Constructing Price Indexes Across Space and Time: The Case of the European Union

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This paper considers the problem of how to construct and reconcile price indexes across space and time. A general taxonomy of panel price index methods, containing four broad classes, is proposed, along with five criteria for discriminating between them. Methods from each of the four classes are then used to compute spatial and temporal price indexes for the 15 countries of the European Union (EU) over the period 1995-2000. Using these panel price indexes I test whether or not price levels and relative prices converged across the EU over this period. (*JEL* C43, E31, O47)

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Comparing the purchasing power of currencies and price levels across countries and how they change over time is an issue of interest to national governments, firms and households, and international organizations such as the International Monetary Fund (IMF), World Bank and European Union (EU). To compare simultaneously price levels and changes in the price level requires the application of index number methods to a panel data set. This is an issue that has received very little attention in the index number literature, particularly in a consumer context. One of the few references on this topic is Hugo Krijnse-Locker and H. D. Faerber (1984). This paper builds on their work in three ways. First, it significantly extends the range of panel methods under consideration. Second, it proposes five criteria for discriminating between panel methods. Third, it explores the underlying graph-theoretic structure of panel methods. A general taxonomy containing four broad classes of methods is constructed, and the strengths and weaknesses of methods from each class are compared.

One reason why panel comparisons have not received more attention in the index-number literature is due to the lack of suitable data sets. The EU's Harmonized Index of Consumer Prices (HICP), for example, is in index format (i.e., the price of each commodity heading in each country is normalized to 100 in the base year). Therefore, although it can be used to make comparisons of inflation rates and by implication changes in the price level across EU countries, it cannot be used to compare price levels and the purchasing power of currencies across countries in a given year. The same is true for the regional consumer price indexes (CPIs) computed by some countries. These cannot be used to compare price levels across regions at a particular point in time. International organizations such as the Organization for Economic Co-operation and Development (OECD) and World Bank, by contrast, make detailed spatial comparisons.[1] The OECD, for example, makes such comparisons at 3 year intervals. By linking together these spatial comparisons using CPI data for one or more countries it should be possible to construct a suitable panel. The OECD commodity headings, however, can differ significantly from one cross-section to the next and hence the data for different years are not directly comparable.

In spite of these difficulties, aggregate panel price indexes have been assembled in the Penn World Table (PWT). The PWT is a product of the International Comparison

Program (ICP) which dates back to the 1960s and has at various times been funded by the United Nations, World Bank and OECD, and has been used extensively by economists to test for convergence in living standards across countries [see for example Robert J. Barro and Xavier Sala-i-Martin (1992)].[2] The PWT currently provides price levels for 168 countries over the period 1950-2000. It is constructed by splicing together at an aggregated level cross-section international benchmarks with time-series data obtained from the individual countries [see Irving B. Kravis, Alan W. Heston and Robert Summers (1982) and Summers and Heston (1991)]. This means that, in the process of constructing it, Kravis, Heston and Summers did not really have to address directly the issue of price index construction on a disaggregated panel data set, although they did have to confront the related problem of reconciling temporal and spatial price indexes which is also addressed in this paper.

The main objective of this paper is to develop a methodology of panel price indexes. Since panel comparisons combine temporal and spatial comparisons, this means that all the issues that arise in the temporal and spatial index-number literatures are also relevant to panel comparisons. For example, one of the key issues in the temporal literature is the debate over the relative merits of chained and fixed-base price indexes, and in the latter case the frequency with which the index should be rebased. In the spatial literature, a large number of alternative multilateral formulae have been proposed, and there is still widespread disagreement as to which formula is best [see Robert J. Hill (1997)]. In addition, in a panel comparison a conflict exists between the temporal and spatial price indexes. This paper proposes a general taxonomy of panel methods couched in a graph-theoretic setting that contains four broad classes. Methods from these classes are then compared using five criteria. The related issue of reconciling temporal and spatial price indexes is also considered. The same methods and criteria can be used to address this problem.

A second objective is to apply this panel index-number methodology to a European-Union panel data set covering the period 1995-2000. The data set was constructed by combining at a disaggregated level the EU's Harmonized Index of Consumer Prices (HICP) with an OECD spatial data set. Price indexes for the 15 member countries of the EU are computed over the period 1995-2000, and the sensitivity of the results to the choice of panel method assessed. Price levels and relative prices are also compared across the EU to determine whether they are converging or diverging over time. I find evidence of convergence in price levels but divergence in relative prices. The paper concludes by discussing some of the implications of these findings.

I. Bilateral Comparisons

The set of time periods is indexed by $t = 1, \ldots, T$, the set of countries by $k = 1, \ldots, K$ and the set of commodity headings by $n = 1, \ldots, N$. The price and quantity data of commodity heading n for country k in period t are denoted, respectively, by p^n_{kt} and q^n_{kt}.

Let $P_{js,kt}$ and $Q_{js,kt}$ denote, respectively, bilateral price and quantity index comparisons between country j in time period s and country k in time period t. Four important bilateral formulae are Paasche, Laspeyres, Fisher, and Törnqvist.[3] These indexes are defined below:

$$(1) \qquad \text{Paasche}: \quad P^P_{js,kt} = \frac{\sum_{n=1}^N p^n_{kt} q^n_{kt}}{\sum_{n=1}^N p^n_{js} q^n_{kt}} \qquad Q^P_{js,kt} = \frac{\sum_{n=1}^N p^n_{kt} q^n_{kt}}{\sum_{n=1}^N p^n_{kt} q^n_{js}}$$

$$(2) \qquad \text{Laspeyres}: \quad P^L_{js,kt} = \frac{\sum_{n=1}^N p^n_{kt} q^n_{js}}{\sum_{n=1}^N p^n_{js} q^n_{js}} \qquad Q^L_{js,kt} = \frac{\sum_{n=1}^N p^n_{js} q^n_{kt}}{\sum_{n=1}^N p^n_{js} q^n_{js}}$$

$$(3) \qquad \text{Fisher}: \quad P^F_{js,kt} = \sqrt{P^P_{js,kt} P^L_{js,kt}} \qquad Q^F_{js,kt} = \sqrt{Q^P_{js,kt} Q^L_{js,kt}}$$

$$(4) \qquad \text{Törnqvist}: \quad P^T_{js,kt} = \prod_{n=1}^N \left(\frac{p^n_{kt}}{p^n_{js}} \right)^{(s^n_{js} + s^n_{kt})/2} \qquad Q^T_{js,kt} = \prod_{n=1}^N \left(\frac{q^n_{kt}}{q^n_{js}} \right)^{(s^n_{js} + s^n_{kt})/2}$$

$$\text{where} \quad s^n_{js} = \frac{p^n_{js} q^n_{js}}{\sum_{i=1}^N p^i_{js} q^i_{js}}.$$

Two main approaches have been used to choose between competing bilateral formulae. The axiomatic approach specifies axioms that a price index should satisfy, and then compares formulae on the basis of which axioms they pass and fail [see Wolfgang Eichhorn and Joachim Voeller (1976), and Bert M. Balk (1995)]. This approach, however, was criticized by Sidney N. Afriat (1977) in that it provides answers without questions. The economic approach, by contrast, is firmly grounded in economic theory. The underlying concept, according to the economic approach, is the cost-of-living

(COL) index defined as follows:

$$COL_{js,kt} = \frac{e(u, p_{kt})}{e(u, p_{js})},$$

where $e(u,p)$ is the minimum expenditure required to reach the utility level u, given prices p. There are three main problems with the economic approach. First, the COL index depends on the reference utility level (unless preferences are homothetic). Second, it assumes a representative consumer.[4] Third, the COL index is not directly observable, although when preferences are homothetic it is bounded from below by Paasche, and from above by Laspeyres. However, these bounds may be quite far apart.[5] One solution to this problem is to appeal to utility maximization. Under this assumption, once a functional form has been specified for the expenditure function, the COL reduces to a function of observable prices and quantities. Diewert (1976) advocated using a price index which is exact for a flexible expenditure function (i.e., one that can approximate to the second order an arbitrary twice continuously differentiable linearly homogeneous function). Diewert refers to such price indexes as *superlative.* Fisher and Törnqvist are superlative, while Paasche and Laspeyres are not. Coincidentally, Fisher and Törnqvist are also the formulae that tend to emerge as best from the axiomatic approach. In recent years, a strong consensus has emerged in the index number literature that bilateral comparisons should be made using superlative index numbers [see Jack E. Triplett (1996)].[6]

II. Multilateral Comparisons

The problem with bilateral formulae in a multilateral context is that, in general, they are not transitive if the weight attached to each commodity heading varies across countries (as it should if comparisons are to take account of differing expenditure patterns across countries).[7] Therefore, when weights vary across countries, a direct comparison between country j in period s and country k in period t will yield a different answer than an indirect comparison via country m in period u, i.e., $P_{js,kt} \neq P_{js,mu} \times P_{mu,kt}$. This is true even for superlative indexes. Transitivity is necessary to ensure internal consistency. Otherwise, more than one estimate of each bilateral comparison will be derivable from the set of price indexes.

Let P_{js} and P_{kt} denote multilateral price indexes for country j in period s and country k in period t, respectively. Multilateral indexes, by construction, are transitive. Hence a bilateral comparison of prices made using a multilateral formula can be expressed as follows:

$$P_{js,kt} = \frac{P_{kt}}{P_{js}}.$$

The bilateral formulae discussed in the previous section, since they are not transitive, cannot be written in this way.

Graph Theory provides a useful framework for analyzing the underlying structure of multilateral price indexes. A graph consists of a collection of vertices linked by edges. In the context of spatial (temporal) comparisons, each vertex represents one of the countries (time periods) in the comparison, while each edge represents a bilateral comparison between a pair of countries (time periods). Three important graphs, depicted in Figure 1 for the case of 5 vertices, are the *star*, *complete* and *chain* graphs.

Insert Figure 1 Here

A large number of multilateral formulae have been proposed in the index number literature [see Balk (1996, 2001), Hill (1997) and Diewert (1999) for surveys of this literature]. Many of these formulae can be described using graphs. Here we focus attention on three classes of multilateral formulae.

A. *Average-Price Methods*

The first class compares each country with an artificially constructed average country. By implication, the underlying structure of such methods is a star graph with an artificial average country at the center of the star. Each bilateral comparison in the star is made using the Paasche price index formula, with the artificial country as the base. In the context of a spatial comparison (i.e., for a fixed value of t) the price index of country k in time period t, P_{kt}, is calculated as follows:

(5) $$P_{kt} = P^P_{Xt,kt} = \frac{\sum_{n=1}^N p^n_{kt} q^n_{kt}}{\sum_{n=1}^N p^n_{Xt} q^n_{kt}} \quad \text{for} \quad k = 1, \ldots, K,$$

where p^n_{Xt} denotes the price of commodity heading n in the artificially constructed average country in period t. The most widely used average-price method is Geary-Khamis [see Robert C. Geary (1958) and Salem H. Khamis (1972)].[8] In particular, it has been used to make comparisons across the OECD countries and by the International Comparison Program (ICP) to construct the Penn World Table.[9] The Geary-Khamis average prices, p^n_{Xt}, are computed as follows:

$$(6) \qquad p^n_{Xt} = \sum_{k=1}^{K} \left(\frac{q^n_{kt}}{\sum_{j=1}^{K} q^n_{jt}} \frac{p^n_{kt}}{P^P_{Xt,kt}} \right) \quad \text{for} \quad n = 1, \ldots, N.$$

The average-price vector, p_{Xt}, and Paasche price indexes, $P^P_{Xt,kt}$, are obtained by solving the system of $N + K$ simultaneous equations in (5) and (6).[10]

The fact that average-price methods use the Paasche formula rather than a superlative formula leads to substitution (or representativity) bias in the results which may seriously distort estimates of both per capita income differentials at a point in time and convergence rates over time [see Daniel A. Nuxoll (1994), Dowrick and Quiggin (1997), and Hill (2000)]. This is because the price vector of the artificial country at the center of the star will not be equally representative of the prices faced by all of the countries in the comparison. Geary-Khamis, in particular, tends to underestimate per capita income differentials across countries, since its average-price vector usually approximates more closely the price vectors of the richer countries in the comparison. Hence the substitution bias tends to be larger for poorer countries.

B. *EKS-Type Methods*

The second class, which includes EKS [Ö. Eltetö and Pál Köves, (1964) and Bohdan J. Szulc (1964)] and CCD [Douglas W. Caves, Laurits R. Christensen and Diewert (1982)], makes bilateral comparisons between all possible pairs of countries. This means that the underlying structure of such methods is a complete graph (see Figure 1). However, to obtain an internally consistent set of multilateral price indexes from a complete graph, the bilateral price indexes must be transitivized using a formula first proposed by Corrado Gini (1931). Alternatively, EKS-type methods can be thought of as the combination of K star spanning trees, each of which has a different country at the center. The EKS-type price indexes are obtained by taking the geometric mean of the price indexes generated by these K star spanning trees. The price index of country k in time period t, P_{kt}, is calculated as follows:

$$P_{kt} = \prod_{j=1}^{K} [(P_{jt,kt})^{1/K}],$$

where $P_{jt,kt}$ denotes the result of a bilateral comparison between countries j and k in period t. The EKS and CCD methods use the Fisher and Törnqvist formulae respectively to make each bilateral comparison. The EKS method is the most widely used method of this type. In particular, it is used by the OECD and Eurostat.[11]

As noted above, EKS-type methods make bilateral comparisons between all possible pairings of countries. It is tempting to conclude that the overall results could be improved by excluding bilateral comparisons between countries with very different consumption patterns on the grounds that such comparisons are less reliable.[12] Furthermore, by excluding some bilateral comparisons, this would allow the remaining comparisons to be made over larger and more detailed baskets of commodity headings. These observations provide the motivation for the minimum-spanning-tree (MST) method.

C. *Spanning-Tree Methods*

The third class of multilateral method discussed here uses spanning trees [see Hill (1999)]. A multilateral comparison between K countries can be made by simply chaining together $K-1$ bilateral comparisons (edges), as long as the underlying graph is a *spanning tree*. A spanning tree is a connected graph that does not contain any cycles. In other words, any pair of vertices in the graph are connected by one and only one path of edges. The reason why there must be no cycles in the graph is to ensure that the price indexes are transitive and hence internally consistent. A total of K^{K-2} different spanning trees are defined on a set of K vertices. Three examples of spanning trees defined on the set of 9 vertices are shown in Figure 2.[13]

Insert Figure 2 Here

The resulting set of multilateral price indexes depends both on the choice of formula used for making the bilateral comparisons and on the choice of spanning tree. The bilateral comparisons should be made using a superlative formula such as Fisher or Törnqvist. Since superlative formulae satisfy the country (time) reversal test (i.e., $P_{js,kt} = 1/P_{kt,js}$), there is no need for directional arrows on the edges in the spanning tree to identify the base country/time period in each bilateral comparison, and hence it does not matter where one starts in the spanning tree when computing the multilateral price indexes.

The choice of spanning tree is more problematic. A criterion is needed for deciding which edges (bilateral comparisons) to include and which to exclude. Ideally, we should use whichever bilateral comparisons are most reliable. Reliability in this context is measured by the sensitivity of a bilateral comparison to the choice of index number formula. The less sensitive a bilateral comparison is to the choice of formula, the more confidence we can have in the result.

Measuring Sensitivity

A number of criteria could be used for measuring the sensitivity of the results of a bilateral comparison to the choice of formula [see Diewert (2002a)]. Hill (1999) uses the Paasche-Laspeyres spread (PLS) defined as follows:

$$PLS_{js,kt} = \left| \ln \left(\frac{P^L_{js,kt}}{P^P_{js,kt}} \right) \right| .$$

The main attraction of the PLS is that it equals zero if the price data satisfy the conditions for either John R. Hicks's (1946) aggregation theorem (i.e., $p^n_{kt} = \lambda p^n_{js} \ \ \forall n$) or the quantity data satisfy the conditions for Wassily Leontief's (1936) aggregation theorem (i.e., $q^n_{kt} = \mu q^n_{js} \ \ \forall n$). In the first case, all bilateral price index formulae give the same answer (i.e., $P_{js,kt} = \lambda$), while in the second case all bilateral quantity index formulae give the same answer (i.e., $Q_{js,kt} = \mu$). Given that price indexes can be derived implicitly from quantity indexes, it follows that in both cases there is no index number problem since the correct price index is exactly determined. This suggests that we can have a higher degree of confidence in a bilateral comparison with a small PLS, since the result should be less sensitive to the choice of index number formula.[14]

However, one problem with the PLS is that the data being consistent with either Hicks or Leontief aggregation are only sufficient conditions for $PLS = 0$. For this reason, Diewert (2002a) advocates the use of relative dissimilarity indexes. He considers a number of such indexes. Here we focus on just one pair of indexes, which Diewert shows have desirable axiomatic properties.

$$(7) \qquad S^P_{js,kt} = \sum_{n=1}^{N} \left[\left(\frac{s^n_{js} + s^n_{kt}}{2} \right) \left(\frac{1}{P^F_{js,kt}} \frac{p^n_{kt}}{p^n_{js}} + P^F_{js,kt} \frac{p^n_{js}}{p^n_{kt}} - 2 \right) \right]$$

$$(8) \qquad S^Q_{js,kt} = \sum_{n=1}^{N} \left[\left(\frac{s^n_{js} + s^n_{kt}}{2} \right) \left(\frac{1}{Q^F_{js,kt}} \frac{q^n_{kt}}{q^n_{js}} + Q^F_{js,kt} \frac{q^n_{js}}{q^n_{kt}} - 2 \right) \right]$$

$S^P_{js,kt}$ in (7) is a relative price dissimilarity measure, while $S^Q_{js,kt}$ in (8) is a relative quantity dissimilarity measure, and $P^F_{js,kt}$ and $Q^F_{js,kt}$ denote Fisher price and quantity indexes. In particular, $S^P_{js,kt}$ equals zero if and only if the data are consistent with Hicks aggregation. Likewise, $S^Q_{js,kt}$ equals zero if and only if the quantity data are consistent with Leontief aggregation. Suppose now that these measures are combined as follows:

$$(9) \qquad S_{js,kt} = \min(S^P_{js,kt}, S^Q_{js,kt}).$$

It follows that a necessary and sufficient condition for $S_{js,tk}$ to equal zero is that the data are consistent with either Hicks or Leontief aggregation. Otherwise, $S_{js,kt} > 0$. It is because of its closer link with Hicks's and Leontief's aggregation theorems that $S_{js,kt}$ is preferred here to $PLS_{js,kt}$ for measuring the sensitivity of bilateral comparisons to the choice of (an acceptable) formula.

Minimum-Spanning Trees and Kruskal's Algorithm

A complete graph defined over K vertices has $K(K-1)/2$ edges. Each vertex in a spatial comparison corresponds to a country and each edge to a bilateral comparison between two countries. The minimum-spanning-tree (MST) method for computing multilateral price indexes requires a weight to be placed on each edge (bilateral comparison). Using the relative dissimilarity measure, $S_{jt,kt}$, as weights, the minimum-spanning tree for year t is the spanning tree with the smallest sum of weights on its edges. The minimum-spanning tree can be computed using Kruskal's algorithm. Kruskal's algorithm selects sequentially the edges (bilateral comparisons) with the smallest weights (in our context relative dissimilarity measures), subject to the constraint that adding each edge does not create a cycle. The program terminates once $K-1$ edges have been selected, since at this point it is no longer possible to select any more edges without creating a cycle. The resulting graph is the minimum-spanning tree.[15]

If the $S_{js,kt}$ measures defined in (9) are used as weights, a reasonable case can be made for arguing that the resulting minimum-spanning tree is the spanning tree that minimizes the sensitivity of the *multilateral* price indexes to the choice of *bilateral* index number formula [see Hill (1999)]. This is because it is constructed from the bilateral comparisons that are least sensitive to the choice of formula.

Multilateral (transitive) price indexes are obtained by chaining a superlative price index such as Fisher or Törnqvist across the minimum-spanning tree. This requires the linking together of $K-1$ bilateral comparisons.

III. Criteria for Multilateral Comparisons on Panel Data Sets

As will become apparent, the standard multilateral methods are inadequate in a panel context. This is because, in price index comparisons over a panel data set, a tension exists between the spatial and temporal comparisons. This tension manifests itself in the criteria of temporal fixity, spatial fixity, temporal consistency, spatial consistency and temporal displacement.

A. *Temporal and Spatial Fixity*

Temporal fixity is an issue that arises in a panel comparison whenever a new time period is added to the data set. For example, consider a panel data set covering the period 1995-2000. Now suppose data for 2001 become available. Temporal fixity, in this case, is the requirement that the results for the years 1995-2000 are unaffected by the inclusion of the data for 2001. This is a very desirable property, since users of statistics, including government, generally do not like it when statistics are revised retrospectively.

Spatial fixity is an issue that arises when more countries are added to a multilateral comparison. It requires that the results for a core set of countries are unaffected by the inclusion of other countries. Spatial fixity for the EU countries is built in to the triennial OECD spatial comparisons.

B. *Temporal and Spatial Consistency*

A panel comparison is *temporally consistent* if it is country separable, i.e., the overall comparison can be broken up into a series of separate temporal comparisons for each country that are then somehow linked together. This means that the temporal results for each country do not depend on the other countries in the comparison.[16]

A panel comparison is *spatially consistent* if it is time separable, i.e., the overall comparison can be broken up into a series of separate spatial comparisons for each year. This means that the spatial results for each year do not depend on the other years in the comparison. In general, it is not possible to maintain both temporal and spatial consistency, while at the same time achieving transitivity.

C. *Temporal Displacement*

The temporal displacement of a particular bilateral spatial comparison, $P_{jt,kt}$, within a broader panel comparison is measured by the time span of the data used to compute it. The temporal displacement of a whole panel comparison is the maximum of the temporal displacements of all the bilateral spatial comparisons, $P_{jt,kt}$, subsumed within it. For example, the temporal displacement of a panel method applied to a data set containing T periods of data must lie between zero and $T-1$.

Temporal displacement is related to Laszlo Drechsler's (1973) notion of characteristicity which he introduced in the context of multilateral spatial comparisons. Characteristicity is the idea that a bilateral comparison between countries j and k subsumed within the broader multilateral comparison should as much as possible depend solely on the price and quantity vectors of countries j and k. It is not possible to simultaneously satisfy characteristicity and transitivity (unless expenditure data are unavailable, in which case elementary indexes can be used).

By implication, all multilateral methods (including all panel methods) violate characteristicity. As far as I am aware, however, no attempt has been made in the index number literature to quantify the extent to which particular methods violate characteristicity. Temporal displacement provides such a measure, from a temporal perspective, for panel price index methods.[17] A higher level of temporal displacement, other things equal, implies reduced characteristicity.

IV. Four Approaches to Constructing Price Indexes on Panel Data Sets

A taxonomy of panel methods containing four broad classes is developed here (see Figure 3). The performance of methods from each class with respect to temporal consistency, spatial consistency and temporal fixity is assessed. All the methods violate spatial fixity.[18] Discussion of temporal displacement is deferred mainly until section V.

Insert Figure 3 Here

A. *Multilateral Methods*

The first class in Figure 3 simply applies standard multilateral methods, such as MST, EKS and Geary-Khamis to the whole panel. The MST method can easily be applied to a panel data set.[19] In this context, each vertex corresponds to a country-time period. This means there will be a total of KT vertices in the spanning tree. The bilateral comparisons within the spanning tree are made using the Fisher index. For the EU countries over the period 1995-2000, the minimum-spanning tree computed using the dissimilarity measure $S_{js,kt}$ in (9), is shown in Figure 4. Price indexes for the EU obtained using the MST, EKS and Geary-Khamis methods are provided in section VII.

Insert Figure 4 Here

The problem with multilateral methods is that in general they violate spatial and temporal consistency, temporal fixity, and have the maximum possible temporal displacement $(T-1)$. This undermines the usefulness of such methods in a panel context. The MST method has the slight advantage over other multilateral methods that it will sometimes satisfy temporal consistency (as it does for example in Figure 4).

B. *Temporally-Consistent (TC) Methods*

Here we consider two subclasses of TC methods as shown in Figure 3. All TC methods violate spatial consistency. Methods in the first subclass also violate temporal fixity.

The first subclass uses Kruskal's algorithm, but as part of a two step-procedure. The $MinTCG$ in the first stage constructs a temporal minimum-spanning tree for each country. This guarantees temporal consistency. In the second stage, Kruskal's algorithm is used to link the temporal results together. This second-stage application of Kruskal's algorithm requires that the $S_{js,kt}$ matrix be modified. Low dummy values must be specified for each bilateral comparison selected in the first stage, to ensure that these same bilateral comparisons (edges) are selected in the second stage. For the EU data set considered in this paper it turns out that the $MinTCG$ spanning tree is identical to the minimum-spanning tree in Figure 4. The Minimum-Chronological-Graph ($MinCG$) method differs slightly from $MinTCG$ in that it requires all the temporal links in the first stage to be chronological. Hence Kruskal's algorithm is only applied in the second stage. For the EU data set, the links between countries for the MinCG method are the same as in Figure 4. The only difference is that, unlike Figure 4, all the temporal links are by construction strictly chronological (for example $N98$ is linked to $N97$ and $N99$ not to $N96$ as it is in Figure 4).

The second subclass like the $MinCG$ method imposes chronological chaining, hence the name chronological graph (CG). However, unlike the $MinCG$ method, CG methods simply choose a reference multilateral spatial comparison to link the chronological chains together.

Insert Figure 5 Here

The CG_{96} method uses a spatial comparison in 1996. This method is graphed in Figure 6. Alternatively, a spatial comparison in another year, say 1999, could be used. This is the CG_{99} method depicted in Figure 7. Results for the EU obtained using the CG_{96}^{MST} and CG_{99}^{MST} methods are provided in section VII.[20]

Insert Figure 6 Here

Insert Figure 7 Here

As noted earlier in section II, the EKS method can be thought of as a geometric mean of the price indexes generated by K star spanning trees, each with a different country in the middle. In an analogous manner, we can take a geometric mean of the price indexes generated by the four graphs CG_{96}^{MST}, CG_{97}^{MST}, CG_{98}^{MST} and CG_{99}^{MST}.[21] This method is referred to here as the $Av(CG^{MST})$ method. One attraction of this method is that it treats all four years symmetrically, and hence is not dependent on the choice of a reference spatial comparison. In general, however, $Av(CG)$ methods violate temporal fixity.

C. *Temporally-Fixed (TF) Methods*

As can be seen in Figure 3, the CG methods discussed above are members of both the TC and TF classes. Here we consider TF methods that violate temporal consistency. $MinTFG$ is a temporally-fixed version of the MST method. It uses Kruskal's algorithm as follows. First it makes an MST spatial comparison for the first year in the data set. In the second stage, Kruskal's algorithm is used to link the vertices for 1996 to those for 1995. To ensure temporal fixity, Kruskal's algorithm must collect all the 1995 vertices in one block. This can be guaranteed by specifying low dummy values in the $S_{js,kt}$ matrix defined over 1995-6 for the bilateral spatial comparisons in 1995. Each additional year is added sequentially in an analogous manner. This sequential approach guarantees temporal fixity. The $MinTFG$ method is illustrated in Figure 8 (the spatial minimum-spanning tree for 1995 is shown in Figure 5).[22] In this particular case, the $MinTFG$ method also satisfies temporal consistency.

Temporal fixity can also be imposed on the EKS method. EKS price indexes are obtained by running a regression that imposes transitivity by minimizing the least squares deviations in logs from Fisher price indexes.[23] In a panel comparison, the least squares problem takes the following form:

$$\min_{(\ln P_{js}, \ln P_{kt})} \left\{ \sum_{s=1}^{T} \sum_{t=1}^{T} \sum_{j=1}^{K} \sum_{k=1}^{K} (\ln P_{kt} - \ln P_{js} - \ln P^F_{js,kt})^2 \right\}.$$

With regard to the OECD data set, temporal fixity can be imposed by solving this least squares problem repeatedly each time adding a new year of data to the panel. In the first stage, only the data for 1995 is included. The second stage uses the data for 1995 and 1996, subject to the restriction that the results for 1995 are held fixed (i.e., they are the same as in the first stage). In the third stage, 1997 is included, and now the results for both 1995 and 1996 are held fixed, etc. This method is referred to here as the temporally-fixed EKS method (TFEKS).

Insert Figure 8 Here

Suppose multilateral spatial comparisons are made at H year intervals, and that temporal comparisons are made using chronological chains. As it stands this will lead to cycles in the graph, and hence the results will be internally inconsistent. One way of preventing cycles in this case is to use the temporal data of only one country in the year that a new multilateral spatial comparison is made. For example, the $TFG^{MST}_{96,99}(Ge)$ method, illustrated in Figure 9, makes spatial MST comparisons in 1996 and 1999.

Temporal price indexes for each country are chronologically chained, except in 1998-9, where only the comparison for Germany is used.

Insert Figure 9 Here

For the EU data set, 15 sets of $TFG^{MST}_{96,99}(x)$ results can be generated by using a different country x as the link between 1998 and 1999. Symmetric treatment of countries is obtained by taking a geometric mean of the 15 sets of results. This method is referred to here as the $Av(TFG^{MST}_{96,99})$ method. Symmetric treatment of countries is often considered highly desirable by international organizations such as the OECD and World Bank (mainly for political reasons). Results for the EU obtained using this method are provided in section VII.

It is also possible to take matters a step further and take the geometric mean of $Av(TFG^{MST}_{96,99})$ and CG^{MST}_{96}. One attraction of this method is that the burden of ensuring transitivity is shared by the 1998-9 temporal comparisons and the 1999 spatial comparisons. It will also satisfy temporal fixity, since it is an average of two temporally-fixed methods.

D. *Spatially-Consistent (SC) Methods*

All the SC methods considered here, with the exception of the $MinSCG$ methods, also satisfy temporal fixity (see Figure 3). The $SCG^{MST}(Ge)$ method makes spatial MST comparisons for each year in the data set. These six MST comparisons are then linked through a chronological chain for Germany. This method is illustrated in Figure 10. As with the $TFG^{MST}_{96,99}$ methods, 15 sets of $SCG^{MST}(x)$ results can be generated by using a different country x as the link between the MST spatial comparisons. Symmetric treatment of countries is obtained by taking a geometric mean of the 15 sets of results. This method is referred to here as the $Av(SCG^{MST})$ method. Results for the EU obtained using this method are provided in section VII.

Insert Figure 10 Here

The $MinSCG^{MST}$ method differs from $SCG^{MST}(x)$ in that it uses Kruskal's algorithm to link the six MST spatial comparisons together. Again, this requires the $S_{js,kt}$ matrix to be altered to ensure that the results for each year form blocks within the graph. This means Kruskal's algorithm is in fact only used to select five edges. This method will not necessarily satisfy temporal fixity.

V. Choosing Between Panel Price Index Methods

A clear consensus has emerged in the index number literature that annual temporal price indexes should be constructed by chaining chronologically either Fisher or Törnqvist price indexes.[24] No clear consensus, however, has emerged in the spatial literature with regard to the choice of multilateral formula. This is one reason for giving greater emphasis to maintaining temporal consistency. A second reason for favoring temporal consistency is that temporal data sets tend to be more reliable than spatial data sets. This is because national governments are more interested in temporal comparisons, and allocate resources accordingly. The infrastructure in national statistical offices, therefore, is primarily geared towards temporal comparisons. In addition, it is easier for a national statistical office to track changes over time in prices and consumption patterns in a country, than it is for an international organization such as the OECD or Eurostat to track changes in prices and consumption patterns across countries. This last point has been made previously by Kravis, Heston and Summers (1982):

> [B]oth the benchmark estimates and the growth rates computed from national data have obvious sources of error. The benchmark estimates rely on place-to-place comparisons based on samples of prices that are ⋯ smaller than the samples used in the national time-to-time comparisons of prices. It is inherently easier to measure time-to-time changes, at least for items sold off the shelf, because it is possible simply to trace the price of a particular item found in a particular outlet from month to month or year to year. (New products are an exception; their introduction into later benchmark comparisons are likely to be more accurate than their treatment in time-to-time indexes.) ⋯ If there is a little variation in quality from one outlet to another, that does not matter so long as the same quality in a given outlet is priced in each period. It is much more difficult to get the average national price for a particular specification of a good in any one country. Then it is necessary to ensure that the same quality of each good is priced in every

outlet. Further possibilities of error are introduced in place-to-place comparisons by the need to hold quality constant not only within each country, but across countries as well. [Kravis, Heston and Summers (1982, p. 326)]

Assuming, as is usually the case, a panel comparison will be updated in due course as new time periods are added to the data set, temporal fixity is also important.[25] This suggests, therefore, that we should prefer methods that maintain temporal fixity and temporal consistency, i.e., CG methods such as CG_{96}^{MST} depicted in Figure 6.

There are two other issues, however, that should be taken into account. First, CG methods lack flexibility, in that they do not adapt to the data. In contrast, the MST, MinTCG, MinCG and MinTFG methods all allow the data, to varying degrees, to decide the best way of linking the country-time periods together.[26] The MinTFG method is particularly attractive since in addition to satisfying (by construction) temporal fixity, it will often also satisfy temporal consistency (as it does for example in Figure 5). Only when temporal consistency is absolutely required should a CG method be used in preference to the MinTFG method.

The second issue is that so far we have ignored the criterion of temporal displacement. The temporal displacement of MinTFG will probably be $T-1$, while for a CG_t method it cannot be less than $(T-1)/2$, where T denotes the number of time periods in the panel. The temporal displacement of a CG_t method is minimized when the reference spatial MST comparison is made in the middle year of the panel (in our case when t equals 1997 or 1998). In contrast, the temporal displacement of $Av(TFG_{t,t+H})$ is $H-1$, where H denotes the time interval between spatial MST (or EKS) comparisons.

Over time, as more periods are added to the panel, T rises while H stays the same. Hence, $Av(TFG_{t,t+H})$ becomes increasingly attractive relative to MinTFG and CG_t with regard to temporal displacement as T rises. Also, as T rises, MinTFG and CG_t methods must extrapolate a single spatial MST comparison over more and more years. This may lead to drift in the spatial results in years further away from the spatial reference year.[27] For example, consider a panel data set covering the period 1982-2002. Suppose further that the panel comparison is made using CG_{85} (i.e., the multilateral spatial comparison is made in 1985). In this case, the temporal displacement would be 17. This means that France and Germany in 2002 are compared indirectly via an

MST comparison in 1985. It is precisely to avoid such scenarios that chaining has been advocated over fixed-base comparisons in the temporal index number literature. (For example, a fixed-base temporal comparison with 1985 as the base would compare 2001 and 2002 indirectly via 1985.) This problem of drift in the spatial results obtained by extrapolating from a previous multilateral spatial comparison is exacerbated by the different treatment across countries of hedonic price adjustment methods for computers and other products experiencing rapid quality change in the CPI. In such cases, $Av(TFG_{t,t+H})$ with spatial MST comparisons made at 3 or 5 year intervals (i.e., $H = 3$ or 5) may be preferable, since it allows the reference multilateral spatial comparison to be updated regularly, thus keeping the temporal displacement reasonably low. This comes at the price of a violation of temporal consistency with each new spatial MST comparison. Also worthy of consideration for determining the price indexes in years t to $t + H$ is a geometric mean of CG_t and $Av(TFG_{t,t+H})$.[28] This hybrid method shares the burden of ensuring transitivity between the $(t+H-1, t+H)$ temporal comparisons and the $t + H$ spatial comparisons.

VI. Reconciling Temporal and Spatial Price Indexes

The conflict between temporal and spatial consistency also arises in a different although related context. Suppose a researcher wants to combine temporal price indexes from one source with spatial price indexes from another source. If spatial results for more than one period are used, then a problem of intransitivity (i.e., internal inconsistency) in the results will arise. For example, price levels across countries in the EU can be compared by combining the consumer price indexes (CPIs) for each country with OECD spatial price indexes. The OECD spatial price indexes are available at 3-year intervals. Over the period 1995-2000, OECD spatial results are available for 1996 and 1999. This case is graphed in Figure 11 for 5 EU countries. Irrespective of the choice of multilateral method for making the spatial comparisons in 1996 and 1999, there will be cycles in the graph and hence the results will be intransitive. For example, consider the following comparison: France98-France99 (Fr98-Fr99). This comparison can be made directly or indirectly. An indirect comparison can be made in an infinite number of ways, many of which will give different answers. Here we consider just 5 indirect methods.

Insert Figure 11 Here

Indirect path 1: Fr98-Fr97-Fr96-Ge96-Ge97-Ge98-Ge99-Fr99

Indirect path 2: Fr98-Fr97-Fr96-It96-It97-It98-It99-Fr99

Indirect path 3: Fr98-Fr97-Fr96-Sp96-Sp97-Sp98-Sp99-Fr99

Indirect path 4: Fr98-Fr97-Fr96-UK96-UK97-UK98-UK99-Fr99

Indirect path 5: Fr98-Fr97-Fr96-Ge96-Ge97-Ge98-Ge99-It99-It98-It97-It96-UK96-UK97-UK98-UK99-Fr99

Some of the panel methods discussed above can be used to impose transitivity in Figure 11 (none of the variants of the MST method can be used since no measure of reliability for the bilateral comparisons is available in this context). The case for using the CG_{96} method also is weaker here. This is because it implies ignoring completely the multilateral spatial comparison for 1999. In addition, as noted earlier, as the number of years in the panel rises CG_{96} becomes increasingly unsatisfactory since drift may occur in the spatial results. For these reasons, $Av(TFG_{96,99})$ or a geometric mean of $Av(TFG_{96,99})$ and CG_{96} may be preferable since they make full use of the available data and allow for periodic updating of the spatial reference. The geometric mean of $Av(TFG_{96,99})$ and CG_{96} is particularly attractive since it allows the burden of ensuring transitivity to be shared by the 1998-9 temporal and 1999 spatial price indexes.

Another approach to resolving this problem was proposed by Summers and Heston (1984) which they refer to as "consistentization" [see also Bettina H. Aten and Heston (2002)]. They begin by assuming that both the temporal and spatial price indexes contain errors. They then run a regression that imposes transitivity by minimizing the least squares deviations in logs from the original price indexes. This method amounts to applying the EKS method directly to a panel. This means it will be subject to the same criticisms as EKS. Aten and Heston note that:

> Because of the reluctance of countries to accept adjustments of their national indexes of growth and price change, we have not pursued this approach in

developing PWT 5.6 and 6.0. [Aten and Heston (2002, p. 3)]

In other words, the Summers and Heston approach violates temporal consistency (in all periods and not just the one of a new spatial comparison). A stronger objection perhaps is that, like EKS, this approach also violates temporal fixity. This latter problem can be fixed, however, by using either the TFEKS or $Av(SCG^{EKS})$ variants on EKS.

VII. An Application of Panel Price-Index Methods to the EU

A. *Constructing a Panel Data Set*

Before these panel methods can be used, it is first necessary to construct a suitable panel data set. This is achieved by splicing together the Harmonized Index of Consumer Prices (HICP) at as disaggregated a level as possible with a cross-section of OECD data.

The HICP data used here cover the period 1995-2000, and consist of annual prices and expenditures for 96 distinct commodity headings, and country weights for the 15 member countries of the European Union (EU).[29] However, not all headings are available for all countries. To ensure comparability, in some cases more aggregated headings are used. In consequence, the number of headings is reduced to 82. For all countries, the price for each heading is normalized to 100 in 1996. The expenditures each year sum to 1000 for each country. The country weights also sum to 1000. Using this data set it is possible to construct temporal price indexes that measure changes in the purchasing power of currencies and the price level in EU countries over time. As was noted earlier, however, it is not possible to construct spatial price indexes that compare the purchasing power of currencies and the price level at a given point in time. Such comparisons can be made using OECD cross-section data. Since 1990 the OECD makes detailed cross-section comparisons of GDP at three-year intervals of its member countries and associated countries in Eastern Europe and the Confederation of Independent States (CIS). This means that two sets of detailed cross-section price and expenditure data are available during the period 1995-2000: namely for 1996 and 1999.

The aim here is to simultaneously compute both temporal and spatial price indexes for the EU member countries. To do this it is necessary to merge the EU and OECD price data at the commodity-heading level in either 1996 or 1999. Since two sets of spatial results are available, the immediate question arises as to which should be used? If both are used this would introduce cycles and hence intransitivities at the level of the commodity headings, which would have to be fixed before the construction of any price indexes could be contemplated. The intransitivities arise because the commodity headings used here are quite aggregated and hence are themselves price indexes. If instead the commodity headings referred to individual products, these price indexes would reduce to simple price ratios which should all be transitive. The intransitivities create a problem analogous to the one discussed in the previous section. Furthermore, the 1996 and 1999 OECD commodity headings do not correspond exactly, which would further complicate the process of harmonization if both spatial data sets were used. In this section I sidestep these issues by using only the 1996 OECD spatial comparisons. This is because the objective of this paper is to focus on how price indexes should be constructed on a panel data set, rather than on how the panel data set itself should be constructed. Also, with a perfect disaggregation (i.e., down to the level of individual commodities) intransitivities at the commodity-headings level should not arise.

The 1996 OECD data set has 162 headings. The first step is to remove the headings relating to capital formation and government consumption, since there are no corresponding HICP headings. This still leaves 141 OECD headings, which must then be matched with the 82 HICP headings. The harmonized data set was constructed to have exactly the same headings as the HICP data set. Only 39 OECD and HICP headings could be matched up exactly. Of the remaining 43 headings in the harmonized data set, 23 were created by matching more than one OECD heading with one HICP heading. For example, 6 OECD headings were combined to match the HICP heading "bread and cereals". The OECD headings were merged using the EKS price index formula. Of the remaining 20 headings, in 7 cases an OECD heading was applied to 2 HICP headings, in 1 case an OECD heading was applied to 3 HICP headings, and in the last case 2 OECD headings were matched with 3 HICP headings. The exact matching of headings is shown in Table 1.

Insert Table 1 Here

Once the harmonization of the two data sets in 1996 is complete, the final step is to scale up (for 1997-2000) and down (for 1995) accordingly each price heading in the HICP data set for each country. As discussed above, in the original HICP data set the prices of all headings in 1996 are normalized to 100. In the harmonized data set – like the OECD data set – the prices in 1996 are normalized to 100 for only one country (Austria). The choice of reference country does not affect the results. Using this harmonized data set both spatial and temporal comparisons can be made across the 15 EU countries.

B. *Sensitivity of the Results to the Choice of Panel Method*

Price indexes for the 15 EU countries over the period 1995-2000 are shown in Table 2. The price indexes are computed using the seven starred methods in Figure 3. For each method in Table 2 the price index for the UK in 1996 is normalized to 1 (since it is the currency-time period with the highest purchasing power). For example, referring to Table 2, we can deduce that, according to the MST method, one British pound in 1996 had the same purchasing power as 57.8 Belgian francs in 2000.

Insert Table 2 Here

By the standards of international comparisons, the results in Table 2 are not that sensitive to the choice of method. The average spread between the largest and smallest price index along each row in Table 2 is 4.9 percent.[30]

The average spread between the CG_{96}^{MST} and CG_{99}^{MST} results in 1996 and 1999 are also of interest, since this indicates the extent of the conflict between the temporal and spatial results. The average spread is 2.5 percent in 1996 and 1.6 percent in 1999. By comparison, the corresponding average spreads between the CG_{96}^{EKS} and CG_{99}^{EKS} results are 2.5 percent in both 1996 and 1999. These findings are similar to those obtained by Krijnes-Locker and Faerber (1984), who considered the consistency between the 1975 and 1980 benchmarks based on consumption data for 63 headings and 9 EU countries. They found that the 1975 results when extrapolated forward differed by 2.4 percent from the 1980 results.

Such discrepancies are too large to ignore. Furthermore, it must be emphasized that for other data sets they could be much larger. Two factors here act to keep the discrepancies smaller than they might otherwise be. First, the EU countries are reasonably homogeneous. Second, the underlying data are not that disaggregated (only

82 headings here and 63 in Krijnes-Locker and Faerber's study). This tends to reduce the magnitude of the observed substitution effect, which drives the sensitivity of the results to the choice of index number method [see Marilyn E. Manser and Richard J. McDonald (1988)].

The average percentage difference in the results generated by each pair of methods is measured by the index L_{ab} defined below:

$$L_{ab} = 100 \left\{ \frac{1}{KT} \sum_{t=1}^{T} \sum_{k=1}^{K} \left[\frac{\max\left(P_{kt}^{a}, P_{kt}^{b}\right)}{\min\left(P_{kt}^{a}, P_{kt}^{b}\right)} \right] - 1 \right\},$$

where P_{kt}^{a} denotes the panel price index in country k in period t obtained using method a. Two attractive features of L_{ab} are first that it is symmetric (i.e., $L_{ab} = L_{ba}$), and second that it is invariant to the choice of base country-time period. For example, in Table 2 the reference country-time period is the UK in 1996. However, if it was changed say to Germany in 2000, L_{ab} would be unaffected.

Table 3 shows the L_{ab} measures obtained from comparisons between all possible pairs of the 7 panel methods. The EKS and Geary-Khamis panel methods emerge as the outliers in Table 3. The biggest discrepancy is between the EKS and CG_{96}^{MST} results which differ on average by 4 percent. This result is surprising since all the methods except Geary-Khamis are derivatives of Fisher indexes. Intuitively, therefore, one would expect Geary-Khamis rather than EKS to be the biggest outlier.

Insert Table 3 Here

C. *Comparing the Quality of the Bilateral Links Across Panel Methods*

For any panel method that uses bilateral comparisons as its basic building blocks (i.e., all variants on the MST and EKS methods) it is possible to compute an average $S_{js,kt}$ for the bilateral comparisons used by that method. The average $S_{js,kt}$ for seven variants on the MST and EKS methods are shown in Table 4. The top six methods (i.e., those with the smallest average $S_{js,kt}$) are all variants on the MST method. The average $S_{js,kt}$ of the CG_{t}^{MST} methods exceed only slightly that of the MST method. By implication, the imposition of chronological chaining here does not increase much the sensitivity of the overall results to the choice of bilateral index number formula.

Insert Table 4 Here

This finding reflects the fact that the minimum-spanning tree is reasonably chronological. Any spanning tree defined on the EU data considered here must have at least 14 non-chronological edges (this is required to link the 15 countries together). The minimum-spanning tree in Figure 4 has 25 non-chronological edges. By comparison, if $PLS_{js,kt}$ were used (see section II), the minimum-spanning tree would have 37 non-chronological edges. This again suggests that $S_{js,kt}$ is a better measure of sensitivity than $PLS_{js,kt}$, since intuitively we would expect a high number of chronological edges in the minimum-spanning tree. It is also interesting to consider the minimum-spanning trees generated by $S^P_{js,kt}$ and $S^Q_{js,kt}$. The former has only 15 non-chronological edges (i.e., it is almost perfectly chronological) while the latter has 42 non-chronological edges. This difference is attributable to the fact that there is much more noise in the expenditure data than in the price data [see Robert C. Allen and Diewert (1981)].

VIII. Testing for Convergence of Price Levels and Relative Prices

A. *Comparing Price Levels*

The price level in country k relative to country b in period t, Z_{kt}/Z_{bt}, is defined here as follows:

$$Z_{kt}/Z_{bt} = \frac{P_{kt}/P_{bt}}{X_{kt}/X_{bt}},$$

where X_{kt}/X_{bt} denotes the exchange rate of country k in period t expressed as the number of units of currency in country k that can be exchanged for one unit of currency in the base country b in period t.[31] The resulting price levels for each of the 7 panel methods considered above are shown in Table 5, with Germany serving as the base country. For each year, therefore, the price level in Germany is normalized to one.

Insert Table 5 Here

The price-level rankings of the 7 panel methods are similar, although not identical.[32] The three Scandinavian countries (Denmark, Sweden and Finland) in most cases have the highest price levels in the EU (about 15 percent higher than Germany), while Greece, Portugal and Spain have the lowest (about 25 percent lower than Germany). The price-level rankings do not change much from one year to the next. This systematic tendency towards lower price levels in poorer countries (in our case Greece, Portugal and Spain) can be explained by the fact that nontradables, in general, are more labor intensive and hence relatively cheaper in these more labor abundant countries. In other words, there is no reason to expect purchasing power parity to hold even in the long run unless real income levels converge [see Kravis and Robert E. Lipsey (1983) and Jagdish N. Bhagwati (1984)].

Differences in price levels across the EU in a given year can be measured by the standard deviation of the logarithm of the price level, Z_{kt}, across the set of countries $k = 1, \ldots, K$.

$$I_t = \sqrt{\frac{1}{K-1}\sum_{k=1}^{K}\left[\ln\left(\frac{Z_{kt}}{Z_{bt}}\right) - \overline{\ln\left(\frac{Z_t}{Z_{bt}}\right)}\right]^2},$$

$$\text{where} \quad \overline{\ln\left(\frac{Z_t}{Z_{bt}}\right)} = \frac{1}{K}\sum_{k=1}^{K}\ln\left(\frac{Z_{kt}}{Z_{bt}}\right).$$

I_t is invariant to the choice of base country b (in this case Germany). Estimates of I_t over the period 1995-2000 for each of the 7 multilateral methods are shown in Table 6.[33]

Insert Table 6 Here

A decrease in I_t over time signals that price levels are converging. This corresponds to the concept of σ-convergence in the growth-convergence literature [see Barro and Sala-i-Martin (1992), Danny T. Quah (1996), and Dowrick and Quiggin (1997)]. Interpretation of the results is complicated by the fact that the set of countries is not the same across all years. The years 1996-1999 cover all 15 EU countries. However, Greece is missing in 2000 and Austria, Denmark, France, Luxembourg and the UK are missing in 1995. Hence we exclude 1995 from Table 6, and provide two sets of results, one covering the period 1996-1999 for all 15 EU countries, and one excluding Greece covering the period 1996-2000. Between 1996 and 1999, according to all 7 panel methods, price levels converged (i.e., I_t fell over time). Excluding Greece, over the period 1996-1999, the same pattern is observed. However, in 2000 prices diverged significantly.[34] In fact, for 6 of the 7 methods [the exception being $Av(TFG^{MST}_{96,99})$], the dispersion of price levels in 2000 was higher than in both 1998 and 1999. This example, where the 7 methods fail to reach a consensus illustrates that studies of convergence can be sensitive to the method used to construct the underlying price indexes. For more heterogeneous groupings of countries such as those usually considered in the convergence literature, the results regarding convergence could be quite sensitive to the choice of index number method. This point is rarely acknowledged in the growth-convergence literature.

B. *Comparing Relative Prices*

The similarity, J_{jk}^t, of the price vectors of two countries j and k in period t can be measured using a variant on the measure I_t discussed above. However, now what is measured is the variance of the logarithm of the price relatives, p_{kt}^n/p_{jt}^n, across the set of goods $n = 1, \ldots, N$. Also, it is necessary to weight each commodity heading by its average expenditure share.

$$(10) \qquad J_{jk}^t = \sum_{n=1}^{N} \left(\frac{s_{jt}^n + s_{kt}^n}{2} \right) \left[\ln \left(\frac{p_{kt}^n}{p_{jt}^n} \right) - \overline{\ln \left(\frac{p_{kt}}{p_{jt}} \right)} \right]^2 ,$$

$$\text{where} \quad \overline{\ln \left(\frac{p_{kt}}{p_{jt}} \right)} = \sum_{i=1}^{N} \left[\left(\frac{s_{jt}^i + s_{kt}^i}{2} \right) \ln \left(\frac{p_{kt}^i}{p_{jt}^i} \right) \right] ,$$

and s_{kt}^n denotes the expenditure share of good n in country k in time period t, as defined in (4). The logarithmic transformation ensures that J_{jk}^t is symmetric (i.e., $J_{jk}^t = J_{kj}^t$).

A measure of the similarity of relative prices across the EU in a given year is obtained by taking the arithmetic mean of J_{jk}^t, denoted by $Av(J^t)$, across all pairs of countries.

$$Av(J^t) = \frac{1}{K(K-1)} \sum_{j=1}^{K} \sum_{k \neq j}^{K} J_{jk}^t$$

Estimates of $Av(J^t)$ for the period 1996-1999 for all 15 EU countries and for 1996-2000 excluding Greece are shown in Table 7. Irrespective of whether or not Greece is included, the results suggest that relative prices have diverged slightly over this period.[35]

Insert Table 7 Here

IX. Implications of Findings

The finding of slight price level convergence in Table 6 is consistent with John H. Rogers (2001). Rogers computes price level indexes for 18 countries (including all members of the European Union) in 1990, 1995 and 1999 using a data set constructed by combining price data from the Economist Intelligence Unit (EUI) with HICP expenditure data.[36,37] Rogers finds evidence of faster convergence in the first half of the

1990s than in the second half (the period covered in this paper). Rogers then goes on to discuss the implications of price level convergence for the European Central Bank (ECB). A necessary implication is that countries with initially lower price levels on average must experience higher rates of inflation during the transition. Differing inflation rates within the Euro-zone means that monetary policy may be too stimulative in some countries and too restrictive in others. This problem could become more severe when the Euro-zone is widened to include relatively low-price countries in Eastern Europe.

The second finding that relative prices have diverged slightly over the same period (1995-2000) is somewhat surprising, given the concurrent tendencies towards greater economic integration in the European Union, and the observed convergence in price levels. As far as I know, this trend has not previously been observed. As noted above, it is not clear how robust it is, and whether the same trend would be observed for more disaggregated data. However, assuming the result is not spurious, the challenge then is to reconcile it with the observed trend towards greater economic integration and price level convergence. One possible explanation is that the convergence of prices has been focused predominantly on tradable goods in such a way that the relative price of tradables and nontradables across countries has diverged enough to cause overall relative prices to diverge.

X. Conclusion

This paper has focused on two main issues. First and foremost it has developed a methodology for constructing panel price indexes, which can also be used for reconciling temporal and spatial price indexes. It is argued that the choice of panel method depends on the properties of the underlying data and on the objective of the exercise. In many panel data sets, the temporal data are more reliable than the spatial data, thus suggesting that temporal consistency should be favored over spatial consistency. The relative importance attached to the criteria of temporal consistency, temporal fixity and temporal displacement then determines which method should be used.

The second focus of the paper is the application of the panel methodology to the European Union. To do this, it was first necessary to compute a suitable panel data set. This was achieved by merging a cross-section of OECD data with the EU's HICP at a disaggregated level. This merged HICP/OECD data set is used to compare price levels and relative prices across countries in the EU over the period 1995-2000. Price levels converged slightly while relative prices diverged. This last finding warrants further investigation.

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ENDNOTES

1. Here the terminology "spatial" refers to comparisons across countries (or regions) at a particular point in time, and "temporal" refers to comparisons for a given country (or region) across different points in time.

2. The PWT is probably the most widely used data set in the field of economics.

3. The history of these formulae is discussed in W. Erwin Diewert (1993).

4. The COL can be generalized to groups [see Diewert (1984)].

5. Steve Dowrick and John Quiggin (1997) propose an innovative way of narrowing these bounds by taking account of indirect comparisons via other country-time periods.

6. Contrary to common perception, however, it is not true that all superlative indexes approximate each other closely [see Hill (2004)].

7. These weights are fixed for elementary indexes. Hence some elementary indexes (e.g., Jevons and Dutot) are transitive. However, others (e.g., Carli) are not [see Diewert (1993)].

8. A number of other average-price methods are discussed in Hill (2000). An attractive feature of average-price methods is that they generate implicit quantity indexes, when expressed in value terms, that literally add up over different levels of aggregation. This additivity property is particularly useful in national accounts comparisons.

9. See, for example, OECD (1996), Summers and Heston (1991) and World Bank (1993).

10. Khamis (1972) proves existence and uniqueness for the Geary-Khamis system.

11. See OECD (1995) and Eurostat (1983).

12. An alternative approach to dealing with this problem was proposed by D. S. Prasada Rao (1999). He develops a weighted version of EKS, that allows different weights to be given to each bilateral comparison. See also Rao and Marcel P. Timmer (2003).

13. Both the star and chain graphs in Figure 1 are also examples of spanning trees. These spanning-trees have been the focus of considerable attention in a temporal context. This is because the star graph is used by a fixed-base price index, while the chain graph is used by a chained price index.

14. In addition, in the case of homothetic preferences, since Paasche and Laspeyres price indexes bound the cost-of-living index, a Fisher price index (which by construction lies between Paasche and Laspeyres) must converge on the cost-of-living index as the PLS approaches zero.

15. See Hill (1999) for a more in depth analysis of the MST method. More detailed explanations of Kruskal's algorithm and the concept of a minimum-spanning tree can be found in any introductory book on Graph Theory. For example, see Robin J. Wilson (1985).

16. As will become clear later, neither temporal fixity nor temporal consistency implies the other.

17. To construct an equivalent measure of spatial displacement is more problematic since there is no corresponding natural ordering of countries.

18. Temporal fixity is more important than spatial fixity in a panel method. This is because new periods of data are continually added to a panel, while new countries are added only at irregular intervals. The addition of new countries can be dealt with on a case-by-case basis as the need arises.

19. The first to do so was Alice Shiu (2003). However, her panel is in index format (like the HICP). An MST constructed on such a data set is problematic since it will not be invariant to the choice of base year.

20. One attraction of EKS, therefore, is that it generates standard errors on the logarithms of the price indexes.

21. Multilateral spatial comparisons in Figures 6 to 11 are depicted as oval boxes since the way the countries are linked will depend on which multilateral method is used. Here we use the MST method, although EKS could also be used. The spatial minimum-spanning trees for the EU data set are shown in Figure 5. The trees for

1996, 1997, 1998 and 1999 each cover 15 countries and hence have 14 edges. Each pairing of trees shares between 11 and 13 common edges. The average number of common edges is 11.8, although only six edges are common to all four trees. If the $PLS_{jt,kt}$ are used as weights instead of $S_{jt,kt}$, the average number of common edges falls to 10.8. This finding suggests that using $S_{jt,kt}$ instead of $PLS_{jt,kt}$ may generate more stable spatial minimum-spanning trees.

22. CG_{95}^{MST} and CG_{00}^{MST} cannot be used in this context since data are not available for all the countries in the EU data set in these years.

23. The fact that five countries are missing from the data set in 1995 is not a problem. These countries simply enter the comparison when the 1996 vertices are linked to 1995. Kruskal's algorithm will determine whether the 1996 vertices for the five countries missing in 1995 link to 1995 or 1996 vertices of the other ten countries. In Figure 8, in all five cases the links are to 1996 vertices.

24. For higher frequency data the case for chronological chaining is less clear cut, due to the possibility of seasonal cycles [see Hill (2001)] or other fluctuations in the data [Marshall B. Reinsdorf (1999) finds evidence of huge weekly fluctuations in coffee prices and purchases in supermarket scanner data].

25. In contrast, as noted earlier, spatial fixity is probably best dealt with on a case-by-case basis. For example, new member countries in the EU could be added to EU comparisons retrospectively, by linking them through bilateral comparisons with a bridge country, such as Austria.

26. The MST, MinTCG and MinCG methods may often select very similar graphs.

27. Drift should not be confused with substitution bias. Since they are derived from Fisher price indexes, MinTFG and CG_t methods will be free of substitution bias.

28. One would almost never want to use CG_t to compute price indexes prior to year t, since this would lead to violations of temporal fixity.

29. For a thorough review of the HICP and its properties see Diewert (2002b).

30. It should be noted that the observed sensitivity of each observation to the choice of method is not independent of the choice of base country-time period, in this case

$UK96$.

31. The exchange rates used are yearly averages obtained from the Yearbook of International Financial Statistics (2001) published by the IMF.

32. By construction, the CG^{MST}_{96}, $Av(TFG^{MST}_{96,99})$ and $Av(SCG^{MST})$ methods generate identical price levels in 1996, since they all use the 1996 minimum-spanning tree in Figure 5. Similarly, the CG^{MST}_{99}, $Av(TFG^{MST}_{96,99})$ and $Av(SCG^{MST})$ methods generate identical price levels in 1999, since they all use the 1999 minimum-spanning tree in Figure 5.

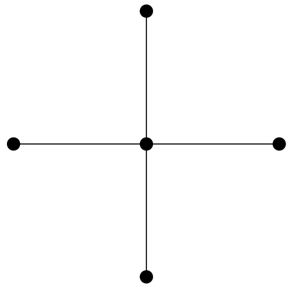
33. Again, by construction, the CG^{MST}_{96}, $Av(TFG^{MST}_{96,99})$ and $Av(SCG^{MST})$ methods generate identical standard deviations in 1996, and the CG^{MST}_{99}, $Av(TFG^{MST}_{96,99})$ and $Av(SCG^{MST})$ methods generate identical standard deviations in 1999.

34. For every method I_t is smaller when Greece is excluded. This shows that Greece is an outlier.

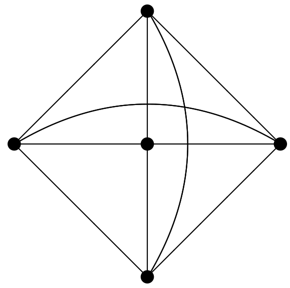
35. It is not clear how robust the findings with regard to convergence in Tables 6 and 7 are to changes in the level of aggregation of the data. The HICP commodity headings are already quite aggregated. If more disaggregated data were used, the results might be different.

36. The EUI data set consists of prices of 168 goods and services in 26 cities in 18 countries. When data on two or more cities in the same country were available, Rogers averaged the prices, to obtain a single set of prices for each country. Expenditure weights were obtained by matching the goods and services in the EUI data set with the headings in the HICP. If more than one good or service were matched with a particular HICP heading, then Rogers used an average price.

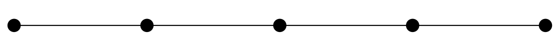
37. This data set is a panel, although Rogers uses only one set of expenditure shares (corresponding to an unspecified year). This means that all his price indexes are of either the Paasche or Laspeyres variety. Nevertheless, this data set could be used to address some issues of price index construction on panel data sets. Given Rogers is interested primarily in price level convergence, however, he does not address this issue.



Star Graph



Complete Graph



Chain Graph

FIGURE 1. — EXAMPLES OF GRAPHS

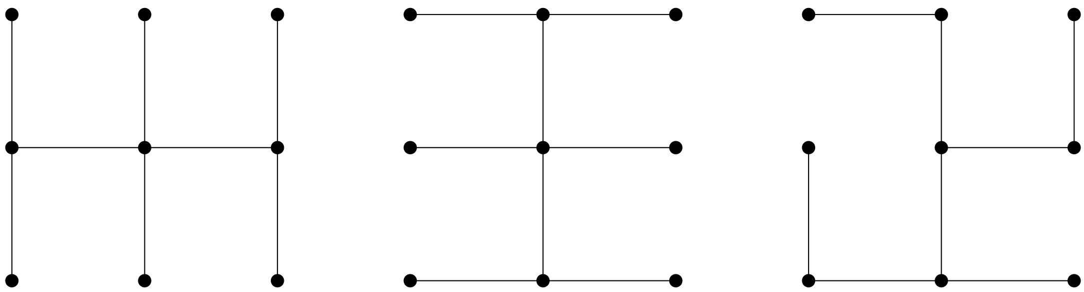


FIGURE 2. — EXAMPLES OF SPANNING TREES

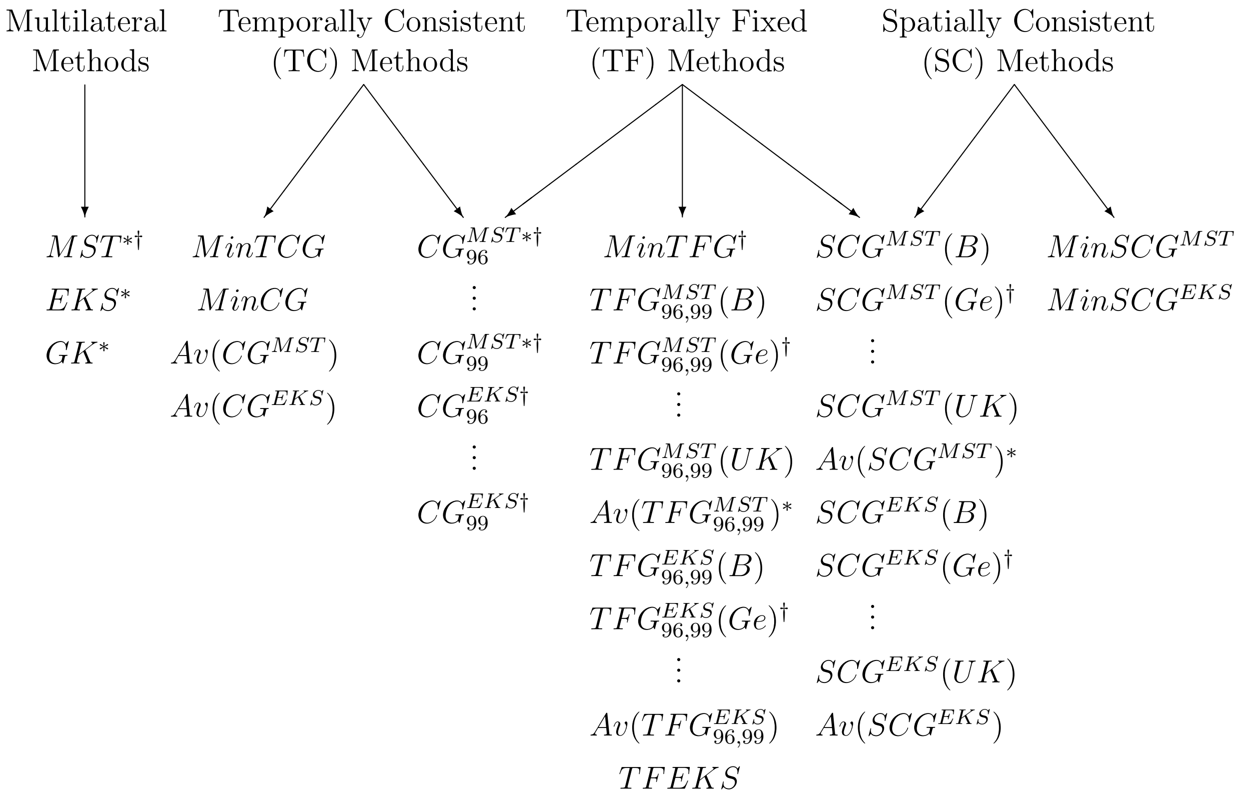


FIGURE 3. — A TAXONOMY OF PANEL PRICE INDEX METHODS FOR THE EUROPEAN UNION (1995-2000)

* denotes a method used in the empirical comparisons later in the paper.

† denotes a method illustrated graphically.

Note: *CG* stands for Chronological Graph.

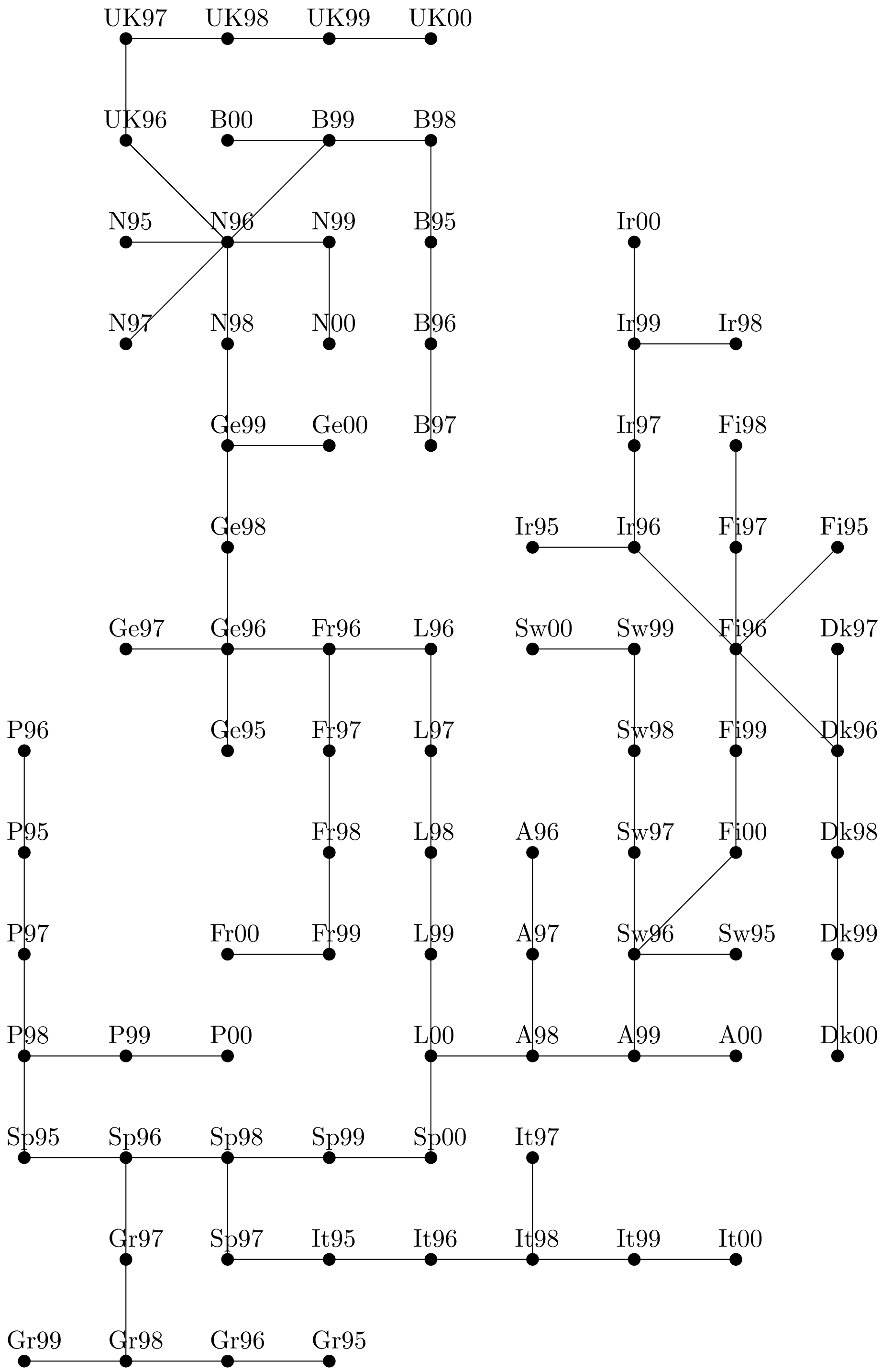


FIGURE 4. — MINIMUM SPANNING TREE FOR EUROPEAN UNION (1995-2000)

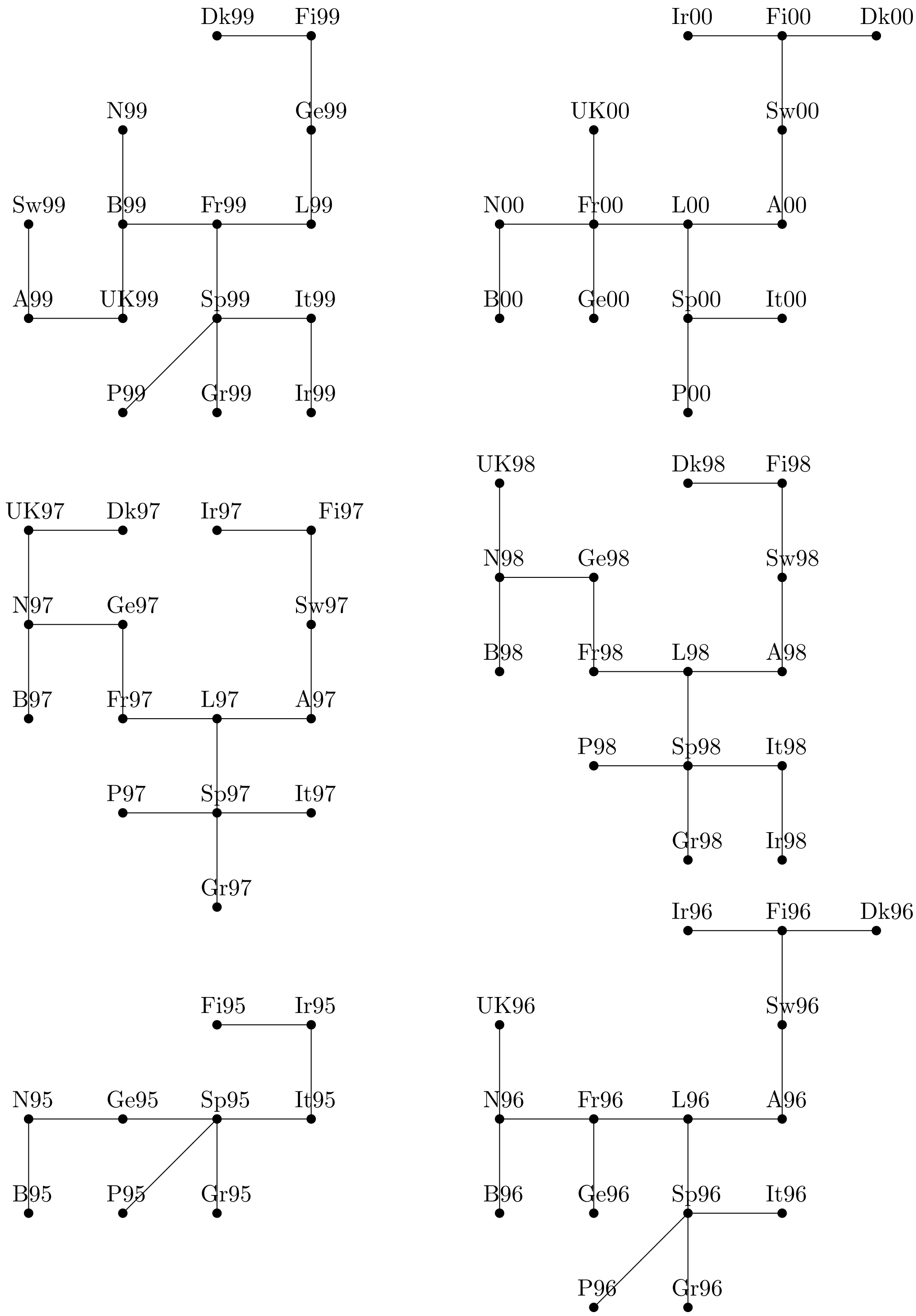


FIGURE 5. — SPATIAL MINIMUM SPANNING TREES FOR EUROPEAN UNION (1995-2000)

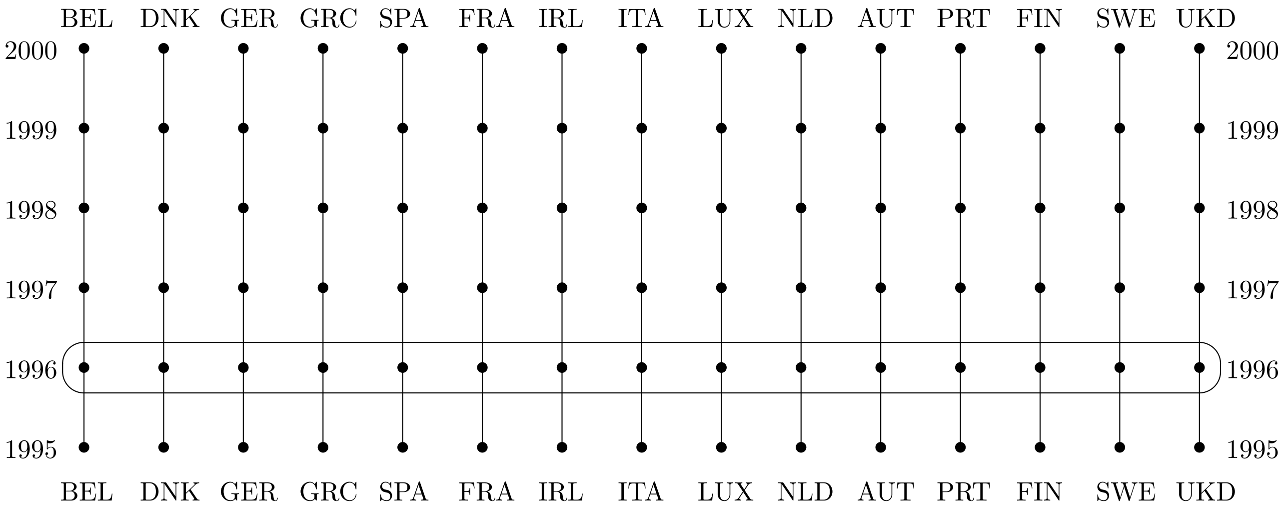


FIGURE 6. — CHRONOLOGICALLY CHAINED GRAPH WITH A SPATIAL COMPARISON IN 1996 (CG_{96}): EUROPEAN UNION (1995-2000)

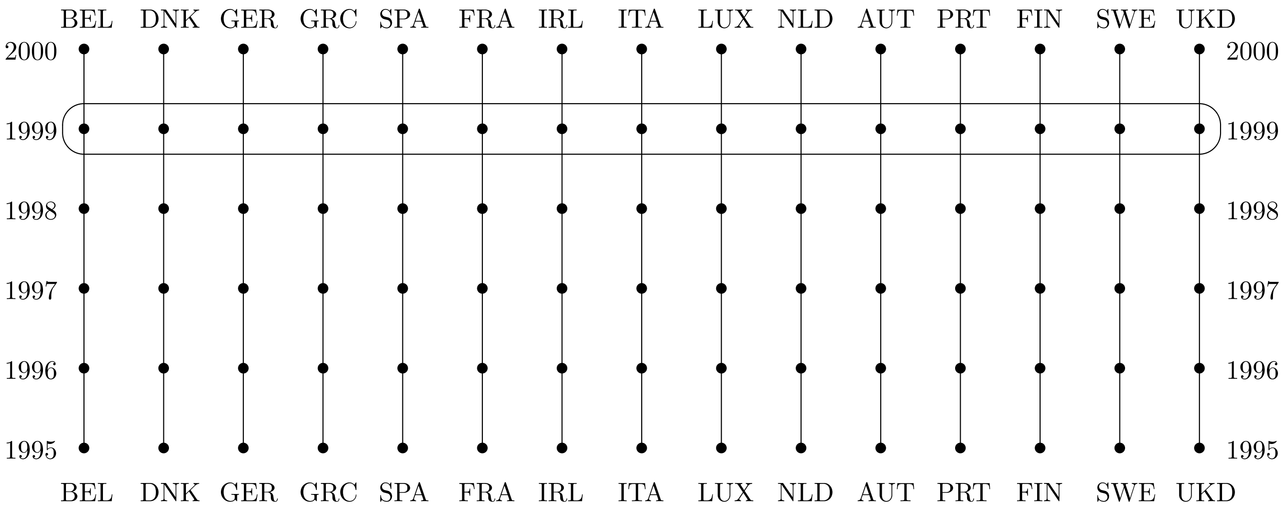


FIGURE 7. — CHRONOLOGICALLY CHAINED GRAPH WITH A SPATIAL COMPARISON IN 1999 (CG_{99}): EUROPEAN UNION (1995-2000)

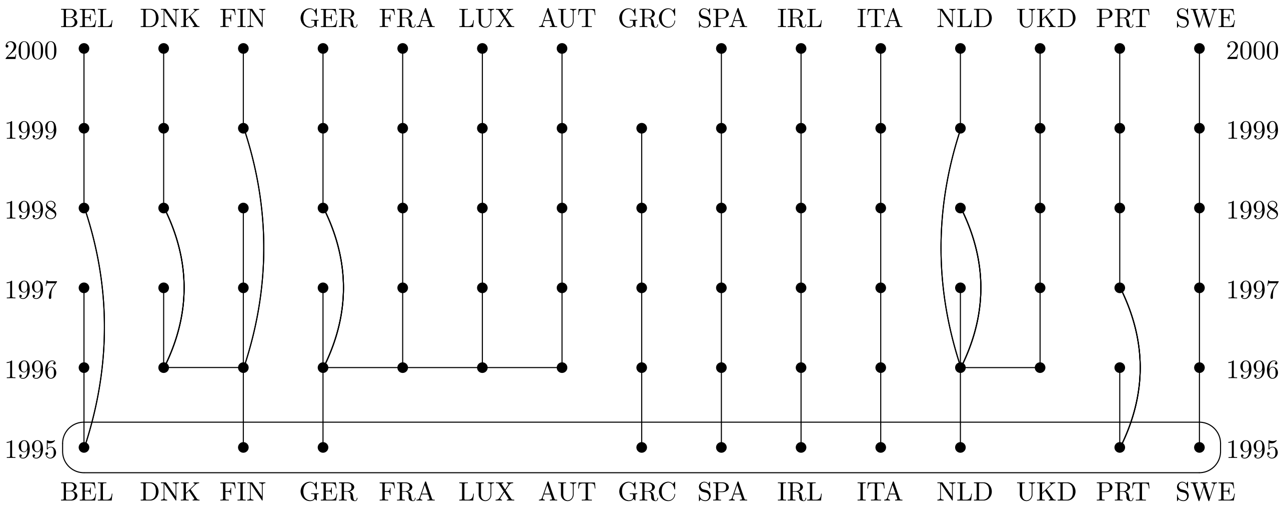


FIGURE 8. — MINIMUM TEMPORALLY-FIXED GRAPH WITH A SPATIAL COMPARISON IN 1995 ($MinTFG$): EUROPEAN UNION (1995-2000)

Note: Vertices for DNK, FRA, LUX, AUT and UKD in 1995 and for GRC in 2000 are not included in the graph due to missing data.

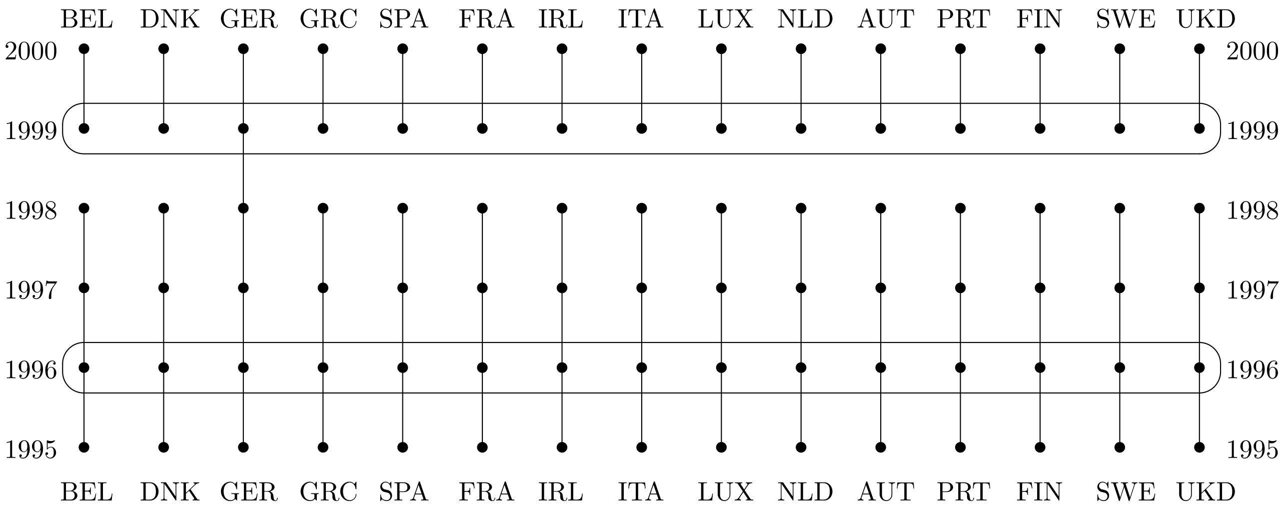


FIGURE 9. — TEMPORALLY-FIXED GRAPH WITH SPATIAL COMPARISONS IN 1996 AND 1999 LINKED THROUGH GERMANY ($TFG_{96,99}$): EUROPEAN UNION (1995-2000)

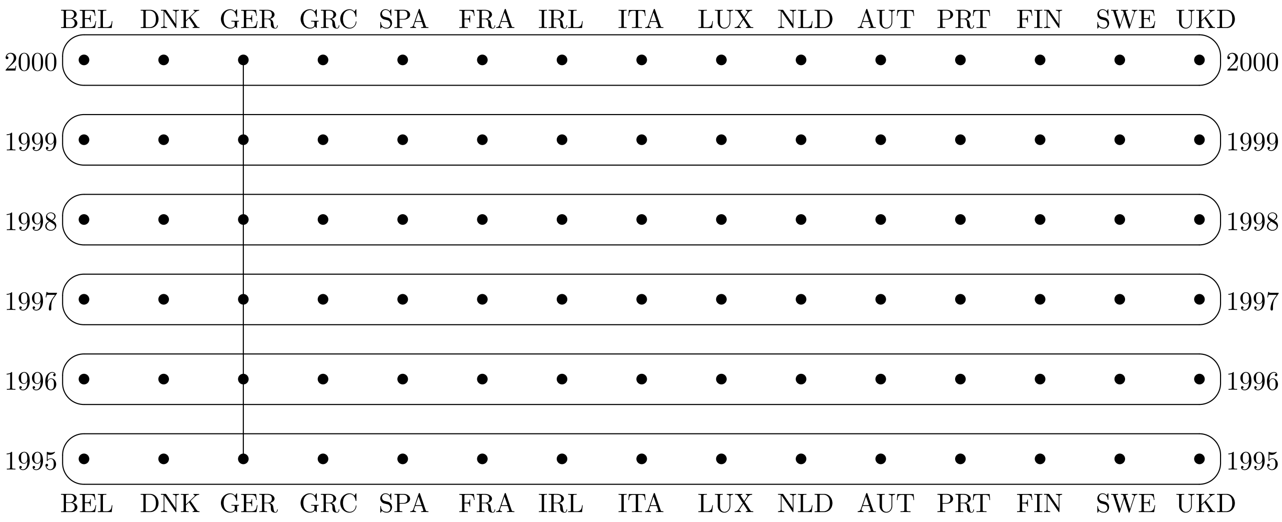


FIGURE 10. — SPATIALLY-CONSISTENT GRAPH (*SCG*) WITH SPATIAL COMPARISONS EACH YEAR LINKED THROUGH GERMANY: EUROPEAN UNION (1995-2000)

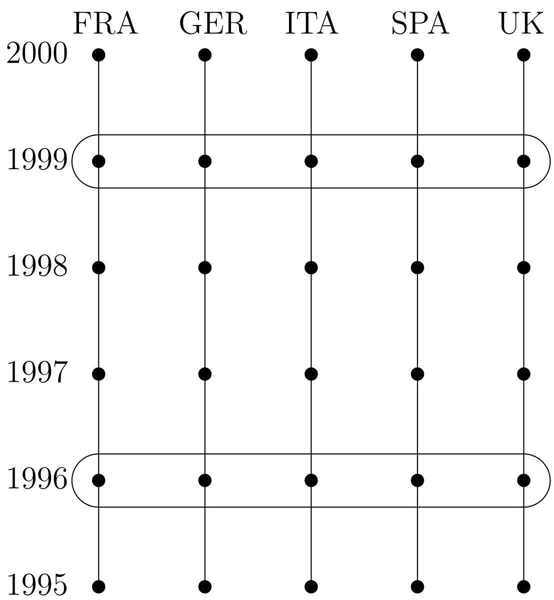


FIGURE 11. — RECONCILING SPATIAL AND TEMPORAL PRICE INDEXES

TABLE 1. MATCHING OF OECD AND HICP DATA SETS

OECD Heading		HICP Heading
1111011	Rice	cp0111 Bread and cereals
1111012	Flour & other cereals	
1111013	Bread	
1111014	Rusks,imperishable bakery products	
1111015	Pasta products	
1111016	Other cereals products	
1111021	Beef	cp0112 Meat
1111022	Veal	
1111023	Pork	
1111024	Lamb,mutton,goat	
1111025	Poultry	
1111026	Delicatessen	
1111027	Proces. & preser.meat prep.in cans,jars	
1111028	Edible offal and other meats	
1111031	Fresh and frozen fish	cp0113 Fish and seafood
1111032	Dried,smoked or salted fish	
1111033	Fresh or frozen seafood	
1111034	Preserv. & processed fish and seafood	
1111041	Fresh milk	cp0114 Milk, cheese and eggs
1111042	Preserved milk	
1111043	Other milk products	
1111044	Cheese	
1111045	Eggs and egg-based products	
1111051	Butter	cp0115 Oils and fats
1111052	Margarine	
1111053	Edible oils	
1111054	Other animal and vegetable fats	
1111061	Fresh fruit	cp0116 Fruit
1111062	Dried fruit & nuts	
1111063	Frozen & preserved fruit, etc.	
1111064	Fresh vegetables	cp0117 Vegetables
1111065	Dried vegetables	
1111066	Frozen vegetables	
1111067	Pres.vegetables & veg.-based products	
1111068	Potatoes, other tuber vegetables	
1111069	Potato products	
1111071	Sugar (raw and refined)	cp0118 Sugar, jam, honey, chocolate
1111075	Jams, jellies, honey and syrups	
1111076	Chocolate & oth.cocoa preparations	
1111077	Confectionery	
1111072	Coffee	cp0121 Coffee, tea and cocoa
1111073	Tea and other infusions	

TABLE 1. MATCHING OF OECD AND HICP DATA SETS

1111074	Cocoa (excl.cocoa preparations)	
1111078	Ice cream	cp0119 Food products n.e.c.
1111079	Condiments & oth.food products nec	
1112011	Bottled water	cp0122 Mineral waters, soft drinks, fruit, juices
1112012	Other soft drinks nec.	
1112022	Spirits and liqueurs	cp0211 Spirits
1112023	Wine	cp0212 Wine
1112024	Beer	cp0213 Beer
1112025	Other alcoholic beverages	
1113011	Cigarettes	cp022 Tobacco
1113021	Other tobacco products	
1121011	Men's clothing	cp0311 Clothing materials
1121012	Ladies' clothing	
1121013	Children's clothing	
1121014	Infant's clothing	
1121015	Materials, yarns, accessories, etc.	cp0312 Garments
		cp0313 Other articles of clothing and accessories
1121021	Repair and maintenance of clothing	cp0314 Cleaning, repair and hire of clothing
1122011	Men's footwear	cp032 Footwear including repair
1122012	Women's footwear	
1122013	Children's and infant's footwear	
1122021	Repairs to footwear	
1131011	Rents of tenants in flats & houses	cp041 Actual rentals for housing
1131013	Repair and maintenance of housing	cp0431 Materials for maintenance/repair of dwelling
		cp0432 Services for maintenance/repair of dwelling
1132011	Electricity	cp0451 Electricity
		cp044 Water/miscellaneous services to dwelling
1132021	Town gas and natural gas	cp0452 Gas
1132022	Liquefield petroleum gas (butan etc.)	cp0455 Heat energy
1132031	Liquid fuels	cp0453 Liquid fuels
1132041	Coal, coke and other solid fuels	cp0454 Solid fuels
1141011	Furniture and fixtures	cp0511 Furniture and furnishings
1141012	Carpets and other floor coverings	cp0512 Carpets and other floor coverings
1141021	Repairs to furniture,fixtures etc.	cp0513 Repair of furniture, furnishings, floor coverings
1142011	Household textiles, other furnishings	cp052 Household textiles
1142021	Repairs to household textiles etc.	
1143011	Refrigerators,freezers & fridge fr.	cp0531/2 Major/small electric household appliances
1143012	Washing machines,spin driers etc.	
1143013	Cookers, hobs and ovens	
1143014	Heaters and air-conditioners	
1143015	Vacuum cleaners,polishers etc.	
1143016	Other major household appliances	
1143021	Repairs to major household appliances	cp0533 Repair of household appliances
1144011	Glassware and tableware	cp054 Glassware, tableware and household utensils

TABLE 1. MATCHING OF OECD AND HICP DATA SETS

1144012	Cutlery and flatware	
1144013	Motorless kitchen & domestic utensils	
1144014	Motorless garden appliances	cp055 Tools and equipment for house and garden
1144015	Small electrical accessories	
1144021	Repairs to glassware,tableware etc.	
1144031	Cleaning and maintenance products	
1144032	Other non-durable household goods	cp0561 Non-durable household goods
1144041	Laundry and dry cleaning	cp0562 Domestic services and household services
1144051	Domestic services	
1150000	MEDICAL CARE	cp06 Health
1161011	Passenger vehicles	cp0711 Motor cars
1161021	Motorcycles and bicycles	cp071_not_711 Motor cycles, bicycles, etc
1162011	Tyres, tubes, parts, accessories	cp0721 Spares parts for personal transport equipment
1162012	Maintenance and repair services	cp0723 Maintenance of personal transport equipment
1162021	Motor fuels,oils and greases	cp0722 Fuels/lubricants for personal transport equip.
1162031	Oth. expenses: to pers.transport	cp0724 Other services for personal transport equip.
1163011	Local by bus, train, tube, tram, taxi }	{ cp0731 Passenger transport by railway
1163021	Long distance by coach and rail }	{ cp0732 Passenger transport by road
		{ cp0735 Combined passenger transport
1163022	Long-distance transport: air + sea	cp0733 Passenger transport by air
		cp0734 Passenger transport by sea/inland waterway
1163031	Other purchased transport services	cp0736 Other purchased transport services
1164011	Postal services	cp081 Postal services
1164021	Telephone, telegraph, telex services	cp08233 Telephone/telefax equipment and services
1171011	Radios & electro-acoustic apparatus	cp0911 Sound and picture recording equipment, etc
1171012	Television-sets and videorecordes	
1171021	Photographic and related equipment	cp0912 Photographic, cinematographic, optical equip.
1171022	Other durable recreational goods	cp0913 Information processing equipment
1171031	Records,tapes,cassettes(audi&video)	cp0914 Recording media
1171032	Sports goods and camping equipment	cp0932 Equipment for sport, camping and recreation
1171033	Games,toys and hobbies	cp0931 Games, toys and hobbies
1171034	Films & oth.photographic supplies	
1171035	Flowers,plants,pets & rel.products	cp0933 Gardens, plants and flowers
		cp0934/5 Pets, veterinary services, etc
1171041	Parts & acces.for repairs recr.goods	cp0915 Repair of audio-visual, photographic equipment
1172011	Entertainment, sport, recreation, culture	cp092 Other major durables for recreation and culture
		cp0941 Recreational and sporting services
1172023	Radio-, TV-licence and rental	
1172024	Photographic & other services nec.	
1173011	Books	cp0951 Books
1173012	Newspapers,magazines etc.	cp0952 Newspapers and periodicals
		cp0953/4 Miscellaneous printed matter; stationery, etc
1174011	Fees: vocat.training,adult educ. etc.	cp0942 Cultural services
		cp10 Education

TABLE 1. MATCHING OF OECD AND HICP DATA SETS

1174021	Compensation of employees	
1174031	Intermediate consumption	
1174041	Consumption of fixed capital	
1181001	Restaurants,take-a-ways & the like	cp1111 Restaurants, cafés and the like
1181002	Pubs,bars,cafes and tearooms	
1181003	Staff canteens	cp1112 Canteens
1181004	Hotels and other lodging places	cp112 Accommodation services
1182001	Services of hairdressers etc.	cp1211 Hairdressing salons and personal grooming
1182002	Durable toilet articles and repair	cp1212/3 Electrical appliances for personal care; etc
1182003	Non-durable toilet articles	
1182004	Jewellery,watches and their repair	cp1231 Jewellery, clocks and watches
1182005	Travel goods and baggage items	cp096 Package holidays
1182006	Other personal goods n.e.c.	cp1232 Other personal effects
1182007	Writing,drawing equipment & supplies	
1182008	Social security and welfare services	cp124 Social protection
1182010	Charges for financial services nec.	cp125 Insurance
		cp126 Financial services n.e.c.
1182011	Fees for other services nec.	cp127 Other services n.e.c.

TABLE 2. PRICE INDEXES FOR THE EUROPEAN UNION (1995-2000, UK96=1)

	MST	EKS	GK	CG_{96}^{MST}	CG_{99}^{MST}	Av(TFG)	Av(SCG)	Max/Min
B00	57.84	56.67	55.62	57.74	58.26	57.50	56.72	1.05
Dk00	14.00	14.55	14.04	13.85	14.00	13.82	14.04	1.05
Ge00	3.10	3.20	3.17	3.08	3.12	3.08	3.09	1.04
Sp00	209.82	219.86	218.24	207.06	212.64	209.85	208.87	1.06
Fr00	10.68	10.90	10.77	10.59	10.70	10.56	10.53	1.04
Ir00	1.19	1.22	1.26	1.18	1.16	1.14	1.15	1.10
It00	2677.75	2790.75	2789.21	2646.10	2702.59	2667.20	2655.67	1.05
L00	61.12	62.97	60.84	60.64	62.09	61.27	60.85	1.04
N00	3.18	3.21	3.22	3.18	3.20	3.16	3.15	1.02
A00	22.89	23.83	23.60	22.58	22.93	22.63	23.01	1.06
P00	227.60	236.00	234.79	222.92	230.69	227.67	225.50	1.06
Fi00	10.36	10.74	10.54	10.24	10.36	10.23	10.32	1.05
Sw00	16.49	16.87	16.08	16.29	16.43	16.21	16.51	1.05
UK00	1.05	1.04	1.04	1.05	1.05	1.03	1.03	1.02
B99	56.56	55.74	54.81	56.46	56.98	56.23	56.27	1.04
Dk99	13.66	14.15	13.65	13.51	13.66	13.48	13.49	1.05
Ge99	3.05	3.14	3.11	3.02	3.06	3.02	3.02	1.04
Gr99	393.39	409.94	385.82	387.97	397.47	392.26	392.52	1.06
Sp99	203.00	212.13	208.79	200.33	205.72	203.03	203.16	1.06
Fr99	10.49	10.73	10.64	10.41	10.52	10.38	10.39	1.03
Ir99	1.13	1.16	1.19	1.12	1.10	1.08	1.09	1.10
It99	2611.10	2718.74	2712.76	2580.24	2635.32	2600.81	2602.50	1.05
L99	59.09	61.14	60.48	58.63	60.02	59.24	59.27	1.04
N99	3.11	3.15	3.18	3.11	3.13	3.09	3.09	1.03
A99	22.48	23.36	23.26	22.18	22.53	22.23	22.24	1.05
P99	221.61	231.69	230.83	217.06	224.63	221.69	221.83	1.07
Fi99	10.08	10.44	10.19	9.97	10.08	9.95	9.96	1.05
Sw99	16.31	16.59	15.84	16.11	16.24	16.03	16.04	1.05
UK99	1.04	1.04	1.04	1.04	1.04	1.03	1.03	1.02
B98	55.96	55.04	54.04	55.86	56.37	55.86	55.80	1.04
Dk98	13.43	13.90	13.44	13.28	13.43	13.28	13.31	1.05
Ge98	3.03	3.12	3.09	3.00	3.04	3.00	3.02	1.04
Gr98	384.85	399.82	375.31	379.54	388.84	379.54	384.95	1.07
Sp98	198.63	207.31	203.64	196.03	201.30	196.03	198.26	1.06
Fr98	10.43	10.66	10.51	10.35	10.46	10.35	10.39	1.03
Ir98	1.11	1.14	1.16	1.09	1.07	1.09	1.06	1.10
It98	2569.39	2676.43	2682.13	2539.02	2593.22	2539.02	2557.08	1.06

TABLE 2. PRICE INDEXES FOR THE EUROPEAN UNION (1995-2000, UK96=1)

L98	58.49	60.40	59.83	58.03	59.42	58.03	58.42	1.04
N98	3.05	3.09	3.12	3.05	3.07	3.05	3.04	1.03
A98	22.36	23.24	23.16	22.06	22.41	22.06	22.19	1.05
P98	217.15	227.51	225.93	212.69	220.10	212.69	216.86	1.07
Fi98	9.94	10.30	10.05	9.84	9.95	9.84	9.85	1.05
Sw98	16.22	16.54	15.84	16.02	16.15	16.02	16.02	1.04
UK98	1.03	1.03	1.03	1.03	1.03	1.03	1.02	1.01
B97	55.46	54.49	53.60	55.38	55.88	55.38	55.12	1.04
Dk97	13.29	13.76	13.30	13.15	13.30	13.15	13.59	1.05
Ge97	3.01	3.10	3.07	2.99	3.03	2.99	2.99	1.04
Gr97	368.37	381.79	360.27	363.29	372.18	363.29	366.65	1.06
Sp97	195.38	203.73	200.31	192.81	198.00	192.81	194.19	1.06
Fr97	10.37	10.59	10.45	10.29	10.39	10.29	10.30	1.03
Ir97	1.08	1.12	1.14	1.07	1.05	1.07	1.07	1.08
It97	2520.30	2625.42	2630.49	2490.51	2543.68	2490.51	2501.92	1.06
L97	57.97	59.81	59.35	57.51	58.88	57.51	57.70	1.04
N97	3.00	3.03	3.06	3.00	3.02	3.00	2.98	1.03
A97	22.20	23.05	22.95	21.90	22.24	21.90	21.96	1.05
P97	212.76	222.47	220.96	208.39	215.65	208.39	210.25	1.07
Fi97	9.82	10.16	9.91	9.71	9.83	9.71	9.70	1.05
Sw97	16.08	16.40	15.72	15.88	16.01	15.88	15.84	1.04
UK97	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01
B96	54.64	53.68	52.80	54.57	55.06	54.57	54.57	1.04
Dk96	13.06	13.52	13.08	12.92	13.07	12.92	12.92	1.05
Ge96	2.97	3.05	3.02	2.94	2.98	2.94	2.94	1.04
Gr96	349.69	362.15	341.23	345.09	353.54	345.09	345.09	1.06
Sp96	191.69	199.75	196.51	189.44	194.54	189.44	189.44	1.05
Fr96	10.24	10.47	10.32	10.16	10.27	10.16	10.16	1.03
Ir96	1.07	1.11	1.12	1.06	1.04	1.06	1.06	1.08
It96	2472.82	2577.65	2580.09	2444.13	2496.31	2444.13	2444.13	1.06
L96	57.18	59.00	58.58	56.74	58.09	56.74	56.74	1.04
N96	2.94	2.98	3.01	2.94	2.97	2.94	2.94	1.02
A96	21.94	22.78	22.69	21.65	21.99	21.65	21.65	1.05
P96	208.85	218.06	216.66	204.59	211.72	204.59	204.59	1.07
Fi96	9.70	10.05	9.80	9.60	9.71	9.60	9.60	1.05
Sw96	15.79	16.15	15.42	15.60	15.73	15.60	15.60	1.05
UK96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
B95	53.68	52.72	51.83	53.61	54.09	53.61	53.79	1.04
Ge95	2.93	3.02	2.99	2.91	2.95	2.91	2.94	1.04

TABLE 2. PRICE INDEXES FOR THE EUROPEAN UNION (1995-2000, UK96=1)

Gr95	323.94	336.99	316.37	319.69	327.51	319.69	327.48	1.07
Sp95	185.05	193.01	189.56	182.88	187.80	182.88	186.76	1.06
Ir95	1.05	1.08	1.09	1.04	1.02	1.04	1.01	1.08
It95	2376.27	2479.07	2479.07	2348.71	2398.84	2348.71	2396.29	1.06
N95	2.90	2.94	2.96	2.83	2.92	2.83	2.91	1.05
P95	202.83	212.19	210.45	198.69	205.62	198.69	203.19	1.07
Fi95	9.59	9.94	9.67	9.49	9.60	9.49	9.25	1.08
Sw95	15.66	16.06	15.34	15.47	15.60	15.47	15.07	1.07

TABLE 3. AVERAGE PERCENTAGE DIFFERENCES IN THE RESULTS GENERATED BY EACH PAIR OF METHODS (L_{ab})

	MST	EKS	GK	CG_{96}^{MST}	CG_{99}^{MST}	Av(TFG)	Av(SCG)
MST	0.000	3.002	2.462	1.011	0.854	1.040	1.021
EKS	3.002	0.000	1.830	4.006	2.746	3.977	3.749
GK	2.462	1.830	0.000	3.100	2.325	3.095	3.041
CG_{96}^{MST}	1.011	4.006	3.100	0.000	1.627	0.305	0.859
CG_{99}^{MST}	0.854	2.746	2.325	1.627	0.000	1.548	1.335
Av(TFG)	1.040	3.977	3.095	0.305	1.548	0.000	0.674
Av(SCG)	1.021	3.749	3.041	0.859	1.335	0.674	0.000

TABLE 4. AVERAGE S_{jk} INDEXES

MST	0.052
CG_{96}^{MST}	0.053
CG_{97}^{MST}	0.054
CG_{98}^{MST}	0.058
CG_{99}^{MST}	0.059
$Av(TFG^{MST})$	0.104
CG_{96}^{EKS}	0.116
CG_{97}^{EKS}	0.118
CG_{98}^{EKS}	0.123
CG_{99}^{EKS}	0.127
$Av(TFG^{EKS})$	0.235
$Av(SCG^{MST})$	0.287
$Av(SCG^{EKS})$	0.641
EKS	0.676

TABLE 5. PRICE LEVELS Z_{kt}/Z_{bk} FOR THE EUROPEAN UNION (1995-2000) (Gexx = 1)

	MST	EKS	GK	CG_{96}^{MST}	CG_{99}^{MST}	Av(TFG)	Av(SCG)
Sw00	1.231	1.221	1.174	1.226	1.220	1.220	1.239
Dk00	1.184	1.193	1.161	1.181	1.178	1.178	1.195
UK00	1.090	1.050	1.054	1.095	1.081	1.081	1.073
Fi00	1.099	1.105	1.092	1.095	1.093	1.093	1.101
A00	1.048	1.058	1.057	1.042	1.045	1.045	1.060
Fr00	1.026	1.016	1.012	1.026	1.023	1.023	1.018
Ge00	1.000	1.000	1.000	1.000	1.000	1.000	1.000
L00	0.955	0.954	0.929	0.955	0.965	0.965	0.957
Ir00	0.952	0.949	0.983	0.949	0.919	0.919	0.927
N00	0.909	0.891	0.900	0.916	0.910	0.910	0.907
B00	0.903	0.859	0.850	0.909	0.905	0.905	0.892
It00	0.872	0.881	0.888	0.868	0.875	0.875	0.870
Sp00	0.795	0.808	0.808	0.791	0.801	0.801	0.796
P00	0.715	0.720	0.722	0.706	0.722	0.722	0.713
Sw99	1.189	1.186	1.155	1.184	1.178	1.178	1.178
Dk99	1.180	1.174	1.131	1.176	1.174	1.174	1.174
Fi99	1.089	1.094	1.078	1.085	1.084	1.084	1.084
A99	1.049	1.058	1.063	1.044	1.046	1.046	1.046
UK99	1.023	0.985	0.995	1.029	1.015	1.015	1.015
Fr99	1.028	1.019	1.020	1.028	1.025	1.025	1.025
Ge99	1.000	1.000	1.000	1.000	1.000	1.000	1.000
L99	0.941	0.945	0.943	0.941	0.951	0.951	0.951
Ir99	0.922	0.921	0.951	0.919	0.890	0.890	0.890
N99	0.908	0.891	0.906	0.914	0.909	0.909	0.909
B99	0.900	0.861	0.855	0.906	0.902	0.902	0.902
It99	0.866	0.875	0.881	0.863	0.870	0.870	0.870
Sp99	0.783	0.795	0.789	0.780	0.790	0.790	0.790
Gr99	0.775	0.784	0.745	0.771	0.780	0.780	0.780
P99	0.710	0.720	0.724	0.701	0.716	0.716	0.716
Sw98	1.185	1.174	1.135	1.180	1.174	1.180	1.175
Dk98	1.164	1.170	1.142	1.161	1.158	1.161	1.158
Fi98	1.081	1.087	1.071	1.078	1.077	1.078	1.075
A98	1.049	1.060	1.066	1.044	1.046	1.044	1.046
Fr98	1.027	1.020	1.015	1.028	1.025	1.028	1.027
UK98	0.995	0.964	0.977	1.000	0.987	1.000	0.991

TABLE 5. PRICE LEVELS Z_{kt}/Z_{bk} FOR THE EUROPEAN UNION (1995-2000) (Gexx = 1)

Ge98	1.000	1.000	1.000	1.000	1.000	1.000	1.000
L98	0.936	0.939	0.939	0.936	0.946	0.936	0.939
Ir98	0.917	0.916	0.946	0.914	0.885	0.914	0.877
N98	0.894	0.878	0.895	0.901	0.896	0.901	0.893
B98	0.895	0.856	0.848	0.901	0.897	0.901	0.896
It98	0.859	0.870	0.880	0.856	0.863	0.856	0.859
Sp98	0.772	0.783	0.777	0.768	0.779	0.768	0.774
Gr98	0.756	0.763	0.724	0.752	0.760	0.752	0.760
P98	0.700	0.713	0.715	0.691	0.706	0.691	0.702
Sw97	1.212	1.202	1.163	1.206	1.201	1.206	1.203
Dk97	1.158	1.166	1.138	1.155	1.152	1.155	1.192
Fi97	1.089	1.095	1.079	1.086	1.084	1.086	1.083
A97	1.047	1.057	1.063	1.041	1.043	1.041	1.043
Fr97	1.023	1.016	1.012	1.023	1.020	1.023	1.023
Ge97	1.000	1.000	1.000	1.000	1.000	1.000	1.000
UK97	0.957	0.932	0.943	0.961	0.949	0.961	0.957
Ir97	0.945	0.953	0.977	0.942	0.912	0.942	0.935
L97	0.932	0.936	0.937	0.932	0.942	0.932	0.935
B97	0.892	0.853	0.847	0.898	0.894	0.898	0.893
N97	0.883	0.870	0.886	0.890	0.885	0.890	0.884
It97	0.852	0.863	0.873	0.848	0.855	0.848	0.851
Gr97	0.776	0.783	0.745	0.772	0.780	0.772	0.778
Sp97	0.768	0.779	0.773	0.764	0.774	0.764	0.769
P97	0.698	0.710	0.712	0.689	0.704	0.689	0.695
Sw96	1.197	1.186	1.144	1.192	1.186	1.192	1.192
Dk96	1.144	1.149	1.122	1.141	1.139	1.141	1.141
Fi96	1.073	1.077	1.062	1.070	1.069	1.070	1.070
A96	1.053	1.060	1.066	1.047	1.049	1.047	1.047
Fr96	1.017	1.008	1.004	1.017	1.014	1.017	1.017
Ge96	1.000	1.000	1.000	1.000	1.000	1.000	1.000
L96	0.938	0.939	0.941	0.938	0.948	0.938	0.938
B96	0.897	0.854	0.849	0.902	0.899	0.902	0.902
N96	0.886	0.871	0.887	0.893	0.888	0.893	0.893
Ir96	0.868	0.872	0.892	0.866	0.839	0.866	0.866
It96	0.814	0.823	0.832	0.811	0.818	0.811	0.811
UK96	0.793	0.769	0.777	0.800	0.789	0.800	0.800
Sp96	0.769	0.777	0.772	0.766	0.776	0.766	0.766

TABLE 5. PRICE LEVELS Z_{kt}/Z_{bk} FOR THE EUROPEAN UNION (1995-2000) (Gexx = 1)

Gr96	0.738	0.741	0.705	0.734	0.742	0.734	0.734
P96	0.688	0.696	0.699	0.679	0.694	0.679	0.679
Fi95	1.075	1.081	1.063	1.072	1.070	1.072	1.033
Sw95	1.074	1.069	1.032	1.070	1.064	1.070	1.032
Ge95	1.000	1.000	1.000	1.000	1.000	1.000	1.000
B95	0.891	0.849	0.844	0.897	0.893	0.897	0.891
N95	0.886	0.869	0.885	0.870	0.888	0.870	0.887
Ir95	0.822	0.824	0.843	0.820	0.794	0.820	0.790
Sp95	0.726	0.735	0.730	0.723	0.733	0.723	0.731
It95	0.714	0.722	0.731	0.711	0.717	0.711	0.718
Gr95	0.684	0.691	0.656	0.680	0.688	0.680	0.690
P95	0.657	0.667	0.669	0.648	0.662	0.648	0.656

Note: Countries are listed by price level in descending order according to the CG96MST method.

TABLE 6. STANDARD DEVIATIONS OF THE LOG PRICE LEVELS (I_t)

Including Greece

	MST	**EKS**	**GK**	**CG_{96}^{MST}**	**CG_{99}^{MST}**	**Av(TFG)**	**Av(SCG)**
1999	0.1506	0.1467	0.1444	0.1523	0.1464	0.1464	0.1464
1998	0.1540	0.1506	0.1498	0.1557	0.1498	0.1557	0.1518
1997	0.1546	0.1524	0.1500	0.1560	0.1500	0.1560	0.1565
1996	0.1654	0.1650	0.1614	0.1661	0.1622	0.1661	0.1661

Excluding Greece

	MST	**EKS**	**GK**	**CG_{96}^{MST}**	**CG_{99}^{MST}**	**Av(TFG)**	**Av(SCG)**
2000	0.1491	0.1479	0.1395	0.1505	0.1446	0.1446	0.1520
1999	0.1453	0.1426	0.1341	0.1468	0.1414	0.1414	0.1414
1998	0.1473	0.1448	0.1374	0.1487	0.1434	0.1487	0.1459
1997	0.1509	0.1494	0.1417	0.1520	0.1465	0.1520	0.1533
1996	0.1603	0.1608	0.1514	0.1607	0.1576	0.1607	0.1607

TABLE 7. AVERAGE VARIANCE OF THE LOG PRICE RELATIVES [Av($J^{\ddagger}$)]

	Including Greece	Excluding Greece
2000	N/A	0.1135
1999	0.1132	0.1095
1998	0.1097	0.1071
1997	0.1052	0.1031
1996	0.1034	0.1013