.3	19.7	21.5	St. Lucia
LVA	18.9	17.9	18.0	18.1	15.9	20.6	Latvia
PAN	18.8	19.2	21.5	17.5	20.0	19.9	Panama
IRN	18.5	17.4	19.2	16.2	15.4	18.3	Iran
DMA	18.1	17.1	17.4	21.8	18.3	23.2	Dominica
VEN	17.6	17.8	17.4	17.3	19.7	20.4	Venezuela
BLR	17.3	16.9	17.1	17.2	16.1	20.8	Belarus
BLZ	17.3	17.7	17.3	22.9	18.0	21.1	Belize
SWZ	16.9	16.4	16.3	16.5	16.3	19.5	Swaziland
VCT	16.7	15.0	15.0	19.4	15.8	20.0	St. Vincent & Grenadines
FJI	16.4	15.9	16.0	16.0	16.2	16.7	Fiji
PER	15.5	15.3	14.5	13.9	15.9	16.2	Peru
BGR	15.4	15.7	18.3	15.5	14.6	18.3	Bulgaria
KAZ	15.4	15.1	14.0	15.1	13.3	18.4	Kazakhstan
MKD	14.2	13.9	13.9	14.0	13.1	14.9	Macedonia
MAR	14.2	13.4	14.7	12.7	12.3	15.5	Morocco
JAM	12.1	12.1	11.8	16.0	12.7	14.2	Jamaica
PHL	11.9	13.0	17.5	12.9	13.6	13.6	Philippines
LBN	11.9	13.5	13.7	13.7	15.2	20.1	Lebanon

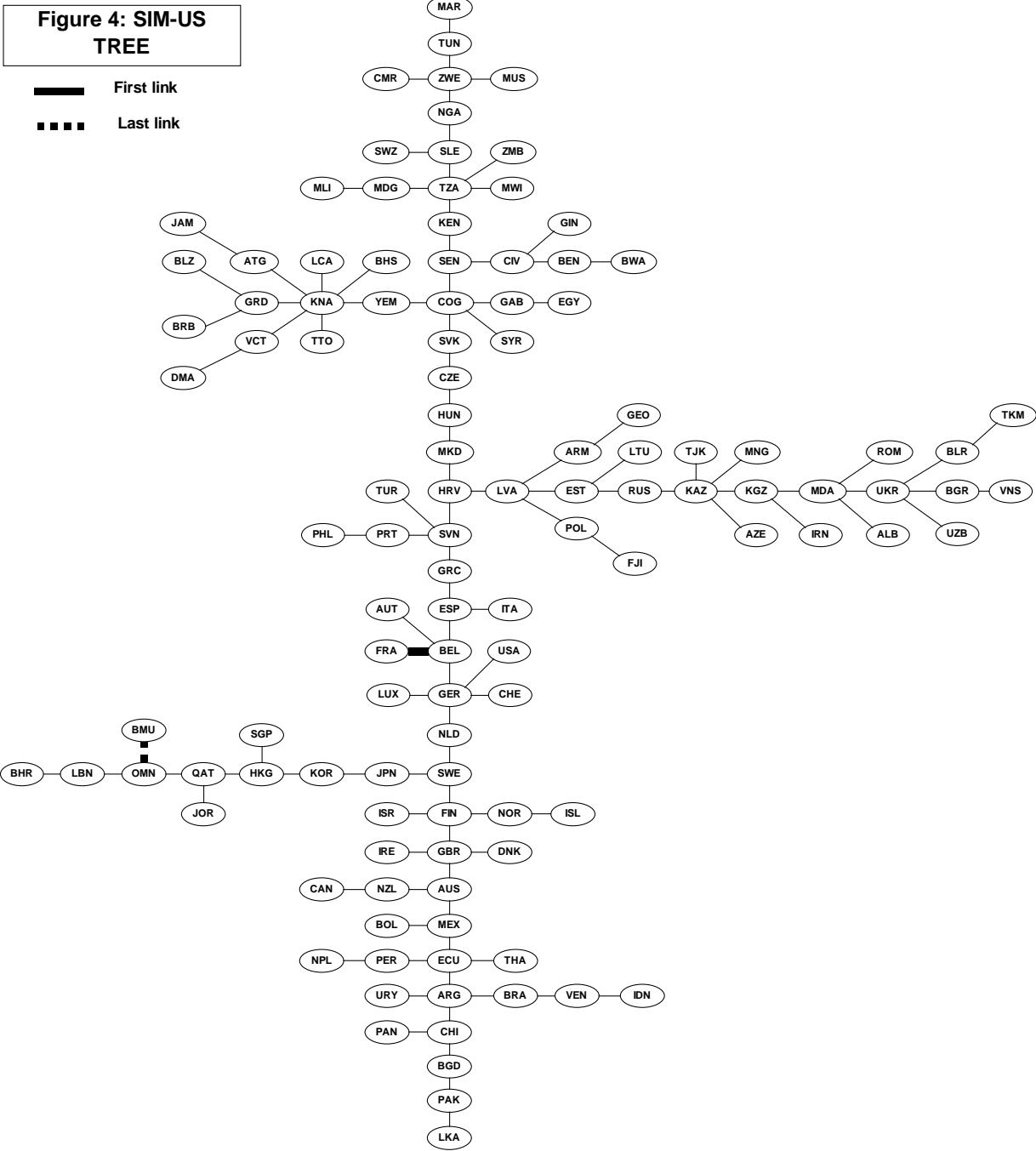
ISO code	Fisher (1)	Eks (2)	Sim Norm (3)	Sim us (4)	Lp Spread (5)	Gk (6)	Country name
UKR	11.8	11.1	9.7	10.9	9.8	13.8	Ukraine
EGY	11.7	12.3	13.9	10.8	11.3	14.8	Egypt
GEO	11.7	10.7	9.5	11.4	10.0	13.8	Georgia
TKM	11.6	12.1	11.9	12.7	12.5	14.3	Turkmenistan
JOR	11.5	11.9	11.9	14.5	16.1	15.0	Jordan
IDN	11.4	11.9	10.9	11.6	13.9	13.6	Indonesia
LKA	11.3	11.0	11.6	9.6	10.9	11.4	Sri Lanka
ECU	10.6	11.0	10.6	10.1	11.6	11.8	Ecuador
ZWE	10.3	10.2	9.9	9.4	9.6	11.6	Zimbabwe
SYR	10.2	10.7	9.9	12.0	9.5	12.7	Syria
ALB	10.1	11.1	11.4	12.1	10.5	12.5	Albania
KGZ	8.5	8.0	9.2	8.2	7.3	9.6	Kyrgyzstan
ARM	8.1	8.2	8.2	8.5	7.2	10.2	Armenia
UZB	7.9	6.9	7.9	6.6	5.9	8.9	Uzbekistan
BOL	7.9	8.0	7.8	7.4	8.2	8.8	Bolivia
AZE	7.9	7.7	7.1	8.1	7.2	9.1	Azerbaijan
GIN	7.0	7.3	7.0	7.2	6.4	9.9	Guinea
MDA	6.8	6.3	5.6	6.3	5.6	8.2	Moldova
PAK	6.5	6.6	6.2	6.0	6.6	7.0	Pakistan
CIV	5.8	5.7	6.6	5.5	5.2	7.0	Cote d'Ivoire
CMR	5.7	5.7	6.4	5.0	5.3	7.3	Cameroon
COG	5.7	5.6	7.5	6.0	5.5	6.1	Congo
VNM	5.3	5.5	6.4	5.4	5.7	6.2	Vietnam
SEN	5.0	5.0	4.7	5.1	4.6	5.7	Senegal
BGD	4.9	4.9	5.2	4.4	4.8	5.2	Bangladesh
KEN	4.0	4.0	4.0	3.9	3.5	4.5	Kenya
NPL	4.0	4.1	3.4	4.0	4.5	5.4	Nepal
MNG	3.9	3.9	3.7	4.3	3.9	4.3	Mongolia
BEN	3.5	3.4	4.3	3.5	3.2	3.9	Benin
SLE	3.3	2.9	3.1	2.7	2.6	4.2	Sierra Leone
ZMB	2.9	2.9	3.1	3.1	3.0	3.1	Zambia
YEM	2.9	2.8	2.5	3.3	2.4	3.7	Yemen
TJK	2.8	2.6	2.4	2.7	2.4	3.3	Tajikistan
MLI	2.7	2.9	2.7	3.0	2.9	3.5	Mali
MDG	2.6	2.8	3.0	3.2	3.1	3.0	Madagascar
MWI	2.3	2.4	2.2	2.5	2.2	2.9	Malawi
NGA	2.2	2.2	2.6	2.2	2.3	2.4	Nigeria
TZA	1.7	1.8	2.4	2.1	1.8	1.9	Tanzania

**Figure 3: PLS TREE**



**Figure 4: SIM-US TREE**

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**Figure 5: SIM-NORM TREE**

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