Office for National Statistics

Article

Chain-linking in business prices

The methodology and practical implementation of chain-linking for business prices, including the technical process of price updating sales data to forecast more representative weights.

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Release date:
20 July 2020

Next release:
To be announced

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1 . Executive summary

We are implementing annually chain-linked business prices in line with international best practice and to improve consistency with other price indices such as the Consumer Prices Index (CPI). This is a significant improvement to the weighting and linking of business inflation statistics, which we previously announced as part of a consultation in 2017. The implementation of chain-linking is recommended by Eurostat over the current method of rebasing for price statistics, as the weighting structures are updated more frequently.

This article focuses on the methodology and practical implementation of chain-linking for business prices, including the technical process of price-updating sales data to forecast more representative weights. This article is part of a collection of articles we are publishing. Other articles published are:

- producer price inflation methods changes: this outlines the move from net to gross basis to measure the headline producer price index, removal of duty and the sources used to compile the weights required for chain-linking
- services producer price inflation methods changes: this outlines the sources used to compile the weights required for chain-linking and a change to the classification framework
- producer price weight change impacts: this discusses the impact of introducing chain-linking and the other new methods on weights used in the Producer Price Indices (PPIs)
- services producer price weight change impacts: this discusses the impact of introducing chain-linking and the other new methods on weights used in the Services Producer Price Index (SPPI)

To complete the collection of articles, we will publish a further two articles to provide the impact of implementing the new methods on the PPI and SPPI. We are planning to publish the PPI and SPPI using the new methods towards the end of 2020.

2 . Introduction

Business prices are a collection of inflation statistics that measure the inflation across the manufacturing and service sectors and include Producer Price Index (PPI), Export Price Index (EPI), Import Price Index (IPI) and Services Producer Price Index (SPPI). To meet international regulations, the weighting structure has been updated historically every five years to reflect changes in the economy. Annual chain-linking is the method of updating weights on an annual basis and statistically linking them to produce a continuous time series. The method changes described in this article apply to the following statistics:

- PPI
- EPI
- IPI
- SPPI

3 . Aim of business price statistics

Our aim is to construct indices that track producer price movements at several different levels of detail in the manufacturing and service sectors.

We collect price data for many manufacturing and service products in the form of a basket of goods. These are weighted together to form indices that measure the price behaviour of broad groupings, up to the headline Producer Price Index (PPI) and Services Producer Price Index (SPPI). These measure the price movements in the manufacturing sector and part of the service sector, respectively.

We construct weights using sales data from Office for National Statistics (ONS) surveys and administrative data for specific periods. The sales data represent the turnover generated by UK companies selling each manufactured product (in the PPI) or service (in the SPPI) to the UK market. For the Import Price Index (IPI) and Export Price Index (EPI), sales of manufactured products are sourced from HM Revenue and Customs' (HMRC's) records. More information about the sales data is available in Services producer prices weights changes: 2020 and Producer prices weights changes: 2020.

The weight for any product group into the higher grouping is equal to the proportion of the products' sales within the total sales for that group. The higher the sales value for a product, the higher its weight into the aggregated price index. See Appendix 1 and Appendix 2 for further details.

4 . Moving to chain-linking

Weights derived from product-level sales data are a snapshot of the structure of the economy at a point in time. This structure shifts over time because of technological progress, new goods and manufacturing techniques being introduced, consumer preference changes, and evolving international supply chains. To keep the basket of goods representative of economic activity, we need product-level sales values and their associated weights to be updated at regular intervals.

Under the European legislative requirement known as Short-Term Business Statistics (STS), we are required to update the sales data used to calculate weights at least every five years. The weights were last updated in 2013 using 2010 sales data. In 2018, the Office for National Statistics (ONS) decided to move from a fixed-base year, where weights are updated every five years, to a new weighting methodology called annual chain-linking. This delivers a substantial improvement in measurement accuracy by updating weights on an annual basis.

Annual chain-linking is a methodology widely used within the ONS, and notably it has been used in the Consumer Prices Index (CPI) since the index was introduced in 1996. Therefore, as well as an increase in quality, adoption of annual chain-linking for the Producer Price Index (PPI) and Services Produer Price Index (SPPI) allows a closer alignment of ONS methodology across our main measures of inflation.

5 . Rebasing – the current method

In the current method, business price indices are calculated using the Laspeyres index formula, which weights prices in proportion to their quantities sold in the base period:

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

where:

$p_{t,i}$ is the price of item i in the current period t.

$p_{0,i}$ is the price of item i in the base period 0.

$q_{0,i}$ is the quantity sold of item i in the base period 0.

This can be expressed as the sum of price relatives weighted by expenditure share from the base period:

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

where:

$$\frac{P_{t,i}}{P_{0,i}} \text{ is the price relative of item } i \text{ in the current period } t$$

$w_{0,i}$ is the expenditure share or weight of item i in the base period 0.

Rebasing is a generic process that updates one or more of the following:

- the weights in an index
- the price reference period of an index number series
- the index reference period of an index number series

As explained, in the current method for producing business prices, weights are updated and indices are re-referenced every five years. Price relatives are also updated so that in the base year, the price relative is 100, and therefore price changes in other periods are comparable to this base year. To update a price relative, the original price relative is divided by the price relative of that item at the new reference period, then multiplied by 100.

To avoid any step change when an index is rebased, a link factor is applied to the historical series to link the new series on, which ensures movements in an index only reflect price movements. The link factor, L, is calculated as follows:

$$L = \frac{I_{New,l}}{I_{Old,l}}$$

where:

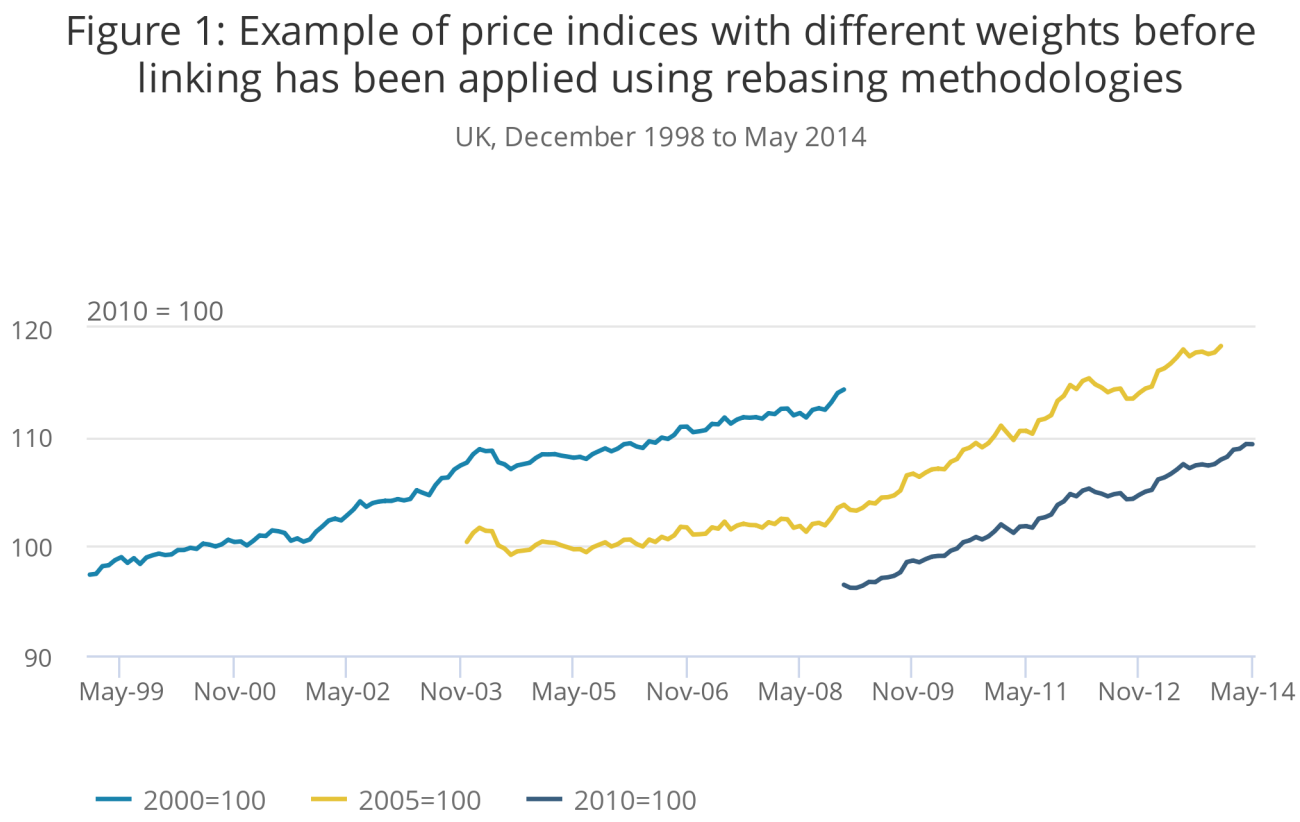
$I_{New,l}$ is the index under the new base conditions in the link period.

$I_{Old,l}$ is the index under the old base conditions in the link period.

This link factor is applied to construct a continuous series over time (Figures 1 and 2).

Figure 1: Example of price indices with different weights before linking has been applied using rebasing methodologies

UK, December 1998 to May 2014



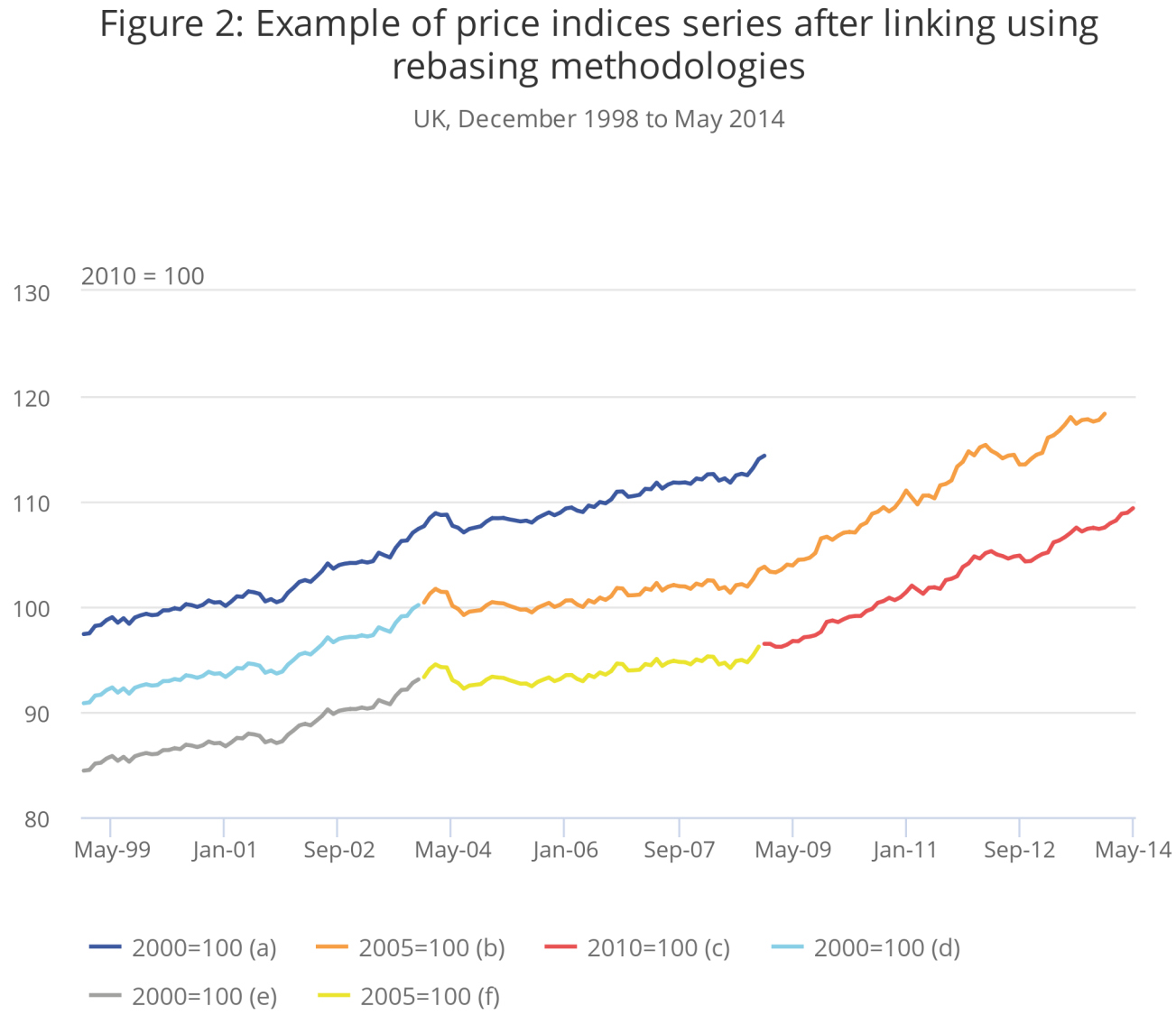
Source: Office for National Statistics – Chain-linking in business prices

Notes:

1. Unless otherwise stated, the data in the chart are for illustrative purposes only and are not intended to represent any real-world trends.

Figure 2: Example of price indices series after linking using rebasing methodologies

UK, December 1998 to May 2014



Source: Office for National Statistics – Chain-linking in business prices

Notes:

1. Unless otherwise stated, the data in the chart are for illustrative purposes only and are not intended to represent any real-world trends.

6 . Overview of chain-linking

The main difference between annual chain-linking and the rebasing methodology is the frequency of updating the index weights and linking the index to create a continuous series. Chain-linking is conducted more frequently than rebasing (that is, annually instead of every five years).

Revised methodologies to enable chain-linking are applied from December 2008 for the Producer Price Index (PPI), Export Price Index (EPI) and Import Price Index (IPI) and from Quarter 4 (Oct to Dec) 2008 for the Services Producer Price Index (SPPI). Between 2008 and 2013, all business prices will use the weights applied in the last rebasing using turnover data from 2010; throughout the articles, these will be referred to as 2010 rebasing weights. From January 2014 onwards, new weights will be applied annually using the new sources and methods outlined in this collection of articles. The necessary linking factors to enable annual reweighting will be updated in the link period, which is the previous December for the PPI, EPI and IPI or Quarter 4 for the SPPI. Therefore, the link period for the first 2014 annual reweighting will be December 2013 for the PPI, EPI and IPI and Quarter 4 2013 for the SPPI. These weights will be referred to by the year the data are sourced.

In chain-linking methodology, when the weights change from one period to the next a new series is generated. To see this, consider two price indices for 2018, one with weights generated using 2010 sales and one with weights generated using 2015 sales. Even though both utilise the same raw price quotes from 2018, they have differences in the weighting structure $w_{t,i}$. This means that the two series for 2018 will exhibit different behaviours. Another way to interpret this is to note that a weight update causes the relative composition of the goods basket (s) we are measuring to change, generating a different series.

However, our aim is to create a single continuous series to allow price behaviour to be tracked over time. This requires a way of linking together the series before and after weights changes. Chain-linking is the process of joining together two indices that overlap in one period by rescaling one of them to make its value equal to that of the other in the same period thus combining them into a single time series. This is achieved by multiplying the index value by the linking factor.

Let us assume that the first change in the weighting structure occurs at time t. The linking factor for an unlinked index I at time t is:

$$L_{t,I} = \frac{\sum_{i \in h} I_{t,i}^{lagged} w_{t-1,i}}{\sum_{i \in h} I_{t,i} w_{t,i}}$$

where:

$w_{t,i}$ is the weight of component i into index I at time t.

$I_{t,i}^{lagged}$ is the unlinked price index of component i with time t item prices aggregated and imputed using the entire lagged t-1 weighting structure (including lagged weights of lower level component indices).

$I_{t,i}$ is the (standard) unlinked price index of component i with time t item prices aggregated the entire time t weighting structure.

The sum is over the set h, which is all the subgroupings that are components of index I.

We apply this to all index values at time z, which could be at or after time t, so linked index at time z, I_z^{linked} is:

$$I_z^{linked} = I_z L_{t,I} \quad z \geq t$$

where: I_z is the unlinked index at time z. This is the price index without any linking factors applied.

These factors stack multiplicatively, so if there is a time t^'>z where another weight change is applied (that is, after time z, the time of the first weight change), the linked series will be:

$$I_{t'}^{linked} = I_{t'} L_{z,I} L_{t,I} \quad t' \geq z$$

The same pattern applies if there are weight changes after time t'.

Consider the linked index at time t: the definition of the unlinked index:

I_z = I at time time t under new weighting structure

The link factor then makes it so that:

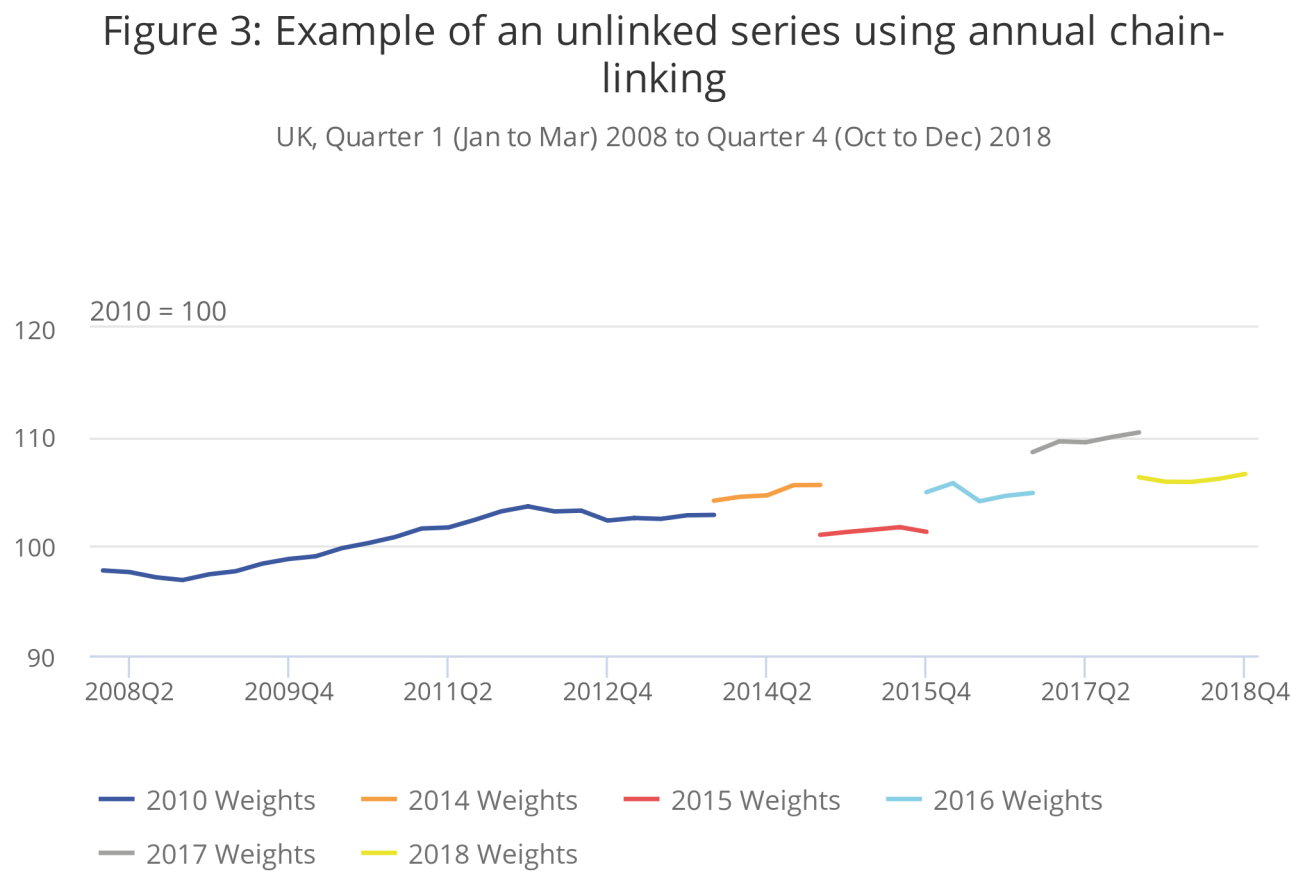
I_z^{linked} = I at time t under old weighting structure

that is, the discontinuity resulting from the weight update is removed.

This is the linking of the two series – using an overlap period where the index is calculated under two different sets of weights, we can calculate the effect of the weight change and compensate for it. Removing this effect allows us to link the two series (before and after the weight change) together. Figures 3 and 4 demonstrate the new approach to chain-linking for the PPI.

Figure 3: Example of an unlinked series using annual chain-linking

UK, Quarter 1 (Jan to Mar) 2008 to Quarter 4 (Oct to Dec) 2018



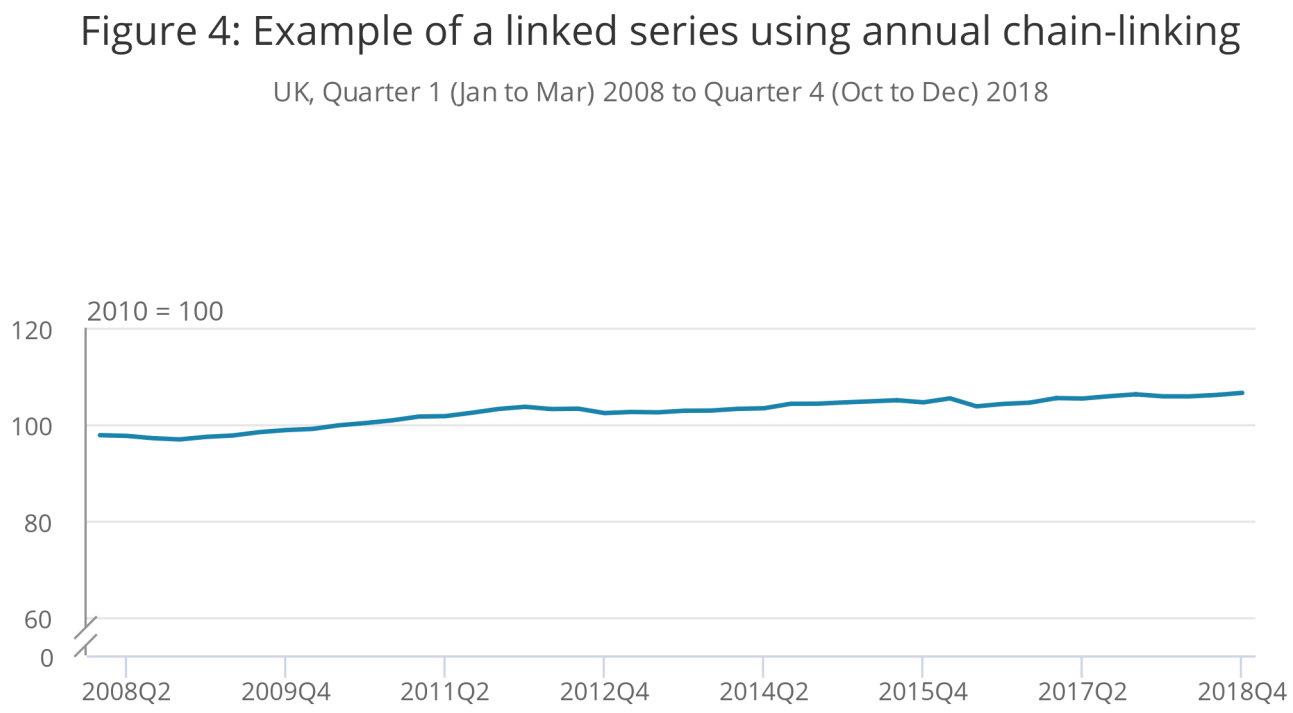
Source: Office for National Statistics – Chain-linking in business prices

Notes:

1. Unless otherwise stated, the data in the chart are for illustrative purposes only and are not intended to represent any real-world trends.

Figure 4: Example of a linked series using annual chain-linking

UK, Quarter 1 (Jan to Mar) 2008 to Quarter 4 (Oct to Dec) 2018



Source: Office for National Statistics – Chain-linking in business prices

Notes:

1. Unless otherwise stated, the data in the chart are for illustrative purposes only and are not intended to represent any real-world trends.

Annual chain-linking, compared to a quinquennial rebasing, maintains a more up-to-date weight pattern. This is beneficial in measuring more dynamic economies such as that of the UK where the structure of the economy may change at a quicker pace. For example, technological advances in the computer industry lead to new products replacing obsolete products more frequently than every five years. Further information on the PPI and SPPI weights changes in the context of the wider economy can be found in Services producer prices weights changes: 2020 and Producer prices weights changes: 2020.

In addition, annual chain-linking reduces substitution bias in our price indices, for example, if a good or service experiences a large increase in price, consumers are likely to switch to cheaper substitutes. This will feed back through to the producers, with relative sales of products changing over time, eventually impacting on what goods and services are produced in the economy. It follows that if we do not update our sales data, this substitution by consumers to cheaper goods could be missed, causing our price indices to show higher prices and inflation than they should. Chain-linking reduces this upwards bias.

7 . Price updating

While the underlying methodology for both annual chain-linking and rebasing is the same, there is a difference in the frequency of updating weights. To adopt annual chain-linking, one of the main challenges to overcome is the requirement for sales data from the previous year to produce the weights for the current year (for example, 2019 sales data are needed for weights used in the compilation of 2020 indices). Sales data are normally provided with a lag, so is not normally available within the timeframe required.

A secondary issue is that sales data to be used as weights need to represent transactions during the link period, which is Quarter 4 (Oct to Dec) for the Services Producer Price Index (SPPI) and December for the Producer Price Index (PPI). It is not always possible to obtain sales data representing a single quarter or month for each service product's or manufacturing product's transactions, as many relevant surveys gather sales data from transactions that occur over the course of a year. For quinquennial rebasing of both the SPPI and PPI, this was not an issue because a whole year of transactions was used as weights.

To align the sales data to the period required, we need to update them. To overcome these issues, a method for estimating the sales during the link period is employed, referred to as price updating. This approach uses the annual total sales, which represent an entire year of transactions, and updates them to represent the sales during the link period (that is, Quarter 4 for the SPPI or December for the PPI).

This is done by calculating and applying a measure of inflation between the year that the given sales cover and the link period. The measure of inflation is determined using the relevant indices from the SPPI or PPI. The price updating formula for a product or service is:

$$S_l = S_y \times \frac{I_l}{\bar{I}_y}$$

where:

S_l are the estimated sales during the link period, l. This is referred to as "price updated sales".

S_y are annual sales for year y.

$\bar{I}_y$ is the average price index value during year y.

I_l is the price index value during the link period, l.

The index values I_l and $\bar{I}_y$ must share the same reference period.

Price updating normally is applied at the Classification of Products by Activity (CPA) six-digit index level, which is the lowest level of aggregation in the PPI and SPPI. However, there is an issue when the index value coverage for a CPA six-digit is not sufficient to enable price updating of its corresponding sales figure. This is most often because of the CPA six-digit product group not having an available index value (for example, because of small sample sizes) for the link period or for the entire year. Where either is the case, alternative approaches are taken that generally require use of a price index from a higher level of aggregation as a proxy.

For example, to produce weights for the 2019 PPI gross sector output indices, UK manufacturers' sales by product (ProdCom) sourced sales are price updated from the annual sales totals for 2016 to estimate sales during December 2018. The price updated sales for December 2018 are then used as weights from January 2019 to December 2019. For further details on these approaches, please see Appendix 3.

A consequence of price updating is a delay in weight movement, as changes in the volume estimates are not considered as part of the method. Once actual sales are received, they may be different to price-updated sales as they include both price and volume changes. However, price updating is an internationally agreed method to be used as part of annual chain-linking to address limitations in the timeliness of the weights data. Price updating is used also in the Consumer Prices Index (CPI) measure (see Consumer price inflation, updating weights: 2020).

8 . Appendix 1: Weighted index

Weighted indices are calculated using sales data as weights and price indices. A weighted index in mathematical form is calculated as:

$$I_{t,h} = \sum_{i \in h} I_{t,i} w_{t,i}$$

This is the price index I for some grouping of products h at time t, denoted $I_{t,h}$.

The sum is over all the components (subgroups of products i that belong in the higher-level grouping h).

$I_{t,i}$ is the index value of subgrouping i within h at time t.

$w_{t,i}$ is the weight of subgrouping i within h at time t.

$$0 \leq w_{t,i} \leq 1, \sum_{i \in h} w_{t,i} = 1$$

We need an appropriate and consistent way of calculating $w_{t,i}$, which determines the importance of each price component within an index. To understand the problem, observe that the aggregated indices are effectively measurements of the price of a basket of goods. This basket needs to be representative of activity in the economy for the index to be a good indicator of price behaviour.

9 . Appendix 2: Calculation of weights

Let the sales of a product grouping i be x_i. Then, the weight of that grouping in the broader grouping h is:

$$w_{t,i} = \frac{x_{r(t),i}}{\sum_{i \in h_*} x_{r(t),i}}$$

where:

h_* are all the subgroupings within h for which we have price data.

$x_{r(t),i}$ are the sales of subgrouping i at time r(t). r is a function of the time t for which we are calculating index values. It defines the time r we are taking sales data from, given the index value we want to calculate is at time t.

Therefore, the weight of any product grouping into a higher grouping is equal to the proportion of its sales within the total sales of that group.

10 . Appendix 3: Price updating coverage issues

The following methods are used when there is not appropriate coverage to carry out price updating at the Classification of Products by Activity (CPA) six-digit level.

Services Producer Price Index and Producer Price Index

The index value used for price updating will be an unweighted average across all the CPA six-digits that share the same CPA four-digit parent of the given CPA six-digit whose sales are being price updated. This applies to both the link period index value and the average index values from the sales year (average of a set of averages), if either are zero or dead for a given CPA six-digit. CPA six-digit index values are based on a Laspeyres methodology.

If the link period index value and/or the average index value from the sales year is still zero after calculating unweighted averages across all CPA six-digit with the same CPA four-digit parent, then we consider all the six digits nested within the next parent index above the CPA four-digit. This process continues ascending from the lowest tier parent until a non-zero index value for both the link period and yearly average is found. These two non-zero values are then used to carry out the price updating process.

Import Price Index and Export Price Index

The coverage in the Import Price Index (IPI) and Export Price Index (EPI) is currently more limited compared to the PPI; therefore, price updating uses a different method. By default, price updating will be performed by the unweighted index value average across all CPA six-digits that share the same CPA two-digit parent as the given CPA six-digit's allocated sales being price updated. This applies to both the index used for the link period index and the sales reference year. If the CPA two-digit parent averages provide a zero value, the next higher-level index will be considered in the same manner as the PPI for price updating.

The reason for using unweighted averages for the SPPI, PPI, IPI and EPI (as opposed to weighted averages) is there being no guarantee that the dead CPA six-digit's siblings that are alive are proportionally representative of the weighted group. It also resolves the circularity issue of using price-updated sales to create weighted averages to generate the next set of price-updated sales. Use of weighted averages could result in cumulative error over time, as price-updated sales would become a function of previous price-updated sales.

In summary, when price updating using groups of CPA six-digits to calculate index averages, we apply the following formula:

$$S_l = S_y \times \frac{\left(\frac{\sum_{i \in h} I_{i,l}}{n}\right)}{\left(\frac{\sum_{i \in h} \bar{I}_{i,y}}{n}\right)}$$

where:

S_l denotes the price updated sales, estimating the sales during link period, l, for a given CPA six-digit.

h is the set defined by all CPA six-digits sharing the same parent as the given CPA six-digit being price updated that are alive.

n denotes the number of elements in the set h.

i is the index identifier, which refers to an element belonging to the set h.

S_y denotes the annual sales for a given year, y, for the given CPA six-digit being price updated.

$I_{i,l}$ denotes the CPA six-digit, i, index value during the link period l.

$I_{i,y}$ denotes the CPA six-digit, i, average index value during the year y.

11 . Authors

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