ADVISORY PANEL ON CONSUMER PRICES -TECHNICAL

Smoothing Volatile Weights

Status: final
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Purpose

1. This paper follows up on recommendations from the Advisory Panel in May 2016. A paper was presented at this panel and an action followed for ONS to provide additional research in to the best methodology to use to smooth volatile weights.

2. This paper reviews the analysis undertaken on smoothing volatile weights. It illustrates a comparison of weights using a 5 year average using most recent Blue Book expenditure and weights as published. Then it provides analysis on the 3 year average. This paper proposes the 3 year average using expenditure from the most recent blue book as a proposed method for smoothing, if smoothing is considered necessary.

Actions

1. Members of panel are invited to:
   a) Consider and comment on whether they believe smoothing is beneficial in any of the three classes.
   b) Comment on whether the 3 year average is still seen as the most suitable smoothing method.
   c) Comment on whether reviewing weights regularly to identify any volatility in weights is needed.

Discussion

3. The lag in which spending data are available means weights reflect spending patterns of two years previously. This is of particular concern when outliers are present. Following Johnson review recommendation 15: "ONS should use more than one year of national accounts data in cases where the weights are particularly volatile, or reflect particular circumstances in the latest year available", the ONS conducted research to identify particularly volatile weights to be considered for smoothing.

4. The research uncovered that most of the volatility in class level weights is due to historical revisions in Household Final Consumption Expenditure (HHFCE) data used to calculate the weights. However, the weights for the following classes: **Fuels and Lubricants, Gas, and Package Holidays** show volatility or reflected particular circumstances (e.g. severe winters in the case of gas) in particular years. The HHFCE data comes from Blue Book editions which are published annually. In the first APCP-T paper two smoothing options were considered:

- **Option 1:** When calculating the weights, use expenditure data from the last **3 years** from the most recent Blue Book. The expenditure data are uprated and averaged appropriately.
- **Option 2:** When calculating the weights, use expenditure data from the last 3 years from the last 3 vintages of Blue Book (taking the expenditure for each year from the Blue Book it is first reported in). The expenditure data is uprated and averaged appropriately.

5. Option 1 was seen as the preferred smoothing option. Option 2 delayed the jump in weight by 2 years, while also being inconsistent with calculation of weights for package holidays. This is due to the data source being different from that used for other items in CPIH. Package holidays use solely Living Costs and Food Survey (LCF) data with no HHFCE data, hence not having any revisions.

6. We have tested three additional methods of smoothing to establish whether the 3 year average is the most appropriate method. The three methods considered were as follows:

   1. 5 year average (using option 1 expenditure data)
   2. 5 year average using unequal weights (using option 1 expenditure data)
   3. Exponential smoothing

   The outcome of these additional methods of smoothing will be summarised first. Comparisons with practices in other National Statistic Institutes are presented in Annex D.

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September, 2017

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Annex A - Additional smoothing methods considered

5 year average

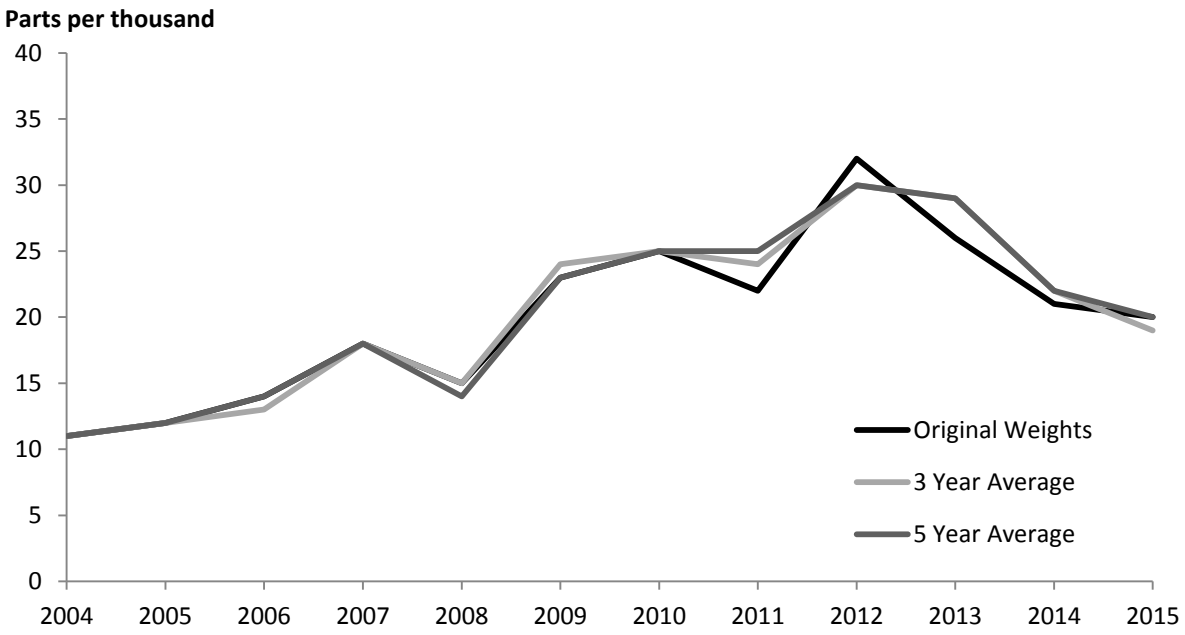
1. The 5 year average is calculated in the same way as option 1 but instead uses expenditure data from the last 5 years from the most recent Blue Book. Previously we used a 3 year average as this is what is used for insurance, as well as being recommended by the Johnson Review. Hence, for example when calculating the 2015 weights you would:

   a. **Use only BB2014**
   b. **From BB 2014 you would take an average of:**
      For both the 3 and 5 year moving average
      1. **The 2013 expenditure**
      2. **The 2012 expenditure uprated to 2013 prices using the index for the item.**
      3. **The 2011 expenditure uprated to 2013 prices using the index for the item.**

      For the 5 year moving average only
      4. **The 2010 expenditure uprated to 2013 prices using the index for the item.**
      5. **The 2009 expenditure uprated to 2013 prices using the index for the item.**
   c. **Uprate the average by the inflation that took place in 2014 for the item.**

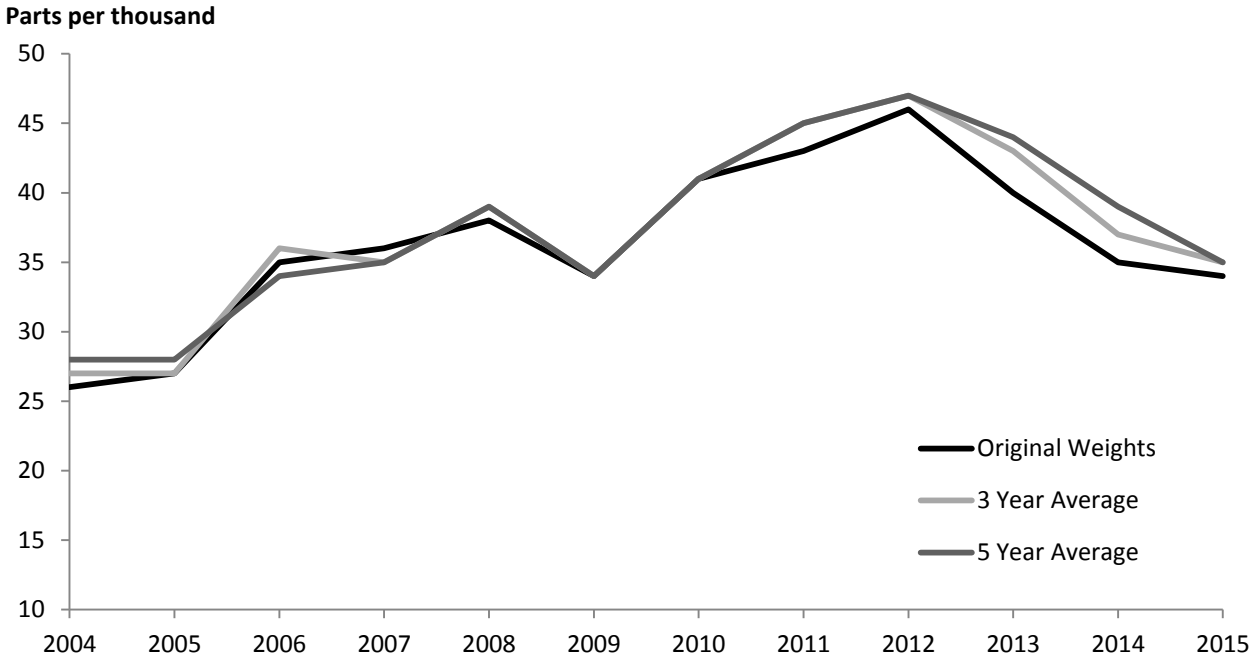
2. Figures 1 and 2 shows the impact of the 5 year average on the weights for Gas and Fuels & Lubricants respectively, and compares them to the 3 year average and weights as published.

Figure 1: CPI weights for Gas 2004-2015



3. In Figure 1 it can be seen that, from 2004 through to 2010, there were no serious revisions or strong inflation; the three series run fairly close together. In 2012 all three series experience a large movement; this was due to upward revision in the HHFCE data. All three series take on the effect of this revision. In 2010 there was an exceptionally cold winter which increased expenditure on gas, this expenditure data was then used to calculate the 2012 weight. Both the 5 year and 3 year average lessen the effect of this high expenditure. They smooth the weight in the same way. However, in 2011 where there is a dip in the Gas weight, the 5 and 3 year average smooth out this dip to different extents. The 5 year average smoothes to a greater extent than the 3 year average which remains closer to the original weight. Onwards from this point, the 3 and 5 year average track closely to one another before converging around the original weight in 2015.

Figure 2: CPI weights for Fuels and Lubricants 2004-2015

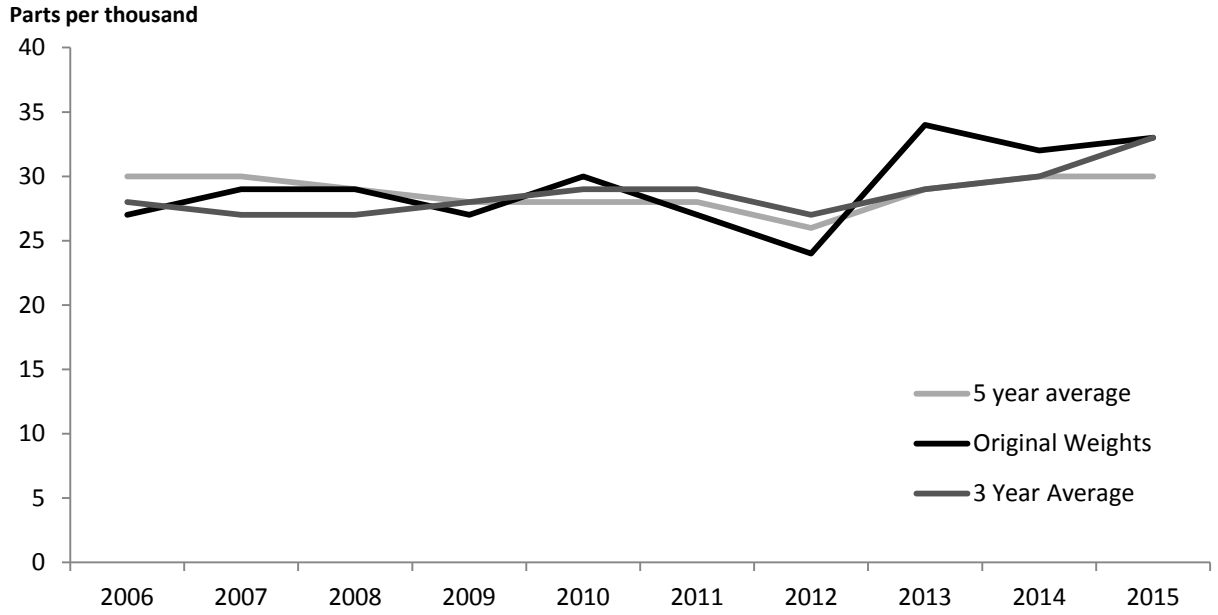


7. The three series of weights for fuels and lubricants run fairly close together when there are no serious revisions or strong inflation, as seen in Figure 2. All three series experience a large fall in weight during 2009 as a result of the fall in the price of petrol during 2008. After 2008 the smoothed weights again closely match the published but post 2010 are slightly higher. Part of the cause of this is high inflation in 2007, 2009 and 2010. The high inflation causes the uprated expenditures to drag the 3 and 5 year averages up in the uprating process. This means the smoothed weights series run slightly higher. However they begin to converge towards the published weight in 2015.

8. Weights for the Package Holidays class are derived using Living Cost and Food Survey (LCF) data rather than HHFCE data. Volatility in the package holidays weights is more likely to represent variability in LCF data rather than particular circumstance in particular years. By taking an

average we hope to reduce the volatility that may be driven by sample variation. The weights can be seen in Figure 3 (the data starts from 2006 due to use of LCF data and no historical revisions). We see that the 3 and 5 year averages show a similar smooth trend. Eradicating the volatility created by the sample variation in LCF data.

Figure 3: CPI weights for Package Holidays 2006-2015



9. With all three classes shown above, it can be seen that the 5 year average produces a smoother series but the 3 year average preserves more of the movements in weights. There is a trade-off between eliminating out of date outliers (as was seen with the spike in Gas in 2012 due to an exceptionally cold winter in 2010) against having up to date expenditure. Although the 5 year average does produce these smoother weights, eliminating the outliers, it does not have up to date expenditure data. As a result the 3 year average manages this trade-off best, especially as smoothing is unlikely to remove outliers completely.

5 year moving average using unequal weights

10. A method using unequal weights in a 5 year moving average was explored. This method of smoothing was chosen to ensure that the smoothed weights remained more representative in a 5 year average. The use of 5 years of expenditure data results in a less up to date average. By using unequal weights, more weight is placed on more recent Blue Book expenditure (e.g. BBt-1 would have a weight of 0.6, where t is the current period, and BBt-2 would have a weight of 0.2 and so on) and some of this is negated. The unequal weights we used in Figures 4, 5 and 6 are shown in Table 1. Different combinations of these were tested, but these seemed to be most suitable.

Table 1: Weighting used in the 5 year moving average using unequal weights

Time	Weight
BBt-1	*0.6*
BBt-2	*0.2*
BBt-2	*0.1*
BBt-4	*0.05*
BBt-5	*0.05*

11. Figures 4, 5 and 6 show the resulting weights created, and contrast them against the 3 and 5 year average as well as the published weights. It is clear to see that the 5 year average with unequal weights led to a smooth that is a closer match to the original weights, as it represents the most recent data. The 5 year average using unequal weights tends to lie between the 3 and 5 year average and the published weights around periods with volatility in weight. This is seen in the latter spectrum of all three graphs below.

Figure 4: CPI weights for Gas including a 5 Year average with unequal weights

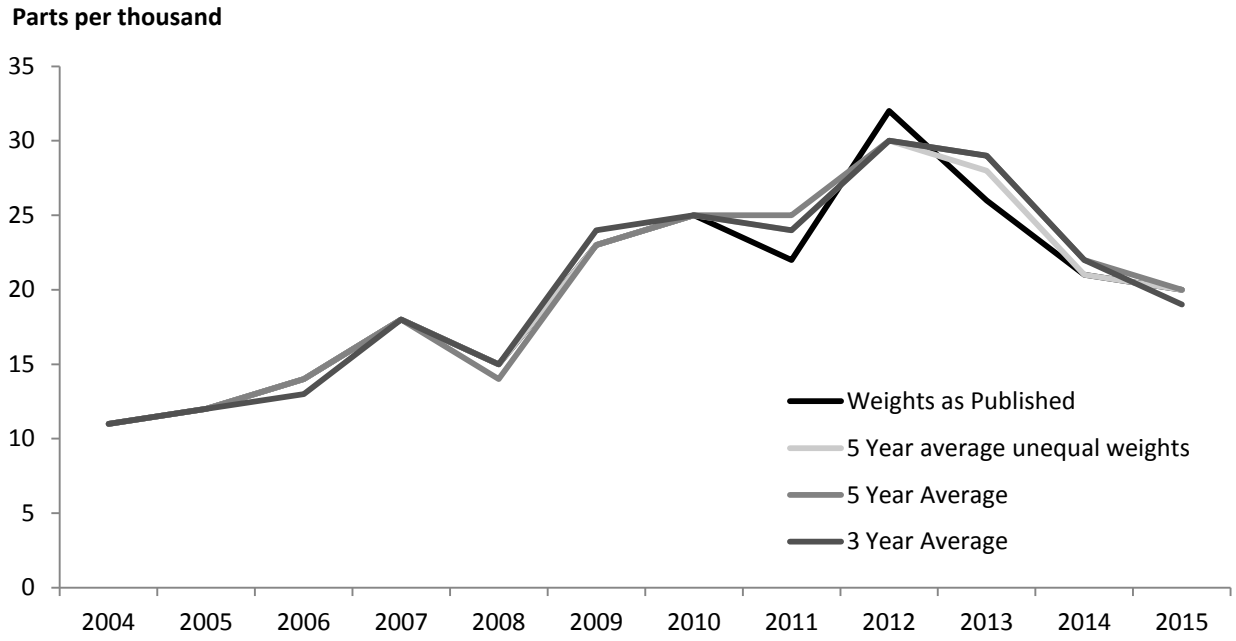


Figure 5: CPI weights for Fuels and Lubricants including a 5 Year average with unequal weights

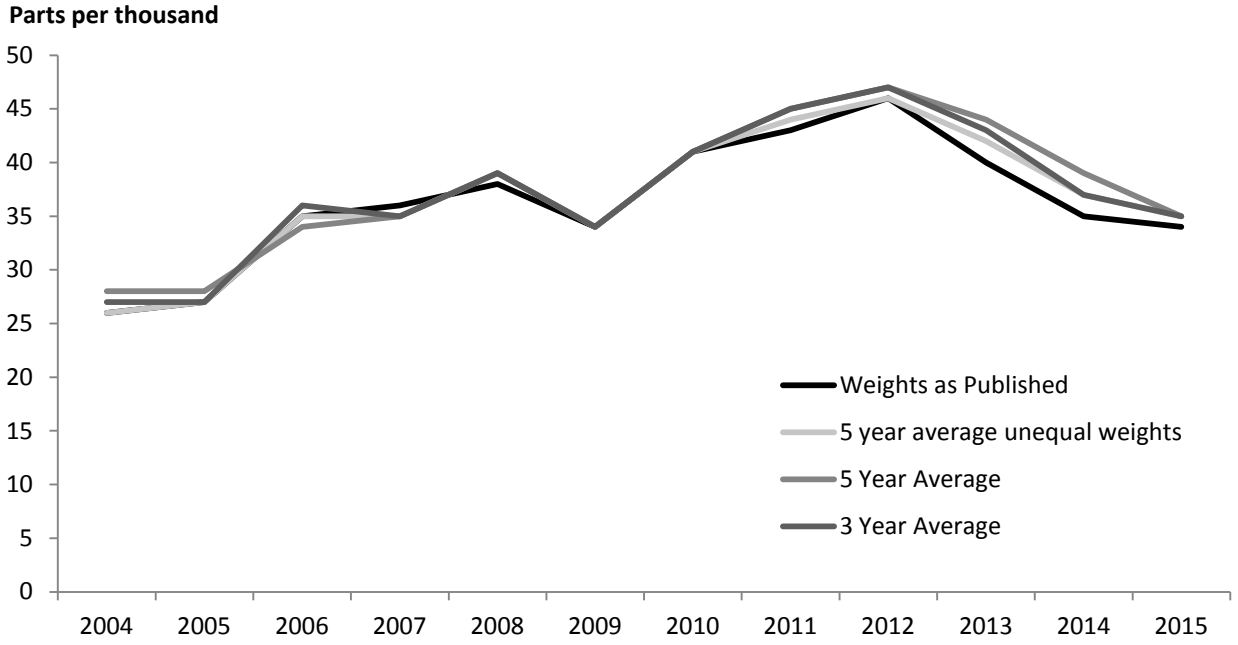
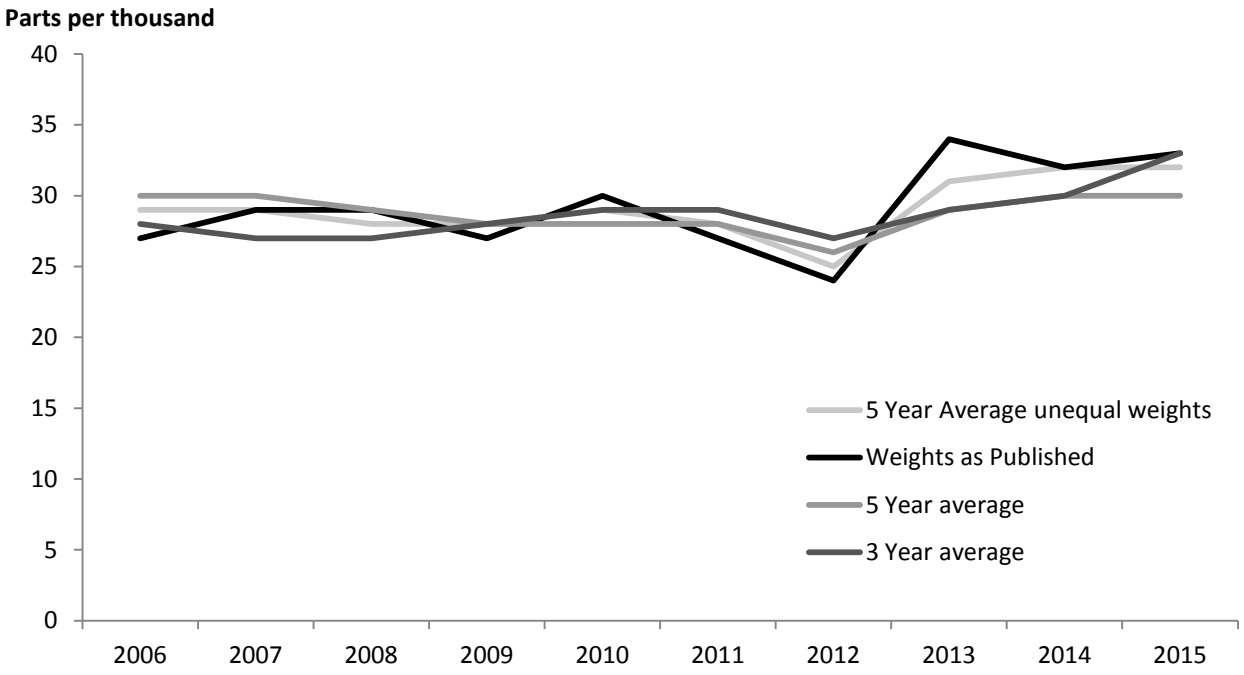


Figure 6: CPI weights for Package Holidays using a 5 Year average with unequal weights



Simple Exponential Smoothing

12. Smoothed weights using a simple exponential smoothing method were also created. This method assumes recent events are more important than those in the past (a similar concept to that used in the 5 year average with unequal weights). This method of smoothing can only be

applied to a non seasonal series, which do not show systematic trends. For Gas, Fuels and Lubricants, and Package Holidays the expenditure used is collected year on year. Therefore these trends will not be picked up in the data and the method can be applied.

13. Figures 7, 8 and 9 represent the exponential smoothing for the weights of the three classes being investigated. It uses smoothing parameters of 0.3 and 0.7, which were chosen in order to contrast the effect of having parameters that are more and less responsive to recent data. The one-step-ahead forecast, used in exponential smoothing, can be expressed as:

$$\hat{x}_{N+1} = \alpha x_N + (1 - \alpha)\hat{x}_N$$

Where α is a smoothing parameter.
When **α = 1**, smoothing is **responsive** to recent observations.
When **α = 0**, smoothing is **unresponsive** to recent observations.

Figure 7: Exponentially smoothed CPI weights for Gas

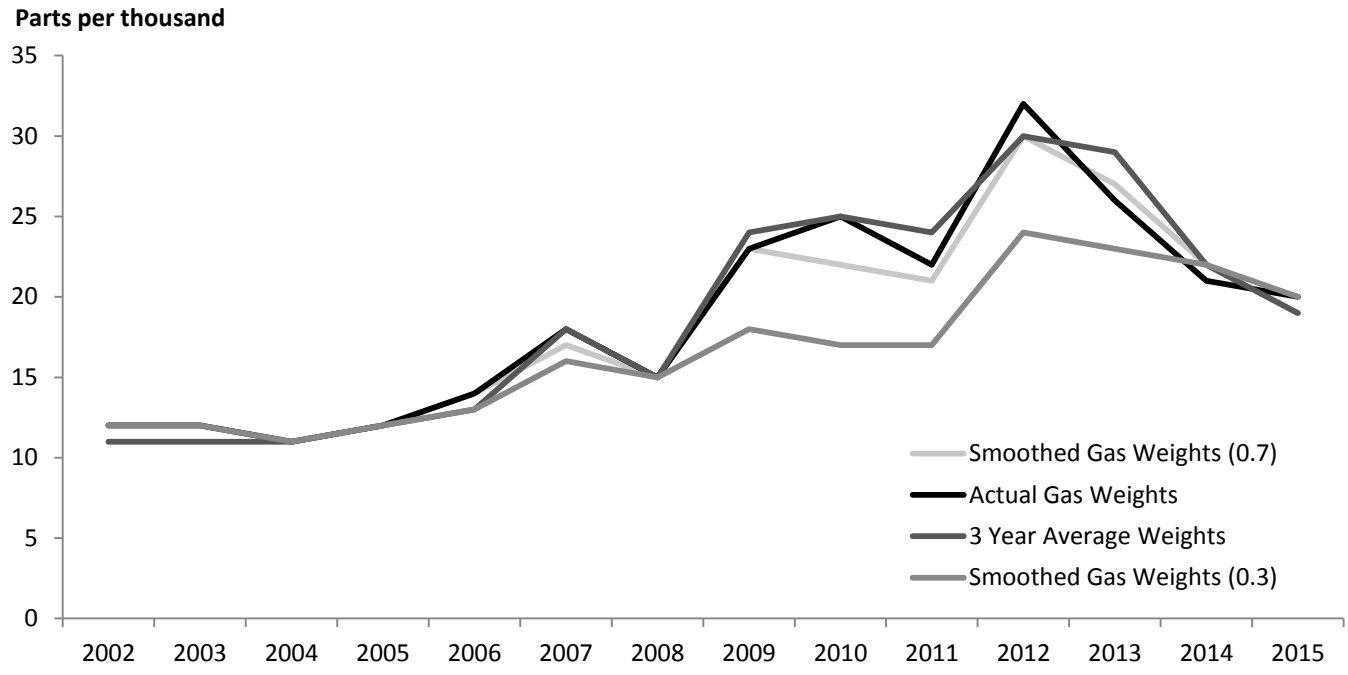


Figure 8: Exponentially smoothed CPI weights for Fuels and Lubricants

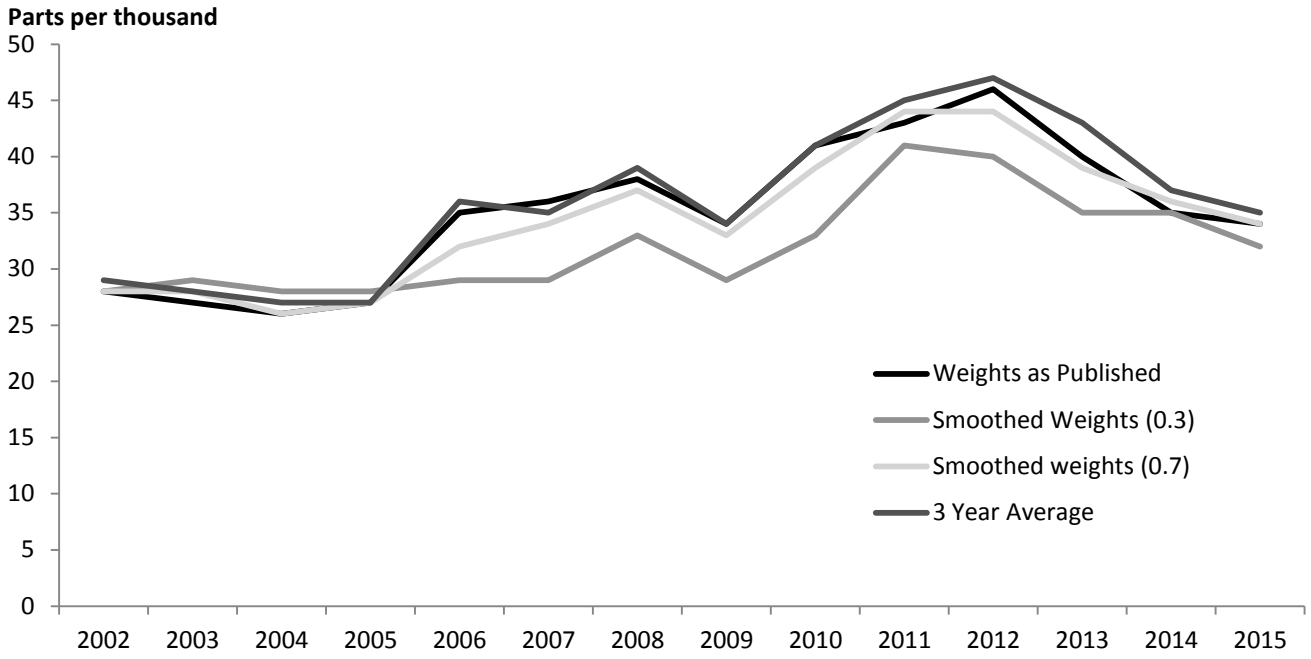
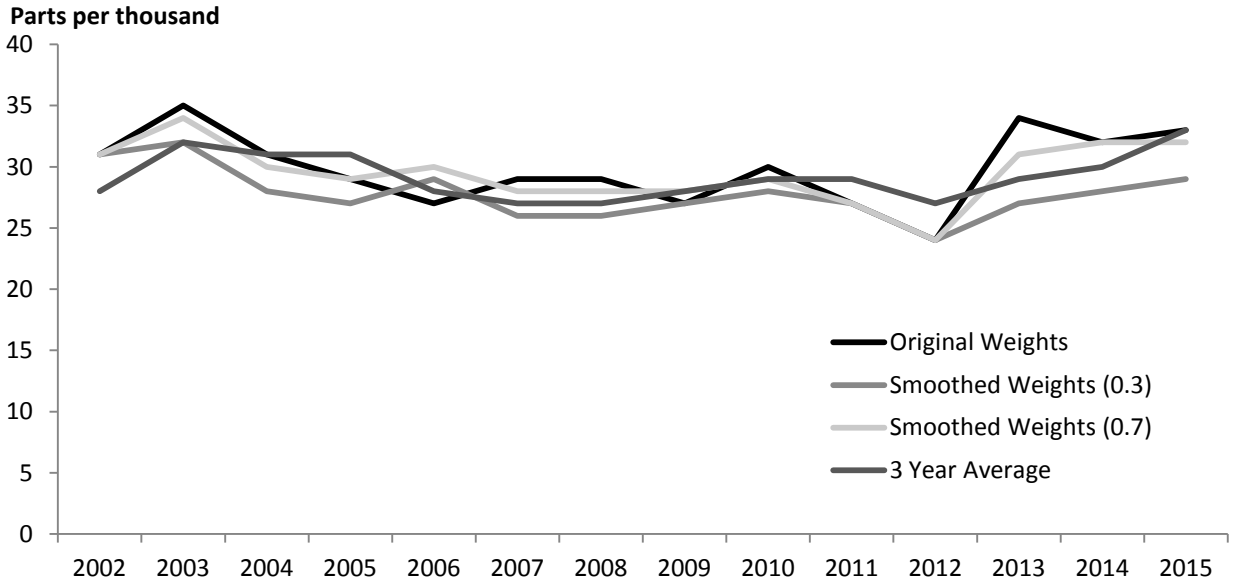


Figure 9: Exponentially smoothed CPI weights for Package Holidays



14. From Figures 7, 8 and 9 it is evident that a smoothing parameter of 0.7 tracks the original weights more closely than a parameter of 0.3 as would be expected given the higher level of responsiveness to recent data using a 0.7 parameter. In Figure 7 the smoothing parameter of 0.3

smoothes the weights to a great extent but deviates greatly from the existing series. In Figure 8 looking at Fuels and Lubricants, however, this same method creates a similar trend to the original weights at a lower level rather than effectively smoothing them. The smoothing parameter of 0.7 is more appropriate to use in the exponential smoothing we require as it remains more representative of the original weights while also smoothing outliers to an extent. The 3 year average had also been plotted in Figures 7, 8 and 9. Exponential smoothing with a parameter of 0.7 smoothes similarly to the 3 year average in the Gas, and Fuels and Lubricants weights, the 3 year average method manages the trade-off between using recent expenditure smoothing volatility better for the Package Holidays weights. This is most evident in the period 2011-2015 of Figure 9.

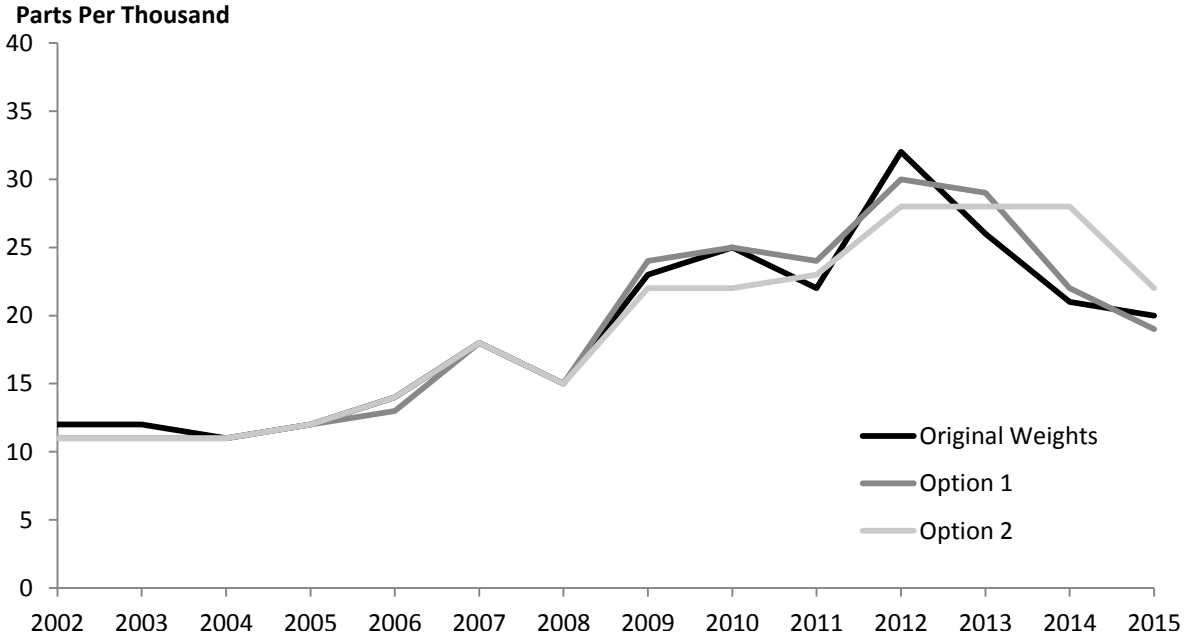
15. From the analysis undertaken, the 3 year average (option 1) was still seen as providing the most representative smoothed weights of the methods considered. The 3 year average is based on more up to date expenditure data than a 5 year average. This means it is able to better preserve the actual movements in weights whilst being able to smooth some effect of outliers, as seen with the exceptionally cold winter in 2010 leading to a spike in Gas weight in 2012.

Annex B - 3 year average and a base year weighted index

1. In this section both option 1 and 2 for the 3 year average are analysed. This demonstrates the advantages of smoothing and it helps to give a picture of why 3 year average using option 1 is an effective approach.

2. CPIH is a Lowe index, which means weights are price uprated to the base year, and that the purpose of price uprating is to bring the expenditure closer to the period we are uprating to, by assuming that quantities remain constant. Therefore that period's expenditure could be seen as the expenditure we are targeting for CPIH. Due to this lag in expenditure data, volatile expenditure or one off shocks in HHFCE data will carry forward to represent this in the current period when weights are created. Hence the smoothing is an attempt to mitigate any circumstances in which this may occur. Figure 10 shows the weights created by option 1 and 2 using the 3 year average.

Figure 10: CPI weights for Gas using 3 year average options 1 and 2



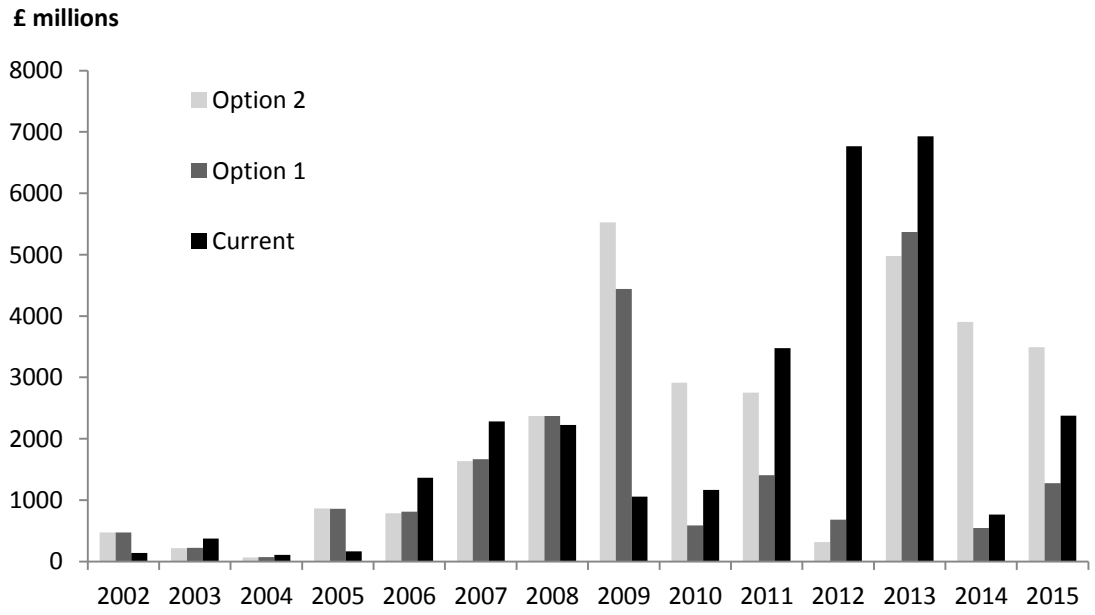
3. Table 2 shows the expenditure differences between the three weighting options (1, 2 and original) and a target base year weighted method for the Gas class. This shows that option 1 results in the lowest average absolute difference (circled in Table 2), meaning that it is the closest series to that of a base year expenditure. Looking specifically at 2012 where there was a spike in expenditure due to an excessively cold winter in 2010, we see that both option 1 and 2 are closer to the base year expenditure compared to the current method (highlighted in green). We see that the smoothing generally works better during the volatile period of 2010-2015.

Table 2: Absolute differences between weighting methods and the base year method in expenditure (£ millions) used to create the CPI weight for Gas 2002-2015

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Average
Option 1	470	222	70	861	811	1667	2371	4439	**588**	**1405**	684	5368	**546**	**1274**	**1484**
Option 2	470	**215**	**64**	864	**785**	**1636**	2371	5525	2911	2751	**318**	**4981**	3902	3493	2163
Current	**138**	372	109	**163**	1363	2283	**2225**	**1059**	1166	3474	6769	6928	766	2376	2085

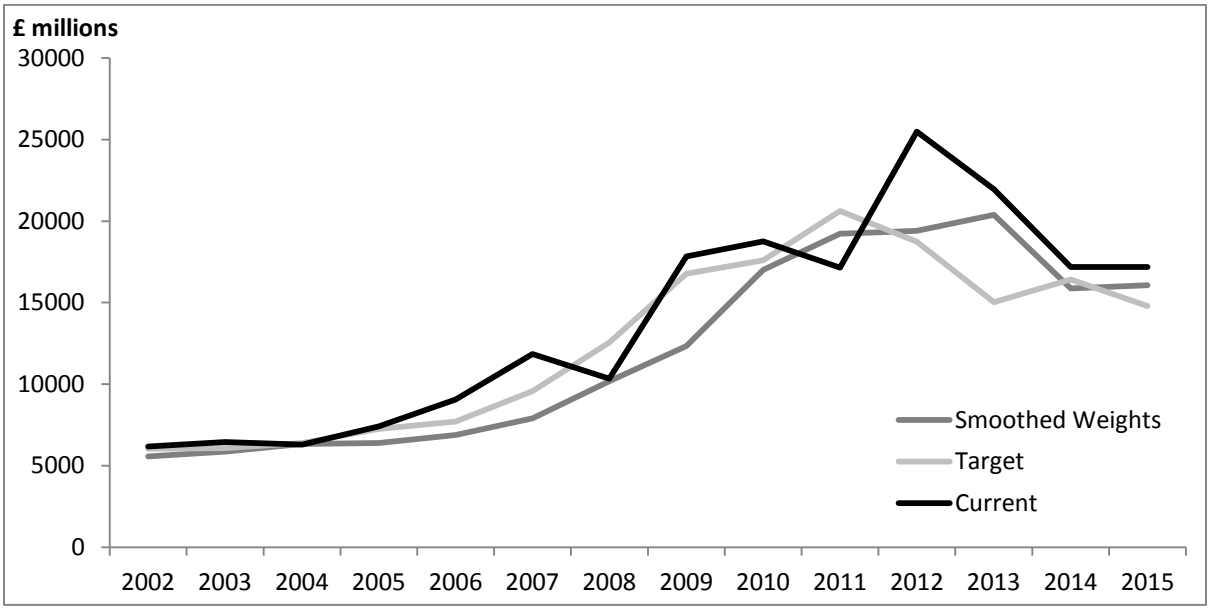
4. Figure 11 charts the values in Table 2, and indicates more clearly the effect of smoothing on the period which is affected by the outlier. The current method in 2012 dominates options 1 and 2.

Figure 11: Absolute differences between weighting methods and the base year method in expenditure used (£ millions) to create the CPI weight for Gas 2002-2015



5. Figure 12 plots the total expenditures of option 1 smoothed weights, a target base year weights method and the current method. We see that the smoothed weights series not only smoothes out the major volatility in expenditure in 2010, but also results in a smoothed series throughout the entire period without majorly deviating away from the current methods expenditure. The only real occasion this occurs is in 2009 which is shown in all three figures.

Figure 12: Expenditure used to create CPI weights for Gas 2012-2015



6. Figure 13 shows the 3 year average using option 1 and 2 for the Fuels and Lubricants class. Table 3 shows the expenditure differences between the three weighting options (1, 2 and original) and the target base year weighted method for the Fuels and Lubricants class. Here the success of smoothing is less clear as the current method total expenditure is often closest to the target method expenditure. In many recent years the smoothed weights expenditure is closer to the target method than the current method (2008, 2009, 2012, 2013 and 2015). However in other cases the current method brings closer figures, particularly in the period up until 2008.

Figure 13: CPI weights for Fuels and Lubricants using 3 Year Averages options 1 and 2

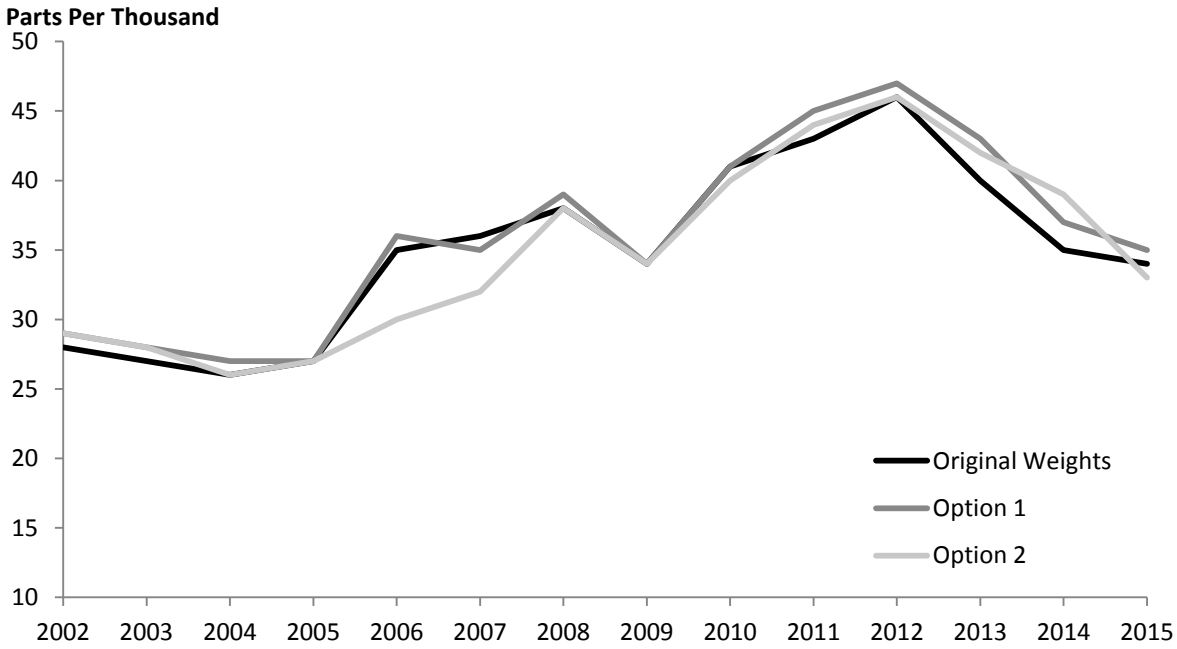


Table 3: Absolute differences between weighting methods and the base year method in expenditure (£ millions) used to create the CPI weights for Fuels & Lubricants 2002-2015

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Average
Option 1	1808	1402	81	5222	2823	340	1717	**5328**	4514	4147	**495**	4778	1946	**551**	2511
Option 2	1808	1401	**8**	5475	6300	2776	2207	5934	**3192**	4613	633	4605	**179**	1801	2924
Current Method	**726**	**518**	34	**4408**	**1136**	**214**	**400**	5964	4630	**236**	4065	**2248**	4308	4771	**2404**

7. Figures 14 and 15 illustrate this further. Where Figure 14 charts the data in Table 3 and Figure 15 plots the total expenditures of option 1 smoothed weights, target base year weights method and the current method for Fuels and Lubricants. We see that before 2010 the smoothed weights expenditure produce a smoothed series well while remaining relatively close to both the current and target method. However, onwards from this point the smoothed weights series is actually just as volatile as the current method even though it may actually be more tightly matched to the target base weight expenditure during some periods. Whilst the smoothed weights are volatile, the trend is closest to the target base period expenditure, which is also volatile.

Figure 14: Absolute differences between weighting methods and the base year method in expenditure used (£ millions) to create the CPI weight for Fuels & lubricants 2002-2015

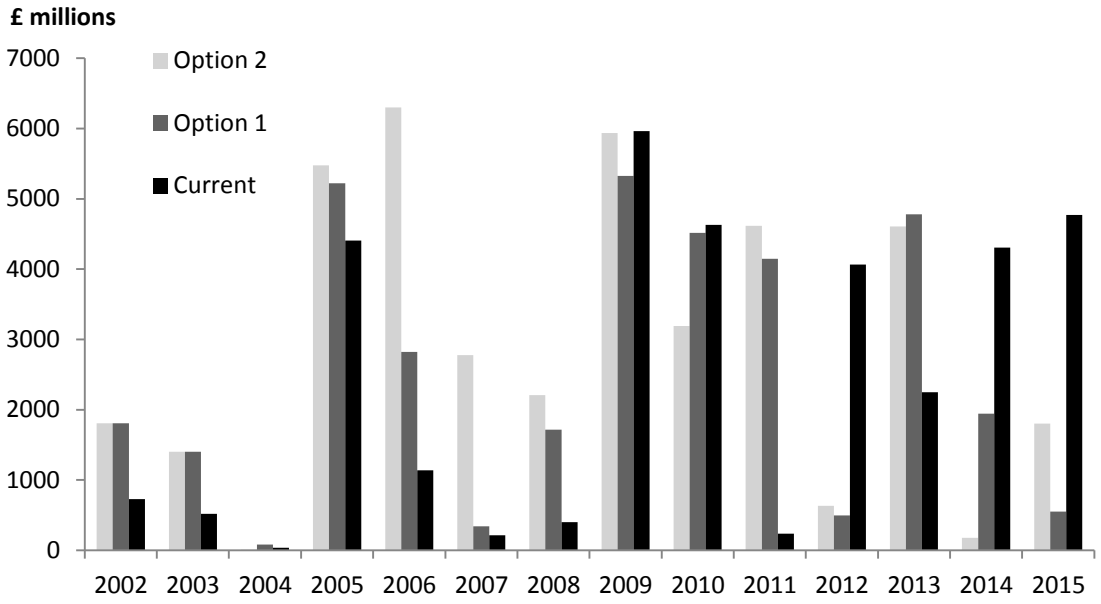
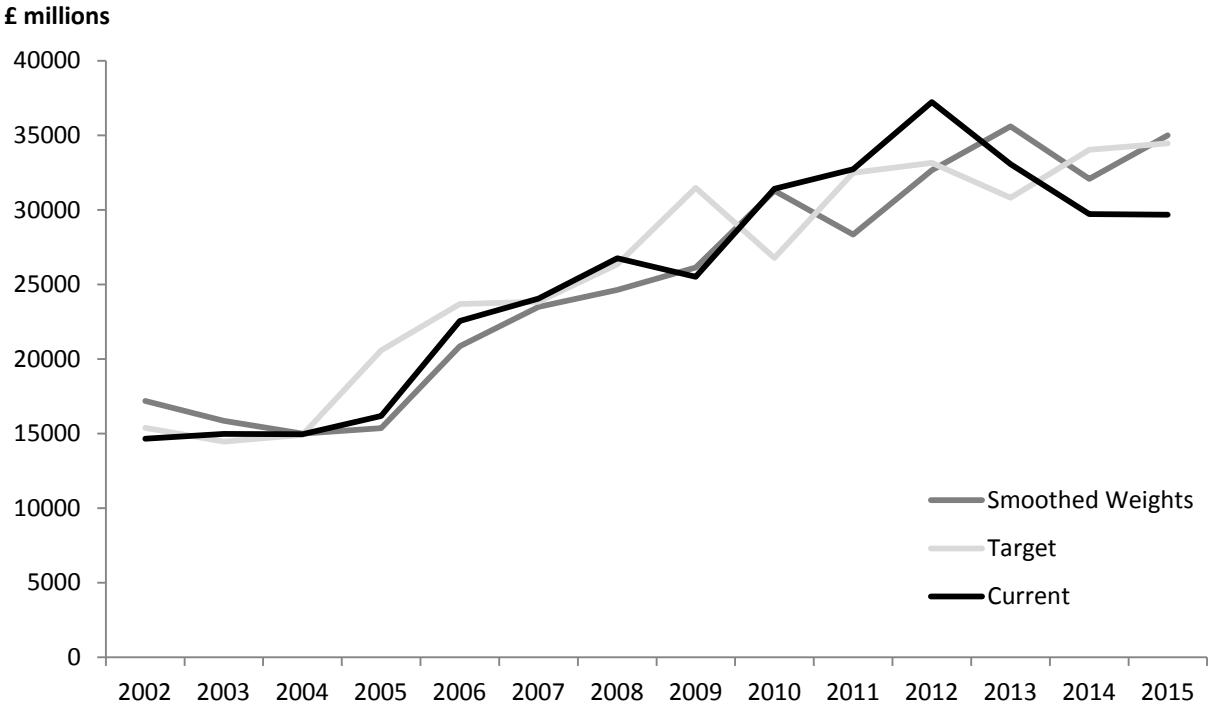


Figure 15: Expenditure used to create CPI weights for Fuels & lubricants 2002-2015



8. Weights for the Package Holidays class are derived using LCF data instead of HHFCE data. LCF data are not revised in later years therefore options 1 and 2 produce the same set of weights. The weights are displayed in Figure 3. Volatility in Package Holidays is more likely to represent sample variability in LCF data rather than particular circumstance in particular years.

9. The analysis which compares the smoothed expenditure to the expenditure there would be if we were creating a base year weighted index cannot be carried out for this class. The reason behind this is because the volatility in the package holidays series is most likely to be driven by sample variation in LCF data which is used to calculate the weights. Despite this we have included graphical analysis for package holidays in Figures 16 and 17.

Figure 16: Expenditure used to create CPI weights for Package Holidays

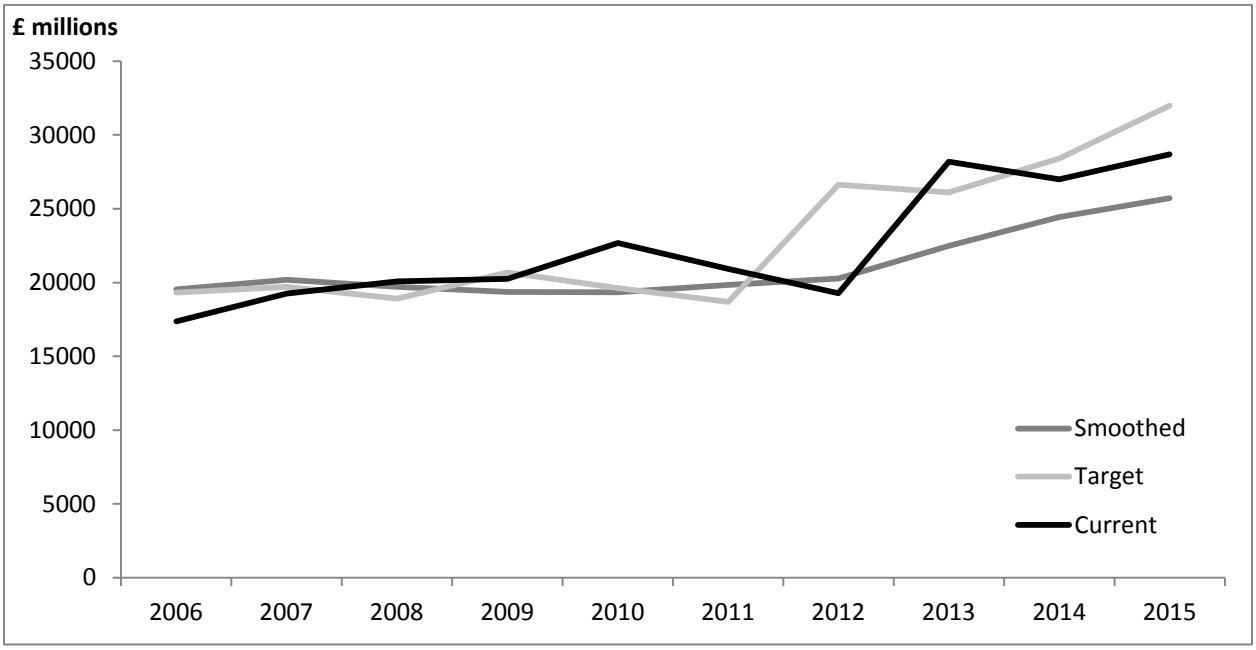
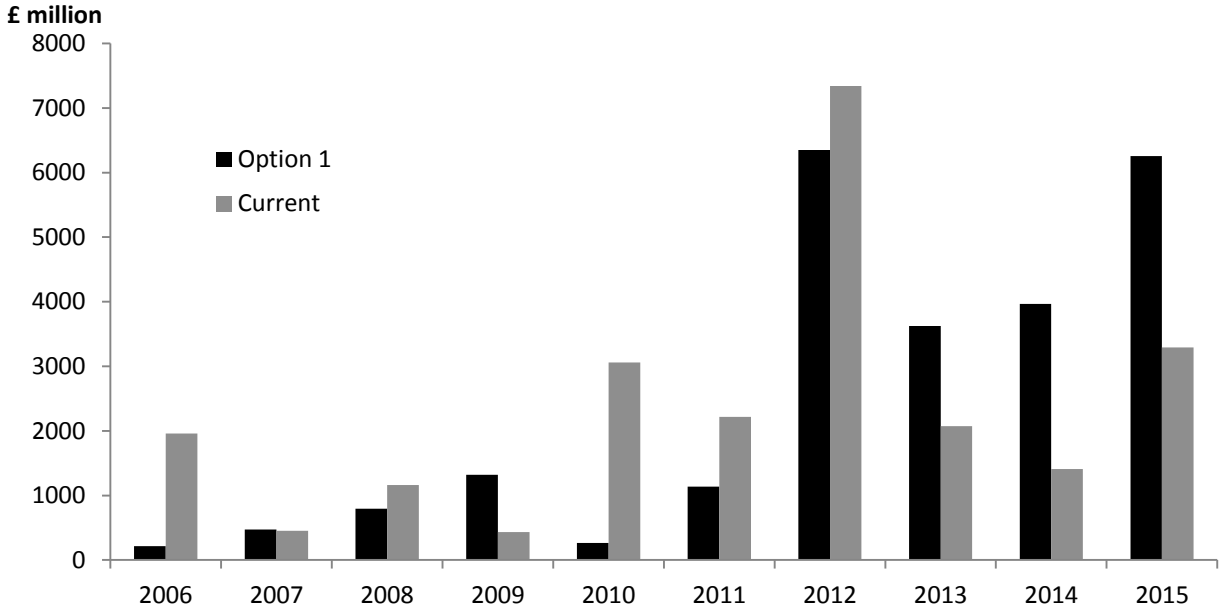


Figure 17: Absolute differences between weighting methods and the base year method in expenditure used (£ millions) to create the CPI weight for Package Holidays 2006-2015



Annex C - Summary

1. On this evidence, we believe the 3 year average should be used if smoothing is considered necessary. It is especially clear in the case for smoothing the Gas class. The 3 year average smoothed expenditure brings it closer to the base year expenditure. The option 1 scenario for this class comes out with the lowest total difference which is the option we prefer to use. This further illustrates the drawbacks of option 2 which has the greatest of differences away from the base year.
2. Whilst unsmoothed weights are often closer to the target base year weights, Figure 15 shows that the smoothed weights are a closer match over the last few years where the trend in the current method is rather steep, albeit with some volatility. However, option 1 is extremely close to that of the current method. When looking at the pure expenditure graph for Fuels and Lubricants (Figure15). We see that the expenditure for the smoothed weights results in data which is largely different to that of the current method, especially in the period after 2011.
3. The aim of price uprating is to better reflect expenditure in the period which one is price uprating to. Smoothing aims to remove any unrepresentative movements or volatility caused by this lag. As a result of this, unusual events from Y-2, such as a cold winter affecting the Gas class in 2010, then going on to affect weights in 2012. In the case of Gas, the smoothing method worked well to smooth out the effect of the cold winter without affecting other year's weights dramatically. This additional analysis identifies that smoothing via the use of option 1 and the 3 year average for Gas works successfully. However in the case of Fuels and Lubricants this provides a more mixed outcome but may still protect against future shocks or volatility.
4. Package Holidays also doesn't have enough evidence behind it to support smoothing in its class. In this class we see that although the 3 year average smoothes the data it results in a smoother series which is quite far away from the original weights in certain years. Thus although the volatility is eradicated and it preserves some of the natural movements in weights, at times they can be inaccurate.

Next Steps

5. From the analysis done regarding smoothing volatility in weights, the 3 year average (option 1) is the recommended method. Given the analysis presented in this paper we believe that smoothing should be applied. We are hopeful this paper provides the evidence to come to a conclusion on whether smoothing is required. We would also like to put in place regular checks on weights specifically to identify this type of volatility. After this we should be able to conclude on this recommendation.

Annex D: International comparisons

1. Little evidence was found of other countries smoothing volatile weights in CPI. Although Italy are using the three year moving average, it says that in some cases the weight reference period is more than 12months i.e. 3 years at levels below COICOP. Other than this there was no indication of smoothing methods being used by NSI's internationally.

2. Eurostat regulation indicates that smoothing can be put in place in cases where volatile weights are present. As the 3 year moving average is being used in Italy, despite maybe, not being used to smooth volatile weights gives further support utilising the 3 year moving average.

3. HICP regulation states "net weights" strictly compiled by only using information from the respective year may reflect one-off effects, while longer-term averages or smoothed weights might be representative of the generally underlying consumption structures. HICP regulation 1617/1999 already establishes the use of three year averages for insurance weights. It also says that, overall the number of cases in which smoothed weights seem to be preferable when weights are updated on an annual basis is limited. However, since the expenditure shares of these categories can be significant, it could be argued that a specific treatment of those weights is justified in terms of its potential quantitative impact on the overall result. Moreover, there are also product categories in which it might be the better strategy to smooth weights over a certain time span, thereby limiting the potential risk of contaminating the analysis of pure price changes via irregular movements over time in weights. While an annual update of weights is desirable in areas in which significant structural changes are identified, there are also products categories in which an annual update of weights might imply the risk to reflect more irregular movements.

4. In terms of actual countries individual Consumer Price indices, no evidence has been found of countries smoothing weights which tend to be volatile year on year. In New Zealand, CPI weights are affected by the economic situation at the time, particularly given that expenditure on some goods and services is collected in the Household Economic Survey on a one year recall basis, meaning that purchases for some items spanned the two year period from July 2008 to June 2010. Also, some goods and services have a weight reference period of three years (e.g. purchase of housing rents, and insurance).

Annex E – Impact of including smoothed weights (3 year) for Fuels and Lubricants, Gas and Package Holidays on CPI

1. Figures 18 and 19 show the impact of including smoothed weights (using a 3 year moving average – option 1) for Gas, Fuels and Lubricants, and Package Holidays in the CPI. The difference between the original CPI and a CPI including the smoothed weights discussed follow a similar trend.

Figure 18: Rounded impact of including smoothed weights (3 year) for Fuels and Lubricants, Gas and Package Holidays on CPI 2006-2014

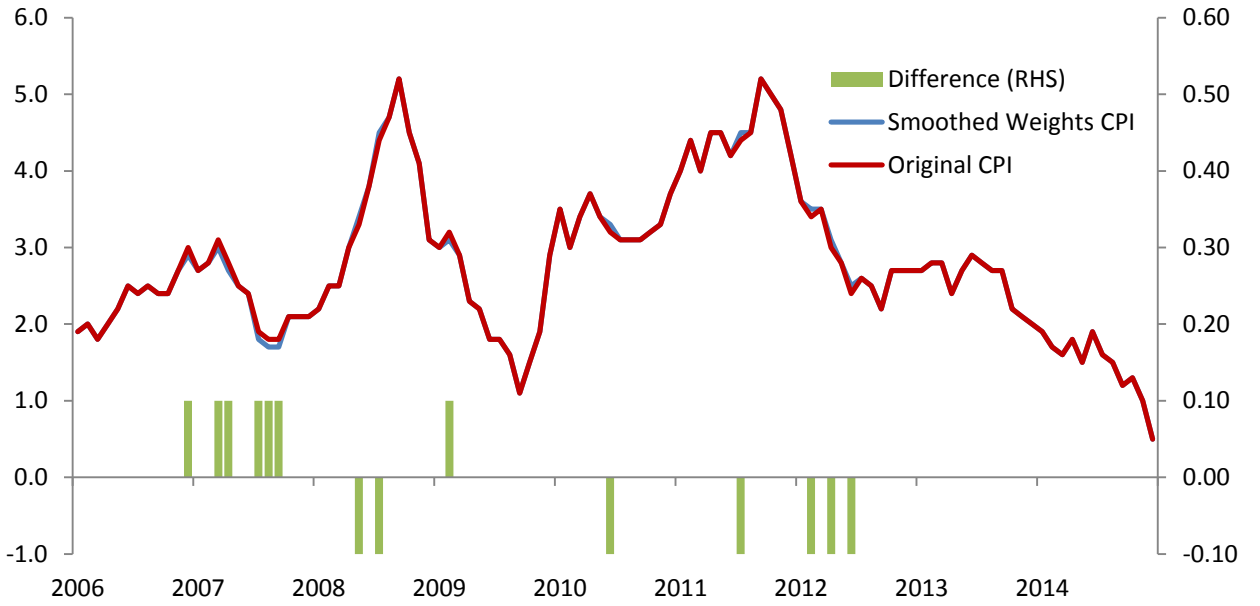


Figure 19: Unrounded impact of including smoothed weights (3 year) for Fuels and Lubricants, Gas and Package Holidays on CPI 2006-2014