Office for National Statistics

International Comparison of the Formula Effect between the CPI and RPI

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Summary

The Office for National Statistics produces two main measures of consumer price inflation – the Consumer Prices Index (CPI) and the Retail Prices Index (RPI). There are a number of differences between the two in their coverage, population base, commodity measurement and methods of construction. Combined, these differences have meant that, for most of its history, inflation measured by the CPI has been lower than the RPI. One of the main reasons for this difference is the method of construction at the initial stage of aggregation, where different formulae are used in the CPI and RPI to combine individual prices. This difference is usually referred to as the formula effect. This article will investigate similar formula effects present in the inflation measures of other countries, and where necessary will attempt to explain why the magnitude of the formula effect experienced by other countries differs from that of the UK.

Introduction

The Office for National Statistics (ONS) publishes two main measures of consumer price inflation – the Retail Prices Index (RPI) and the Consumer Prices Index (CPI). The RPI was introduced in 1947 and was made official in 1956. The CPI was introduced in 1996 as the Harmonised Index of Consumer Prices (HICP). HICPs were developed across the European Union for assessing whether prospective members of the European Monetary Union would fulfil the criteria set out by the Maastricht Treaty for Monetary Union Convergence. In December 2003 the National Statistician decided that the UK version of the HICP would be renamed the Consumer Prices Index (CPI). This decision was concurrent with the Chancellor of the Exchequer's Pre-Budget Report (2003) announcement that the UK inflation target would in future be based on the HICP, replacing the Retail Prices Index excluding mortgage interest payments (RPIX).

Since its introduction, inflation (over a 12 month period) measured by the CPI has generally been lower than RPI inflation by an average of 0.9 percentage points. The two indices are similar in their construction; they both track the changing cost of a fixed basket of goods over time, and both are produced by combining approximately 180,000 price quotes for over 650 representative items. There are, however, a number of key differences which lead to the gap between the two measures:

- There are certain coverage differences between the CPI and RPI. The CPI excludes a number of items included in the RPI such as owner occupiers' housing costs, council tax, buildings insurance and house depreciation. The RPI excludes university accommodation fees, foreign student university tuition fees, unit trust and stockbroker charges – all of which are included in the CPI
- The CPI and RPI measure price change for different target populations. The CPI includes, in principle, expenditure by all UK households (although spending by UK households abroad is excluded), all residents of institutional households, and all foreign visitors to the UK. The RPI, on the other hand, covers only the expenditure of private UK households (including expenditure abroad), and excludes very high-income householders, and pensioner householders who derive at least three quarters of their income from state pensions and benefits. This leads to differences in the expenditure weights, which can impact on the gap between the two indices
- The CPI and RPI use different formulae to aggregate individual price quotes into elementary aggregate indices (EAs) for individual items. The CPI predominantly uses the geometric mean (also known as the Jevons index), supplemented in most cases by a particular form of the arithmetic mean known as the ratio of average prices (the Dutot index). The RPI predominantly uses a combination of the Dutot and the arithmetic average of price relatives (the Carli index). This leads to a difference between the two indices known as the 'formula effect'

For full details on the differences between the CPI and RPI, see Gooding (2011).

Before 2010, the difference in the formulae used at the EA level contributed around 0.5 percentage points to the overall CPI-RPI gap. Following improvements to the price collection procedures for clothing items in 2010, the contribution from the formula effect has increased to an average of 0.9 percentage points.

The remainder of this paper sets out the causes of the formula effect, compares the size of this effect with that observed in other countries, and explains the reasons behind the differences.

Causes of the formula effect

In the UK, both the CPI and RPI are produced using around 180,000 individual price quotes collected each month. At the lowest level of aggregation, known as the elementary aggregate (EA) level, there is no expenditure share information available to allow the calculation of a weighted average, meaning that a simple unweighted average of the prices is taken. There are generally three established formulae used to calculate these unweighted averages, or EA indices (see Annex B for details):

- The arithmetic mean of price relatives[1] (Carli)
- The ratio of arithmetic mean prices (Dutot)
- The geometric mean[2] (Jevons)

[1] A price relative is the ratio of the price of an individual product in the current period and the base period.

In the CPI, a Jevons is used to calculate 70% of EAs, with the remainder mostly using the Dutot, except for certain special cases which use alternative methods. In the RPI, however, 55% of EAs are calculated using the Carli, and 35% with the Dutot. The remaining EAs in the RPI are calculated using other methods, such as a weighted Laspeyres[3] index. The use of the Carli in the CPI is, in practice, prohibited by the set of legally binding European regulations which govern its production.

As a general mathematical result, when using a Jevons to combine a set of values, the result will always be lower than the corresponding Carli result, except when all of the values are the same (in which case there is no difference). The size of the difference depends on the variation of the price relatives; as the variance of the price relatives increases, so does the difference between the Jevons and Carli results. In contrast, the Jevons can be either higher or lower than the Dutot. This relationship between the Carli and the Jevons is the reason for the recent increase in the formula effect following improvements to the measurement of clothing prices. All of the improvements made have the potential to increase the variation in the price relatives, thus widening the gap between the two results. A full explanation of the three formulae, and the theory surrounding them, is available in Fenwick & Roe (2004).

There are a number of arguments which can be used to choose between the different EA formulae, based on both statistical and economic theory. The statistical arguments are based upon the axiomatic approach to index number theory. This theory provides a number of different axioms[4] which can be used to determine the choice of index number formula based on its mathematical properties. This approach assumes that prices and quantities are independent.

The economic arguments are based upon the economic approach to index number theory, which takes the view that quantities consumed are dependent on prices (among other things), and that a consumer will choose a combination of goods and services that they gain the greatest satisfaction from subject to what they can afford. Based on certain assumptions regarding consumer preferences, economists believe that if a price index is being used for adjustments to the cost of living, EA formulae (and higher level indices) should reflect that when individual prices change within a year, consumers may vary their purchasing behaviour accordingly in order to maximise their satisfaction, or utility. These changes in purchasing behaviour can be measured as the constant elasticity of substitution. When the constant elasticity of substitution[5] is close to one, this effect can be shown to be accounted for by the Jevons, whereas the Dutot and Carli imply that quantities purchased remain fixed, regardless of any changes in relative prices. Full details of the statistical and economic arguments can be found in the ILO CPI manual (ILO 2004). As can be

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[2] The geometric mean of price relatives is always equal to the ratio of geometric mean prices.

[3] A Laspeyres index is a fixed weight, or fixed basket, price index which uses the basket of goods and services of the base period.

[4] A self-evident truth that requires no proof.

[5] The elasticity of substitution measures the willingness of a consumer to substitute between goods in response to relative price change. A constant elasticity of substitution of one represents a situation where a change in relative prices will lead to a proportional change in quantities purchased.

seen in Annex A, Table 1, different National Statistics Institutes (NSIs) have cited a number of different reasons when changing the EA formulae they use.

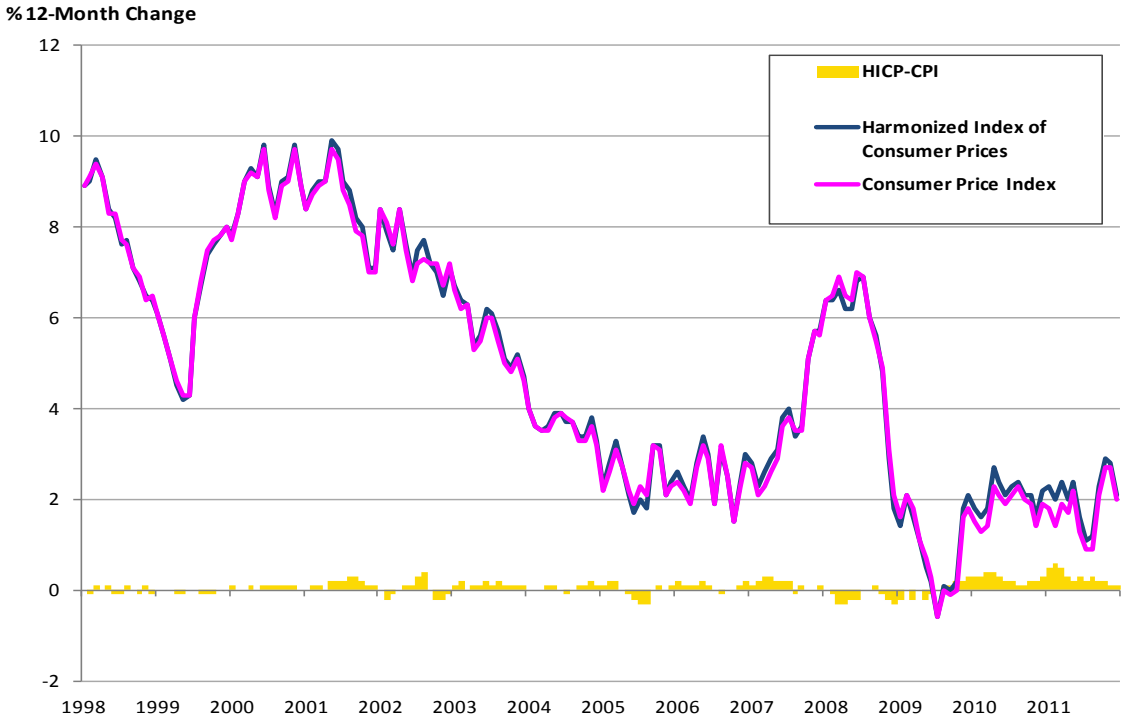
Comparison and explanation

This section considers the formula effects in other countries, and the reasons for any differences in size to the UK's formula effect.

Europe

All EU countries produce a HICP in addition to their national measure of consumer price inflation (which is usually called the consumer price index). In most of these countries, the same elementary aggregate formulae are used in both indices. The only EU country that has been found to use different formulae in their HICP and national CPI, other than the UK, is Slovenia. Slovenia uses a geometric mean at the EA level of their HICP. In their national CPI, however, they exclusively use a Dutot formula. This is because historically the Dutot has always been used in their CPI, and the Statistical Office of the Republic of Slovenia has no plans to change this in the short term. They also stated that they have received no criticism for the difference in measurement of their two indices. This is likely to be owing to the fact that the gap between their two indices is comparatively small (see Figure 1). On average since 1998, the total gap between the Slovenian CPI and HICP has been 0.1 percentage points. Figure 1 below shows the two all-items indices between January 1998 and December 2011.

Figure 1: Slovenian HICP and CPI



Source: Statistical Office of the Republic of Slovenia

Unlike ONS, the Statistical Office of the Republic of Slovenia does not publish a breakdown of the different effects accounting for the gap between their CPI and HICP. However, they do state that the difference between the two indices is mainly caused by differences in the weights because of the different concepts of consumption associated with the two indices. Therefore it is likely that the formula effect gap between the Slovenian CPI and HICP is very small. This can be explained by the fact that the Dutot is used in the Slovenian CPI, and the Jevons is used in the HICP; these indices are, in general, much closer together than a Dutot or Jevons and a Carli.

Changes in elementary aggregate formulae

Another way of comparing the size of the formula effect in other countries relative to the UK is to examine studies carried out by NSIs in other countries that have changed the EA formulae in their CPI. As a result of the introduction of the HICP, and the increased interest in the impact of EA formulae following the Boskin Commission (1996), many countries have made changes to their EA formulae over the past 15 years. A detailed list of NSIs that have done this, and their reasons, is provided in Annex A, Table 1.

Reasons for differences in the formula gap

Based on the available evidence, it appears that the formula effects observed by other countries are considerably smaller than that in the UK. According to O'Donoghue and Wilkie (1998), when the HICP was first introduced, most EU countries reported a formula effect of 0.1 percentage points or less, which is demonstrably smaller than the effect in the UK. Using the examples of other National Statistical Institutes, the following section considers some of the reasons why the UK's formula effect might be larger than in other countries.

Very few countries outside the EU have been found to produce more than one general measure of consumer price inflation. Countries that only have one general measure of inflation cannot have a formula effect.

Most countries use the same elementary aggregate formulae in all of their measures of consumer price inflation. While factors such as commodity coverage and population base could lead to a difference between the measures, there will be no formula effect.

The size of the formula effect depends on which elementary aggregate formulae are used. Many countries, when changing their EA formulae, were switching from a Dutot to a Jevons. These two formulae produce results that are much closer together than when changing from a Carli to Dutot, or Carli to Jevons. An example of this is when France switched from a Dutot to a Jevons in 1997, based on their view that the Jevons allows for a greater degree of consumer substitution behaviour (Lequiller 1997). It was estimated by Lequiller that this change would have the effect of reducing the French CPI by 0.1 percentage points per year, which is lower than the average effect seen in the UK. Similarly, New Zealand changed from the use of a Dutot to a Jevons in 2006 because they felt it would better reflect consumer substitution. A study of the changes (Ha & Xie 2004) estimated that, had the Jevons been used between December 2000 and September 2003, inflation measured by their CPI would have been approximately 0.2 percentage points lower.

The Canadian CPI has undergone two changes in EA formulae. In 1978, Statistics Canada abandoned the use of the Carli in favour of the Dutot, based on their concerns over an upward bias caused by 'price bouncing'. This is where a return to the original base price does not necessarily lead to the index reverting to its original value. Then, in 1995, they became one of the first NSIs to switch from the use of a Dutot to a Jevons index. This decision was based on both axiomatic and economic reasoning, such as the perceived benefit that, unlike the Dutot, the Jevons does not give increased importance to particularly high prices in the sample (Ducharme 1997). Ducharme presents findings which state that the formula effect in Canada at the time could have ranged between 0 and 0.1 percentage points.

In 1994 Statistics Canada carried out a study of the differences between the results from applying various EA formulae to actual price data for a wide variety of items (Schultz 1995). The results showed that there is generally only a small difference between the Dutot and the Jevons. The more striking results came when comparing these two formulae with the Carli. The study showed that there can be very large differences between indices produced using a Dutot or Jevons and a Carli. For example, after a 4-year period, the annually linked index for bananas calculated using a Dutot stood at 123.0, and the comparable index calculated with a Jevons stood at 123.5. In contrast, the comparable index produced with a Carli was 166.3. Extrapolating the results across all goods and services, this research suggests that the large formula effect observed by the UK is a result of the use of the Carli in the RPI but not the CPI. Results from a similar study carried out on Australian fruit and vegetable prices (Woolford 1994) further support this view.

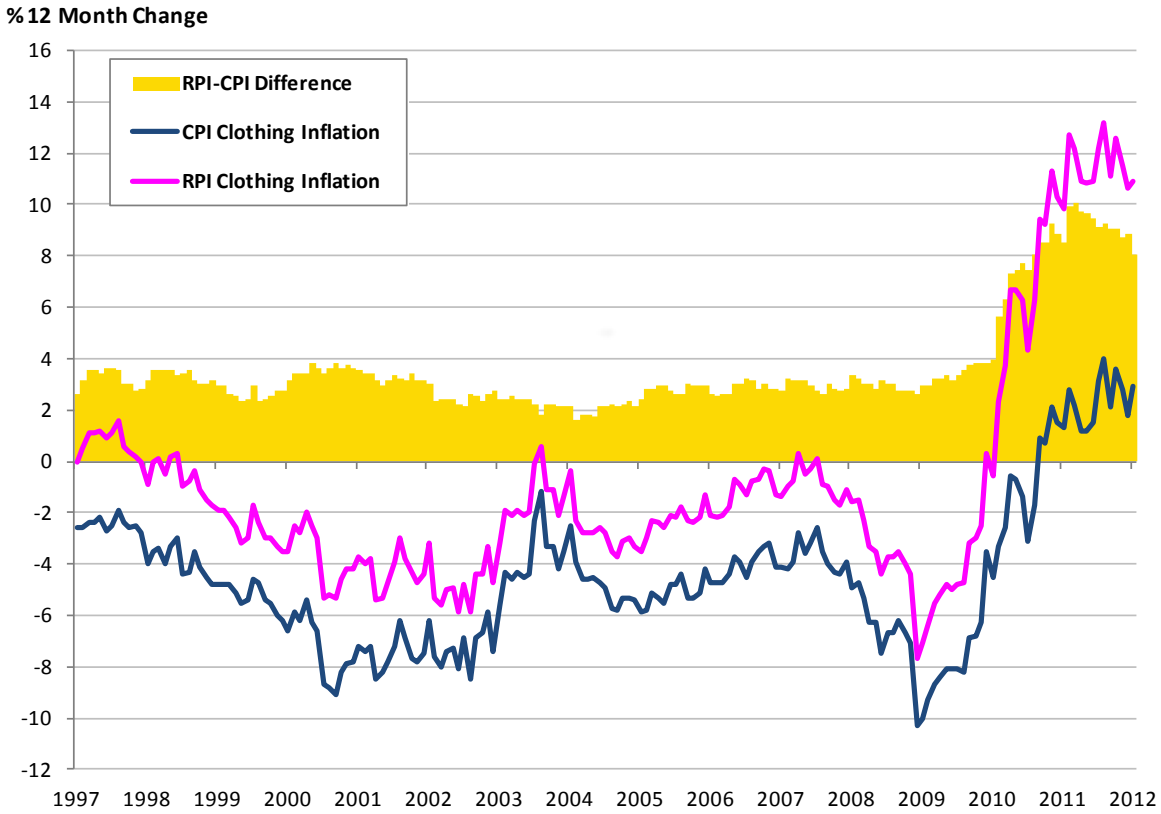
Following the Boskin Commission (1996), the Bureau of Labor Statistics (BLS) in the United States made various changes to the way in which they calculate their CPI in order to reduce the size of a number of different biases. One such change was to switch the formula used at the EA level from a Laspeyres-type index with estimated weights, which had some similarities with the Carli, to a Jevons index in 1999. This change was made because they felt that the Jevons would better account for consumer substitution behaviour. For details see the article by Dalton et al. (1998) which introduced the change. The article states that BLS expected the implementation of the Jevons to reduce measured annual inflation by 0.2 percentage points per year. This effect was lower than the estimate of 0.25 percentage points given by the Boskin Commission, as the Jevons was not implemented in every EA in the US CPI. Based upon either of these estimates, however, the formula effect observed by the US is lower than the effect in the UK, although it is somewhat higher than the effect observed by the majority of countries discussed above, that were changing from a Dutot to a Jevons. Similar to the example in the US, when Australia switched from the use of a Carli to a Jevons in 1998, they estimated a formula effect of between 0.1 and 0.2 percentage points (McLennan 1998).

Other factors can impact on the size of the formula effect. The evidence that the UK formula effect is larger than the formula effects of countries that were switching from both Dutot and Carli indices suggests that there must be other elements of the methodology used in the UK CPI and RPI which impact upon the size of the UK formula effect. These are discussed in detail in Fenwick (1999). One of these factors is the relative heterogeneity of some UK EAs when compared with those in other countries. This means that there is a greater degree of variation between each of the individual products within an EA, and therefore there can be greater variation between their prices, which leads to a widening of the gap between the Carli and the Jevons.

This effect is particularly pronounced among clothing items, which, in December 2011, accounted for over 50% of the total formula effect. This could be because clothing item descriptions in the UK CPI and RPI are relatively broad. For example, Women's Dress – Casual/Formal, is much less specific than Frozen Fish Fingers, 8-12 pack, and will lead to much greater variation in price relatives. The more homogeneous items, such as food and drink items, are likely to use the Dutot in both the CPI and RPI, and so it follows that for these products there will be no formula effect. If it is proven possible to introduce greater homogeneity into the clothing EAs, creating more suitable conditions for the Dutot, that would provide support for the introduction of the Dutot into the CPI and RPI clothing indices, thus eradicating the formula effect within clothing.

The formula effect has become more prominent following methodological improvements which were made to the price collection practices for clothing in January 2010. These changes allowed greater heterogeneity within the clothing EAs, and thus led to an increase in the variation of price relatives. More details of this can be found in Morgan & Gooding (2010). The impact of these improvements upon the formula effect can be seen in Figure 2 below, which shows the annual CPI and RPI clothing indices between January 1997 and January 2012, and the difference between them.

Figure 2: United Kingdom clothing indices in CPI and RPI



Source: Office for National Statistics

Another factor that may explain the relatively large UK formula effect is the use of January as the base month. Fenwick (1999) demonstrates clearly that over time there has been an increasing prevalence of 'January sales', where the prices of many items will be reduced in January following

the Christmas period, and will then jump back up in February once new stock has come in, particularly in the case of clothing items. This is likely to increase the variation in the price relatives, leading to a widening in the formula effect gap between the Carli and the Jevons. In contrast, most European countries now use a December base month in line with HICP guidelines.

Conclusion and next steps

The research in this article has shown that the UK has a large formula effect when compared with other countries. This is predominantly owing to its use of the Carli for some EAs in the RPI and the Jevons for some equivalent EAs in the CPI, and the statistical matters associated with this as outlined earlier in the article.

The Office for National Statistics has instigated a programme of work to examine the causes of the formula effect and to determine how unjustifiable causes of this effect can be removed. This work is initially focussed on the measurement of clothing prices and consists of a number of strands. There is an aim to implement any resultant improvements into the measurement of clothing inflation from early 2013.

Changes to price collection procedures

One identified cause of the large formula effect in the UK is the heterogeneity of some elementary aggregates. If elementary aggregates can be made more homogeneous, this would create more favourable conditions for compiling EAs using the Dutot, as discussed earlier in the article. As such, ONS is investigating a number of ways that this could be achieved. This strand of work will involve a pilot survey to examine the effect that more tightly defined product descriptions and the introduction of a greater number of seasonal items has on the variation of the price relatives.

Lower level stratification

Another possible method of making elementary aggregates more homogeneous is to stratify them by outlet type. This strand of work will explore the effect of stratifying clothing items by outlet types where prices might be expected to behave differently, for example combining price quotes from high street stores, department stores and supermarkets into EA indices and then weighting these together.

Consumer behaviour

As has been discussed in this article, many NSIs have changed their elementary aggregate formulae based on the level of consumer substitution behaviour that they believe occurs at that level of aggregation. Depending on the amount of substitution behaviour that is believed to occur, different elementary aggregate formulae are deemed to be appropriate. As such, ONS is investigating methods of measuring this consumer substitution behaviour at the elementary aggregate level, with particular focus on clothing items. This work will feed into the discussion over which elementary aggregate formulae are most appropriate for clothing items in the UK CPI and RPI.

Elementary aggregate formulae under current conditions
Rather than looking for ways to minimise the size of the formula effect, an alternative option would be to change the elementary aggregate formulae used in the CPI and RPI so that they are consistent, thus eradicating the formula effect for clothing altogether. In order for this to happen, all governance procedures and legislation surrounding the two indices would need to be met. This strand of work will examine all of the evidence for and against each of the elementary aggregate formulae, in order to decide which formulae are most appropriate for the UK CPI and RPI in practice under current conditions.

Elementary aggregate formulae in unconstrained conditions
As well as the above work strand, ONS will also carry out research to determine which formulae the UK would choose if it were unconstrained by current practices and governance structures.

Further information on this work programme will be published via the Consumer Prices Advisory Committee. These papers can be found at:

www.ons.gov.uk/ons/guide-method/development-programmes/other-development-work/consumer-prices-advisory-committee/index.html

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Further Information

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Annex A

Table 1

Summary of countries that have changed their EA indices and their reasons

Country	Index	Previous EA formula used	New EA formula used	Date of change	Reasons cited for change
Australia	CPI	Carli	Jevons	1998	Consumer substitution
Belgium	IPC	Dutot	Dutot (Jevons for cars and PC's)	2006	'Eurostat preference'
Canada (1)	CPI	Carli	Dutot	1978	Axiomatic (price bouncing)
Canada (2)	CPI	Dutot	Jevons	1995	Axiomatic (transitivity and influence of high priced items), Consumer substitution
Denmark	CPI	Carli/Dutot	Jevons (weighted)	2000	Axiomatic (price bouncing)
France	CPI	Dutot	Jevons	1997-1999	Consumer substitution
Iceland	CPI	Dutot	Jevons/Dutot	1997	Axiomatic
Ireland	CPI	Dutot	Jevons	2002	Axiomatic (transitivity)
Italy	NIC	Carli/Dutot	Jevons	1999	Introduction of more heterogeneous EAs through an increase in prices collected
Luxembourg	CPI	Carli	Jevons	1996	Eurostat regulation
Netherlands	CPI	Dutot	Jevons/Dutot	2010	Introduction of more heterogeneous EAs through scanner data
New Zealand	CPI	Dutot	Jevons	2006	Consumer substitution
Norway	CPI	Dutot	Jevons	1999	Boskin report recommendation
Sweden	CPI	Dutot	Jevons	2005	Consumer substitution
Switzerland	CPI	Unchained Carli	Jevons	2000	Transitivity and elasticity of substitution, Boskin report
US	CPI	Laspeyres (estimated weights)	Jevons	1999	Consumer substitution

Source: Various referenced papers and correspondence with NSIs.

Table 2

Summary of HICP producing countries, and the EA formulae they use

Country	National CPI EA formula	HICP EA formula
Austria	Jevons	Jevons
Belgium	Dutot	Dutot
Bulgaria	Jevons	Jevons
Croatia	Jevons	Jevons
Czech Republic	Dutot	Dutot
Denmark	Jevons	Jevons
Estonia	Dutot	Dutot
Finland	Jevons	Jevons
France	Jevons	Jevons
Germany	Dutot	Dutot
Greece	Jevons	Jevons
Iceland	Jevons/Dutot	Jevons/Dutot
Ireland	Jevons	Jevons
Italy	Jevons	Jevons
Lithuania	Dutot	Dutot
Luxembourg	Jevons	Jevons
Malta	Dutot	Dutot
Netherlands	Jevons/Dutot	Jevons/Dutot
Norway	Jevons	Jevons
Poland	Jevons	Jevons
Portugal	Jevons	Jevons
Romania	Jevons	Jevons
Slovakia	Dutot	Dutot
Slovenia	**Dutot**	**Jevons**
Spain	Jevons	Jevons

Sweden	Jevons	Jevons
Switzerland	Jevons	Jevons
UK	**Dutot/Carli**	**Jevons/Dutot**
USA	Jevons	Jevons

Source: http://epp.eurostat.ec.europa.eu/portal/page/portal/hicp/methodology/national_practices http://stats.oecd.org/mei/default.asp?lang=e&subject=8 and correspondence with NSIs.

Annex B

The three established elementary aggregate formulae.

Carli

The Carli, or Arithmetic Mean of Price Relatives, is used to calculate approximately 35% of EAs in the RPI. It is calculated as the arithmetic average of the price relatives between a period *t* and base period 0.

$$I_{t,0} = \frac{1}{n}\sum_{i=1}^{n}\frac{p_{i,t}}{p_{i,0}}$$

where $I_{t,0}$ is the price index, n is the number of price quotes, and $p_{i,t}$ is the price of item i at time t.

Dutot

The Dutot, or Ratio of Arithmetic Mean Prices, is used to calculate approximately 55% of EAs in the RPI, and 30% of EAs in the CPI. It is calculated by dividing the average price in period *t* by the average price in period 0.

$$I_{t,0} = \frac{\sum_{i=1}^{n}\frac{p_{i,t}}{n}}{\sum_{i=1}^{n}\frac{p_{i,0}}{n}}$$

Jevons

The Jevons, or Geometric Mean of Price Relatives (left), is used to calculate 70% of EAs in the CPI. This formula is algebraically equivalent to the Ratio of Geometric Mean Prices (right).

$$I_{t,0} = \sqrt[n]{\prod_{i=1}^{n}\frac{p_{i,t}}{p_{i,0}}} \qquad I_{t,0} = \frac{\sqrt[n]{\prod_{i=1}^{n}p_{i,t}}}{\sqrt[n]{\prod_{i=1}^{n}p_{i,0}}}$$