NERA
ECONOMIC CONSULTING

Review of Ofgem's Draft Determination of Real Price Effects for RIIO-ED1

Prepared for the Energy Networks Association

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1. Overview

NERA has been commissioned by the Energy Networks Association (ENA) to critically review Ofgem's approach to Real Price Effects (RPEs) as part of its RIIO-ED1 Draft Determinations.[1]

1.1. Ofgem's Approach to Setting RPE Allowances for ED1

As Ofgem describes in its Draft Determinations documents, its RPE forecast is built up as follows:

- Ofgem selects a number of indices that it considers are relevant measures of the changes in DNOs' costs in the following categories: labour (general and specialised), materials, plant and equipment and transport and other costs. Reviewing Ofgem's choice of indices is outside the scope of this assignment, so we take these choices as given, and assume that the selected indices track reasonably closely the evolution of input prices faced by the DNOs;
- Ofgem then forecasts how each of the selected indices will change over the period between 2012/13, as this is the year used as a price base in DNOs' business plans and in the ED1 cost assessment, and 2022/23, at the end of the ED1 period. Ofgem uses a combination of third party forecasts of its selected indices (where available), and long-term averages. In Chapter 2 we review both Ofgem's use of third party forecasts, and its approach to calculating long-term averages;
- Ofgem then reduces its RPE forecast for the whole forecast period to account for the "structural change" in RPI that took place in 2010. Because DNOs' allowed revenues are indexed to changes in RPI, Ofgem asserts that a lower RPE is required in future. We review the case for applying this adjustment, and the required quantum of any adjustment, in Chapter 3;
- In a final stage, Ofgem weights the forecast indices together based on the share of a notional DNO's cost structure that each index is intended to track. Ofgem then inflates the DNOs' allowances using this combined "totex index" to compute a monetary value for the RPE allowance.. The method used to weight indices together is outside of the scope of this review.

1.2. Key Findings

As discussed in detail in the remainder of this report, we conclude (in Chapter 4) that, at a high level, Ofgem's approach constitutes a reasonable basis for forecasting the real input price inflation that DNOs will experience over the period to 2022/23. However, we have identified a number of errors and shortcomings in Ofgem's implementation of this approach that cause the result Ofgem obtains to materially *understate* the forecast RPE for ED1. The effect of the problems we have identified is summarised in the tables in Table 1.1, which

[1] Ofgem (30 July 2014), "RIIO-ED1: Draft determinations for the slow-track electricity distribution companies – Business plan expenditure assessment", https://www.ofgem.gov.uk/ofgem-publications/89068/riio-ed1draftdeterminationexpenditureassessment.pdf.

shows the impact of these factors on allowed RPEs. Table 1.2 shows our estimate of the associated impact on ED1 allowances by DNO.

Table 1.1
Summary of Errors in the Ofgem RPE Analysis: Impact on Forecast RPEs

Issue	Impact on RPEs *(percentage points)*
Short-term wage forecasts	+0.2% on General Labour in 2014/15-15/16 +1% on Specialist Labour in 2014/15-15/16
Estimation window	+0.4% on Specialist Labour from 2016/17
Estimation approach	0.29% (on average) on Totex in each forecast year from 2014/15
RPI adjustment	Around +0.25% on Totex each year +0.4% on Transport/Other Costs each year

Source: NERA

Table 1.2
Summary of Errors in the Ofgem RPE Analysis: Impact on ED1 Allowances (£Mn)

	Allowance using NERA ARMA/ARIMA Composite RPE indices (before smart grids and IQI) (£m)	Allowance using Ofgem RPE indices (before smart grids and IQI) (£m)	Difference in Allowance (£m)
ENWL	1,830.9	1,802.3	28.6
NPGN	1,259.6	1,239.9	19.7
NPGY	1,713.8	1,687.9	26.0
WMID	1,852.6	1,822.6	30.0
EMID	1,973.5	1,943.9	29.6
SWALES	1,031.8	1,014.9	16.9
SWEST	1,448.2	1,424.7	23.5
LPN	1,724.2	1,693.7	30.5
SPN	1,711.3	1,683.8	27.5
EPN	2,549.3	2,509.6	39.8
SPD	1,571.3	1,545.7	25.5
SPMW	1,679.7	1,654.0	25.7
SSEH	1,104.1	1,087.9	16.2
SSES	2,367.4	2,332.9	34.5

Source: NERA Analysis

2. Ofgem's Calculation of Forecast RPEs

2.1. Ofgem's Approach

Having selected the indices it considers to be relevant for tracking the costs of the inputs purchased by DNOs, Ofgem's approach to forecasting RPEs using these indices applies the following procedure:

- First, it calculates the (fiscal) year-on-year growth in each index that is considers is most relevant for measuring changes in DNOs' costs (see the preceding chapter). It then deducts RPI growth to obtain year-on-year real growth in each index, i.e. above the change in RPI.[2]
- It then averages across fiscal years to obtain a long-run historical real growth rate in each index:
  - In implementing this procedure, Ofgem aggregates forecasts of several indices within some of the individual cost categories it has defined.
  - For the materials (capex), specialist labour and plant/equipment categories, Ofgem uses two or more indices to calculate a long-run historical average growth rate. Ofgem calculates the long-run historical growth rate for each index and then takes an unweighted average of the results.
- These calculated long-term growth rates define the forecast RPEs across the various cost categories, albeit with some exceptions:
  - For 2013/14, the rate of change in each index is derived from the published (i.e. outturn) rates of change in the indices Ofgem has used for each cost category.
  - From 2014/15 onwards, Ofgem uses forecasts of each index, either based on long-term growth rates or, where available, third party forecasts. In practice, as stated in Chapter 1, third party forecasts are only used for general and specialist labour in 2014-15 and 2015-16. For these years, the Ofgem forecast is based on the HM Treasury "consensus" forecasts of real earnings growth.
- Finally, Ofgem converts these forecasts into an index with a base year of 2012/13, to ensure consistency with other elements of the RIIO-ED1 cost assessment, i.e. its index takes a value of 1 in 2012/13 which is inflated over time at the forecast RPE growth rate.

We review Ofgem's use of the HM Treasury short-term wage forecasts in Section 2.2, and its approach to calculating long-run historical average growth rates in Sections 2.3 and 2.4.

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[2] For the years since 2010, as discussed in the next chapter, it also reduces the historic rate of change in RPI by 40 basis points to account for its assumed impact of a step change in the series.

2.2. Use of Third Party Forecasts

2.2.1. Ofgem has failed to adjust for expected differences between inflation in public and private sector pay

As noted in Chapter 1, Ofgem uses indices tracking average earnings in the private sector of the economy to measure of the rate of wage inflation faced by DNOs. However, to forecast changes in this index in 2014/15 and 2015/16, Ofgem uses the HM Treasury "consensus" forecasts, which are for whole economy earnings growth, not for the private sector in particular. It chose the consensus forecasts because they were published more recently than alternative forecasts of inflation in private sector earnings (e.g. as published by the OBR).

Hence, Ofgem's short-term forecast of wages in the private sector, as faced by DNOs, may be biased if, during 2014/15-2015/16, wages in the economy as a whole (including both the private and public sectors) are expected to grow less quickly than wages in the private sector alone.

Ofgem dismisses this point, observing that "*Historically there has been no systematic difference between private sector and whole economy wage growth*" and that public and private wage growth ought to track one another "*in the longer-term*".[3]

However, Ofgem's defence of this approach is invalid, because the HM Treasury consensus forecasts are applied for 2014/15 and 2015/16, not over the long-term. Although the flow of labour between sectors may link the long-run averages of public sector and private sector wage growth, it is unlikely that this relationship will hold over a two-year period. Wages in one sector may fall for several years in a row before workers have the time and opportunity to switch to more lucrative jobs. Some workers may never have the opportunity to switch, since demand for their skills in the other sector may be limited.

This argument is not purely theoretical: there is strong evidence that public sector wage growth will lag private sector wage growth in the short term. When the government announced pay awards for 2014-15, it stated that "*continued pay restraint remains central to the government's deficit reduction strategy*". The Chief Secretary to the Treasury said that the government was delivering on its "*commitment to a one percent pay rise for all except some of the most senior public sector workers*".[4] Since 1% is well below the consensus forecast for whole economy wage growth in 2014-15, expected private sector wage growth must exceed expected public sector wage growth.

If public sector wages are expected to grow more slowly than private sector wages, estimates of whole-economy wage growth will understate the labour costs faced in the private sector (including DNOs). The obvious way to address this problem is to use an explicit forecast of private sector wages. However, such a forecast may not be available in recent publications. The next best option is to back out the implied private sector earnings growth forecast from the whole economy and public sector earnings growth forecasts.

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[3] Ofgem (July 2014), p. 144.

[4] UK Government: *"Public Sector Pay Awards for 2014-15"*, Website News Announcement, 13th March 2014.

The HM Treasury consensus publications do not contain forecasts for public sector earnings growth or the public sector share of employment, but the OBR *Economic and fiscal outlook* does. We used the most recent OBR figures to convert the HMT consensus forecasts for whole economy earnings growth into forecasts for private sector earnings growth.[5] We then used Ofgem's methodology to convert our results into RPEs for 2014/15 and 2015/16.

It is not possible to compare our results directly to those of Ofgem because more recent HM Treasury consensus data has become available following the publication of the Draft Determination. However, we compare our results to those we would have obtained if we had applied Ofgem's methods to the most recent data. Using the August HM Treasury consensus forecast,[6] we find that private sector earnings are expected to fall by 0.7% in 2014/15 and by 0.1% in 2015/16. If we had failed to adjust for the private-public discrepancy, we would have found that DNOs' general labour costs were expected to fall by 0.8% in 2014/15 and by 0.3% in 2015/16.

Table 2.1
Converting Whole Economy Forecasts to Private Sector Forecasts

		Calendar		Fiscal	
Source	**Forecast**	**2014**	**2015**	**2014-15**	**2015-16**
HMT	Average earnings	1.6%	2.9%	-	-
OBR	Public sector paybill per head growth	1.3%	1.9%	-	-
-	Implied private sector pay growth	1.6%	3.1%	-	-
OBR	RPI	2.5%	3.4%	-	-
-	***Whole economy real pay growth***	-0.9%	-0.5%	***-0.8%***	***-0.3%***
-	***Implied private sector real pay growth***	-0.8%	-0.3%	***-0.7%***	***-0.1%***

Source: NERA analysis

Hence, this analysis shows that Ofgem's method to forecasting general labour costs for 2014/15 and 2015/16 understates the RPE based on the private sector wage growth index by around 0.1 to 0.2 percentage points.

2.2.2. Ofgem's short-term forecasts ignore the faster growth observed historically in the wages paid to specialist labour

Ofgem applies this short-term forecast of wage inflation in the economy as a whole to both the specialised and general labour categories. It adopts this approach on the basis that "*a*

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5 We used the following relationship: whole-economy wage growth = public sector share of employment * public sector wage growth + private sector share of employment * private sector wage growth. We used 16% as the public sector share of employment – estimates of this vary widely, but 16% appears conservative as, for example, Chris Rhodes: "Public Sector Employment and Expenditure by Region", House of Commons Note, 14th July 2014, cites 18%, but this is for the UK as a whole, which includes higher totals for Northern Ireland for example.

6 As used by Ofgem.

general labour forecast is a good proxy for movements in specialist labour prices in the short term".[7]

It is not reasonable to assume that specialist wage growth will *exactly match* general wage growth. By using the BEAMA Electrical Labour and BCIS Civil Engineering indices to calculate long-run growth rates for specialist labour, Ofgem acknowledges that industry-specific indices contain information about changes in labour costs that economy-wide indices do not. It is therefore inconsistent for Ofgem to ignore this distinction when setting RPEs at the beginning of the regulatory period.

Since there are no industry-specific earnings growth forecasts, the simplest approach is to add a specialist labour premium to the forecast of general labour costs. This approach combines historical evidence on wage growth differentials with expected economy-wide movements in labour market conditions.

We calculated a specialist labour premium in three steps. First, we averaged growth rates across the BEAMA and BCIS indices to create a single series of specialist earnings growth rates. Second, we took the difference between specialist earnings growth and whole economy earnings growth in each year for which both figures were available. (We used the ONS AWE Whole Economy index rather than the ONS AWE Private Sector index because we planned to add the specialist wage premium to a whole economy forecast, not a private sector forecast.) Third, we averaged across years to obtain a specialist labour premium of 1.0%.

Table 2.2
UK Real Wage Growth (1997-2014)

Specialist wage growth (BEAMA and BCIS)	1.5%
Whole economy wage growth (ONS)	0.5%
Difference	***1.0%***

Source: NERA analysis

To reflect the long-run trend of specialised labour costs rising faster than earnings in the economy as a whole, Ofgem should therefore add a premium of around 1 percentage point to the HM Treasury consensus earnings growth forecasts when calculating the specialist labour RPE for 2014/15 and 2015/16. This approach also ensures consistency with the RPE indices for 2012/13-2013/14 and 2016/17-2022/23, which are based on long-run trend growth in specialist labour indices.

2.2.3. Ofgem's use of an earnings index to forecast labour costs may understate wage inflation

An allowance for real price effects should ideally track the *price* of the factor inputs required by the DNOs. However, there is a risk that forecasts of Average Weekly Earnings (AWE),

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[7] Ofgem (July 2014), p. 116.

which Ofgem uses for the labour RPE, conflate two effects: changes in the price of labour (i.e. changes in wages), and changes in the composition of employment in the economy. The composition effect is the effect on average earnings of a change in the number of people working in jobs or professions with different rates of pay, as opposed to an increase in wages for a given set of jobs within individual companies.

The AWE is calculated as estimated total pay for the whole economy, divided by the total number of employees. Changes in the composition of the workforce (e.g. a shift of the relative number of employees between high-paying and a low-paying industries, changes in the age structure of employees or mix of skills etc.) would therefore be reflected in the AWE, as the ONS' Quality and Methodology Information and the Bank of England both note.[8,9]

We estimate that the composition effect could have an impact of about 16bps on the labour RPE,[10] depressing the AWE growth, suggesting that outturn labour RPE might be in fact higher than the measured growth by the AWE index in the near term. However, whether and to which extent DNOs experience a different composition change to the overall economy is difficult to assess given limited data, and the quantum of this effect can be volatile from year-to-year. For these reasons, we take a conservative approach and do not suggest any revision to Ofgem's forecast to remove the composition effect from forecast RPEs.

2.3. Estimation Window

As described in Chapter 1, Ofgem forecasts RPEs based on long-run trend growth in its selected price indices, or, where third party forecasts are available in the short-term, it uses these alternative sources and then reverts to forecasts based on historic average growth rates in the long-term. Ofgem's approach of extrapolating long-term historic trends, using as much historic data as possible to estimate trend growth rates, is an objective forecasting method in cases where credible third party forecasts are not available.

2.3.1. In principle, we support the use of the longest possible data series to calculate long-term growth rates

The choice of an estimation window to calculate long-term average growth rates, and thus extrapolate long-term historic trends, is guided by two considerations: the number of data points in the final sample and the relevance of the final sample to the coming regulatory period. In general, these may be competing considerations. A longer time series will produce a more precise estimate of the average growth rate *if* there have not been any major

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8 ONS (2011), "AWE Quality and Methodology Information", http://www.ons.gov.uk/ons/guide-method/method-quality/quality/quality-information/business-statistics/quality-and-methodology-information-for-average-weekly-earnings.pdf, p.2.

Bank of England (2014), "Inflation Report", http://www.bankofengland.co.uk/publications/Pages/inflationreport/2014/ir1403.aspx, p. 34.

9 Note that number of hours worked are not per se affecting the AWE, they may have an indirect impact on the composition effect if additional hours worked are linked to an overtime pay.

10 Based on the AWE data that Ofgem uses since financial year 2001/02, removing the composition effect would lead to an increase in yearly RPE growth of about 25bps. The composition effect is reportedly not present in the AIE data Ofgem uses for earlier years. Therefore the change to Ofgem's long-run average is less than 25bps – it reduces to 16bps per year.

disruptions to the processes driving that growth (such as permanent shifts in the supply of or demand for a particular input). Otherwise, additional data from further back into the history of a data series may not contain additional information about likely future growth rates.

The implications of a given movement in the data are not always clear. For example, it may not be obvious (over a relatively short time series) whether an observed shock to a series is a one-off event or part of a fairly regular pattern. Statistical tests can help, but they require further assumptions (such as a particular distribution of growth rates) and are unlikely to give conclusive results over relatively short time series. Hence, in our view, the most objective approach is usually to rely on the longest history of data available, unless there is clear evidence of a structural change in the series.

We recommend that Ofgem considers whether structural breaks have occurred in the historic time series it uses to forecast RPEs, but our review of the indices it used did not provide any clear evidence of a structural break.

2.3.2. However, in practice, Ofgem does not use all available data

As noted above, Ofgem states that it *"uses the longest possible data series for calculating the historical average"*,[11] which is an approach that we support in principle. However, Ofgem has not followed this approach consistently. For instance, although some of the indices that Ofgem used started relatively recently, some of these indices have predecessors that can be used to extend the data series. Because such ONS indices are associated with Standard Industrial Classification codes, it is straightforward to match current indices to their predecessors. Additionally, some index providers break their indices into parts associated with different base years. These can easily be consolidated into a single index with a single base year.

In particular, we found predecessors (with different index labels) for two of Ofgem's plant and equipment indices. We also found longer time series for both of its existing labour indices and one of its existing plant and equipment indices.[12,13]

- The extensions to Ofgem's labour indices are shown as dashed lines in Figure 2.1. The average real growth rate over the entire historical period is 1.8% (shown as the highest

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11 Ofgem (30 July 2014), "RIIO-ED1: Draft Determinations for the slow-track electricity distribution companies – Business plan expenditure assessment", https://www.ofgem.gov.uk/ofgem-publications/89068/riio-ed1draftdeterminationexpenditureassessment.pdf, p. 114.

12 We appended PLLQ (Machinery and equipment input PPI) to K5W6 (Machinery and equipment input PPI). We appended PLMH (Machinery and equipment output PPI) to K389 (Machinery and equipment output PPI). The older data is from the *Annual Abstract of Statistics.* In addition, we found longer time series for BCIS 70/1 (Labour and supervision in civil engineering), BEAMA (Electrical labour) and BCIS 70/2 (Plant and road vehicles: providing and maintaining).

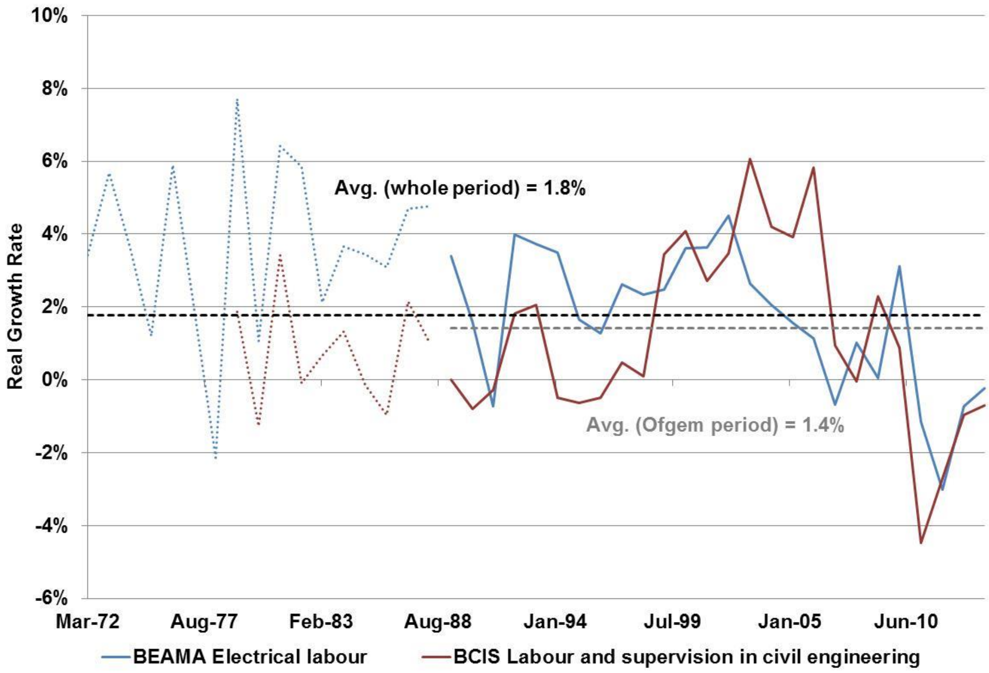
13 We used these indices to produce a single (extended) series of growth rates for each index. We did not make any additional modifications to Ofgem's methods: we simply applied those methods to a longer time series. For visual clarity, the averages in the figure do not include the 40bp deduction for the RPI "formula effect". Applying the deduction gives real growth rates of 1.4% and 1.0% respectively.

horizontal black dashed line in the figure).[14] This is almost 50 basis points above the average over the historical period selected by Ofgem.

- The extensions to Ofgem's plant and equipment indices are shown as dashed lines in Figure 2.2. The average over the entire historical period (before the deduction for the RPI "formula effect") is -0.9%. In this case, the average growth rate using the extended series is exactly the same as the average over Ofgem's chosen estimation window.

Given Ofgem's belief that using the longest possible estimation window produces the most reliable estimate of the long-term growth rate in the RPE, it should use the growth rates given above instead of its current growth rates. Before any deduction for the RPI "formula effect", the appropriate long-term growth rate is therefore 1.8% for specialist labour, and no change is required to the plant and equipment RPE.

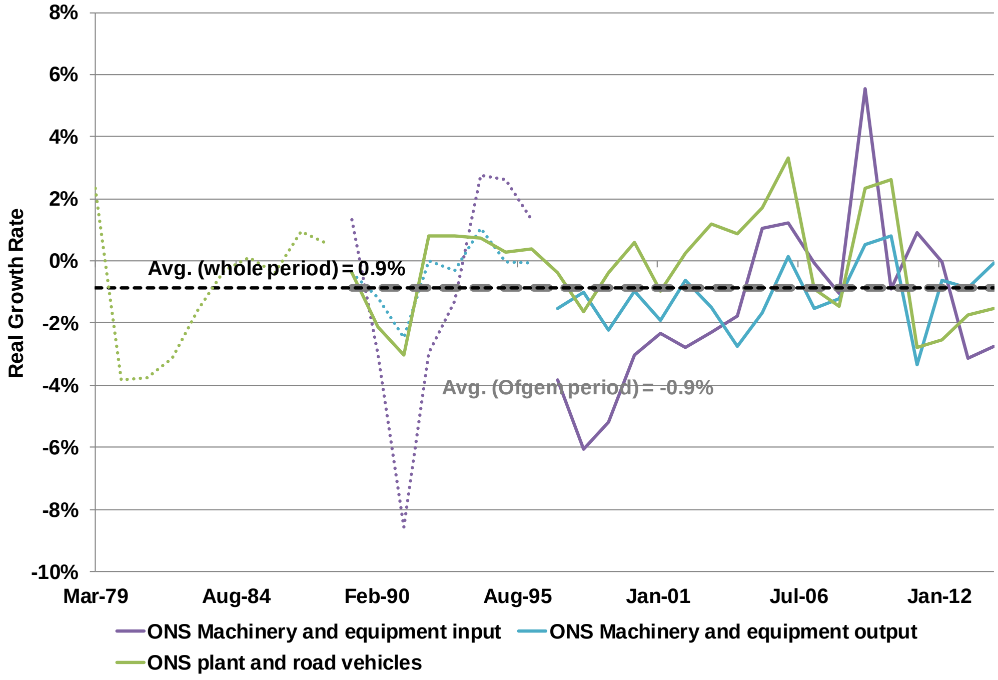
Figure 2.1
Extensions to Ofgem's Labour Indices



Source: NERA analysis

[14] We use the same method for aggregating indices that Ofgem does: we find the average growth rate for each index and average across the results.

Figure 2.2
Extensions to Ofgem's Plant and Equipment Indices



Source: NERA analysis of ONS data

2.4. Estimation Technique

2.4.1. Alternative approaches to extrapolating long-term trends

As described above, we agree that basing RPEs on long-term historic trends constitutes an objective approach in conditions where reliable third party forecasts of relevant indices are not available. However, in practice, there exists a range of approaches for calculating long-term growth rates and extrapolating historic trends in data series, and Ofgem's Draft Determinations documents do not consider alternatives or justify the chosen approach. A range of potential methods for extrapolating historic trends in data series are as follows:

1. **Long-run historic arithmetic average:** this is Ofgem's approach to estimating RPEs. It entails taking a long series of annual growth rates for the index in question, summing all observations and dividing this sum by the total number of observations. In Ofgem's analysis, this estimated average is used to calculate the RPE where third party forecasts are not available.
2. **Long-run historic geometric average:** (sometimes called the Compound Annual Growth Rate or CAGR) this approach is similar to Ofgem's approach, however it uses a geometric rather than an arithmetic average. The geometric average takes the multiplicative product of the index under examination. The *nth* root of this product is then calculated, where *n* represents the number of observations used to compute the product. Under this approach, this estimated geometric mean growth rate would be used to define the long-term RPE.
3. **Simple Ordinary Least Squares (OLS) regression:** a simple OLS regression can be used to estimate the relationship between the natural logarithm of an index and a trend

growth rate, according to the model shown below. The β coefficient in the equation below represents the long-term average growth rate in the index, which would be used to define the long-term RPE.

$$Ln\ (Deflated\ Index)_t = \alpha + \beta \times Time\ Trend + e_t$$

4. **Autoregressive Integrated Moving Average (ARIMA) regression:** this approach uses the same model as method (3), but the random error component, e_t, is modelled as an Autoregressive Integrated Moving Average (ARIMA) process, and the index may be differenced a number of times (the "I" in ARIMA) to create a "stationary" time series process.

   The use of an ARIMA process allows explicit modelling of the "persistence" of shocks to the cost index. In other words, if the index is currently below trend due to a negative shock, the ARIMA modelling approach allows one to compute a forecast of how quickly it returns to the long-term trend. The length of "persistence", and the degree to which the series converges to trend following a random shock, can be calibrated statistically by selecting the ARIMA process that best-fits the historic data.[15] Under this approach, the RPE would be modelled by generating predicted values from the ARIMA model.

$$Ln\ (Deflated\ Index)_t = \alpha + \beta \times Time\ Trend + e_t$$

$$e_t = \rho_1 \times e_{t-1} + \ldots + \rho_m \times e_{t-1} + \varphi_0 \times u_t + \varphi_1 \times u_{t-1} + \ldots + \varphi_n \times u_{t-n}$$

2.4.2. Evaluation of estimation approaches

Table 2.3 evaluates these alternative approaches to extrapolating long-term trend growth in price indices. For the reasons described in the table, we consider that it would be possible to obtain more reliable estimates of future RPEs than those emerging from Ofgem's approach by using the ARIMA approach. We consider that the minor increase in complexity surrounding this approach is justified on the grounds that it has much more desirable theoretical properties.

[15] We would typically run a series of 25 models that allowed for an AR process (i.e. *m*) of between 0 and 4 lags, an MA process (i.e. *n*) of between 0 and 4 lags. Then, we choose between alternative model specifications by comparing the Bayesian Information Criterion statistic across models.

Table 2.3
Evaluation of Possible Approaches to Extrapolating Long-Term Trends in Cost Indices

	Advantages	Disadvantages
Arithmetic Average	• Very transparent, used widely in regulation • Produces a reasonably accurate estimate of the long-term average growth rates	• If used in forecast years, makes no allowance for deviations from trend, and the possibility that indices will revert to trend in the future • Does not account for the effects of macroeconomic cycles on estimate trend growth rates, e.g. if the estimation window includes more recessionary than growth periods, or vice versa.
Geometric Average	• Produces a *precise* estimate of the trend growth rate achieved between specific points in time[16]	• But, can be sensitive to particular start and end points in the series, making it potentially unreliable as a guide to the future • Same disadvantages as the arithmetic average approach
OLS	• Like the arithmetic average approach, it is transparent and produces accurate growth rates • Less widely used in regulation	• Slightly more complex than arithmetic or geometric average approaches • Otherwise, it has similar disadvantages to the arithmetic average approach
ARIMA	• Can estimate a trend growth rate, as per other methods • But has theoretically desirable properties, as it better accounts for short-term dynamics, and provides a more reliable basis for forecasting inflation where indices are currently above or below trend	• More complex, but can be implemented relatively easily in standard statistical software packages • Possible scope for subjectivity in calibrating ARIMA processes, but this can be mitigated, to some degree, by using econometric model selection procedures, e.g. the Box-Jenkins procedure, drawing on the Bayesian Information Criterion.

Source: NERA

16 For example, a two year index with values 100, 150, 120 has growth rates of 50% in year 1 and -20% in year 2. The arithmetic average of the two growth rates is 15%, yielding an estimated index of 100*(1+15%)*(1+15%) = 132.3. The geometric average of the two growth rates is 9.5%, yielding an estimated index of 100*(1+9.5%)*(1+9.5%) = 120, exactly as the actual index.

However, we are not trying to exactly represent an end point of our RPE series, as we do not know the end point. Instead, we are calculating the best estimate of expected growth in the next year, for which the arithmetic average is more accurate assuming that each year is an independent draw from an identical distribution; a plausible assumption.

2.4.3. Impact of using the more reliable ARIMA method for rolling forward long-term growth rates

We show the RIIO-ED1 forecasts of the totex index using each of these four approaches in Figure 2.3. The chart shows that the ARIMA approach starts lowest, but finishes highest as the estimated short-term dynamics return to the trend rate of growth. The growth rates for the index extrapolated using arithmetic and geometric averages and the OLS method all increase linearly since these methods estimate a single long-run trend rate.

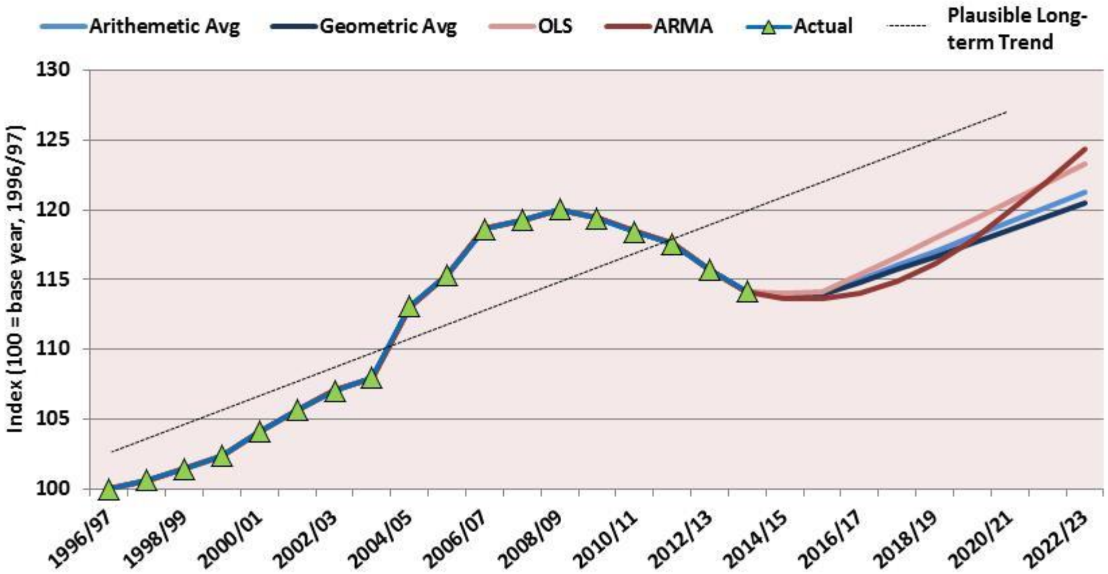
In statistical terms, all three methods besides the ARIMA modelling approach effectively assume permanent persistence of the recent shocks to the price indices that occurred during the recession. Or in other words, they assume the time series processes all follow a random walk with a drift term defined by the long-run average growth rate, in which the indices have no tendency to revert to mean growth rates. In practice, the assumption that these indices will not revert to trend, i.e. that they follow a random walk, can be tested, and where the assumption of a random walk does not hold, a mean reverting ARIMA process is more appropriate and should be applied.

Given that many price indices are currently below trend, the effect of using a mean reverting ARIMA process is generally to increase the forecast growth rate in the next few years, as such models will tend to forecast reversion to trend, as Figure 2.3 illustrates. However, the figure also shows that growth rates using the ARIMA approach may be lower than trend in the very short-term, reflecting a slow return to the trend growth rate. The ARIMA approach therefore mimics the cyclical movement around the trend that is typically seen in the outturn indices over their history. In contrast, Ofgem's forecast based on the arithmetic average growth rates, and indeed the other forecasting approaches, fail to revert to this long-term trend.

The overall impact of using the ARIMA approach instead of the arithmetic average approach therefore varies by year, but we have estimated (see more details in 0) it increases the estimated annual RPE for totex by between 0.01 and 0.7 percentage points on average over the 2015/16-2022/23 period.[17] Therefore a central estimate of the impact of using the ARIMA approach is an increase of 0.29 percentage points on average over the 2014/15-2022/23 period.

[17] In our differenced model, ARIMA(p,1,q), we find an annual average growth rate increase of 0.01 percentage points above Ofgem's arithmetic average long-term trend rate. In our non-differenced model, ARIMA(p,0,q), we find an annual average growth rate increase of 0.7 percentage points above Ofgem's arithmetic average long-term trend rate. See 0 for more details.

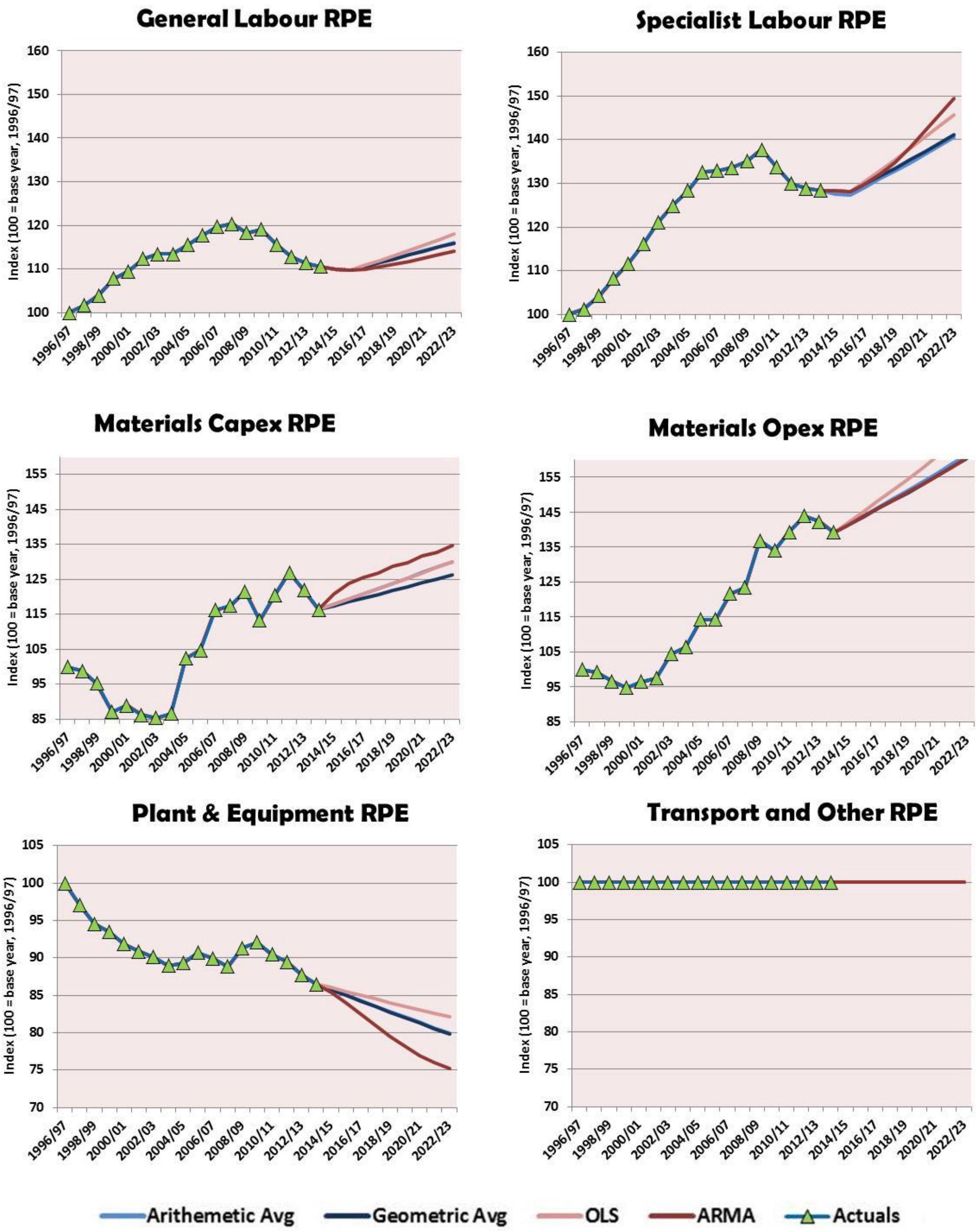
Figure 2.3
Forecast Totex RPE Using Different Estimation Methods



Source: NERA analysis. Note: all forecasts include HMT Consensus forecasts for labour for 2014/15 and 2015/16, as per Ofgem's approach. The dashed black line in the chart shows a plausible long-term trend, based on Ofgem's arithmetic average of the long-term trend (i.e. the dashed line is parallel to Ofgem's arithmetic average forecast line). The chart shows the average yearly forecasts between the ARMA and ARIMA models, described in Appendix A.

Figure 2.4 shows ARIMA forecasts for each of Ofgem's RPE categories, which are weighted together, as per Ofgem's approach, to generate the totex index shown in Figure 2.3. As is reflected in our forecast of the totex index, the indices for individual categories of inputs all exhibit stronger reversion to trend when using the ARIMA approach than the arithmetic growth rate approach.

Figure 2.4
Comparison of Estimation Methods by Cost Category



Source: NERA analysis. Note: labour forecasts include HMT Consensus forecasts for 2014/15 and 2015/16, as per Ofgem's approach. The chart shows the average yearly forecasts between the ARMA and ARIMA models, described in 0.

2.5. Conclusions

Although we consider that some features of Ofgem's approach to forecasting RPEs for the ED1 period are objective and robust, in this chapter, we have identified a range of problems with the implementation of this approach that mean it is understating the forecast RPE for the 2012/13-2022/23 period:

- Ofgem has used third party forecasts of wage growth in the economy as a whole to forecast private sector wage growth in 2014/15 and 2015/16. This approach is biased, because public sector wage growth is currently expected to be lower than private sector wage growth in the next 2 years;
- Ofgem has also used third party forecasts of wage growth in the economy as a whole to forecast wage growth for specialised labour in 2014/15 and 2015/16. This approach is biased, because wage rates for specialised labour have tended to grow faster over time than wages for general labour;
- If Ofgem is to maintain consistency with its own methodology, it must use longer time series for specialist labour and plant/equipment in making its forecasts, as more published data is available than it has used; and

We recommend that Ofgem use an ARIMA approach to extrapolating long-term historic trends, in order to account for the fact that many indices are currently "below trend". Failing to adopt such an approach, and extrapolating the current value of indices using long-term historic average growth rates, ignores the potential for indices to revert to their underlying long-term trends as the economy recovers from the recent recession.

3. Ofgem's Adjustment for the "Step Change" in RPI

In the Cost Assessment Appendix to its Draft Determination, Ofgem adjusts its RPE calculations for a 2010 "step change" in RPI.[18] It makes three adjustments. First, it subtracts 40bp from measured RPI beginning in fiscal year 2010/11. Second, it subtracts 40bp from the HM treasury consensus forecasts of RPI before using them to forecast real wage growth. Third, it subtracts 40bp from its long-term growth forecasts for each input category.

Section 3.1 provides the necessary context for understanding Ofgem's decision, and Section 3.2 discusses Ofgem's rationale. Section 3.3 argues that the 40bp adjustment is arbitrary in light of prior changes to the RPI. Section 3.4 considers the size of the adjustment that ought to be made, *assuming* that Ofgem is justified in making one. Section 3.5 discusses the impact of possible future changes to RPI. Section 3.6 considers the implications of the adjustment for the Transport/Other input categories.

3.1. Background

There is more than one method for aggregating individual price changes into an economy-wide index. The RPI and CPI use different formulae at the lowest level of aggregation: an arithmetic and a geometric average respectively. The implication is that the RPI is more sensitive than the CPI to increases or decreases in variation in the sample of price changes.[19] If a modification to ONS data collection methods raises the variation in a quantitatively important sample, the wedge between the RPI and CPI is likely to increase.

In 2010, ONS made some modifications to its data collection methods for clothing and footwear. These modifications raised the variation of the relevant samples. In December 2010, ONS analysed the wedge between the RPI and CPI and concluded that the portion of the wedge attributable to the difference in formulae ("the formula effect") had gone up by 32bp as a result of the change.[20] The OBR said in a 2011 working paper that it expected the long-term effect of the change to fall between 30 and 50bp.[21] More recently, the Bank of England said in its February 2014 inflation report that it expected the formula effect that influences the difference between CPI and RPI to remain about 40bp above its pre-2010 average.[22]

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[18] Ofgem (30 July 2014), "RIIO-ED1: Draft determinations for the slow-track electricity distribution companies – Business plan expenditure assessment", https://www.ofgem.gov.uk/ofgem-publications/89068/riio-ed1draftdeterminationexpenditureassessment.pdf, p. 119.

[19] ONS (December 2010), "CPI and RPI: Increased impact of the formula effect in 2010", http://www.ons.gov.uk/ons/guide-method/user-guidance/prices/cpi-and-rpi/cpi-and-rpi--increased-impact-of-the-formula-effect-in-2010.pdf, p. 3.

[20] Ibid., p. 1.

[21] Miller, R. (November 2011), "The long-run difference between RPI and CPI inflation", http://budgetresponsibility.org.uk/wordpress/docs/Working-paper-No2-The-long-run-difference-between-RPI-and-CPI-inflation.pdf, p. 10.

[22] Bank of England (February 2014), "Costs and prices", *Inflation Report 2014*, http://www.bankofengland.co.uk/publications/Documents/inflationreport/2014/ir14feb4.pdf, p. 34.

3.2. Ofgem's Decision

In its ED1 Draft Determination, Ofgem states that RPI has "*experienced a step change relative to underlying cost inflation in the economy*".[23] Specifically, Ofgem asserts, RPI growth will be 40bp higher each year than it would have been in the absence of a step change. Since DNOs' cost allowances are indexed to the RPI, this means that DNOs will receive larger allowances than they would have received in the absence of a step change. Ofgem's adjustments are attempts to offset this effect.

Ofgem refers the reader to its February 2014 decision[24] on the equity market return for RIIO-ED1 for more detail. In that decision, Ofgem states that "*a problem with the calculation methodology*" for the RPI has led to "*an enduring increase of around 0.4 per cent per annum in the RPI*".[25] It notes that the RPI has been de-designated as a National Statistic (for reasons related to the formula effect).

Ofgem's decision is somewhat misleading. The UK Statistics Authority did not de-designate the RPI as a National Statistic because of the 2010 changes or the rise in the formula effect. It did so because ONS was *not* willing to contemplate major changes to the RPI, such as a switch from an arithmetic to a geometric mean.[26] ONS had declined to bring the RPI in line with international practice, stating that "*there is significant value to users in maintaining the continuity of the existing RPI's long time series without major changes*".[27]

Therefore, the RPI was de-designated as a National Statistic precisely *because* ONS wanted to preserve its suitability for long-term indexation. It was not de-designated because of any alleged step change. Neither the UK Statistics Authority nor ONS has ever recommended that users adjust for changes to the RPI formula by deducting 40bp per year (or making any adjustment whatsoever).

3.3. Prior Changes to the RPI

ONS publishes a new Consumer Price Indices Technical Manual[28] every year. This publication demonstrates that the CPI and RPI are subject to frequent methodological adjustments. (ONS considers all of these to be "routine" updates, in contrast to the "major" changes considered and rejected in 2013.) For example:

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23 Ofgem (July 2014), p. 119.

24 Ofgem (17 February 2014), "Decision on our methodology for assessing the equity market return for the purpose of setting RIIO-ED1 price controls", https://www.ofgem.gov.uk/ofgem-publications/86366/decisiononequitymarketreturnmethodology.pdf.

25 Ofgem (17 February 2014), p. 9.

26 UK Statistics Authority (March 3013), "Assessment of compliance with the Code of Practice for Official Statistics: the Retail Prices Index", http://www.statisticsauthority.gov.uk/assessment/assessment/assessment-reports/assessment-report-246---the-retail-prices-index.pdf, p. 2.

27 ONS (10 January 2013), "National Statistician announces outcome of consultation on RPI", http://www.ons.gov.uk/ons/dcp29904_295002.pdf, p. 1.

28 See ONS (2014), *Consumer Price Indices Technical Manual*, http://www.ons.gov.uk/ons/rel/cpi/consumer-price-indices---technical-manual/2014/index.html.

- Prior to 1994, collectors used their own judgment to choose outlets within a particular location. Afterwards, formal sampling methods were introduced. However, collectors continued to use their own judgment to choose items in a particular category within a particular outlet. In 2004, formal sampling methods were applied to certain goods.[29]
- Prior to 1995, the choice of locations for sampling "*largely reflected the location and availability of civil servants*" required to carry out the work. In 1995, ONS introduced strict rules for selecting locations. By 1999, it had moved to complete random sampling.[30]
- In 1996, ONS decided to draw from fewer locations but to collect more quotations for highly variable commodities and fewer quotations for less variable commodities.[31]
- In 2000, ONS introduced a new procedure for determining locational boundaries. Locations were defined around a central shopping centre and "grown outward" at a rate depending on the level of retail activity.[32]
- Prior to 2011, prices for out-of-stock seasonal items were carried forward until a new price was available. After 2011, ONS introduced a method for calculating "imputed" prices.[33]
- Various other changes pertaining to particular categories of items (e.g. telephone service, new cars, fruits and vegetables) have been introduced over time.

It is simply not practicable for Ofgem to review every change in the RPI and adjust its RPE calculations accordingly. In this case, Ofgem has proposed a particular adjustment based on a figure reported in an OBR working paper, and its focus on the 2010 step change was not part of a regular series of reports but an investigation of an issue that happened to interest the author.

There are three implications. First, Ofgem cannot reasonably expect to be informed about every quantitatively important change to the RPI in future. Second, even if it were perfectly informed, it would have an incentive to "cherry-pick", imposing deductions for changes that exert upward pressure on the RPI but dismissing changes that exert downward pressure as unimportant. Third, Ofgem certainly has not analysed and corrected for past methodological changes listed above. Some of these changes may have had large quantitative effects, but (since ONS methods and analytical capabilities were less advanced 20 years ago than they are today) there is likely to be little evidence either way.

In light of these observations, we consider Ofgem's 40bp deduction to be an arbitrary adjustment. By cherry-picking and adjusting for one particular change in RPI, Ofgem's resulting RPE forecast may be biased downwards.

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29 ONS (2014), p. 25.

30 ONS (2014), p. 21.

31 ONS (2014), p. 28.

32 ONS (2014), p. 22.

33 ONS (2014), p. 54.

3.4. Scale of the Proposed Adjustment

Even if we were to adopt Ofgem's view that it is appropriate to adjust the forward-looking RPE to reflect the impact of the change in RPI that took place in 2010, recent data shows that the 40bp adjustment would be excessive.

The "formula effect", as defined and calculated by ONS, can be summarised as "*the difference between the CPI and RPI*" arising from different formulae used to aggregate price changes. However, it is *literally* the difference between the actual CPI and a recalculated CPI using the RPI formula.[34] Put simply, it is the effect of the CPI formula on the CPI, not the effect of the RPI formula on the RPI. Since the two indices differ in other ways (e.g. they include different items and place different weights on the items they both include) these two effects may not be identical.

Northern Powergrid makes the same observation in a January 2014 response[35] to Ofgem's consultation[36] on its methodology for setting the equity market return. Northern Powergrid notes that the correct way to determine the effect of the RPI formula on the RPI is to compare the RPI to the RPIJ, which uses a geometric mean at the elementary aggregate level but is otherwise equivalent to the RPI. Since ONS has calculated the RPIJ over a long time series (beginning in 1997), it is possible to determine the effect of the 2010 step change by comparing the pre-2010 difference between RPI and RPIJ to the post-2010 difference.

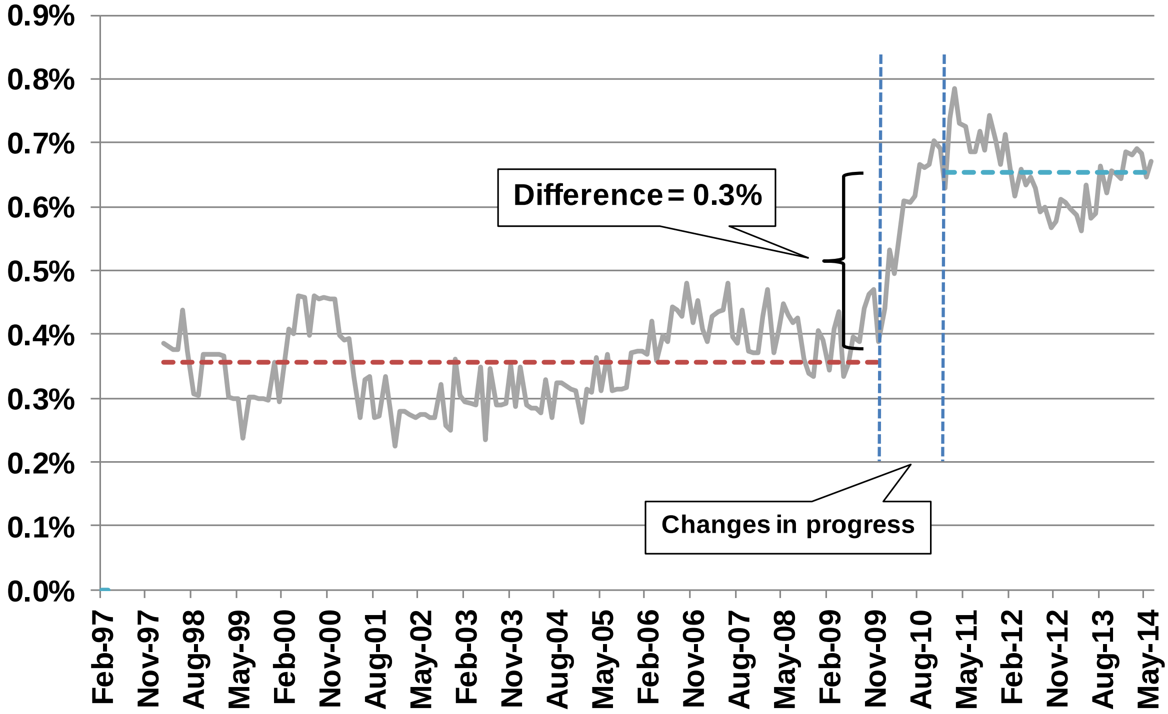
We agree with the Northern Powergrid comment, suggesting comparing RPI and RPIJ is a more appropriate method for estimating the increase in RPI due to the methodological change that ONS implemented in 2010. Hence, using this approach, in Figure 3.1 we compute rolling year-on-year growth rates for RPI and RPIJ. We then compute the average difference in growth rates across each period. (We omit 2010 since the new data collection methods were implemented gradually over the course of the year.) We find that the true formula effect over this period is 30bp, which is 10bp below the formula used by Ofgem.

34 ONS (2010), "Consumer Prices Index and Retail Prices Index – analysing differences", http://www.ons.gov.uk/ons/guide-method/user-guidance/prices/cpi-and-rpi/consumer-price-index-and-retail-price-index---analysing-differences.pdf, p. 2.

35 Northern Power Grid, 7 January 2014, "Appendix 2 to the consultation", https://www.ofgem.gov.uk/ofgem-publications/85473/eqmrworkshop7jan2014npgpresentation.pdf, slide 3.

36 Ofgem (6 December 2013), "Consultation on our methodology for assessing the equity market return for the purpose of setting RIIO price controls", https://www.ofgem.gov.uk/ofgem-publications/85020/consultationonequitymarketreturnmethodologyletter.pdf.

Figure 3.1
Difference between RPI and RPIJ



Source: NERA analysis of ONS data

3.5. Future Changes to RPI

The latest ONS work programme for consumer price statistics from October 2013 indicates that a further change in the data collection method of clothing might be implemented as soon as 2015.[37] The improvement of the clothing price collection methodology is set out as one of the focus projects. ONS introduced a pilot price collection in 2012 based on a revised methodology which aims at "*introducing greater consistency to the price collection for clothing and hence reduce the volatility within clothing inflation indices*".[38] The National Statistician's Consumer Prices Advisory Committee (CPAC) finds in its pilot update report that the revised collection methodology of the pilot results in a smaller gap between the RPI and CPI, reducing the "formula effect" on average by around 12 per cent.[39]

While a final conclusion on the implementation of the revised methodology for the main clothing price collection has not been reached yet, the pilot project and the ONS work programme indicate that further changes to the RPI may be expected, which are likely to

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[37] ONS (2013), "Work Programme for Consumer Price Statistics", http://www.ons.gov.uk/ons/guide-method/user-guidance/prices/cpi-and-rpi/work-programme-for-consumer-price-statistics.pdf, p. 12.

[38] ONS, Consumer Prices Advisory Committee (2012), "Update on clothing pilot price collection", http://www.ons.gov.uk/ons/guide-method/development-programmes/other-development-work/consumer-prices-advisory-committee/cpac-papers/update-on-clothing-pilot-price-collection.doc, p. 10.

[39] Ibid, p.9.

reduce the "formula effect". This suggests that Ofgem's downward adjustment of 40bps for RIIO-ED1would more than offset the impact of the change in RPI.

The ONS work programme presents a number of other projects and proposed amendments for consumer price statistics, which include:

- Implementation of temporal sampling for specific items in the basket of goods and services, as opposed to currently single index day sampling;
- Continued development of Northern Ireland private rental data for inclusion in CPI/RPI in the future;
- Updating the sample frame used to select locations for the local price collection;
- Considering new data collection methods such as the use of scanner data; etc.

Hence, it is clear that during the ED1 period, further changes that may *reduce* the formula effect may be implemented. This reinforces the conclusion that Ofgem's proposed 40bps adjustment for the whole forecast period materially overstates the impact of the 2010 structural change in RPI on the real input price inflation (i.e. above RPI) that DNOs will expect to face in the coming regulatory period. This evidence also shows that reviews and modifications to the RPI calculation methodology will continue to be part of the regular work programme of the ONS, so controlling for particular changes in price indices constitutes cherry-picking.

3.6. Adjustment to Transport/Other Categories

In this section, we set aside the reservations stated in the previous sections to address a different question: assuming RPI really did experience a 40bp "*step change*" in 2010, should the RPE for Transport/Other be set equal to negative 0.4%, as per Ofgem's Draft Determination?

Rather than estimating input cost indices for Transport/Other, Ofgem says it assumes that these categories "*move in line with economy wide inflation*".[40] It is natural to read this line as a commitment to set zero RPEs for these categories. However, Ofgem assumes that transport and other inputs grew in line with the RPI until 2010. After that, Ofgem assumes, transport and other inputs continued growing at the same rate, but RPI growth jumped upward by 0.4% per year. Putting these assumptions together, Ofgem concludes on RPEs of -0.4% for Transport/Other.

This approach would be valid if the 2010 adjustments had divorced the RPI from underlying price inflation, but there is no evidence that this is the case. Indeed, ONS refers to the 2010 adjustments as "*methodological improvements*" despite their likely effects on the RPI-CPI wedge.[41] ONS could easily have reversed the adjustments once it had investigated their effects, but it chose not to do so. This suggests that, in ONS' view, the 2010 adjustments made the RPI a *better* measure of underlying price inflation.

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[40] Ofgem (July 2014), p. 119.

[41] ONS (December 2010), "CPI and RPI: Increased impact of the formula effect in 2010", p. 2.

As long as Ofgem remains committed to indexing DNOs' costs to the RPI, it should use the RPI in its best available form. It should not attempt to roll back changes implemented by ONS. Specifically, it should not assume that underlying inflation is 0.4% below the RPI growth rate. We therefore recommend that, rather than assuming that nominal growth in Transport/Other costs is 0.4% below RPI growth, Ofgem should tie Transport/Other cost allowances directly to the RPI (i.e. it should set zero RPEs for these categories).

3.7. Conclusion

In light of prior changes to the RPI, we believe that the case for an RPI adjustment is weak. We consider 30bp (10bp below the adjustment used by Ofgem) to be the upper bound on *any* plausible adjustment, based on the difference between RPI and RPIJ.[42]

However, given that the RPI has undergone other structural changes in the past, and will continue to do so in the future, it would be selective to adjust for this effect without considering the possible effect of other changes to the way RPI is (or will be) calculated. In this case, it would be inappropriate to apply any RPI adjustment at all. However, reflecting the relatively significant nature of the change in RPI that took place in 2010, we recommend that a more reasonable adjustment for the RPI effect would be to reduce by 50% the maximum RPI adjustment that we consider to be potentially justifiable (30bps), giving a negative adjustment of 15bps instead of Ofgem's assumption of 40bps.

Additionally (and separately) we recommend that Ofgem raise the RPE for Transport/Other from -0.4% to 0.0%. If this correction to a 0.0% RPE was not made, Ofgem would be rolling back changes the ONS made to RPI measurement to improve it as a measure of retail price inflation. Ofgem should use the best possible measure of RPI, as dictated by the relevant authority on this calculation, the ONS.

[42] We note that a smaller adjustment (or the absence of an adjustment) would reduce measured growth rates for 2010-14 and short-term earnings growth forecasts but would raise the "baseline" forecasts computed from long-term historical averages.

4. Conclusion

4.1. Problems with the Ofgem Approach

As discussed above in the body of this report, while we agree that some features of Ofgem's approach to setting RPE allowances are robust and objective, we have identified a range of problems with Ofgem's implementation of its approach to setting allowed RPEs for the ED1 control period:

- **Use of third party wage forecasts in the short-term:**
  - Ofgem has used third party forecasts of wage growth in the economy as a whole to forecast private sector wage growth in 2014/15 and 2015/16. This approach is biased, because public sector wage growth is currently expected to be lower than private sector wage growth in the next 2 years; and
  - Ofgem has also used third party forecasts of wage growth in the economy as a whole to forecast wage growth for specialised labour in 2014/15 and 2015/16. This approach is biased, because wage rates for specialised labour have tended to grow faster over time than wages for general labour, and so, in the absence of any evidence to the contrary, should be assumed to continue growing at a faster rate over the next two years.
- **Calculation of long-term average growth rates:**
  - If Ofgem is to maintain consistency with its own methodology, it must use longer time series for specialist labour and plant/equipment in making its forecasts, as more published data is available than it has used; and
  - We recommend that Ofgem uses an ARMA approach to extrapolating long-term historic trends, in order to account for the fact that many indices are currently "below trend". Failing to adopt such an approach, and extrapolating the current value of indices using long-term historic average growth rates, ignores the potential for indices to revert to their underlying long-term trends as the economy recovers from the recent recession.
- **The RPI effect**:
  - In light of prior changes to the RPI, we believe that the case for an RPI adjustment is weak. We consider 30bp (10bp below the adjustment used by Ofgem) to be the upper bound on *any* plausible adjustment.
  - However, given that the RPI has undergone other structural changes in the past, and will continue to undergo changes in the future, it would be selective to adjust for this effect without considering the possible effect of other past changes to the way RPI is calculated. In this case, it would be inappropriate to apply any RPI adjustment at all. However, reflecting the relatively significant nature of the change in RPI that took place in 2010, we recommend that a more reasonable adjustment for the RPI effect would be to reduce by 50% the maximum RPI adjustment that we consider to be potentially justifiable (30bps), giving a negative adjustment of 15bps instead of Ofgem's assumption of 40bps.
  - Additionally (and separately) we recommend that Ofgem raise the RPE for Transport/Other from -0.4% to 0.0%.

4.2. Impact of Problems Identified

The effect of the problems we have identified is summarised in the tables below: Table 4.1 shows the impact of on allowed RPEs, and Table 4.2 shows our estimate of the associated impact on ED1 allowances by DNO.

Table 4.1
Summary of Errors in the Ofgem RPE Analysis: Impact on Forecast RPEs

Issue	Impact on RPEs *(percentage points)*
Short-term wage forecasts	+0.2% on General Labour in 2014/15-15/16 +1% on Specialist Labour in 2014/15-15/16
Estimation window	+0.4% on Specialist Labour from 2016/17
Estimation approach	0.29% (on average) on Totex in each forecast year from 2014/15
RPI adjustment	Around +0.25% on Totex each year +0.4% on Transport/Other Costs each year

Source: NERA

Table 4.2
Summary of Errors in the Ofgem RPE Analysis: Impact on ED1 Allowances (£Mn)

	Allowance using NERA ARMA/ARIMA Composite RPE indices (before smart grids and IQI) (£m)	Allowance using Ofgem RPE indices (before smart grids and IQI) (£m)	Difference in Allowance (£m)
ENWL	1,830.9	1,802.3	28.6
NPGN	1,259.6	1,239.9	19.7
NPGY	1,713.8	1,687.9	26.0
WMID	1,852.6	1,822.6	30.0
EMID	1,973.5	1,943.9	29.6
SWALES	1,031.8	1,014.9	16.9
SWEST	1,448.2	1,424.7	23.5
LPN	1,724.2	1,693.7	30.5
SPN	1,711.3	1,683.8	27.5
EPN	2,549.3	2,509.6	39.8
SPD	1,571.3	1,545.7	25.5
SPMW	1,679.7	1,654.0	25.7
SSEH	1,104.1	1,087.9	16.2
SSES	2,367.4	2,332.9	34.5

Source: NERA Analysis

Table 4.3 sets out our recommendations for Totex RPE indices over the 2012/13-2022/23 period, shown as both annual percentage changes and indices with a base year of 2012/13. These indices account for the impact of all the various suggested revisions to Ofgem's approach set out in this report, and summarised above in Table 4.1. To produce the totex indices in Table 4.3 we have applied the same weightings as used by Ofgem to combine the RPE forecasts for each of the price indices it uses to represent changes in DNOs' costs over time. Further breakdowns of our estimated RPEs are shown in Appendix B.

Table 4.3
Recommended Revisions to Ofgem Totex RPE Indices

	NERA		Ofgem		Type
	Real Growth Rate	Index (Base = 2012/13)	Real Growth Rate	Index (Base = 2012/13)	
2012/13		100		100	
2013/14	-1.33%	98.7	-1.33%	98.67	Actual
2014/15	-0.23%	98.4	-0.3%	98.38	Forecast
2015/16	0.14%	98.6	-0.1%	98.28	Forecast
2016/17	0.29%	98.9	0.5%	98.75	Forecast
2017/18	0.57%	99.4	0.5%	99.22	Forecast
2018/19	0.90%	100.3	0.5%	99.69	Forecast
2019/20	1.13%	101.5	0.5%	100.17	Forecast
2020/21	1.39%	102.9	0.5%	100.65	Forecast
2021/22	1.46%	104.4	0.5%	101.13	Forecast
2022/23	1.51%	106.0	0.5%	101.62	Forecast

	NERA		Type
	Real Growth Rate	Index (Base = 2012/13)	
2012/13		100	
2013/14	-1.33%	98.7	Actual
2014/15	-0.23%	98.4	Forecast
2015/16	0.14%	98.6	Forecast
2016/17	0.29%	98.9	Forecast
2017/18	0.57%	99.4	Forecast
2018/19	0.90%	100.3	Forecast
2019/20	1.13%	101.5	Forecast
2020/21	1.39%	102.9	Forecast
2021/22	1.46%	104.4	Forecast
2022/23	1.51%	106.0	Forecast

Source: NERA

Appendix A. ARIMA Forecasting Analysis

As described in Section 2.4 above, we have recommended that ARIMA models provide a more reliable basis for rolling forward historic trend growth rates than Ofgem's approach of relying arithmetic growth rates because of its ability to account for the short-run dynamics of the price indices Ofgem has used. This section elaborates on the procedure we use to forecast RPEs using this approach.

A.1. The ARIMA Model

The Autoregressive Integrate Moving Average (ARIMA) model allows our forecast indices to move above or below the long-term trend rate in the short-term, rather than just sticking to the long-term trend rate as in Ofgem's approach. The statistical model takes the following form:

$$(1) \qquad Ln\ (Deflated\ Index)_t = \alpha + \beta \times Time\ Trend + e_t$$

Deflated index refers to the cost index we are interested in modelling, where "deflated" means net of RPI. In this basic form, the deflated index is assumed to grow yearly at a given percentage, represented by the β parameter, estimated by the model. However, each year the model can deviate from the trend line due to statistical "noise", as represented by the residual in the equation, the "e_t" term. These residuals could include any cyclical macroeconomic factors causing the deflated index to depart from its long-term trend growth rate, and statistical factors such as inaccuracies in measuring real price trends data.

In some cases, these deviations from the trend may be permanent, and in other cases indices may return to their trend growth rate after a period of time. The ARIMA model allows for such features of the data, by explicitly modelling potential correlation in the error terms over time. In particular, the error terms take the following form in an ARIMA model:

$$(2) \qquad e_t = \rho_1 \times e_{t-1} + \ldots + \rho_m \times e_{t-m} + \varphi_0 \times u_t + \varphi_1 \times u_{t-1} + \ldots + \varphi_Q \times u_{t-n}$$

Lastly, fitting an ARIMA model requires that the data is "stationary", which means the mean and variance of the data does not change over time. Typically, the use of "differences" of the modelled index, i.e. using growth rates rather than the index itself, is intended to ensure the series is stationary.[43] The order of "integration" of a variable (the "I" in ARIMA) refers to the number of times it is necessary to take differences of a series before it becomes stationary.

Hence, from the above description and equations, we must specify three parameters to estimate an ARIMA model:

1. The number of differences required to make the series stationary: use of growth rates rather than the index itself would be a difference of 1. However, more differencing may be required to make the series stationary.

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[43] Fitting an ARIMA model to non-stationary data risks producing spurious correlations, for more detail see Granger, C. and Newbold, P. *Spurious Regressions In Econometrics* Journal of Econometrics (1974), pp.111-120.

2. The number of lags of the Autoregressive (AR) process (*m*): this represents the number of time periods for which the AR component (e_t) remains in the forecast equation; and
3. The number of lags of the Moving Average (MA) process (*n*): this represents the number of time periods for which MA component (u_t) remains in the forecast equation .

The “Box-Jenkins” approach to estimating forecast models using time-series data provides one standard approach for choosing between alternative ARIMA model specifications.[44] In the following sections we describe our selection of the above ARIMA parameters, which draws on this approach.

A.2. Selecting the Order of Integration

As described in Section A.1, an ARIMA model requires a stationary data series, or at least a data series that is stationary around a long-term trend (i.e. “trend stationary”). The common statistical test used to determine if a series is non-stationarity is called the Augmented Dickey-Fuller (ADF) test,[45] which we run for the ten indices Ofgem uses to estimate RPEs. The ADF test works by testing the null hypothesis that a series has a unit root, and so is non-stationary, against the hypothesis that it is a stationary series. The results of our ADF tests for stationarity (shown in Table A.1), when read alongside the literature of the application of these tests, lead us to the conclusion that it is somewhat uncertain whether the data series considered here are stationary or not. For instance:

- The ADF test requires an assumption on how many lags of the relevant variable to include in the model used in the test (i.e. reflecting the persistence of the index’s underlying process). In the absence of any clear theoretical guidance on the appropriate number of lags to include, we have therefore performed this test using a range of up to five lags, with the p-values from this range of tests reported in Table A.1. The table shows that the ability to reject the null, e.g. at the 5% significance level, is highly sensitive to the number of lags employed;
- The ADF test has non-stationarity as the null hypothesis, as noted above. Because traditional hypothesis testing methodologies accept the null unless there is strong evidence against it, unit root tests of this sort often conclude there is a unit root, even if the underlying process is stationary (or trend stationary). This problem is exacerbated by the fact that unit root tests generally have low statistical “power”, i.e. the probability of rejecting the null, even if the null is not true, is relatively low;[46] and
- ADF tests are sensitive to the span of the data series employed for the modelling. Hence, if we had data spanning a larger number of years, and hence business cycles, we might find different conclusions with regard to the stationarity of the series.[47]

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44 Kennedy, Peter *A Guide To Econometrics - 5th ed.* (2003, Blackwell Publishing), p.320.

45 Or the Augmented Dickey Fuller test where the data generating process contains more than one lagged value of the dependent variable.

46 Kennedy, Peter *A Guide To Econometrics - 5th ed.* (2003, Blackwell Publishing), p.351.

47 Kennedy, Peter *A Guide To Econometrics - 5th ed.* (2003, Blackwell Publishing), p.353.

Table A.1
ADF Test Results (p-values) for the Range of Price Indices

	P-Values per no. of lags in Dickey Fuller test					
	0	1	2	3	4	5
ONS Private sector labour	0.61	0.41	**0.08**	**0.00**	1.00	1.00
BCIS Labour and supervision in civil engineering	**0.00**	0.97	0.73	0.72	**0.02**	**0.00**
BEAMA Electrical labour	**0.00**	1.00	0.99	1.00	0.99	0.99
Pipes and accessories: copper	0.65	0.54	0.39	0.10	**0.00**	0.35
BCIS Pipes and accessories: aluminium	0.57	0.56	0.43	**0.08**	**0.00**	0.27
BCIS Structural steelwork materials: civil engineering work	0.59	0.60	0.40	0.11	**0.00**	**0.07**
BCIS FOCOS RCI Infrastructure and materials	0.36	0.23	**0.04**	**0.00**	0.50	0.31
ONS Machinery and equipment output PPI	0.79	0.81	0.83	0.85	0.87	0.88
ONS Machinery and equipment input PPI (K5W6)	0.68	0.74	0.78	0.82	0.84	0.87
BCIS Plant and road vehicles: providing and maintaining	**0.00**	0.59	0.39	0.91	0.58	0.71

Source: NERA analysis

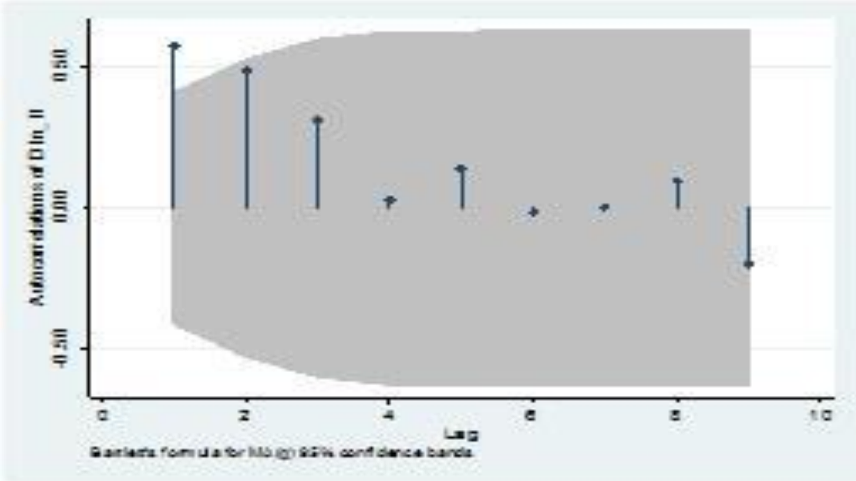
There is therefore some uncertainty over whether the series is non-stationary, in which case differencing of the series would be required before estimating AR and MA terms, or it is stationary, in which case no such adjustment is required. Given the need for objectivity in the model selection process, we have therefore adopted the approach of estimating ARIMA(p,0,q) and ARIMA(p,1,q) models, i.e. both with and without first differencing of the series.[48]

A.3. Selecting the Number of AR and MA Lags

As described in Section A.1, we select the number AR and MA lags in the ARIMA processes on the basis of the Bayesian Information Criterion (BIC), which is a common statistical tool used for the purposes of model selection. Before applying the BIC, we check the series' correlogram – a chart used to graphically show likely AR lags present in the series – to see whether AR lags are likely to be important in the data. An example correlogram for the first difference of the general labour data series is shown in Figure A.1. The lines represent the estimated size of persistence in the series for each given number of lags (the grey shaded area represents 95% confidence intervals for these estimates).

48 We also performed ADF tests on the differenced series, and were able to reject the null hypothesis that each of these series was non-stationary at the 5% significance level. This conclusion held across a range of tests that employed different numbers of lags.

Figure A.1
General Labour Correlogram



From examining correlograms, we concluded that most series are likely to have AR lags of at least 1. Therefore, for each index, we test the statistical properties of models with combinations of 1 to 4 AR lags and 0 to 4 MA lags. This results in 20 estimated models per index, which we estimate separately for both the ARIMA(p,0,q) and ARIMA(p,1,q). We then examine the BIC for each model, choosing the model with the most favourable (lowest) BIC result from each set of models. For example, Table A.2 shows the BIC results for the 20 models estimated for the General Labour index, based on the ARIMA(p,0,q) specification. The rows indicate the lags of the AR process, and the columns indicate the lags of the MA process. The minimum value in this table is -143.471, therefore the BIC indicates that the best model has 2 AR lags and 1 MA lag, and is therefore the model selected for the General Labour index.

Table A.2
BIC Results for the General Labour Index for a Range of AR and MA Lags

		MA Lags				
		0	1	2	3	4
AR Lags	1	-126.953	-130.491	-131.337	-131.824	-130.174
	2	-135.962	-143.471	-97.783	-89.6023	-134.716
	3	-136.353	-104.875	-97.5077	-88.6322	-82.6385
	4	-133.965	-102.103	-94.6179	-91.4621	-83.6967

Source: NERA analysis. For General Labour the short-term HM Treasury Consensus forecast, used by Ofgem, is included in the estimation.

A.4. Results of ARIMA Estimation

After selecting the ARIMA parameters, as described in Sections A.2 and A.3, we then proceed to estimate the ARIMA models and use them to forecast the relevant price indices into the ED1 period using both the ARIMA(p,0,q) and ARIMA(p,1,q) specifications.

Both model specifications give forecast RPEs for the ED1 period higher than the current Ofgem approach, with the ARIMA(p,0,q) approach producing higher RPE growth than the ARIMA(p,1,q) approach, as the former predicts greater mean reversion of the series. Because of the apparently cyclical nature of these price indices, we consider that the ARIMA(p,1,q) approach may therefore be more realistic. However, we acknowledge there is some subjectivity involved in choosing between these alternatives, so we have taken a straight average of the forecasts emerging from them. Overall, the average forecasts emerging from these models shown in the figures below indicate an RPE growth rate 0.35% higher than the Ofgem approach over the forecast period.

Figure A.2
Forecasts Using ARIMA Models: ARIMA(p,0,q) Model

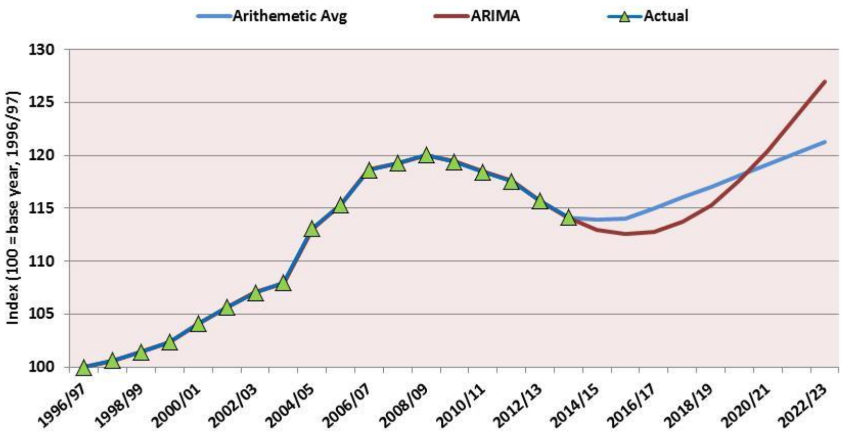


Figure A.3
Forecasts Using ARIMA Models: ARIMA(p,1,q)

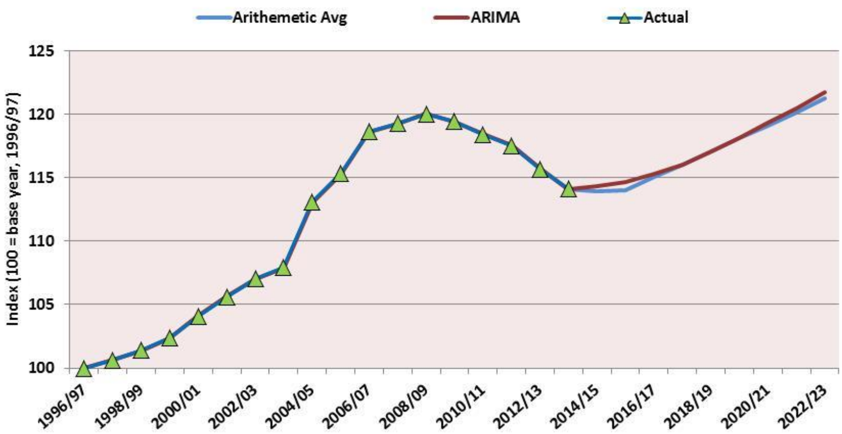


Figure A.4
Forecasts Using ARIMA Models: Average of Two Models

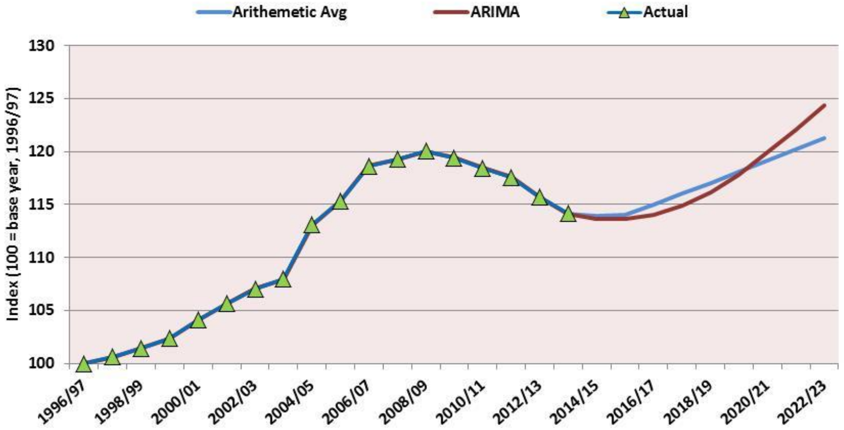


Table A.3
ARIMA(p,0,q) Model Coefficients and Diagnostic Statistics (Using Ofgem Data Windows)

		Labour (gen)	Labour (spec)		Materials (capex)			Materials (opex)	Plant and Equipment		
		AWE/AWI Earnings Index	BCIS Labour and supervision in civil engineering	BEAMA Electrical labour	Pipes and accessories: copper	BCIS Pipes and accessories: aluminium	BCIS Structural steelwork materials: civil engineering work	BCIS FOCOS Infrastructure Materials	ONS Machinery and equipment output PPI	ONS Machinery and equipment input PPI (K5W6)	BCIS Plant and road vehicles: providing and maintaining
Autoregression Terms											
L1	*Coeff*	1.93	1.90	1.94	1.80	0.55	1.81	1.88	0.61	1.90	
	P-Val	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	
L2	*Coeff*	-0.98	-0.99	-0.98	-0.98	-0.49	-0.99	-0.99		-1.00	
	P-Val	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	
Moving Average Terms											
L1	*Coeff*	-1.00	-0.37	-1.00	-1.57		-1.97	-1.98		-1.95	1.40
	P-Val						0.00	0.00		0.00	0.00
L2	*Coeff*		-1.22		0.21		1.00	1.00		1.00	0.73
	P-Val		0.00		0.70						0.00
L3	*Coeff*		-0.37		0.40						
	P-Val		0.14		0.58						
L4	*Coeff*		1.00								
	P-Val										
Other Vars											
Time	*Coeff*	0.01	0.02	0.01	0.02	0.00	0.02	0.02	-0.01	-0.02	0.00
	P-Val	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.40
Constant	*Coeff*	4.50	4.25	4.41	4.14	4.44	4.14	4.06	4.91	5.04	4.56
	P-Val	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diagnostic Stats											
Observations		26	29	29	23	23	23	24	18	18	27
log likelihood		79.88	86.95	82.67	37.29	46.75	26.01	48.55	57.52	50.62	78.71
f-test		0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.40

Source: NERA analysis. Note, some AR and/or MA coefficients may have p-values indicating that they are statistically insignificant from zero at the 5/10% significance levels. This should not necessarily be interpreted as meaning that extrapolating the price indices using an ARIMA is not necessary, as the ARIMA processes have been selected to best fit the observed historic data. Also, where our analysis suggests that a model with an AR (MA) component of order p (q) is appropriate, we have included all lower lags too, such that the AR (MA) components at p-1, p-2,…,1 (q-1 ,q-2,…1) are all included in the model.

Table A.4
ARIMA(p,1,q) Model Coefficients and Diagnostic Statistics (Using Ofgem Data Windows)

		Labour (gen)	Labour (spec)			Materials (capex)		Materials (opex)	Plant and Equipment		
		AWE/AWI Earnings Index	BCIS Labour and supervision in civil engineering	BEAMA Electrical labour	Pipes and accessories: copper	BCIS Pipes and accessories: aluminium	BCIS Structural steelwork materials: civil engineering work	BCIS FOCOS Infrastructure Materials	ONS Machinery and equipment output PPI	ONS Machinery and equipment input PPI (K5W6)	BCIS Plant and road vehicles: providing and maintaining
Autoregression Terms											
L.ar	*Coeff*	0.61	1.51	0.54	0.24	-0.48	-0.44	-0.03	-0.14	1.90	-0.30
	P-Val	0.01	0.00	0.00	0.33	0.43	0.19	0.92	0.58	0.00	0.09
L2.ar	*Coeff*		-0.95				0.33			-1.00	0.69
	P-Val		0.01				0.31			0.00	0.00
L3.ar	*Coeff*		0.84								
	P-Val		0.00								
L4.ar	*Coeff*		-0.59								
	P-Val		0.00								
Moving Average Terms											
L.ma	*Coeff*		-1.00			-1.93	0.67			-2.88	0.98
	P-Val					0.51	0.01				
L2.ma	*Coeff*					-2.25	-0.67			2.88	-0.98
	P-Val					0.49					0.00
L3.ma	*Coeff*					0.62	-1.00			-1.00	-1.00
	P-Val									0.00	
L4.ma	*Coeff*					2.56					
	P-Val										
Other Vars											
Constant	*Coeff*	0.01	0.02	0.01	0.01	0.00	0.01	0.02	-0.01	-0.02	0.00
	P-Val	0.27	0.00	0.02	0.47	0.01	0.11	0.08	0.00	0.00	0.99
Diagnostic Stats											
Observations		25	28	28	22	22	22	23	17	17	26
log likelihood		73.66	79.61	76.82	28.31	43.43	20.32	41.88	52.87	45.32	76.38
f-test		.	.	.	.	.	.	.	.	.	.

Source: NERA analysis. Note, some AR and/or MA coefficients may have p-values indicating that they are statistically insignificant from zero at the 5/10% significance levels. This should not necessarily be interpreted as meaning that extrapolating the price indices using an ARIMA is not necessary, as the ARIMA processes have been selected to best fit the observed historic data. Also, where our analysis suggests that a model with an AR (MA) component of order p (q) is appropriate, we have included all lower lags too, such that the AR (MA) components at p-1, p-2,…,1 (q-1 ,q-2,…1) are all included in the model.

Appendix B. Detailed RPE Estimates

Table B.1 and Table B.2 show a detailed breakdown of Ofgem's RPE forecasts, after accounting for the various changes recommended in the body of this report (summarised in Table 4.1). To move from the projections shown in Table B.1 to those shown in Table B.2 we have applied the same weightings that Ofgem uses in its RPE analysis. Also, for comparison against Table B.2, we also present the impact of using the ARIMA forecasting method, and no other adjustments to the Ofgem approach, in Table B.3.

Table B.1
Forecasts RPEs by Expenditure Category

	Load-related capex	Non-load-related capex - asset replacement	Non-load-related capex - other	Faults	Tree cutting	Controllable opex	Totex
2014/15	-0.14%	-0.14%	-0.18%	-0.24%	-0.47%	-0.30%	-0.23%
2015/16	0.28%	0.27%	0.23%	0.10%	-0.11%	0.00%	0.14%
2016/17	0.43%	0.38%	0.36%	0.25%	0.20%	0.18%	0.29%
2017/18	0.73%	0.66%	0.64%	0.51%	0.49%	0.42%	0.57%
2018/19	1.18%	1.06%	1.05%	0.80%	0.75%	0.65%	0.90%
2019/20	1.43%	1.30%	1.28%	1.03%	0.97%	0.86%	1.13%
2020/21	1.80%	1.62%	1.61%	1.27%	1.17%	1.05%	1.39%
2021/22	1.76%	1.62%	1.60%	1.38%	1.32%	1.20%	1.46%
2022/23	1.74%	1.63%	1.60%	1.46%	1.42%	1.30%	1.51%

Table B.2
Forecasts RPEs by Input Category

	General Labour	Specialist Labour	Materials (capex)	Materials (opex)	Plant and Equipment	Transport and Other
2014/15	-0.55%	0.45%	0.16%	0.29%	-1.39%	0.00%
2015/16	-0.15%	0.85%	0.71%	0.27%	-1.26%	0.00%
2016/17	0.22%	0.48%	0.91%	0.41%	-1.14%	0.00%
2017/18	0.53%	0.67%	1.32%	0.68%	-1.04%	0.00%
2018/19	0.81%	0.86%	2.19%	1.06%	-0.98%	0.00%
2019/20	1.05%	1.04%	2.54%	1.50%	-0.95%	0.00%
2020/21	1.24%	1.22%	3.27%	1.96%	-0.96%	0.00%
2021/22	1.39%	1.39%	2.95%	2.38%	-0.97%	0.00%
2022/23	1.49%	1.53%	2.74%	2.72%	-0.99%	0.00%

Table B.3
Forecasts RPEs by Input Category (Impact of ARIMA Method Only)

	General Labour	Specialist Labour	Materials (capex)	Materials (opex)	Plant and Equipment	Transport and Other
2014/15	-0.60%	-0.60%	0.31%	0.44%	-1.35%	0.00%
2015/16	-0.20%	-0.20%	0.86%	0.42%	-1.42%	0.00%
2016/17	0.23%	1.04%	1.06%	0.56%	-1.85%	0.00%
2017/18	0.55%	1.57%	1.47%	0.83%	-1.83%	0.00%
2018/19	0.83%	2.16%	2.34%	1.21%	-1.86%	0.00%
2019/20	1.08%	2.65%	2.69%	1.65%	-1.66%	0.00%
2020/21	1.28%	2.95%	3.42%	2.11%	-1.51%	0.00%
2021/22	1.45%	3.08%	3.10%	2.53%	-1.17%	0.00%
2022/23	1.56%	3.11%	2.89%	2.87%	-0.93%	0.00%

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