Extrapolation of PPPs over time using CPIs data: methods and interpretation

Preliminary version

Biggeri, Luigi
University of Florence, Department of Statistics
Viale Morgagni 59
Florence 50134, Italy
E-mail: biggeri@ds.unifi.its

Laureti, Tiziana
University of Naples "Parthenope", Department of Statistics and Mathematics
Via Medina, 40
Naples 80133, Italy
E-mail: tiziana.laureti@uniparthenope.it

1. Introducion

The difficulties and costs involved in the construction of Purchasing Power Parities (PPPs) for international comparisons impose restrictions on the frequency of their computation that is only carried out in benchmark years: for example the last two International Comparison Program (ICP) data collections took place between 1993 and 1996 and in 2005, and the next will be carried out this year. Consequently the estimation of PPPs for non-benchmark years is highly demanded by the International Economic Organizations and researchers in various fields.

The PPPs for non benchmark years are usually estimated in the simplest way possible, by extrapolating the PPPs of the benchmark year using the price deflators of GDP and its components and/or the Consumer Price Indices (CPI) for each country considered if the updating refers to the PPP for household Consumption.

However, when the extrapolated PPPs are compared with those based on the last benchmark round, there are great differences between them and therefore a great deal of debate over the consistency between the two sets of results arises.

Although the PPPs from two subsequent benchmarks are not completely comparable due to the various changes in data collection procedures and methodology used for their computation, the large differences in the results cast doubt on the comparability of the resulting PPPs over time and these differences need to be interpreted both from a statistical and an economic point of view.

Much research has been focused both on the methods for extrapolating the PPPs and on the interpretation of the above-mentioned differences. Some of these studies are not only aimed at explaining the consistency and the differences between the results of the PPPs benchmark rounds, but also present ideas and tools for improving the methods for the extrapolation over time of the PPPs.

The aim of this paper is twofold. Firstly, to discuss the methods used and proposed for the temporal extrapolation of the PPPs. Secondly, to analyse the differences between the formula used for constructing the PPPs over time in order to suggest a more adequate method for extrapolating the PPPs at least in the case of household consumption.

The paper is organised as follows.

Section 2 reviews the methods used and proposed for the temporal extrapolation of the PPPs and for

analysing coherence between computed PPPs in two different benchmark years and between the extrapolated PPPs and those based on the last benchmark round. The objective is to summarize the characteristics that should have an adequate method for extrapolating the PPPs.

Section 3 presents a method for explaining, both statistically and economically, the divergences of the PPPs over time (without considering the differences imputed to the definition and methods of collection of data) . This approach is based on the decomposition of the formulae into components which refer to the prices and to the system of weights respectively. The two components can be interpreted economically and their computation could also be useful for extrapolating the PPPs.

In Section 4 we present some suggestions for improving the method used for extrapolating the PPPs for Household Consumption, using most of the data collected for the computation of the Consumer Price Indices (CPIs) bearing in mind the characteristics of the two factors obtained from the decomposition of the formulae.

2. Methods for extrapolating PPPs over time and for analyzing the coherence between computed and/or extrapolated data

The need for annual estimates of the PPPs for international comparisons has been evident since the beginning of their construction. In 1984, Locker and Faerberg published an important paper concerning space and time comparisons of PPPs where the theoretical problems of consistency between the spatial results and temporal indices were discussed and methods for extrapolating PPPs and interpolating them between two benchmark years were presented. Although this topic was put aside for many years, over the last decade there has been a growing interest in this issue and several papers have been published, especially concerning the coherence between PPPs and SNA based estimates of GDP.

Considering the extrapolation of PPPs widely, we can group the methods and analyses in the following way:

i. Methods used in the common practice for extrapolating PPPs: the inconsistencies of the extrapolated and computed PPPs and PPP–based National Accounts
ii. Methods and tools for improving the interpolation or extrapolation of PPPs or PPP-based GDP;
iii. Methods for analysing the coherence between the spatial and temporal measure of price changes in order to estimate the factors of the resulting differences;
iv. Methods for updating PPPs the following year by using direct newly-collected data.

Below a summary of the characteristics of these methods are presented.

i. Methods used in the common practice for extrapolating PPPs: the inconsistencies of the extrapolated and computed PPPs and PPPs –based National Accounts

It is common practice (World Bank, 2008b and OECD-Eurostat, 2006) to extrapolate PPPs or PPP-based GDP, and its components, for a non benchmark year by using the price deflators of GDP and its components and/or the Consumer Price Index (CPI) for each country considered if the updating refers to the PPP for household Consumption.

The formula for extrapolating PPPs at macro level from time t-1 to time t can be written as follows:

$$\widehat{PPP}_t = PPP_{t-1}^{lj} \cdot \left(I_{t-1,t}^{j} \Big/ I_{t-1,t}^{l} \right)$$

where $\widehat{PPP}_t$ denotes the extrapolated PPPs at the time t and $I_{t-1,t}^{j}$ and $I_{t-1,t}^{l}$ are the price deflators of the two countries l and j for which the parities have been computed at the time t-1. If all the parities are then referred to a numeraire country it is necessary to divide the values of each country for the data of the

numeraire country.

The $I^{j}_{t-1,t}$ and $I^{l}_{t-1,t}$ used for compute the PPPs for GDP are the price deflators of national GDP, that being a ratio between GDP at current prices and at constant prices, is an implicit price index of the Paasche type.

The $I^{j}_{t-1,t}$ and $I^{l}_{t-1,t}$ used for computing the PPPs for Household Consumptions are the national CPIs, that are usually price index of the Laspeyres type.

Comparisons of the extrapolated PPPs with computed PPPs in the subsequent benchmark year usually differ greatly and large differences are found between PPPs and PPPs-based National Accounts. Therefore there has been a great deal of debate concerning the consistency of the different estimates arises carried out by various researchers, (Locker and Faerber, 1984; Nuxol, 1994; Dalgaard and Sorensen, 2002; Deaton and Heston, 2010, and papers they quoted[1]).

The researchers have underlined several inconsistencies between the different estimates that can be grouped as follows (the most important of them are presented also in the ICP and OECD Handbooks on PPPs):

- inconsistencies due to the changes in data collection procedures and methodology, in different definitions of products and baskets of goods, etc.. Moreover it is important to note that the national GDP deflators' expenditure structure does not reflect comparable baskets of goods and services among countries;
- inconsistencies due to the price index numbers used for the extrapolation (inflator/deflator): the common practice, as already mentioned, is to use implicit index from GDP deflator (Paasche type) or explicit CPIs (usually Laspeyres type), while the PPPs are based on a Fisher type index and by construction they reflect the current prices and expenditures of the benchmark years. On the other hand, the purpose of the temporal price indices and of the parities are not the same; moreover, as Locker and Faerber (1984, pag. 63) pointed out, different extrapolation factors should be applied when different formulas are used for the calculation of PPPs.
- inconsistency due to the fact that the extrapolation over time of the PPPs is carried out at macro or GDP level: this procedure does not allow for the structural changes in the relative prices and in the expenditures of the different countries compared[2]; in order to take into account the changes in structures of relative prices and expenditures it is necessary to compute the extrapolation starting from a detailed level, as the individual product or the Basic Headings (BH) at least.

ii. Methods proposing tools for improve the interpolation or extrapolation of PPPs or PPP-based GDP

Much research has been carried out to try to improve the extrapolation or interpolation of PPPs or PPP-based GDP by using different tools and methods than the simple price indices (see for example: Johnson et al, 2009; Feenstra et al., 2009; Ravaillon, 2010; Rao et al., 2010).

Johnson et al., 2009, presented an evaluation of the Penn World Tables and of their methodology for estimating growth rates of GDP for non-benchmark years, examining specifically the problem of data revisions across time. The paper proposed also the construction of a new chained series, with all data valued at common international prices, and based on a greater use of the disaggregated data collected for the different benchmark years.

Feenstra et al., 2009, provided a framework for making real income comparisons across countries and over time that satisfy transitivity in the field of consumption, by means an empirical experiment using data from the 1980 and 1996 ICP.

Rao et al., 2010, presented an econometric framework for the construction of a consistent panel of

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[1] Most of the debate was carried out during the discussions concerning the correct estimates of the real growth

[2] The differences in comparison over space are more important because the patterns of relative prices and of expenditure are much more different

PPPs which makes it possible to combine all the PPP benchmark data from various rounds. A regression model along with data on country specific price movements are combined using state-space formulation and optimum predictions of PPPs were used. The procedure was applied for deriving inter-temporal estimates for the PPPs and GDP, for the period from 1970 to 2005. The method allows for a coherent projection based on all the data from all the benchmarks.

Ravaillon, 2010, focused on the changes observed in PPPs between ICP rounds, analysing the reasons for these changes and found that they made sense. The paper presents a model for the changes in PPPs (actually for the Price Level Index derived from them) and taking into account the results of the empirical analysis, proposes the inclusion of the dynamic Penn effect explicitly into the extrapolation of PPPs for non-benchmarks years.

iii. Methods for analysing the coherence between spatial and temporal measure of price changes in order to estimate the factors of the resulting differences

Following the analysis of Dalgaard and Sorensen (2002), Rhoades (2003) proposed a method essentially for checking the coherence of the changes in PPPs over a period of time and the changes in the implicit deflators of GDP over the same period. This method was also evaluated and applied by researchers of the Australian Bureau of Statistics (Tessema and Rossiter, 2009). The author proposed a framework for making a comprehensive and exact reconciliation between SNA-based real growth and PPP-implied real growth by analyzing the differences in the respective formulae employed, in order to identify the sources of inconsistencies. The differences between the ratio of implicit deflators and the ratio of PPPs have been explained in terms of various factors and particularly in terms of differences in weights, relative prices and index formula substitution effects. By using the framework suggested it is possible to compute the impact of the variations of basic input data, of the different treatment and revisions of weights. An empirical application of the method using the European Comparison Program (ECP) data from 1996 to 2000 is presented.

The ABS study discusses the method proposed by Rhoades (2003) and presents an empirical analysis to data extracted from the 1999 and 2002 aggregate databases of the ECP. The study pointed out that the relative contributions of prices remained as a dominant factor and that the results of the analysis and the estimation of the different effects appear to have good practical implication for post hoc analysis to inform the calculation of future PPP projections.

iv. Methods for updating PPPs the following year by using direct newly-collected data .

Recently, Dikhanov et al (2011), proposed a method for estimating PPPs for non-benchmark years that is an extension of the last calculated PPP benchmark using additional data collected in the next year of prediction and some inter-product and intra-country price correlations made against the benchmark year exercise The method, which is substantially of the “inferential” type, uses a limited number of core products for which the necessary data is collected mainly in the capital cities and the computation of the PPPs for the full list of products is carried out by means of adjustment procedures. The method has been applied in the Asia and Pacific Regions on an experimental basis.

At the end of this presentation of the research concerning PPP extrapolation it is clear that the reasons of the inconsistencies between the extrapolated and computed PPPs and PPPs–based National Accounts have been very carefully examined. Some studies have tried to measure the factors that affect the inconsistencies, but the measure has never been used for the extrapolation of PPPs and in most cases the analyses have only been carried out at macro level and for some of its components.

The proposal made by Dikhanov et al. (2011) is the only direct /indirect (inferential) computation for an updating of PPPs with a clear meaning and where the consistency of the PPPs in both benchmark and non benchmark years is obtained by construction. However, it is necessary to collect data in the next year of

prediction at least for the core items and it is difficult to know how reliable the estimations will be. Besides it may not be possible to carry out the exercise for all the countries involved in the ICP.

The methods presented should undergo further investigation, but we think that it is not only necessary to study the way to give the two benchmarks of PPPs consistency by means of price index numbers, but also to find a new methodological tool for extrapolation using consistent "extrapolation factors" which should be applied when different formulas are used for the calculation of PPPs.

In conclusion, in our opinion there it is necessary to examine the problems of extrapolation of PPPs over time taking into account the inconsistencies mentioned above, while considering separately the inconsistencies caused by definition problems and the collection of data and those due to the formulae used for computing the PPPs in two different years (t-1 and t). We focused on the analyses of the differences concerning the formulae for binary comparisons between countries and at Basing Heading (BH) level in order to avoid bias in the extrapolation phase. Moreover, the common subsequent stages of the construction of PPPs cannot be extrapolated. The aim of this analysis was to try to decompose the differences in order to find components that: 1) should satisfy the consistency of the extrapolation exercise, which would not otherwise be possible using CPIs or the implicit deflator (Paasche index) and 2) can be more easily estimated with the data collected for the computation of the CPIs.

For this reason, the analyses described in the following sections have a general value even if they must essentially refer to the PPPs computed for Household Consumption.

3. The comparisons of PPPs over time: decomposition of the differences for improving the extrapolation of PPPs

With the aim of identifying useful factors to be used for extrapolating PPPs for non benchmark years, we analysed the relationship between the formulae used for calculating two PPPs, referring to years t-1 and t. As already mentioned above, we only considered the binary PPPs at the basic heading level.

In order to illustrate our analyses we referred to the method currently used in the Eurostat-OECD comparison for calculating and aggregating PPPs known as the asterisk method[3] or EKS*. At the basic heading level the method proceeds by calculating two separate Jevons indices for each pair of countries. One Jevons index (called the Laspeyres type PPP) covers products that are representative in the first country, considered as the base country. The other (called the Paasche type PPP) covers products that are representative in the second country. Of course, some products may be representative in both countries and therefore included in both indices. The geometric mean of these two PPPs is then taken to derive a single binary PPP between the two countries (called the Fisher type PPP). Once all of these bilateral parities have been constructed for each pair of countries in the region, the EKS formula is used to make them transitive. The EKS adjustment is not of interest at this stage of extrapolation but will be considered later[4].

Taking two countries j and l and considering country l as the base country, the first Jevons index, PPP_L^{lj} is expressed by:

$$PPP_L^{l,j} = \prod_{k=1}^{R_{n_l}} \left(\frac{p_k^j}{p_k^l} \right)^{w_k^l} = \frac{\prod_{k=1}^{R_{n_l}} \left(p_k^j \right)^{w_k^l}}{\prod_{k=1}^{R_{n_l}} \left(p_k^l \right)^{w_k^l}} \qquad [1]$$

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3 The EKS* method is so called because it makes use of the distinction between representative and unrepresentative products, the representative products being identified in the product lists by an *

4 Two observations are important for our aims. First, the EKS method is applied with the constraint that the results obtained must differ as little as possible from the original binary Fisher type PPPs- Second, the EKS adjustment could be considered an additive element in the decomposition of formula (Cfr. Roades, 2003, pag. 3).

Where ${}^{R}n_l$ is the number of products that are representative in country l (or representative in both countries) and priced in both l and j; the weights are defined as $w_k^l = 1/{}^{R}n_l$ if product k is representative in country l and $w_k^l = 0$ if product k is not representative in country l and p_k^j is the price of item specification k in country j and p_k^l the price of the same specification in country l.
The temporal variation from time t-1 to time t of the binary PPP referring to countries j and l is expressed by:

$$\frac{PPP_{L,t}^{lj}}{PPP_{L,t-1}^{lj}} = \frac{\prod_{k=1}^{{}^{R}n_l}\left(p_{k,t}^{j}\right)^{w_{k,t}^{l}} \Big/ \prod_{k=1}^{{}^{R}n_l}\left(p_{k,t}^{l}\right)^{w_{k,t}^{l}}}{\prod_{k=1}^{{}^{R}n_l}\left(p_{k,t-1}^{j}\right)^{w_{k,t-1}^{l}} \Big/ \prod_{k=1}^{{}^{R}n_l}\left(p_{k,t-1}^{l}\right)^{w_{k,t-1}^{l}}} \qquad [2]$$

Following the idea developed in the paper by Biggeri and Laureti (2009) by taking the natural logarithms and by adding and subtracting the ratio between the hybrid index (for countries j and l) obtained by using the weights of the base period t-1 and the price of the each country at time t, after simple algebra, we can state that:

$$\frac{PPP_{L,t}^{lj}}{PPP_{L,t-1}^{lj}} = \frac{\prod_{k=1}^{{}^{R}n_l}\left(p_{k,t}^{j} / p_{k}^{j,t-1}\right)^{w_{k,t-1}^{l}}}{\prod_{k=1}^{{}^{R}n_l}\left(p_{k,t}^{l} / p_{k}^{l,t-1}\right)^{w_{k,t-1}^{l}}} \cdot \frac{\prod_{k=1}^{{}^{R}n_l}\left(p_{k,t}^{j}\right)^{w_{k,t}^{l}-w_{k,t-1}^{l}}}{\prod_{k=1}^{{}^{R}n_l}\left(p_{k,t}^{l}\right)^{w_{k,t}^{l}-w_{k,t-1}^{l}}} \qquad [3]$$

Obviously, $PPP_{L,t-1}^{lj}$ can be extrapolated at time t by multiplying it by the two factors on the right hand side of the formula [3].

The first product on the right hand side of [3] represents the divergence between the movement in price changes from time t-1 to time t in the two countries compared (price effect). In fact, this factor is the ratio between two consumer price indices in the two countries j and l, calculated following the weighted Jevons index using the weights of country l at time t-1.

The second product, which refers to the weight effect (WE), is related to the impact of the difference in the consumption structures of the two countries.

These decompositions give us a better understanding of the temporal variation of the formulae used for constructing PPPs from an economic point of view based on the distributions of price changes and the consumption expenditure shares in the two countries (Biggeri and Laureti, 2009).

It is worth noting that the weight effect in [3] will be zero if the representative products in the base country l do not change throughout the time period considered. Exceptionally in this case the variation of the binary PPPs formulae is only explained by the price effect.

A similar decomposition can be obtained for the difference between basic heading PPPs, at time t-1 and t by using the second Jevons index (the Paasche type PPP) for countries j and l. Let ${}^{R}n_j$ be the number of products that are representative in country j (or representative in both countries) and priced in both l and j. Therefore the weights are defined as $w_k^l = 1/{}^{R}n_j$ if product k is representative in country l. We can state that:

$$PPP_P^{l,j} = \prod_{k=1}^{{}^{R}n_j}\left(\frac{p_k^j}{p_k^l}\right)^{w_k^j} = \frac{\prod_{k=1}^{{}^{R}n_j}\left(p_k^j\right)^{w_k^j}}{\prod_{k=1}^{{}^{R}n_j}\left(p_k^l\right)^{w_k^j}} \qquad [4]$$

$$\frac{PPP^{lj}_{t,k}}{PPP^{lj}_{t-1,k}} = \frac{\prod_{k=1}^{R_{n_j}} \left(p^j_{k,t} / p^j_{k,t-1} \right)^{w^j_{k,t}}}{\prod_{k=1}^{R_{n_j}} \left(p^l_{k,t} / p^l_{k,t-1} \right)^{w^j_{k,t}}} \cdot \frac{\prod_{k=1}^{R_{n_j}} \left(p^j_{k,t} \right)^{w^j_{k,t} - w^j_{k,t-1}}}{\prod_{k=1}^{R_{n_j}} \left(p^l_{k,t} \right)^{w^j_{k,t} - w^j_{k,t-1}}} \qquad [5]$$

where the factors “weight effect” and the “ price effect” are equivalent to those identified in [3].

4. Suggestions for a better method for extrapolating the PPPs for Household Consumption based on CPIs data over time

As shown in the previous section, in order to obtain a consistent and correct extrapolation of the PPPs from time t-1 to t, it is necessary to start from the extrapolation of the two binary PPPs of the Laspeyeres and Paasche types at the level of Basic Heading, and then to follow the usual steps of PPP construction, that is computing subsequently the binary Fisher type PPPs, the EKS adjustment for achieving transitivity and finally the aggregation of PPPs above the BH to obtain the PPPs for Household Consumption. In this section we briefly examine the data required for implementing the various phases of the extrapolation procedure and the issues that could arise.

From formulae [3] and [5] it is clear that the price indices to be used for the extrapolation of PPPs must be of the Jevons type. The CPIs, usually computed by the National Statistical Institute (NSIs) cannot give an exact extrapolation of the binary BH PPPs, because they always cause bias. Even if we were in an optimal situation in which the countries involved in the PPP computation have a similar economic structure (from an expenditure point of view) and have sufficiently detailed and codified data in their CPI data set, the direct use of CPIs for extrapolating BH PPPs would not be correct, although the bias would be probably small.

However it is possible to use the detailed price data collected for computing the CPIs in l and j countries (and in all countries involved in the computation of the PPP program) at time t-1 and t in order to calculate the factors reported in formula [3] and [5] and carry out the extrapolation of all binary BH PPPs.

In actual fact a problem arise due to the differences between the PPP and CPI definition of baskets of products to be priced and the collection of data. A part of the necessary prices required for updating the PPPs may not be included in the CPI surveys. In this case the methods suggested in ICP and ECP exercises for solving the problem of missing PPPs and reference PPPs could be used. Many useful suggestions for this purpose can also be found in the paper by Dikhanov et al. (2011).

However, this fact confirms once again that we cannot postpone the development of a complete integration of the PPP activity with the CPI compilation in order to achieve an increased coherence between the results of the PPP and CPI calculations. The integration would also enable us to compute the PPPs at reduced intervals of time (for example each year), taking into account the high frequency of collection of data for CPI purposes, thus overcoming the difficulties linked to the use of CPIs for the temporal updating of the PPPs (Rao, 2001; Biggeri and Laureti, 2009; Ward et al., 2008).

Another issue may arise if we consider the weights used for the computation of the Jevons indices at BH level. We can only obtain the exact results of the extrapolation when the number of products considered and the representative products remain the same. Therefore it is necessary to evaluate the problem of eventual changes in the representative products for each country. On the other hand if the suggestions made by some authors to introduce weights into parities estimation at BH are followed, it will be necessary to consider them in the computation of the two components (of price changes and weight differences) as specified in formulae [3] and [5].

Let us assume that it is possible to obtain a quite reliable estimation of the factors reported in formula [3] and [5] and carry out the extrapolation from time t-1 to time t of all binary BH PPPs of Laspeyeres and Paasche types for the countries involved in the Comparison Programme. The geometric mean of these two

PPPs for each pair of countries can then be used for obtaining a single binary PPP between each pair of countries – that is the Fisher type PPP. Moreover as the Fisher type PPPs are intransitive, an adjustment to achieve transitivity will be easily carried out using the EKS method.

Then the aggregation of PPPs above the level of BHs up to the level of Household Consumption can be carried out using the methods suggested by ECP, which requires the computation of a weighted average using the expenditure on the BHs of each pair of countries as weights at time t. In this case, the data available used as system of weights for the computation of CPIs should be rearranged to be employed for the aggregation of the PPPs above the BHs. However, since the CPIs are usually of the Laspeyres type, the system of weights may refer to the base period of one or more years before. In this event it may be necessary to wait a few years in order to obtain the data for period t.

On the other hand, for economies which have sufficiently detailed and codified data in their CPI data set – like the European countries where the CPIs are of the yearly chained Laspeyres type, with the base period and system of weights renewed every year - it might be possible to get the expenditure system of weights for computing the aggregation of PPPs above the BHs and obtain the extrapolated PPPs for Household Consumption in a yearly consistent series, that will certainly improve their estimation and also facilitate checks of their capability for measuring and comparing the "real" household consumptions in different countries[5].

5. Concluding remarks

The major elements of our study are:

a. to extrapolate PPPs for GDP and/or Household Consumption, we must start extrapolating the matrix of binary PPPs of the Laspeyeres and Paasche types at the level of Basic Heading;

b. whenever consistent extrapolations of PPPs at BH level for Household Consumptions are required computed as Jevons indices the existent corresponding sub-indices from the CPIs cannot be used and therefore it is necessary to use the data collected in the CPI survey for computing the necessary adequate indices for the extrapolation (see formulae [3]and [5]);

c. the proposed procedure for extrapolating PPPs for Household Consumption requires a lot of work, but it is applicable not only to the EU countries but also to many other countries by integrating it, if necessary, with the procedure proposed by Dikhanov et al. (2011).

In order to check the practical problems and difficulties for the implementation of the proposed procedure, some empirical small-scale exercises are being carried out.

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ABSTRACT

The Purchasing Power Parities (PPPs) for international comparisons are computed in benchmark years: for example the last two International Comparison Program (ICP) data collections took place between 1993 and 1996 and in 2005. The PPPs for non-benchmark years are estimated by extrapolating the PPPs from the most recent ICP round according to the deflators of GDP and its components in each country considered.

When the extrapolated PPPs are compared with those based on the last ICP round, great differences between them are usually found. As many authors pointed out, this issue is particularly important since the estimates of GDP (at PPP) must be revised for many countries, and therefore a great deal of debate over the consistency between the two sets of results arises.

Although the PPPs from two subsequent benchmarks are not completely comparable due to the various changes in data collection procedures and methodology used for their computation, the large differences in the results cast doubt on the comparability of the resulting PPPs over time and these differences need to be interpreted both from a statistical and an economic point of view.

The aim of this paper is twofold. Firstly, to discuss the methods used and proposed for the temporal extrapolation of the PPPs. Secondly, to analyse the differences between the formula used for constructing the PPPs over time in order to suggest a more adequate method for extrapolating the PPPs at least in the case of household consumption, starting with the extrapolating of the matrix of binary PPPs of the Laspeyeres and Paasche type at the level of Basic Headings.