NERA
ECONOMIC CONSULTING

Estimating Real Price Effects and Ongoing Efficiency

Prepared for UK Power Networks

5 April 2013

Project Team

Graham Shuttleworth

James Grayburn

George Anstey

Matthew Mair

NERA Economic Consulting
15 Stratford Place
London W1C 1BE
United Kingdom
Tel: +44 20 7659 8500
Fax: +44 20 7659 8501
www.nera.com

Disclaimer

Extracts of this report may not be reproduced or redistributed without the written permission of NERA, and NERA accepts no liability whatsoever for the actions of third parties in this respect. This report may not be sold without the written consent of NERA. This report is intended to be read and used as a whole and not in parts. Separation or alteration of any section or page from the main body of this report is expressly forbidden and invalidates this report.

All opinions, advice and materials provided by NERA are included, reflected or summarized herein as the "NERA Content". There are no third party beneficiaries with respect to the NERA Content, and NERA disclaims any and all liability to any third party. In particular, NERA shall not have any liability to any third party in respect of the NERA Content or any actions taken or decisions made as a consequence of the results, advice or recommendations set forth herein.

The NERA Content does not represent investment advice or provide an opinion regarding the fairness of any transaction to any and all parties. The opinions expressed in the NERA Content are valid only for the purpose stated herein and as of the date hereof. Information furnished by others, upon which all or portions of the NERA Content are based, is believed to be reliable but has not been verified. No warranty is given as to the accuracy of such information. Public information and industry and statistical data are from sources NERA deems to be reliable; however, NERA makes no representation as to the accuracy or completeness of such information and has accepted the information without further verification. No responsibility is taken for changes in market conditions or laws or regulations and no obligation is assumed to revise NERA Content to reflect changes, events or conditions, which occur subsequent to the date hereof.

Contents

Executive Summary

NERA Economic Consulting (NERA) was commissioned by UK Power Networks (UKPN) to estimate the real price effects (RPEs) and expected improvement in productivity ("ongoing efficiency") to inform UKPN's well-justified business plan. This report sets out our estimates of both future RPEs and future productivity growth, drawing principally on publicly available information. Applying these rates to base year costs would allow UKPN to recover its efficient costs and ensure value-for-money for network customers.

Estimating Real Price Effects

Our approach to estimating RPEs follows Ofgem's approach at RIIO-T1/GD1 in so far as we draw on independent, publicly available forecasts for input prices where available, and otherwise rely on long-term historical averages. We measured real price movements relative to RPI. Our estimates of RPEs are therefore applicable only if UKPN's future revenues are also indexed to RPI. If Ofgem decides to use RPIJ (or any inflation index other than RPI) in the price control formula, we would need to re-estimate RPEs relative to that other inflation index.

As required by Ofgem, we also set out separate RPEs for four categories of inputs: (1) labour; (2) materials; (3) equipment and plant; and (4) transport and other.[1] We reviewed a wide set of input price series and evaluated the candidate series according to three criteria:

- **Coverage:** We considered of how closely the series measures changes in costs close to the input categories identified by Ofgem (or subcategories within those categories of inputs).
- **Empirical Fit**: We compared whether the index matched recent trends in UKPN's input prices where suitable data was available.
- **Information Value**: We examined whether each series consisted of a wide sample or a long data series.

Applying these criteria, we identified a shortlist of indices for each category or subcategory of inputs. Where possible, we produced short-term forecasts for 2013/14 and 2014/15 and a long-term forecast for the 8-year RIIO price control period 2015/16-2022/23 ("2015-2023").

For our long-term forecasts, our central or mid-point forecast is based on the average historical RPE for all the indices that meet our criteria. We identified an upper and lower bound based on the fastest-growing and slowest-growing index for each input category.

RPEs for labour

In relation to short-term forecasts of real wages, we identified two relevant independent short-term forecasts:

---

1 Ofgem (2012), *Strategy Consultation for RIIO-ED1*, pages 84-85.

- HM Treasury ("HMT") provides a short-term "consensus forecast" for average weekly earnings in the whole economy.
- The Joint Industry Board (JIB) forecasts provide a proxy for labour market conditions in the electricity (contracting) industry.

At present, the JIB forecasts predict lower real wage growth in the short term than the HMT Consensus forecasts.

For long-term forecasts, we identified two relevant long run wage series:

- the BEAMA electrical labour index (BEAMA); and
- the ONS series of Average Weekly Earnings (AWE) in the private sector, which replaced the Average Earnings Index (AEI) in 2000. In our calculations, we treated the growth rate in the AWE as a continuation of the growth rate in the AEI.

To calculate RPEs, we converted all these series into real terms, i.e. we calculated growth rates relative to RPI.

For short-term forecasting, the HMT consensus forecast has to be adjusted, as it covers the whole economy, whereas the long-term ONS series covers just the private sector and is more relevant to DNOs. To calculate the adjustment, we calculated the historical difference between the ONS's average weekly earnings index *for the whole economy* and one of the following:

- either the BEAMA electrical labour index;
- or a "composite index", i.e. an average of the BEAMA electrical labour index and the ONS index *of private sector wages*.

We then added each of these differences to the HMT Consensus forecast to provide separate upper bound (BEAMA) and mid-point (composite index) short-term forecasts consistent with the long-term forecasts. We used the JIB rates as our lower bound for the short term forecast.

For long-term forecasts, we use the historical long run average rate of growth for the two wage series, BEAMA and ONS private sector, relative to RPI. The historical trends in the "composite index" (the average of these two series) gives real wage growth of 1.3% p.a., with a range running from 0.8% (ONS private sector only) to 1.8% (BEAMA electrical labour only). See Table 1.

Table 1
Labour RPEs (Percent per Annum)

	Outturn	Short Term (ST)		Long Term	Average
Labour RPE	2012/13	2013/14	2014/15	2015 - 2023	2013-2023
NERA Mid-Point	-1.1%	-0.5%	-0.3%	1.3%	0.8%
Upper Bound	-1.1%	-0.1%	0.1%	1.8%	1.2%
Lower Bound	-1.2%	-1.4%	-1.0%	0.8%	0.3%

Source: NERA analysis.

RPEs for materials

For materials RPEs, we did not calculate a separate short-term forecast for 2014 and 2015, as no relevant independent forecasts are available. Instead, we calculated long run historical RPEs for the principal cost categories, drawing on average historical RPEs relative to RPI for the following Producer Price Index (PPI) series:

- Transformers and switchgear (comprising 30% of materials costs): “Electric Motors, Generators and Transformers” and “Electricity Distribution and Control Apparatus”;
- Cables (25%): “Insulated Wire and Cables” and “Cold Drawn Products”; and,
- Other (45%): “RCI Infrastructure Materials”.

Overall, we estimated a long term trend RPE of 1.0% which we used as the basis for our forecasts. To construct a range, we selected only the fastest growing series in each sub-category for the upper bound (which gave a trend RPE of 1.2%), and the slowest growing series in each sub-category for the lower bound (which gave a trend RPE of 0.7%). See Table 2.

Table 2
Materials RPEs (Percent per Annum)

Material RPEs	Outturn 2012/13	Short Term (ST) 2013/14	2014/15	Long Term 2015-2023	Average 2013-2023
NERA Mid-Point	-2.0%	1.0%	1.0%	1.0%	0.7%
Upper Bound	-1.6%	1.2%	1.2%	1.2%	1.0%
Lower Bound	-2.3%	0.7%	0.7%	0.7%	0.5%

Source: NERA analysis.

RPEs for equipment and plant

For equipment and plant RPEs, we used the PAFI Road and Plant Vehicle index supplied by BCIS, and two PPIs for Machinery and Equipment (inputs and outputs). From these indices, we estimated a long term trend of *minus* 0.6%, relative to RPI. To put bounds on this estimate, we considered just the fastest growing series for the upper bound, which gave a trend RPE of *minus* 0.2%, and the slowest growing series for the lower bound, which gave a trend RPE of *minus* 1.5%. See Table 3.

Table 3
Equipment and Plant RPEs (Percent per Annum)

Equipment RPEs	Outturn 2012/13	Short Term (ST) 2013/14	2014/15	Long Term 2015 - 2023	Average 2013-2023
NERA Mid-Point	-2.6%	-0.6%	-0.6%	-0.6%	-0.8%
Upper Bound	-1.9%	-0.2%	-0.2%	-0.2%	-0.4%
Lower Bound	-3.7%	-1.5%	-1.5%	-1.5%	-1.7%

Source: NERA analysis.

We found no evidence that the growth in transport and other costs was significantly different to RPI, so we assigned these categories an RPE of 0%.

RPEs by category of DNO expenditure

We calculated input prices for the expenditure categories of (1) network investment and (2) operational activities by weighting our forecast RPEs, based on a forecast cost structure from 2014 to 2023 that UKPN provided. These estimates are set out in Table 4.

Table 4
RPEs by Category of Expenditure (Percent per Annum)

	2012/13	2013/14	2014/15	2015 - 2023	Average 2013 - 2023
Operational Activities					
Upper	-1.1%	0.0%	0.2%	1.6%	1.1%
Mid	-1.1%	-0.3%	-0.1%	1.2%	0.7%
Lower	-1.2%	-1.1%	-0.8%	0.8%	0.3%
Network Investment					
Upper	-1.2%	0.1%	0.3%	1.4%	0.9%
Mid	-1.3%	-0.2%	0.0%	1.0%	0.6%
Lower	-1.5%	-0.9%	-0.6%	0.6%	0.1%

Source: NERA Analysis of ONS and BEAMA data, using UKPN cost weights.

Estimating Improvements in Productivity ("Ongoing Efficiency")

As with RPEs, our approach to estimating ongoing efficiency follows the framework set out by Ofgem in its recent strategy decision document.[2] Specifically, we use historical trends in productivity observed in the EU KLEMS database, drawing on the comparator sectors identified by Ofgem at DPCR5 and at RIIO-(E)T1 as relevant to electricity networks.

Total Factor Productivity (TFP) growth is measured as (1) the long-run average annual growth rate in physical outputs *minus* (2) the long-run annual average growth rate in physical inputs. Calculation of TFP raises a number of important theoretical and data measurement issues, many of which are highlighted in the official guidance to using EU KLEMS. Specifically, TFP not only measures technological change but also captures the effect of average movements to/from the frontier, economies of scale, variations in capacity utilisation, and measurement error.[3] For the reasons we set out below, TFP measured in this way has also been described as the "residual" or the "Measurement of Our Ignorance".[4]

The data issues imply that we should not place weight on productivity estimates for narrowly defined sectors or for short periods. Instead we must use long-term trends in the average for widely drawn comparator sectors (i.e. averages for DPCR5 comparator sectors) and the

2 Ofgem (2013) Strategy decisions for the RIIO-ED1 electricity distribution price control: Tools for cost assessment, chapter 4.

3 OECD (2001) Measuring Productivity, Measurement of aggregate and industry level productivity growth, OECD manual. Available on-line: http://www.oecd.org/std/productivity-stats/2352458.pdf

4 Jorgenson, D.W. and Griliches, Z. (1967) The explanation of productivity change, Review of Economic Studies, vol. 34 (3) p. 249.

whole economy. We show below that the productivity results for our proposed productivity measures are not very sensitive to the time period selected.

In terms of productivity measures, we discuss whether we should draw on gross output (GO) or value-added (VA) measures of productivity. Measures of GO TFP and GO PFP (Partial Factor Productivity) are consistent with Ofgem's intended application of productivity growth estimates to all factors of production when setting the final price for DNOs' gross output. We therefore use the GO measures in the EU KLEMS database. Specifically, we draw on GO TFP productivity estimates as our estimate for on-going productivity for the "network investment" expenditure category, and GO PFP for labour, energy, materials and services ("LEMS") for the "operational activities" expenditure category.

Table 5 sets out the mid-point and range of estimates for the two expenditure categories drawn from the relevant long-term measures of GO productivity growth for DPCR5 comparator sectors and for the whole economy, as well as Ofgem's decision for NGET at RIIO-(E)T1.

Ofgem's mid-point estimates of productivity growth are higher than our mid-point estimates, primarily because Ofgem included VA TFP as well as GO TFP within the range used to provide conclusions for RIIO-T1. (Ofgem also cited TFP and PFP estimates set out in network companies' business plans.) Estimates of VA TFP are systematically higher than estimates of GO TFP, due to differences in their definition. However, Ofgem noted that VA measures may not be well-suited to its intended purpose.

Table 5
Productivity Estimates (Percent per Annum)

Ongoing Efficiency Estimate	Operational Activities	Network Investment
NERA Mid-Point	0.7%	0.6%
NERA Upper Bound	1.1%	0.8%
NERA Lower Bound	0.4%	0.4%
Ofgem RIIO-T1/GD1	1.0%	0.7%

Source: NERA analysis.

Change in Unit Costs: RPEs Net of Productivity Growth

Table 6 sets out our estimates of the net effect of RPEs (raising real prices) and productivity growth (reducing real prices) for the period 2013-2023.

Table 6
Combined Effect of RPEs and Productivity Growth, by Category of Expenditure (Percent per Annum)

Average 2013-2023	RPE	Efficiency	Net Effect
Operational Activities			
Mid-Range	0.7%	0.7%	0.0%
Upper Bound	1.1%	0.4%	0.7%
Lower Bound	0.3%	1.1%	-0.8%
Network Investment			
Mid-Range	0.6%	0.6%	-0.1%
Upper Bound	0.9%	0.4%	0.5%
Lower Bound	0.1%	0.8%	-0.7%

Source: NERA analysis.

We cross-checked our estimates of the combined effect of RPEs and productivity growth against long run changes in units costs, using EU KLEMS and COPI data. The combination of RPEs and productivity growth needs to satisfy this cross-check, or else the estimates of RPEs and/or productivity growth need to be re-considered. For both operational activities and network investment, we found that, our estimates fall within the range of historical changes in unit costs in comparator sectors, and thus satisfy this cross-check.

1. Introduction

In a price or revenue cap regime where allowed revenues are indexed by the change in a general price index minus an efficiency term "X", to allow a regulated entity to recover its costs, X has to be set to allow for the change in real input prices faced by the firm net of the expected improvement in its total factor productivity (TFP). We briefly derive this result below, and then describe the objective and structure of this report.

1.1. Defining X

As set out in equation (1), to enable a regulated entity to recover its costs, the change (Δ) in the output prices or average revenue (ΔR) of firm j should equal the change in its input prices (ΔIP) minus the change in its total factor productivity growth (ΔTFP):[5]

$$\Delta R_j = \Delta IP_j - \Delta TFP_j \qquad (1)$$

Under an RPI-X regime, the change in allowed revenue (ΔR) is set equal to the change in a general price inflator (ΔRPI) and an efficiency factor X:

$$\Delta R_j = \Delta RPI - X_j \qquad (2)$$

By combining equations (1) and (2) and re-arranging terms,[6] we can show that:

$$-X_j = [\Delta IP_j - \Delta RPI] - \Delta TFP_j \qquad (3)$$

The first term on the right-hand side of equation (3) is referred to by Ofgem as the real price effect (RPE). For the second term, TFP, Ofgem uses the term "ongoing efficiency" and we use the Ofgem term for the sake of consistency.

1.2. Objective and Structure of This Report

Ofgem requires each electricity distribution network owner (DNO) to submit its assumptions about expected RPEs and ongoing efficiency over the control period as part of its business plan submission for RIIO-ED1.[7] UK Power Networks asked NERA to calculate RPEs and ongoing productivity improvements for inclusion to its business plan.

This report proceeds as follows:

---

5 As explained below, we carried out our calculations after converting indices into log values, meaning that the subtraction described in equation (1), e.g., corresponds to the following equation:
(Rate of change in revenue) = (1+ Input Price inflation)/(1+TFP growth) -1.

6 For a more detailed derivation see: NERA (2007) The Line in the Sand: The Shifting Boundary Between Markets and Regulation in Network Industries, Chapter 5, *Elusive Efficiency and the X factor in Incentive Regulation: The Tornqvist v. DEA/Malmquist Dispute*,

7 Ofgem (2013), Strategy decisions for the RIIO-ED1 electricity distribution price control Tools for cost assessment, Supplementary Annex to RIIO-ED1 Overview Paper, (26e/13), 04 March 2013, page 19,

- Chapter 2 sets out our methodology for calculating RPEs;
- Chapter 3 provides our recommended RPEs for UKPN’s business plan;
- Chapter 4 calculates the long-run productivity improvement likely to be experienced by DNOs; and
- Chapter 5 concludes.

We provide further details on the precise data and methods used in Appendices A to C.

Our analysis suggests that RPEs for UKPN will be positive over the RIIO-ED1 price control, as its input prices grow more quickly than RPI. On the other hand, long run trends suggest that electricity distribution networks are likely to experience an increase in productivity which will reduce their costs over time. After combining these offsetting trends, our analysis suggests that the expected change in the cost of each unit of output will be *minus* 0.3% per annum for opex and *minus* 0.1% per annum for capex in real terms.

2. Approach to Estimating Real Price Effects

Real Price Effects (RPEs) capture the difference between changes in the general retail price index (RPI) and changes in the DNOs' own costs. Ofgem calculates separate RPEs for opex and capex in order to adjust DNOs' allowed revenues to reflect the relative inflation in different elements of their costs.[8] Our approach to estimating RPEs is similar to Ofgem's at RIIO-T1/GD1; we use objective forecasts for the short run (where available), and the trend rate of relative price inflation for the long run. We reviewed a wide range of publicly available series in order to select the most effective data for forecasting the RPEs likely to be experienced by the DNOs. We weighted the RPEs by *input* cost categories to identify separate RPEs for the DNOs' main *expenditure* categories, capex and opex.

- Section 2.1 defines RPEs and explains their role in regulation in Great Britain;
- Section 2.2 explains our approach to calculating RPEs using forecast data and historical trends;
- Section 2.3 summarises how we selected the data and calculated the RPEs for five input categories to make best use of available information about the likely future evolution of DNOs' input prices;
- Section 2.5 explains how we weighted the RPEs for each of the *input* categories to convert them into RPEs for *expenditure* categories, i.e. opex and capex.

2.1. Background on Real Price Effects in RIIO-ED1

Ofgem links the allowed revenues of the electricity distribution networks to retail prices in the wider economy. However, DNOs do not procure the same basket of goods as consumers in retail markets. As a result, DNOs' input prices may evolve differently over time from general retail price inflation. Ofgem therefore adjusts DNOs' revenue allowances to allow them to recover their actual or expected costs. In RIIO-ED1, as in DPCR5 and RIIO-T1/GD1, Ofgem intends to adjust base revenues in order to "account for this differential between RPI inflation and expected input price inflation".[9] Specifically, Ofgem will calculate Real Price Effects (RPEs) by the following formula:

RPE = Input Price Inflation *minus* Retail Price Inflation

As part of its strategy consultation for RIIO-ED1, Ofgem explained that it proposed to calculate RPEs based on a methodology for each of the following categories of inputs (following the approach it adopted in RIIO-T1/GD1):[10]

- Labour;
- Materials;

8 At RIIO-GD1, Ofgem also calculated RPEs for repex, but we understand that it will only calculate opex and capex for RIIO-ED1

9 Ofgem (2012), *Strategy consultation for the RIIO-ED1 electricity distribution price control Tools for cost assessment, Supplementary annex to RIIO-ED1 overview paper*, page 84, para 11.7

10 Ofgem (2012), *Strategy Consultation for RIIO-ED1*, pages 84-85.

- Equipment and plant; and
- Transport and Other.

In RIIO-T1/GD1, Ofgem also combined the RPEs for each of these categories of *inputs* into RPEs for categories of *expenditure* based on the weights of each input in each category of expenditure.[11] We presume that Ofgem will also calculate RPEs for expenditure categories in RIIO-ED1.

2.2. Our Approach to Calculating RPEs

Market-based forecasts of input price inflation for electricity distribution business are not available for the coming eight-year price control period. Supply and demand models to calculate the resulting prices for labour and materials would be complex and would require a large number of assumptions. In practice, therefore, regulators in the UK use less subjective approaches to estimate RPEs, relying on a combination of published forecasts and historical trends:

- Published forecasts for more general sectors of the economy, such as market forecasts of wages and/or commodities, reflect likely future changes in the economy as a whole, but may not reflect trends in the electricity sector specifically. Such forecasts are rarely available for the long term, even for general inputs.
- Historical trends in the difference between input price inflation and retail price inflation can be used to predict these trends into the future. Historical trends in input price inflation for electricity distribution are directly relevant to the electricity sector. They are only suitable for predicting future prices to the extent that the future is similar to the past. However, evidence from economic literature suggests that economies (and by extension the real prices of factors of production such as labour and materials) exhibit stable trend rates of growth in the long run.[12]

Using published forecasts and long run historical trends is consistent with regulatory precedent in the UK. Regulators of the energy, water and transport sectors use historical trends and forecast data to set allowances after accounting for input price inflation.[13] To assess RPEs in RIIO-T1/GD1 and previous price controls, Ofgem reviewed a combination of forecast and historical data. We used forecasts and long run historical trends to estimate RPEs

---

[11] For the GDNs, Ofgem used a notional weighting of each input category in each expenditure category. For the Transmission Companies, Ofgem used the weightings that each company submitted as part of its business plan.

[12] Under the Solow growth model, wages in an economy in steady-state with constant capital per unit of labour will grow at a rate equal to the (constant) growth in marginal labour productivity. Returns to capital inputs (such as plant, equipment and machinery) similarly grow at a constant rate based on their marginal productivity. The productivity of labour and capital inputs are driver by exogenous technical progress over the long term. A discussion of the findings on economic growth and productivity can be found in: Temple (1999), "The new growth evidence", *Journal of Economic Literature*, page 112-156. The relevance of the Solow Model as an explanation of economic growth is explained in: Mankiw, Romer and Weil (1992), "A Contribution to the Empirics of Economic Growth", *Quarterly Journal of Economics*. Jones (1995) observes that the empirical evidence is that income exhibits a trend rate of growth in Jones (1995), "Time Series Tests of Endogenous Growth Models", *Quarterly Journal of Economics.*

[13] See for example Ofwat (2008), Setting price limits for 2010-15: Framework and approach, March 2008, section 5.4. and Competition Commission, Heathrow / Gatwick quinquennial review: Final report, Competition Commission, 3 October 2007, Appendix D para. 166-168.

for EDF Energy's networks at DPCR5 and we have followed the same approach again in this report.

2.3. Methodological Overview

Our approach relies on identifying and selecting forecast and historical series which reflect the likely evolution of the costs of electricity distribution networks over the next regulatory period (RIIO-ED1) as closely as possible. Proprietary series are available for measuring and forecasting the evolution of costs faced by electricity distribution businesses. Although relevant to the industry, however, proprietary forecasts run the risk of being non-transparent, with assumptions and methodologies that are not entirely clear and with values which cannot be subjected to regulatory scrutiny by Ofgem. As a result, when calculating RPEs, we only investigated potentially suitable data that was in the public domain, including data sources that Ofgem has relied upon in the past.

We evaluated each candidate series based on the following three criteria:

- **Coverage:** We evaluated whether an index (or combination of indices) is intended to measure the evolution of costs for a category of expenditure close to the categories identified by Ofgem. For example, an index measuring the prices of transformers and switchgear covers the costs of electricity distribution companies more closely than a general manufacturing index or economy wide materials index.
- **Empirical Fit:** We compared whether the index matched recent trends in UKPN's input prices where suitable data was available. Our test for empirical fit included reviewing the evolution of the series over time as well as the mean level of growth.
- **Information Value:** We examined whether each series added information to the average. Data from longer time series and series constructed from a larger sample of items are less likely to be distorted by anomalous data points, such as the business cycle effects or individual procurement contracts. Where data series were only available for a short period of time and had small survey sample sizes, we considered excluding the data. Similarly, we considered excluding series which evolved similarly to other series which closely matched the costs of the DNOs, as they added no new information.

By applying these criteria, we identified the series which provide the most objective and reliable evidence for calculating RPEs. We present the average indices we considered for our final comparison in chapter 3 and describe our evaluation of each series against the criteria listed above in Appendix A, below.

Our approach required us to calculate average rates of growth for different input price indices which were available for different periods of time. In each case, we estimated historical trends over the longest time period for which each index was available.

In selecting forecast data series, we considered only objective market-based forecasts, such as the observed prices of traded commodities, and reputable government sources, such as the HM Treasury consensus forecasts based on market expectations of wage inflation. Our analysis took account of forecast data where such forecasts: (1) were objective, transparent and from a reputable source or market-based; and (2) provided compelling evidence about the evolution of input prices for electricity distribution networks (i.e. they were closely related to DNOs' costs). Where forecasts of DNO input prices were not available directly, we considered forecasts of related inputs and made any adjustments necessary to convert a forecast of one input into a forecast price for another input.

No market-based forecasts are available more than two or three years ahead, so for longer term forecasts we assumed that RPEs revert to their long run historical trend. Our approach to combining short term forecasts and long term trends assumes that RPEs converge on the long run trend rate of growth by the end date of the short term forecast, i.e. that short term forecasts are required – and are therefore produced – only for periods when RPEs are expected to deviate from the long term trend. In order to test our results for sensitivity to this assumption, we also provide RPEs which revert immediately to the long term trend and ignore short term forecasts.

2.4. Definitions of Input Costs

Ofgem listed four input cost categories in its Strategy Decision for RIIO-ED1:

- Labour;
- Materials;
- Plant & Equipment;
- Transport and other.

Ofgem does not define these cost categories in its Strategy Consultation, or in its Strategy Decision for RIIO-ED1, or in the Initial or Final Proposals for RIIO-T1/GD1. We were unable to find standard definitions of Ofgem's input cost categories in accounting, business or economics textbooks. These cost definitions are therefore slightly ambiguous. For instance, in the case of an electricity distribution network, a transformer or cable could either be regarded as *equipment* for the purposes of delivering electricity or *materials* for the purposes of building or maintaining a network.

In the absence of any concrete definition of the input cost categories, we inferred Ofgem's intended definitions from its work at RIIO-T1/GD1. We used two key pieces of evidence to define the split between equipment and materials:

- In its Initial Proposals at RIIO-T1/GD1, Ofgem proposed using PPIs measuring the costs of equipment and machinery to calculate *materials* RPEs.[14]
- Ofgem published input shares for each of the input categories for a notional GDN (see Table 2.1, below). The share of *equipment* costs in capex is 4%, which appears low if Ofgem intends equipment to include compressor stations and pipelines (the gas sector equivalent of transformers and wires in the electricity sector).

We have therefore assumed that Ofgem's input cost categories have the following meanings:

- Labour – the full cost of wages for electricity distribution companies' staff, including bonuses, but excluding taxes on the employer and pension contributions.

[14] For example, Ofgem reviews two series entitled "Electricity distribution and control apparatus" and "Machinery" as candidate series to measure RPEs for materials costs. See Ofgem (27 July 2012) RIIO-T1/GD1: Initial Proposals – Real price effects and ongoing efficiency appendix, p.11.

- Materials – physical goods used in the manufacture and maintenance of the electricity distribution network that become fixed assets as part of the network or are used up in maintaining the network.[15] These cost items include cables, transformers, switchgear and building materials such as aggregates.
- Equipment – machinery that distribution networks use to construct, maintain and repair the network.[16] Equipment falling within this definition includes tools, drills and vehicles such as vans or construction vehicles.
- Transport and other – fuel necessary for transporting materials and staff and other costs.

If Ofgem intended to apply different definitions, the principal effect would be to reclassify the series we have chosen from one category of expenditure to another. Our conclusions would remain largely unchanged on average.

2.5. Calculating RPEs for Opex and Capex

In RIIO-T1/GD1, Ofgem converted its estimated RPEs for DNOs' *inputs* (labour, materials etc.) into RPEs for three categories of *expenditure* (opex, capex and repex). Ofgem calculated RPEs for categories of expenditure by taking a weighted average of the RPEs for input categories, where the weights reflected the share of each input in the category of expenditure:

- For the transmission companies (NGG, NGET, SHETL and SPT), Ofgem used the input cost shares of opex and capex reported by the companies in order to calculate RPEs for expenditure categories; and
- In the case of the Gas Distribution Networks, Ofgem employed a notional structure for opex, capex and *repex*, a category of costs that only applies to GDNs.

We asked UKPN to provide data on its own expected shares of input costs for each category of expenditure over RIIO-ED1. We used the data provided to us by UKPN, for the period 2014 to 2023, to calculate the weighted average RPE for two categories of expenditure: opex and capex. See Table 2.1 below.

---

15 See for example online definitions of materials in general at www.ventureline.com/. "MATERIALS are physical goods (and their cost) used in the manufacture of a product, often separated into DIRECT MATERIAL (that which goes directly into the product such as cream into ice cream, or steel into cars) and INDIRECT MATERIAL (that which is used in maintaining the manufacturing environment such as cleaning fluids or oil for lubrication of manufacturing equipment). Indirect materials are usually part of the overhead component of cost. The term material, when used without the direct or indirect qualifier, usually refers to direct materials."

16 See for example online definitions of equipment in general at www.ventureline.com. "EQUIPMENT is generally determined by the meeting of three tests: a. Has an acquisition cost that is equal to or more than the cost hurdle for classifying capitalized assets. Includes: Invoice amount, sales tax, freight costs, installation costs, costs for the initial complement of supplies needed to place the asset into service, accessory and auxiliary apparatus necessary to make it usable for the purpose for which it was acquired; less trade or trade in discounts and/or educational allowances Excludes: Federal Excise tax, duty, insurance, maintenance and warranty costs; and, b. Has a useful life of two or more years If the item will not have a useful life of more than two years it is considered expendable material, even if it costs more than the level for determining a capital asset; and, c. Is a stand-alone item. The item is not permanently attached to or integrated into a building or structure."

Table 2.1
UKPN's Forecast Cost Structure (2014–2023)

Expenditure Share	Opex	Capex
Labour	83%	65%
Materials	10%	20%
Equipment and Plant	0%	8%
Other	6%	7%

Source: NERA analysis

3. Calculation of Real Price Effects for Input Categories

Our approach to calculating RPEs consisted of reviewing the available series according to our criteria and selecting the most appropriate indices to reflect the costs faced by DNOs. Appendix A provides a detailed review of all of the indices that we identified as candidates. This chapter summarises the results of that investigation, and proceeds as follows:

- Section 3.1 presents the results for labour;
- Section 3.2 presents the results for materials;
- Section 3.3 presents the results for plant/equipment;
- Section 3.4 presents the results for transport and other costs; and
- Section 3.5 concludes.

Our analysis suggests that DNOs will experience a higher RPE for labour over the course of RIIO-ED1 than Ofgem assumed for the network companies during RIIO-T1/GD1. On the other hand, our estimated RPEs for materials and plant and equipment are lower than Ofgem's estimates for the transmission and gas distribution companies. We agree with Ofgem that there is limited evidence for a non-zero RPE assumption for the "transport and other" cost category.

3.1. Labour

Distribution companies employ a wide variety of staff, from specialist electrical engineers and construction workers through to management and administrative staff. In its RIIO-ED1 Strategy Decision, Ofgem explained that the data available to assess RPEs consisted of indices measuring "wages for the general economy and more specialist industries".[17] This section sets out the series we selected and a summary of the reasoning behind this selection (see Appendix A.2, below, for a detailed evaluation of all of the series we considered).

3.1.1. Historical series

Our review revealed the two historical series that provide the strongest basis for estimating labour RPEs, according to our criteria:

- **Private Sector Average Weekly Earnings (AWE) index**, published by the ONS since 2000, is a broad-based index based on a wide survey of private sector companies. This index superseded the Average Earnings Index (AEI), published by the ONS until 2010, which we append to AWE series to extend it into the period before January 2000. Our analysis showed that there was no systematic difference between private sector wages in general and wages in industries such as construction, transport, and engineering. A broad index for private sector earnings is also a good proxy for the evolution of generalist staff.
- **Electrical Labour Index**, published by the British Electrotechnical and Allied Manufacturers Association (BEAMA), consists of monthly data beginning in 1970. This

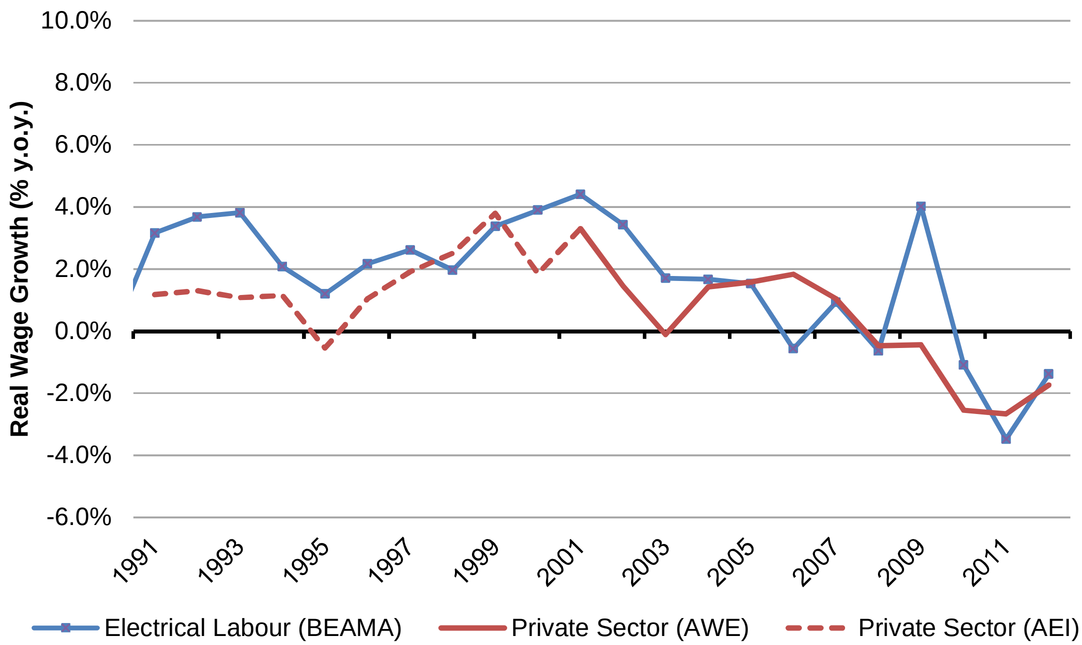
[17] Ofgem (2013), *Strategy consultation for the RIIO-ED1 electricity distribution price control Tools for cost assessment*, page 84, para 11.10.

specialist index is more narrowly focused on the specific labour categories employed by UKPN, including highly qualified electrical engineers and semi-skilled electrical labour.

Figure 3.1 shows both of these series in real terms since January 1991. We have extended the series of annual changes in AWE backwards in time from January 2001 by appending annual changes in the AEI. Over the period we studied, average annual private sector wage growth has been 0.83% per annum in real terms, with the electrical labour index growing by 1.75% per annum in real terms, a difference of roughly 0.9% per annum.

Our proposed measure of the long-run trend RPE is the unweighted average of the RPEs for the private sector and for electrical labour. This average is 1.3% per annum.

Figure 3.1
Labour RPEs (Electrical Labour and Private Sector Wages)
Year on Year Rates of Change by Calendar Year
(Percent per Annum)



Source: NERA Analysis of ONS and BEAMA Data[18] *AWE is used from January 2000, AEI for all earlier years.*

UKPN provided us with recent data on the proportion of Full Time Equivalent (FTE) staff attributed to "Direct Costs" and "Closely Associated Indirects and Business Support". We understand from UKPN that, as a rule, staff classed under "Direct Costs" are electrical labourers, whilst other staff are general labour. "Direct Costs" account for 53% of FTEs, whilst other staff account for 47%. However, these proportions change slightly over time. Therefore, an unweighted average, which places a 50% weight on the cost of electrical labour

[18] Real growth calculated against RPI CHAW "All items".

and a 50% weight on the cost of general labour, is a reasonable approximation to the cost of the labour force employed by UKPN.

3.1.2. Forecast data

The primary market-based forecast we consulted is published by HM Treasury, which produces wage growth forecasts and predictions for the whole economy for the next two years, by surveying independent forecasts. In the latest available publication (February 2013), the median forecasts were:

- In 2013: RPI inflation of 2.9% and wage growth of 2.2%, leading to an RPE of -0.7%.[19]
- In 2014: RPI inflation of 3.0% and wage growth of 2.5%, leading to an RPE of -0.5%.[20]

A second source of market-based forecasts for wages in the electricity sector was available from the Joint Industry Board for the Electrical Contracting Industry.[21] The so-called “JIB Rates” indicate the wage rates that a distribution network can expect to pay. “JIB rates” have remained flat since 2010, but are due to rise in January 2013 and 2014 by the following amounts for a “Technician”:

- In 2013: a rise of 1.5% (real rise of -1.4% after subtracting forecast RPI); and
- In 2014: a rise of 2.0% (real rise of -1.0% after subtracting forecast RPI):[22]

We note that forecast growth in “JIB rates” is lower than forecast growth for earnings in the economy as a whole. We also note from our discussions with UKPN that, in practice, wage settlements do not always reflect the published rates. Therefore, we propose to use the JIB rates only to place a lower bound on our short term forecast of real wage growth.

Our proposed central measure of labour RPEs for electricity distribution companies is a composite index, calculated as the unweighted average of:

- the BEAMA index of Electrical Labour costs; and
- the Average Weekly Earnings for the private sector (supplemented by earlier data on Average Earnings Index for the private sector).

In practice, wages in the electricity industry have risen more quickly over time than in the economy as a whole. Since 2000, the BEAMA index of electrical labour has grown by 1.5% per annum more than Average Weekly Earnings in the private sector, and by 1.4% per annum more than Average Weekly Earnings in the whole economy. As a result, the short term (2013 and 2014) forecast RPEs for the whole economy would not be consistent with our forecasts for the long run trend in growth of earnings for electrical labour.

---

19 HM Treasury (2013), *Forecasts for the UK Economy: A Comparison of independent forecasts*, February 2013, page 8.

20 HM Treasury (2013), *Forecasts for the UK Economy: A Comparison of independent forecasts*, February 2013, page 11.

21 http://www.jib.org.uk/

22 See http://www.jib.org.uk/handbook.aspx?cid=13, accessed 28 February 2013. Percentages are reported after (after accounting for rounding hourly rates to whole numbers.

We measured the average difference between (1) wage growth in the economy as a whole and (2) labour costs for electricity distribution companies. We measured the latter as the average of (2a) the BEAMA electrical labour index and (2b) Average Weekly Earnings in the private sector. Over the longest period for which data was available for all three of these indices, the trend annual rate of growth in (1) was on average 0.23 percentage points higher than the trend annual rate of growth in (2).[23] We therefore adjusted the forecast labour RPEs for the whole economy to derive a forecast for the private sector, by adding a premium of 0.23% per annum.

Our resulting forecasts for the labour RPE faced by electricity distribution companies were -0.5% in 2013 and -0.3% in 2014.

3.1.3. Range of Results

Our recommended labour RPEs consist of two central scenarios, bounded by high and low estimates. See Table 3.1 below for a summary. The starting point for our estimates are estimates for the current year (2012/13) and long term historical trends observed since 1990:

- **RPEs for 2012/13:** The RPE for 2012/13 is the actual difference in current year growth rates between RPI and a measure of wage inflation:
  - Using our composite measure of real wage growth for electricity distribution companies (the unweighted average of earnings growth in the private sector and in the BEAMA electrical labour index), our central estimate is *minus* 1.1% per annum;[24]
  - We define our upper bound by examining only growth in the BEAMA index, which was *minus* 1.1% in 2012/13 and has averaged 1.8% since 1990.
  - We define our lower bound by examining only growth in the Private Sector AWE and AEI indices, which was *minus* 1.2% in 2012/13 and has averaged 0.8% since 1990.
- **Long Term Trend RPEs:** Using the long term historical trend in the same indices, we derive long term forecasts:
  - our central estimate is 1.3% per annum, the average difference observed since 1990 between our composite measure and RPI inflation;
  - our upper bound is 1.8% per annum, the average difference observed since 1990 between the BEAMA index and RPI inflation; and
  - our lower bound is 0.8% per annum, the average difference observed since 1990 between the private sector AWE/AEI indices, and RPI inflation.

We then defined two scenarios for the transition from the current values to the long term trends:

---

[23] January 2000 to November 2012.

[24] Note, we extrapolate the RPE for 2012/13 to the end of the financial year where a few months at the end of the financial year were missing.

- **First Transitional Scenario – Near Term Forecast for 2013/14 and 2014/15:** In our first transitional scenario, before reverting to long run trends from 2015, we adopted specific short term forecasts for real wage growth in 2013/14 and 2014/15:
  - Our central case takes the HM Treasury consensus forecast for real wage growth in 2013 and 2014 and adds a premium of 0.23%, to reflect the long run difference between (1) growth in AWE earnings index for the whole economy and (2) wage growth in the electrical and private sectors (our average of the BEAMA electrical labour index and private sector earnings);[25]
  - Our upper bound takes the HM Treasury consensus forecast and adds a premium of 0.55%, to represent the long run difference between (1) growth in AWE earnings index for the whole economy and (2) growth in the BEAMA electrical labour index; and
  - Our lower bound uses the forecast real growth in JIB rates in 2013 and 2014, i.e. *minus* 1.4% and *minus* 1.0% respectively.
- **Second Transitional Scenario – No Near Term Forecast:** For our second transitional scenario, our forecast RPEs revert immediately from 2013/14 to the long run trend rate of 1.3% per annum.

Table 3.1
Labour RPEs, Year on Year Rates of Change by Financial Year
(Percent per Annum)

Labour RPEs	2012/13	2013/14	2014/15	2015 - 2023	Average
Near Term Forecast					
NERA Mid-Point	-1.1%	-0.5%	-0.3%	1.3%	0.8%
Upper Bound	-1.1%	-0.1%	0.1%	1.8%	1.2%
Lower Bound	-1.2%	-1.4%	-1.0%	0.8%	0.3%
No Near Term Forecast					
NERA Mid-Point	-1.1%	1.3%	1.3%	1.3%	1.1%
Upper Bound	-1.1%	1.8%	1.8%	1.8%	1.5%
Lower Bound	-1.2%	0.2%	0.2%	0.8%	0.5%

Source: NERA analysis of ONS, BEAMA and HMT Data

3.2. Materials

For the purposes of this analysis, we have defined materials as inputs into electricity distribution networks that become subsumed as part of the network themselves or are used up in less than two years in the course of the network's business. For example, we consider materials to include wires and cables, transformers, aggregates and building materials. This section includes the final series we selected and a summary of the reasoning behind the selection of these series. See Appendix A.3 for a detailed evaluation of all of the series we considered.

[25] Calculated since January 2000, when AWE data is first available.

3.2.1. Historical series

We understand from UKPN that its materials costs comprise three sub-categories weighted as follows:

- transformers and switchgear with a 25% weighting,
- wires and cables with a 30% weighting; and
- residual materials costs including construction materials with a 45% weighting.

We reviewed the available Producer Price Indices (PPIs) to assess which met our criteria of (1) covering each of these sub-categories as accurately as possible, (2) offering a long time series with a reliable breadth of participation and (3) cross-checking against the historical unit costs incurred by UKPN.

UKPN did not have detailed unit price information on its materials expenditure. Much of the cost information that UKPN has covers not only the materials costs incurred by the business in procuring transformers or cabling, for example but also other costs, such as the labour costs of installing transformers or cabling. In the course of our review, we rejected PPIs based on commodity prices. We also rejected alternatives based on related manufactured products (such as copper piping) which may be indicative of the costs of inputs purchased by UKPN (such as copper wiring) but where series with a more relevant coverage were available. For full details on this review of the available series consult section A.3.

Our analysis resulted in us selecting the following series to calculate the RPEs for electricity distribution:

- **Transformers and Switchgear:** We took an equal weighting of two Producer Price Indices published by the ONS: "Electric Motors, Generators and Transformers" and "Electricity Distribution and Control Apparatus". Both series offered relevant coverage for this sub-category of costs and had long time series data available (from 1987).
- **Wires and Cables:** We took an equal weighting of two other PPIs, "Cold Drawn Wire" and "Other Electronic and Electric Wires and Cables", as the two series that offered relevant coverage and for which long term data (from 1987) is available;[26] and
- **Other materials:** We used the FOCOS Infrastructure Resource Cost Index (RCI) as a broad index with a wide sample and a long sample period. The RCI tracks materials costs which are not specific to DNOs, providing quarterly data from 1990 and annual data from 1985.

Figure 3.2 shows the annual rates of change in these series since 1988. The different materials indices follow very different paths:

- **Transformers and Switchgear: "**Electricity Distribution and Control Apparatus" and "Electric Motors, Generators and Transformers" had relatively stable RPEs over time. Over the period since 1987 for which data is available, "Electricity Distribution and

---

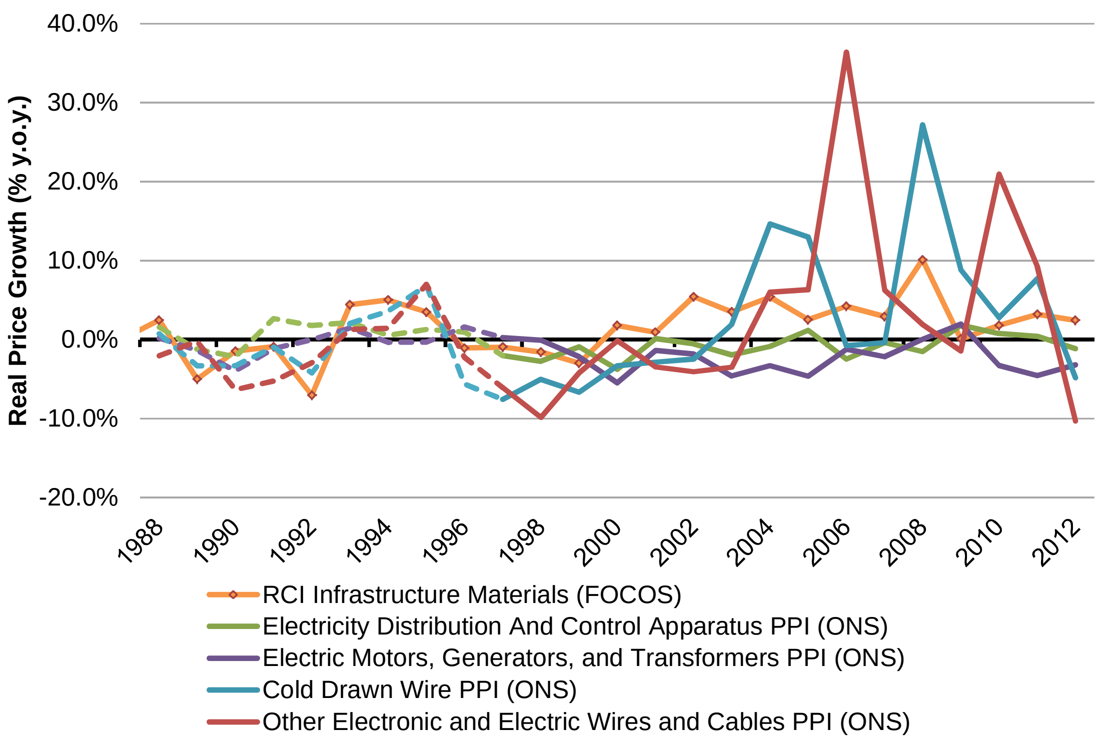
[26] As described in A.3, we appended two earlier ONS PPI series to chosen series, choosing the series which included he most similar items.

Control Apparatus" had an average RPE of -0.26% and "Electric Motors, Generators, and Transformers" had an average RPE of -1.64%.

- **Wires and Cables:** The PPIs for "Cold Drawn Wire" and "Other Electronic and Electric Wires and Cables" are more volatile and also have the higher RPEs, averaging 2.24% and 2.05% per annum, respectively, since 1987. This may reflect the minimal processing required to manufacture wiring from commodities whose prices are themselves volatile.
- **Other:** The Resource Cost Index is an average of indices for different categories of materials inputs and the averaging makes it less volatile over time. Its average RPE since 1987 is 1.54% per year.

We calculated unweighted averages of the PPI growth rates within each category of expenditure. We then weighted these growth rates by the proportions of total expenditure given above. The average trend RPE for materials resulting from using these five indices for the three subcategories is 1.0% per annum.

Figure 3.2
Electrical Materials RPEs, Year on Year Rates of Change by Calendar Year (Percent per Annum)



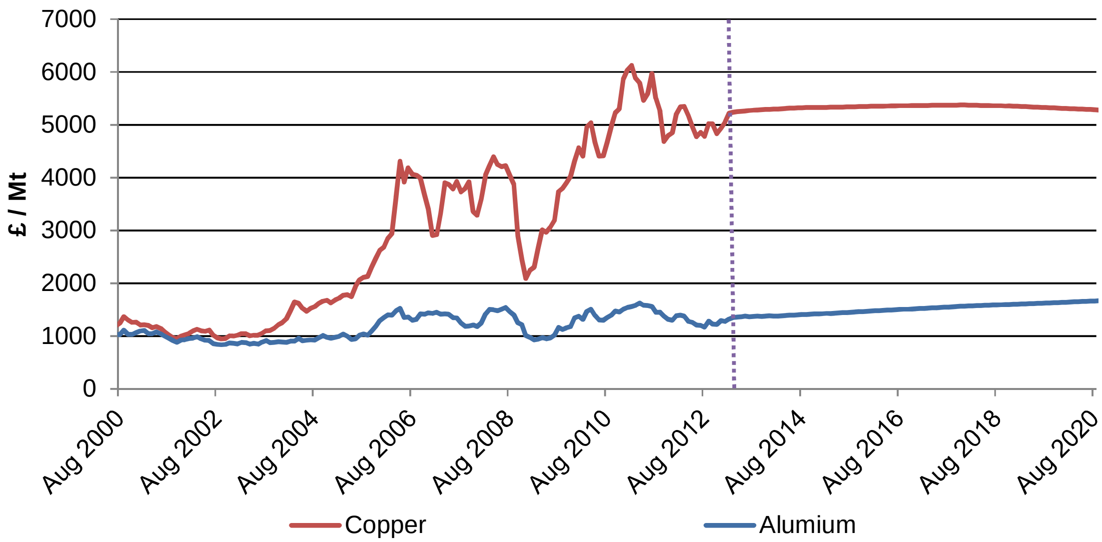
Source: NERA analysis of BIS and ONS data.

3.2.2. Forecast data

No detailed, objective and market-based forecasts of input prices for materials costs were available. On the other hand, commodities are traded in deep and liquid markets. To the extent that prices of the manufactured materials bought by electricity distribution networks depend on the prices of the underlying commodities, it would be possible to forecast the prices of materials based on the future prices of their constituent commodities.

The principal commodities relevant to the materials costs faced by a distribution network are copper, steel, aluminium and crude oil. As Figure 3.3 shows, the prices of copper and aluminium have diverged markedly over the last decade, with copper prices increasing fivefold whilst aluminium prices have risen roughly 70%. The Figure also shows the forward curves for these commodities, which represent the market's current expectation of future prices.[27]

Figure 3.3
Copper and Aluminium Prices: Historical and Forward (£/Mt)



Source: NERA analysis of London Metal Exchange data, via Bloomberg.[28]

The price of crude oil is also a key determinant of the cost of the materials needed by a distribution network. Figure 3.4 shows that, in sterling terms, the price of crude oil is close to record levels, at around £80/bbl. The forward curve indicates that conditions in the market are expected to ease, with prices on forward contracts falling.

Finally, steel prices are also a determinant of the costs of materials faced by a distribution network. In Figure 3.5 we present steel prices (available from the LME since 2008) confirming the pattern in Figure 3.3, whereby future metal prices are largely flat, being determined by the cost of storing the commodity to sell in the future.

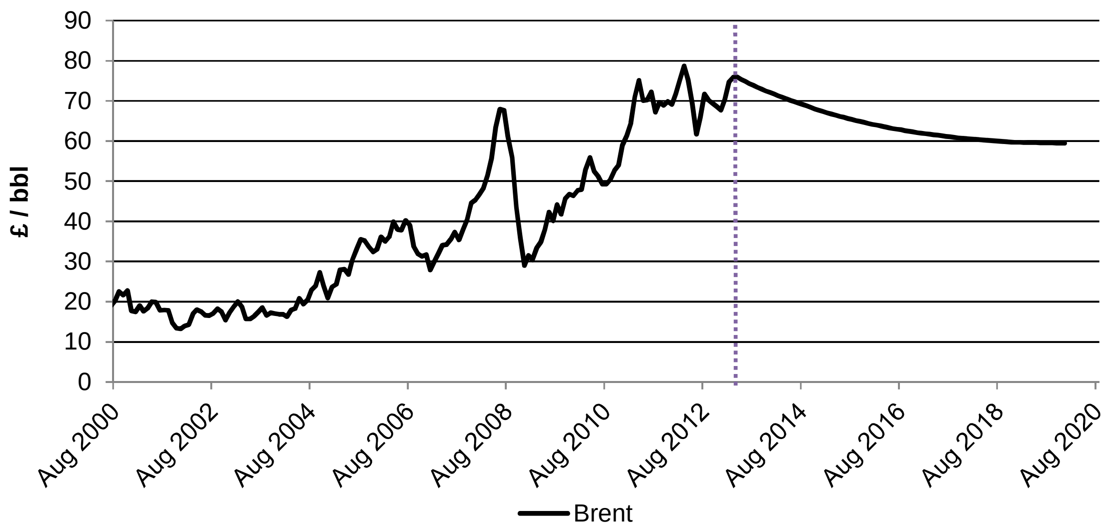
---

27 Reeve, T. and Vigfusson, R. "Evaluating the Forecasting Performance of Commodity Futures Prices", August 2011, provides evidence that futures prices are the (weakly) best forecast of commodity prices, compared to trend growth or a random walk.

28 Prices correct as of 18 February 2013. US$ prices are converted to sterling using the prevailing spot or forward rate, as appropriate.

These market forecasts provide, in principle, an objective basis for forecasting the future materials cost faced by a distribution network. However, we found the correlation between changes in commodities prices and changes in DNOs' input prices to be weak (see Appendix C). We therefore concluded that there was no strong justification for basing a forecast of real price changes on expected changes in commodity prices.

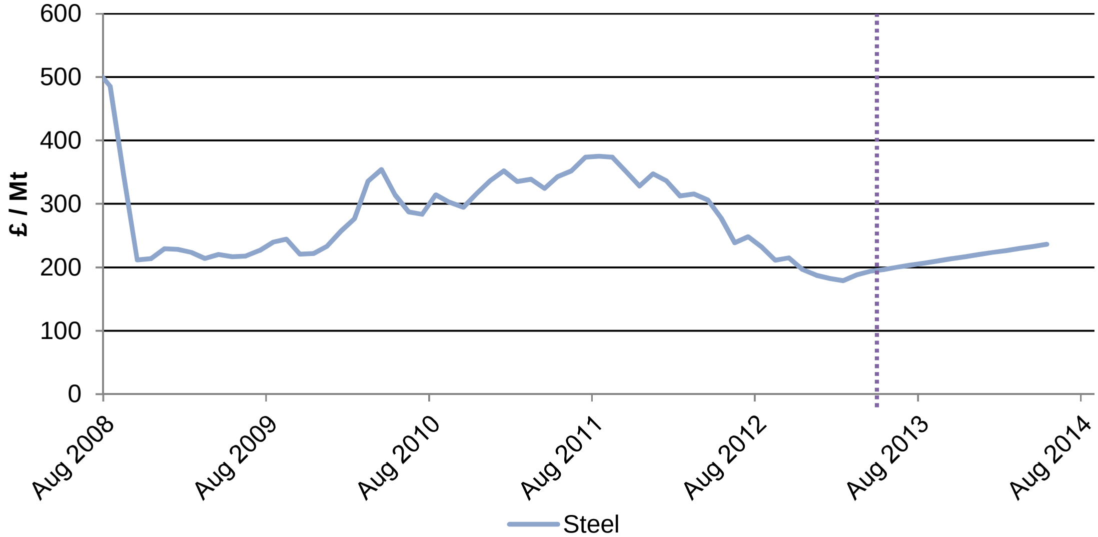
Figure 3.4
Crude Oil Price: Historical and Forward (£/bbl)



Source: NERA analysis of Bloomberg data.[29]

[29] Prices correct as of 18 February 2013. US$ prices are converted to sterling using the prevailing spot or forward rate, as appropriate.

Figure 3.5
Steel Price: Historical and Forward (£/Mt)



Source: NERA analysis of London Metal Exchange data, via Bloomberg.[30]

3.2.3. Conclusion

Our recommended RPEs for materials consist of a single scenario bounded by a range, as follows:

- For 2012/13, our RPE is a weighted average measure of real input price growth for electricity distribution companies.
  - Weighting the series covering Transformers (30%), Cables (25%) and Other Materials (45%) as described above gives a mid-point estimate of -2.0% per annum.[31]
  - Our upper bound uses only the fastest growing index in each category ("Electricity Distribution and Control Apparatus" and "Cold Drawn Wire");
  - Our lower bound uses only the slowest growing index in each category ("Electric Motors, Generators and Transformers" and "Other Electronic and Electric Wires and Cables").
- From 2013/14 onwards, our forecast RPE reverts to the long run trend rate of growth in this weighted average series, of 1.0% per annum. Our upper bound for this trend is 1.2% per annum and our lower bound is 0.7% per annum.

[30] Prices correct as of 18 February 2013. US$ prices are converted to sterling using the prevailing spot or forward rate, as appropriate.

[31] Note, we extrapolate the RPE for 2012/13 to the end of the financial year where a few months at the end of the financial year were missing.

Table 3.2
Materials RPEs (Percent per Annum)

Material RPEs	2012/13	2013/14	2014/15	Long Term
NERA Mid-Point	-2.0%	1.0%	1.0%	1.0%
Upper Bound	-1.6%	1.2%	1.2%	1.2%
Lower Bound	-2.3%	0.7%	0.7%	0.7%

Source: NERA analysis of ONS and BIS data.

3.3. Plant and Equipment

For the purposes of this analysis, we have defined plant and equipment as inputs into electricity distribution which last more than two years and which do not become fixed assets as part of the network. Examples of equipment would include tools and machinery for construction, maintenance and repair. Examples of materials include cabling and transformers (which later become fixed assets within the network). This section describes the final series we selected and summarises the reasoning behind the selection of these series. (See Appendix A for a detailed evaluation of all of the series we considered.)

3.3.1. Historical series

We reviewed the available Producer Price Indices to assess which met our criteria of (1) covering each of these sub-categories as accurately as possible, (2) offering a long time series with a reliable breadth of participation and (3) cross-checking against the historical unit costs incurred by UKPN.

We reviewed a range of PPIs which could reflect the evolution of equipment input prices for electricity distribution companies. We found PPIs for general machinery and equipment indices, plant and road vehicles and specialist indices for electrical equipment. The specialist indices for electrical equipment included cabling and transformers, which represent "materials" in the context of an electricity distribution network. For the purposes of calculating RPEs, "equipment" constitutes the tools, machinery and vehicles used by the electricity distribution network. General machinery and equipment indices offer a better proxy for the evolution of these costs.

UKPN could not provide detailed unit price information that accurately recorded its equipment costs alone, as opposed to the cost of equipment including materials and/or labour costs. As a result we were unable to check UKPN's historical unit costs against our proposed indices.

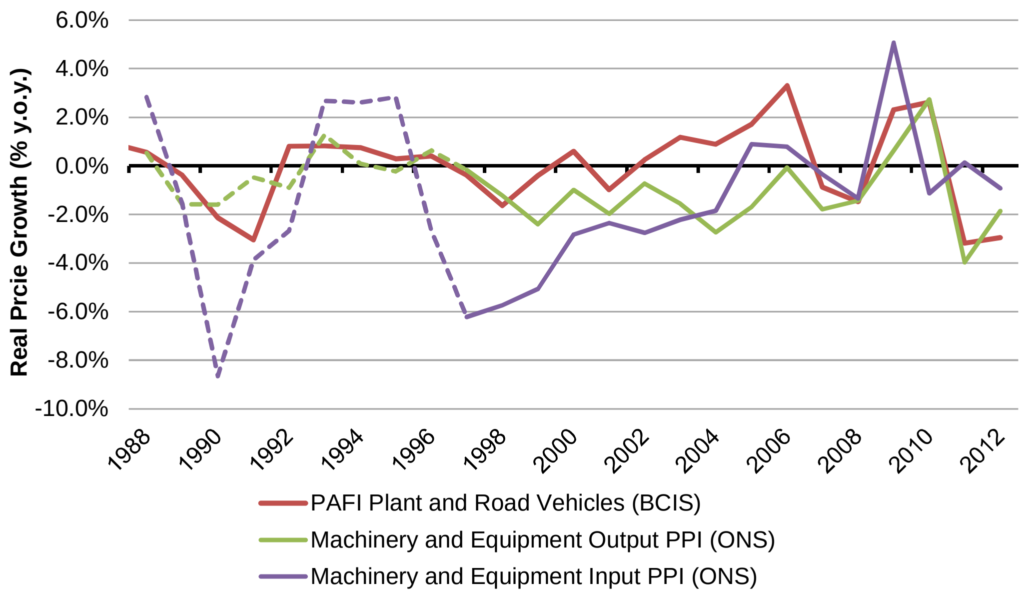
We selected the following series to calculate the RPEs for electricity distribution (Ofgem also used these series to calculate equipment RPEs at RIIO-T1/GD1.):

- **Machinery and Equipment Input PPI:** a broad index of the costs of *purchasing* machinery and equipment including the categories of equipment likely to be purchased by a DNO. The average RPE in this series from 1987 to 2012 is *minus* 1.27% per annum.
- **Machinery and Equipment output PPI**: a broad index of the costs of *producing* machinery and equipment, including the costs of manufacturing equipment likely to be purchased by a DNO. The average RPE in this series from 1987 to 2012 is *minus* 0.88% per annum.

- **Plant and Road Vehicles**: a broad index of the costs of plant and road vehicles including vehicles necessary for a DNO to carry out its activities. The average RPE for this series since 1987 is *minus* 0.04% per annum.

Figure 3.2 shows the evolution of these series, as year on year rates of change.

Figure 3.6
Equipment RPEs, Year on Year Rates of Change by Calendar Year (Percent per Annum)



Source: NERA analysis of BCIS and ONS data.

3.3.2. Forecast data

Detailed, objective and market-based forecasts of input prices for equipment costs were not available. Although in principle, we could use commodities price forecasts to estimate the likely evolution of equipment costs, in practice our analysis suggests that the linkages between equipment PPIs and commodities prices are weak. For further details see Appendix C.

3.3.3. Conclusion

Our recommended equipment RPEs are as follows:

- Our RPE for 2012/13 is our measure of real input price growth for electricity distribution companies, an average of the index of “Plant and Road Vehicles” and both “Machinery and Equipment" indices of -2.6%.
- The upper bound is provided by the “Materials and Equipment Output” series (the fastest growing) and the lower bound by the “Materials and Equipment Input” series (the slowest growing); and
- Our forecast RPE reverts to the long run trend rate of -0.6% from 2013/14 onwards.

Table 3.3
Equipment RPEs (Percent per Annum)

Equipment RPEs	2012/13	2013/14	2014/15	Long Term
NERA Mid-Point	-2.6%	-0.6%	-0.6%	-0.6%
Upper Bound	-1.9%	-0.2%	-0.2%	-0.2%
Lower Bound	-3.7%	-1.5%	-1.5%	-1.5%

Source: NERA analysis of ONS and BCIS data.

3.4. Transport & Other

Transport and other costs capture all of the DNO's costs that do not specifically fit into the other categories of labour, materials and equipment and plant. As a broad basket of miscellaneous costs, the evolution of these cost items might be expected to reflect the broad basket of products that enter the RPI.

At RIIO-T1/GD1, Ofgem reviewed the evidence for assuming an RPE for electricity networks. In its Strategy Decision for RIIO-ED1, Ofgem stated that it did not intend to provide a separate RPE for the costs of transport:

> "We note that we did not provide an RPE for road fuel in our most recent decision on the RPE assumptions for RIIO-T1 and GD1. The evidence we considered suggested that changes in historical cost indices were not materially different from changes in the RPI. These costs also represented a small element of overall costs for the transmission and gas distribution networks. If a DNO proposes that an RPE for road fuel costs should be provided then it will need to provide evidence to the contrary."[32]

After reviewing the evidence, we agreed with Ofgem that there is limited evidence that transport costs merit a separate RPE. We also agree that the impact is not likely to be material given the proportion of total DNO costs accounted for by transport.

3.5. Conclusions

We reviewed the available evidence to establish an estimate of the real price effects faced by an electricity distribution network, presented in Table 3.4 for our mid-range estimates. We adopted indices of prices that provide suitable coverage of a network's costs, using outturn data for our estimates of 2012/13. Where available, we adopted near term market forecasts, and then assumed a return to long term trend growth from 2015.

---

[32] Ofgem (2013), *Strategy Decision for RIIO ED1: Tools for Cost Assessment*, (26e/13), 4 March 2013, page 22, para 4.23.

Table 3.4
RPEs For Ofgem's Four Cost Categories (Including Near Term Forecasts)

RPE	2012/13	2013/14	2014/15	2015-2023
Labour	-1.1%	-0.5%	-0.3%	1.3%
Materials	-2.0%	1.0%	1.0%	1.0%
Equipment & Plant	-2.6%	-0.6%	-0.6%	-0.6%
Other	0.0%	0.0%	0.0%	0.0%

Source: NERA analysis.

As shown in Table 2.1, UKPN's forecast cost structure is:

- **Labour**: 83% of opex and 65% of capex;
- **Materials**: 10% of opex and 20% of capex;
- **Plant and Equipment**: 0% of opex and 8% of capex; and
- **Transport and Other**: 6% of opex and 7% of capex.

Using these shares, we converted our RPEs for each category into high level RPEs for operational activities (opex) and network investment (capex), as shown in Table 3.5.

Table 3.5
RPEs Assuming Notional Expenditure Share

	2012/13	2013/14	2014/15	2015 - 2023
Operational Activities				
Upper	-0.7%	0.0%	0.1%	1.0%
Mid	-0.5%	-0.2%	-0.1%	0.5%
Lower	-0.8%	-0.7%	-0.5%	0.5%
Network Investment				
Upper	-1.0%	0.1%	0.3%	1.2%
Mid	-0.2%	-0.1%	-0.1%	0.3%
Lower	-1.2%	-0.7%	-0.5%	0.5%

Source: NERA analysis. Expenditure shares are those forecast by UKPN..

4. Estimating "Ongoing Efficiency"

Ofgem uses the term "ongoing efficiency" to mean "the productivity improvement that even the most efficient DNO should be able to achieve".[33] In this report, for consistency with Ofgem's terminology, we also use the term "ongoing efficiency" to mean the expected improvement in productivity.

Based on the evidence set out in this chapter, we conclude that the expected ongoing efficiency improvement would lie between 0.4% and 0.8% p.a. for expenditure on network investment (capex), and between 0.4% and 1.1% p.a. for expenditure on operational activities (opex).

The remainder of this chapter is structured as follows:

- Section 4.1 sets out our overall approach to estimating ongoing efficiency;
- Section 4.2 describes the EU KLEMS dataset, the theoretical assumptions, and data measurements issues;
- Section 4.4 sets out our preferred productivity measures; and,
- Section 4.5 sets out our results and conclusions.

4.1. Overall Approach

In setting revenue allowances for the next regulatory period, Ofgem includes an assumption in relation to the ongoing productivity improvement that will be achieved by the frontier company over the price control period.[34] Specifically, Ofgem has proposed an adjustment to two expenditure categories – "operational activities", and "network investment" – for expected productivity growth ("ongoing efficiency") over the period from 2012/13 to 2022/23, the anticipated end of the RIIO-ED1 regulatory period.[35]

Our overall approach to estimating ongoing efficiency broadly follows the framework set out by Ofgem in its recent strategy decision document. [36] Specifically, we propose to draw on historical trends in productivity for comparator sectors set out in the EU KLEMS dataset. Ofgem used this dataset to estimate ongoing productivity at RIIO-T1/GD1 and for its proposed approach at RIIO-ED1.

---

33 See for example: Ofgem (2013), Strategy decisions for the RIIO-ED1 electricity distribution price control: Tools for cost assessment, para. 4.40

34 See: Ofgem (2012) Strategy consultation for the RIIO-ED1 electricity distribution price control: Tools for cost assessment, p. 86. Although Ofgem refers to the frontier company as the basis for this rate of efficiency improvement, that is in effect just a way of referring to the long term trend rate of growth in productivity for the sector, separately from known, company-specific improvements that might lead to higher rates of growth in productivity at some companies over some (short) periods.

35 In fact, in its latest Business Plan Data Tables, Ofgem proposes to apply ongoing efficiency assumptions to granular levels of expenditure, such as reinforcement, replacement, etc. It is not possible to distinguish TFP estimates for these sub-categories, and hence we propose to apply a single TFP for network investment to all these categories.

36 Ofgem (2013) Strategy decisions for the RIIO-ED1 electricity distribution price control: Tools for cost assessment, chapter 4.

For comparator sectors, we draw on the comparators for electricity DNOs identified by Ofgem and the industry at DPCR5, as well as for National Grid Electricity Transmission (NGET) at RIIO-T1.[37] We also present data for the electricity, gas and water supply industry (EGWS) and whole economy.

We considered other sources of data, such as productivity data published by the Office for National Statistics (ONS). However, the ONS productivity measures are focussed on labour productivity and the ONS does not publish productivity estimates for the wider set of factors of production employed by DNOs other than on an "experimental basis".[38] We therefore do not draw on ONS data.

4.2. EU KLEMS Dataset: Theoretical And Data Issues

In this section, we briefly describe the two different KLEMS datasets, the growth accounting model, its theoretical assumptions, and data measurement issues. We draw conclusions on how we interpret the EU KLEMS data given the theoretical and data issues.

As set out above, we have drawn on EU KLEMS Growth and Productivity Accounts to estimate ongoing productivity over RIIO-ED1.[39] The database contains industry-level measures of outputs, inputs, and productivity for the US, Japan and 25 European countries for the period from 1970 onwards.[40] These measures include the input categories of capital (K), labour (L), energy (E), materials (M), and services (S).

EU KLEMS publishes two datasets.

- NACE[41] 1.1 dataset – which contains productivity data where output is measured on the basis of both gross output (GO) and value added (VA).[42] The data series covers the period from 1970 to 2007.
- NACE 2 – which contains productivity measures based on VA output measures only, and follows a different sector classification from NACE 1.1. The data series runs from 1997 to 2007 but productivity estimates prior to 1997 are estimates compiled by "back-casting".[43]

---

37 In terms of comparator sectors, Ofgem notes that it will focus on those industry sectors with similarities to DNOs, for example, the sectors with significant asset management roles. See: Ofgem (2012) op. cit., p. 86.

38 Source: ONS (2007) The ONS Productivity Handbook, Chapter 2, Section 2.4. Link: http://www.ons.gov.uk/ons/guide-method/method-quality/specific/economy/productivity-measures/productivity-handbook/index.html

39 http://www.euklems.net/euk09i.shtml

40 O' Mahony, M. and Timmer, M.P. (2009) Output, Input and Productivity Measures at the Industry Level: The EU KLEMS database. The Economic Journal, Volume 199, Issue 538 pp. F374-F403, Abstract. See: http://onlinelibrary.wiley.com/doi/10.1111/j.1468-0297.2009.02280.x/pdf

41 NACE stands for the *Nomenclature générale des activités économiques dans les Communautés Européennes*, and is the obligatory statistical classification introduced by the EU in 1990. Source: ONS (1997) Annual Abstract of Statistics, p.1.

42 We explain GO and VA terms in section 4.4.1.

43 NACE 2 is based on a revised industry classification. The EU KLEMS website notes that: "*The National Accounts (NA) data in the new classification is typically provided for shorter time series than were previously available in the*

To estimate ongoing productivity, we draw on the NACE 1.1. data. We are principally interested in GO rather than VA measures of TFP as we discuss in section 4.4.1 below. Only the NACE 1.1. dataset contains GO data; it was used by Ofgem for RIIO-T1 and RIIO-GD1.

4.2.1. The growth accounting framework

The EU KLEMS productivity measures apply the growth accounting framework drawn from seminal work by Jorgenson and Griliches.[44] The framework is based on production possibility frontiers where gross output is determined by capital, labour, intermediate outputs, and technology. Each industry can produce a set of outputs, but must purchase a minimum volume of distinct intermediate inputs, capital, and labour to produce these outputs. The production function is given by:

$$Y = f(K, L, X, T) \quad (1)$$

where *Y* is an index of outputs, *K* is an index of capital service flows, *L* is an index of labour inputs, and *X* is an index of intermediate outputs, and *T* is available technology. The KLEMS database also divides total intermediate inputs (*X*) into three groups: energy, materials and services (*E*, *M*, *S*). These input and output indices, which are used to calculate TFP, are indices of physical quantities rather than indices of prices or unit costs (as discussed in the earlier chapters of this report).

Taking logs, and making other simplifying assumptions (as we discuss below), we can represent the shift in the production function as the expenditure-share weighted growth of input indices and technological change (TFP):

$$\Delta \ln Y_t = s_t^K \Delta \ln K_t + s_t^L \Delta \ln L_t + s_t^X \Delta \ln X_t + \Delta \ln TFP_t^Y \quad (2)$$

where s^i denotes the average share of input i in the nominal cost of total output, and the factor shares sum to unity (i.e. $s^K + s^L + s^X = 1$). This equation states that growth in the volume of output can be accounted for by growth in intermediate outputs, capital services, labour services, and a measure of multifactor or total factor productivity (TFP). TFP is unobservable, and so it must be measured as the difference between the growth in the output index and the growth in the input indices, as can easily be seen by re-arranging equation (2).

In turn, each individual factor of production is calculated as an index of different input types. For example, labour input is calculated as a quantity index of individual labour types, as follows:

$$\Delta \ln L_t = \sum_l s_{l,t}^L \Delta \ln L_{l,t} \quad (3)$$

NACE 1 classification. We back-cast time series of output and labour data using growth rates from the earlier data in the NACE 1 classification. These imputations are denoted in grey in the new release." Link: http://www.euklems.net/eukNACE2.shtml

44 O' Mahony, M. and Timmer, M.P. (2009) Output, Input and Productivity Measures at the Industry Level: The EU KLEMS database. The Economic Journal, Volume 199, Issue 538 p. F374. See: http://onlinelibrary.wiley.com/doi/10.1111/j.1468-0297.2009.02280.x/pdf . The framework is: Jorgenson, D.W. and Griliches, Z. (1967) The explanation of productivity change, Review of Economic Studies, vol. 34 (3) pp. 249-83.

where the term on the right-hand side represents the growth (Δ) in $L_{l,t}$, the hours worked by labour type *l*, weighted by the average share of each type *l* in the total value of labour compensation or total wage bill (s^L_l). The KLEMS database classifies labour into 18 different categories by educational attainment, gender and age.[45]

For some materials and capital inputs, in the absence of any direct measure of physical quantities, we calculated growth in physical quantities as the real increase in total expenditure on such inputs divided by the real increase in the prices of those inputs.

4.2.2. What does TFP measure?

TFP (as set out in the KLEMS dataset) is a measure of disembodied technological change or technical change that is "costless" in the form of an expansion of general knowledge, adoption of better management techniques, more efficient organisation, etc.[46] Costless technological change contrasts with productivity change achieved at a cost, which is referred to as "embodied" technological change because the new technology is normally embodied in an investment. For example, advances in the design and quality of capital and intermediate products, achieved through research and development within the capital goods producing industry, offer their customers costly or "embodied" technological change, when they invest in new vintages of capital equipment. Similarly, productivity increases resulting from an expansion of human capital through investment in education are also "costly" or "embodied" (literally) in certain personnel.

In the EU KLEMS database, technological change embodied in new capital goods is captured in the measurement of capital by using *quality-adjusted* prices and costs as weights in calculating the change in capital inputs. Likewise, the construction of the labour input index takes into account both hours worked and changes in the skill composition of the labour force, so that it reflects technological change embodied in labour.[47] As a result, an improvement in the educational attainment and skill base of the workforce, and hence in its productivity, is not reflected in the estimate of residual TFP, but is captured as an increase in labour inputs, as well as in outputs.

Economic growth is a measure of both costless and costly technological change. KLEMS TFP estimates for the whole economy (reflecting only costless technological change) will therefore be lower than long run estimates of the rate of economic growth.[48]

---

45 O' Mahony, M. and Timmer, M.P. (2009) op. cit., F379

46 The technical change measured is described as costless because it occurs in addition to the remunerated contribution of factor inputs to production – remuneration being captured by the income share of labour and capital.

47 OECD (2001) Measuring Productivity, Measurement of aggregate and industry level productivity growth, OECD manual.; p. 116 Available on-line: http://www.oecd.org/std/productivity-stats/2352458.pdf

48 The growth in real GDP can be viewed as the growth in capital inputs, labour inputs, and total factor productivity. See ONS (2007) ONS Productivity Handbook, Section, 3.1, p.21.

4.3. Theoretical Assumptions and Data Measurement Issues

4.3.1. Theoretical assumptions

The growth accounting framework rests on a number of assumptions about the real economy. It assumes that factor markets are competitive, so that marginal revenues are equal to marginal costs. To explain, the weights on the inputs (as set out in equation (3)) ensure that inputs which have a higher price also have a larger influence over the input index. So, for example, a doubling of hours worked by a high-skilled worker receives a greater weight than a doubling of hours worked by a low-skilled worker, due to the former's higher wage rate. This higher wage rate is assumed to reflect a higher level of inputs per hour worked.[49]

The growth accounting framework also assumes that there are constant returns to scale (CRS). The weights placed on the components of output, e.g. labour compensation as a proportion of nominal output, are intended to approximate production elasticities (i.e. the percentage effect on outputs of a 1% change in individual inputs).[50] If the assumption of CRS does not hold, then the TFP measure will reflect the effect of scale economies as well as productivity growth.

The framework also assumes that there is full utilisation of inputs, and that all companies are technically efficient.[51]

In practice, we can assume that these conditions will hold over the long run, and thus that long run estimates of TFP reflect productivity growth (as opposed to scale economies, removal of technical inefficiency, etc.) Ofgem made this assumption for RIIO-T1/GD1.[52] By contrast, we note that the Competition Commission has in the past assumed that an element of TFP reflects systematic catch-up, but we do not consider that there is a strong case for making such an adjustment in the context of RIIO-ED1 and the EU KLEMs data.[53]

---

49 See: O' Mahony, M. and Timmer, M.P. (2009) op. cit., F394. For example, if the weightings reflect marginal cost, and the factor market is competitive (such that the worker's compensation equals his/her output value), then a change in the composition of labour does not affect TFP. However, if these conditions do not hold, the residual TFP measure will pick up any deviations from the assumption that marginal costs equal marginal revenues (in both labour and other factor markets). For example, in the case of imperfect competition, an increase in pricing above marginal cost will be picked up by a decline in the residual TFP measure.

50 OECD (2001) Measuring Productivity, Measurement of aggregate and industry level productivity growth, OECD manual.; p. 18 Available on-line: http://www.oecd.org/std/productivity-stats/2352458.pdf

51 This assumption is not as strong as one might expect. Technical efficiency can include some apparent "inefficiency" in production, if the management cost of eliminating the problem would exceed the value of the increase in output or the reduction in inputs. Thus "technical efficiency" may not require the elimination of all "X-inefficiency" in the management of a firm. Technical efficiency means only that the owners and managers of the firm ("principals") are managing their employees ("agents") and other inputs so as to maximise the firm's profits.

52 See: Ofgem (2013) RIIO-T1/GD1 Real price effects and ongoing efficiency appendix, para. 3.21, p. 19

53 For a discussion of the Competition Commission's adjustment, see: Ofgem (2013) RIIO-T1/GD1 Real price effects and ongoing efficiency appendix, paras. 3.13-3.21.

4.3.2. Data measurement issues

The guidance notes on the methodology and the construction of the KLEMS database highlight a number of health warnings with the data. [54]

- **Data collection**

In general, the data is likely to be less reliable for more narrowly defined industries as more detailed industry specifications tend to draw on a wider range of data sources (which may not be consistent or complete). The guidance also notes that data from further back in the time series has a greater likelihood of measurement error.[55]

- **Output data**

Measuring output volumes over long periods necessitates identifying and adjusting for changes in quality, generally by constructing a quality-adjusted price deflator. If quality changes are not taken into account, we would understate productivity improvements. Adjusting for quality can be particularly difficult in the services sector, e.g. for financial and business services, as well as for high-technology industries where there is rapid quality changes, e.g. changes in the power of computers.[56] However, the problems are prevalent in a number of sectors: for example, utility sectors have achieved substantial improvements in quality of service since privatisation.

- **Input data**

In relation to input measures, as we have noted above, the KLEMS database distinguishes labour inputs for 18 different categories which necessitates the use of labour force survey data, where there are issues over the consistency of measuring labour input over time.[57] In relation to capital, capital inputs are measured as a flow of services rather than a stock of capital (which is not observed). The measurement of the capital input requires estimates of capital depreciation which vary by asset and industry and are held constant over time, although asset lives are likely to change over time.[58] A better approach is to measure physical quantities of capital assets. However, such data is not always available: hence the database uses measures of expenditure or cost divided by a price index.

---

[54] O' Mahony, M. and Timmer, M.P. (2009) Output , Input and Productivity Measures at the Industry Level: the EU KLEMS database. Link: http://www.euklems.net/eukNACE2.shtml . We also draw on: OECD (2001) Measuring Productivity, Measurement of aggregate and industry level productivity growth, OECD manual, pp. 21-24. Available on-line: http://www.oecd.org/std/productivity-stats/2352458.pdf

[55] O' Mahony, M. and Timmer, M.P. (2009) op. cit., F390. The authors state: "*As a general rule the reliability of the data is likely to be lower [...] the more we more from the industry level identified in the National Accounts. This is because to break down the national accounts series, we often had to rely on additional data sources* […]."

[56] OECD (2001) Measuring Productivity, Measurement of aggregate and industry level productivity growth, OECD manual, pp. 21-24. Available on-line: http://www.oecd.org/std/productivity-stats/2352458.pdf

[57] O' Mahony, M. and Timmer, M.P. (2009) op. cit., F380

[58] The authors also note that one of the more stringent assumptions in capital services measurement is the assumption of constant returns to scale as capital services are constructed employing user costs of capital as weights assuming an ex post rate of return. It is assumed that the total value of capital services for each industry equals its compensation for all assets. This approach yields an internal rate of return that exhausts capital income and is consistent with returns to scale. See: O' Mahony, M. and Timmer, M.P. (2009) op. cit., F394 and Appendix B.

The measurement of capital input is also sensitive to the assumption of full utilisation. The variable use of capital inputs, i.e. the measurement of machine hours, is rarely used in the construction of the KLEMS database. Instead, KLEMS records the fixed capital stock. Consequently, a higher rate of capacity utilisation in periods of expansion is accompanied by output measures that show rapid growth whilst input measures remain stable, thus producing a rise in measured TFP. The converse holds for periods of recession. In such conditions, only long term measures of TFP provide any indication of the underlying trends.

4.3.3. Short-term vs. long-term measurement errors

The authors note that for some sectors the TFP estimate is negative, representing technical regress, which would appear implausible. The authors acknowledge that industries could experience negative TFP in the short-run but it is unlikely over the long-run.[59] Our analysis of TFP shows that around a third of all industry sectors have a negative long-run TFP measure, as illustrated in Figure 4.1. This highlights the potential for measurement errors in inputs and outputs, as described above. The negative TFP estimates do not imply that we should exclude such sectors from our analysis; but provide an indication of the extent of measurement error in the industry TFP estimates and the need to use broad averages where possible. See Appendix B for further definition of factor productivity measures.

4.3.4. Conclusions on the use of EU KLEMS data

In summary, TFP not only measures disembodied technical change but it also reflects efficiency change, economies of scale, variations in capacity utilisation, and measurement error.[60] For the reasons described in this chapter, TFP has also been described as the "residual" or the "Measurement of Our Ignorance".[61]

The theoretical and data measurement issues with the KLEMS dataset demonstrate that we need to interpret the productivity estimates with caution. In particular, the potential issues suggest that we should not place weight on the productivity estimates associated with any particular sector but potentially place greater weight on aggregate industry measures. (We will return to the use of industry specific or composite TFP issues in our discussion of productivity results for our comparators in section 4.5.)

We also consider that we should draw on longer time-series evidence (i.e. from 1970-2007). For example, a longer time period may help smooth for changes in scale effects, changes in capacity utilisation, and changes in efficiency, which are picked-up in the residual TFP measure. As set out in Appendix B, we show that the estimates of our proposed productivity measures are not very sensitive to the time period selected.

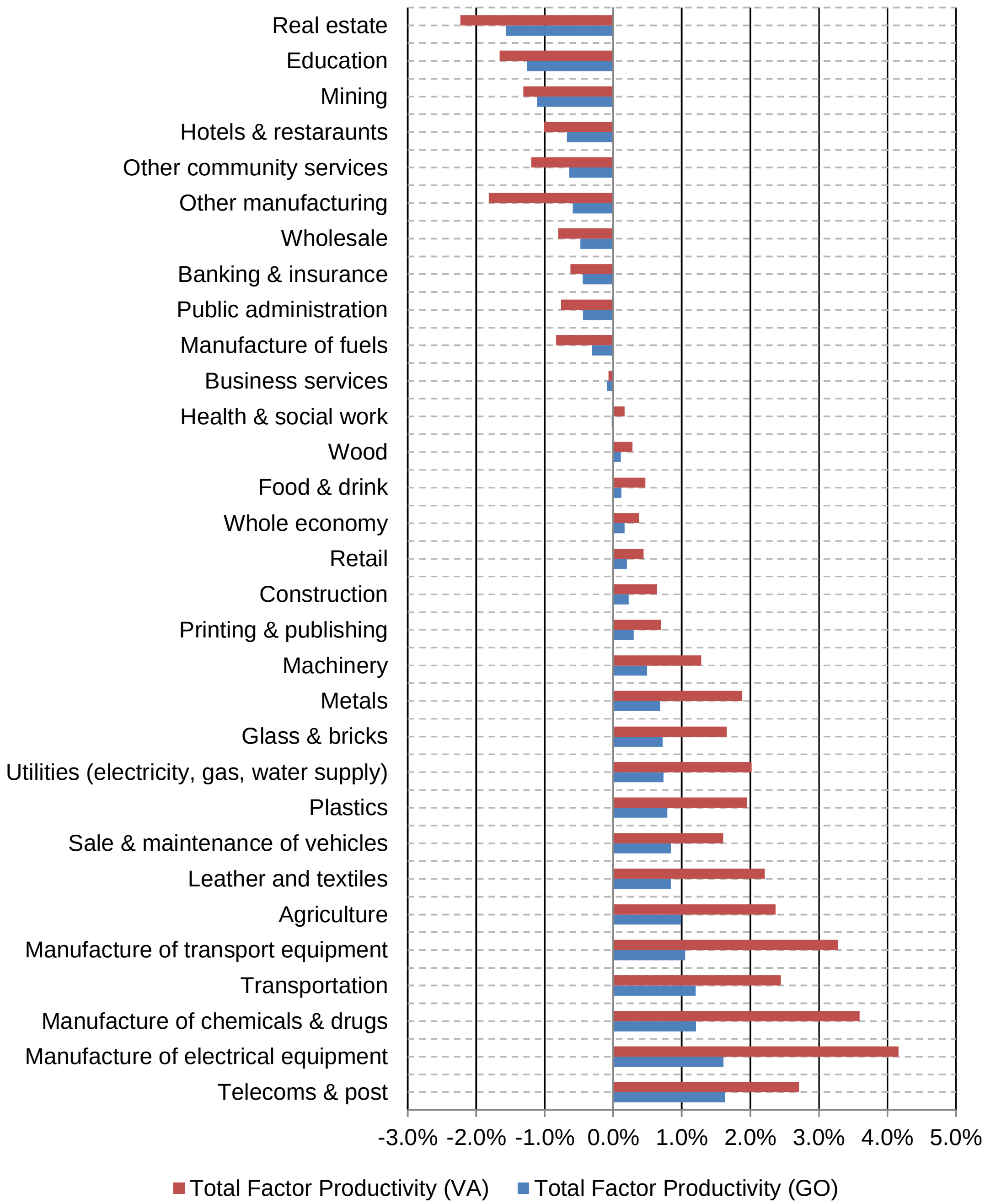
---

59 TFP includes the effect of technical innovation as well as the effects from organisational and institutional change. For example, successful reorganisation of a business to streamline the production process might decrease TFP as resources are diverted to the reorganisation process.

60 OECD (2001) Measuring Productivity, Measurement of aggregate and industry level productivity growth, OECD manual. Available on-line: http://www.oecd.org/std/productivity-stats/2352458.pdf

61 Jorgenson, D.W. and Griliches, Z. (1967) The explanation of productivity change, Review of Economic Studies, vol. 34 (3) p. 249.

Figure 4.1
Negative TFP Estimates Indicate The Magnitude Of Measurement Error
(1970-2007, p.a.)



Source: NERA analysis of EU KLEMS data.

4.4. Different Measures Of Productivity

We draw on LEMS productivity measures as our proxy for on-going productivity for the operational activities expenditure category, as UKPN's operational activities will draw on labour, energy, materials and services (or LEMS) inputs. For "network investment" we draw on TFP estimates as our measure of on-going productivity as UKPN's network investment activities will draw on capital as well as other inputs.

For both measures, there are a number of choices in relation to whether we use GO or VA measures of TFP for our network expenditure, and whether we adjust LEMS for the effect of capital substitution in determining productivity for operational activities. We explain our approach below.

We provide mathematical definitions of the different productivity measures in Appendix B.

4.4.1. GO or VA output measure?

In relation to the TFP measure, we have considered whether to use a gross output (GO) or value added (VA) measure to construct the output indices. GO measures use an index of all outputs produced by an industry, and TFP based on GO is calculated as the growth in the outputs index minus the growth in the index for all factors of production (i.e. KLEMS). In simplified algebraic terms (e.g. ignoring factor shares), GO TFP is:

GO TFP = GO index/ KLEMS input index

By contrast, VA output measures are calculated by subtracting (an index) of intermediate (EMS) outputs from an index of gross output, and VA TFP is calculated as the net output index minus the growth in the index of capital and labour inputs (or primary inputs). A value added measures presents the maximum amount of value added that can be produced given the inputs of the firm (or industry), i.e. labour and capital, for given prices of intermediate inputs and outputs. Value-added TFP is systematically higher than gross output TFP. In simplified algebraic terms, it is:

VA TFP = (GO index – EMS index)/ (KLEMS – EMS input indices)

The correct productivity measure (i.e. GO or VA) depends on its intended use. As at RIIO-T1/GD1, we understand that Ofgem will apply a productivity measure to all factor inputs in order to set the final price for DNOs' gross output rather than specifically to the labour and capital inputs employed by DNOs. This implies that we require a productivity measure(s) which reflects the growth rate of total output minus the growth in all inputs, i.e. a GO measure. By contrast, it is not clear to us how VA productivity measures could be used for the intended purpose.[62,63]

---

[62] Ofgem also acknowledges the difficult with applying value-added measures in its Initial Proposals document for RIIO-T1 and GD1. Ofgem states: "T*he VA measure of productivity only allows us to evaluate the impact of the use of labour and capital on outputs, and thus limiting the costs that this can be applied to. Therefore, to fully evaluate the productivity improvements that a network company can make would require making additional assumptions about the use of intermediate inputs.*" Ofgem (27 July 2012) RIIO-T1/GD1: Initial Proposals – Real price effects and ongoing efficiency appendix, para 3.15, p.19.

4.4.2. LEMS productivity measure: constant capital or capital substitution?

As set out above, we calculate LEMS productivity as our estimate for productivity associated with operational activities (as these inputs correspond to the factors relevant to UKPN's operational activities).

LEMS productivity measures will also reflect the extent of capital substitution. An increase in capital employed per labour input will result in an increase in output per worker and an improvement in LEMS productivity. Following Ofgem's approach at RIIO-T1/GD1, we also calculate LEMS productivity measures adjusting for the impact of capital substitution on LEMS productivity, i.e. we correct for that element of LEMS or labour PFP which is explained by a reduction in LEMS or labour expenditure share in total output. We refer to such PFPs as "constant capital" measures. The use of a LEMS measure based on constant capital depends on Ofgem's overall approach to setting cost allowances.

For example, if Ofgem makes a separate adjustment to allowed operating expenditure for changes in capital inputs (e.g. through its approach to comparative efficiency modelling), then a LEMS measure based on constant capital should be employed. Otherwise using a LEMS measure which reflects the effects of capital substitution will result in a double-adjustment.

Alternatively, if Ofgem does not make an adjustment to allowed operating expenditure for changes in capital share, a LEMS measure which captures the scope for capital substitution should be employed.

Ofgem does not appear to have a systematic approach to adjusting operating cost allowances for changes in input factor shares (e.g. for an increase in capital), although the change in operating expenditure from increased capital expenditure may be partly captured in comparative efficiency modelling.

In setting allowed revenues, Ofgem needs to decide how it will take account of capital substitution. There are two options. If Ofgem applies a LEMS productivity estimate at constant capital, then it needs to make an additional adjustment to operating expenditure to allow for capital-labour substitution. If it applies a LEMS productivity measure which reflects capital substitution, the implicit assumption is that the rate of capital substitution for DNOs will be the same as for the comparator set. In this report, we set out both LEMS measures.

---

[63] We also understand that there are advantages and disadvantages to the use of GO and VA productivity indices but these issues are secondary to the intended use. For example, GO based TFP measures are less sensitive to changes to the vertical integration of the sector, e.g. to outsourcing. Value-added based TFP measures vary with the level of purchased services. On the other hand, for labour productivity, value-added measures are less sensitive to changes in the vertical integration of the sector. OECD (2001) Measuring Productivity, Measurement of aggregate and industry level productivity growth, OECD manual, p.31. Available on-line: http://www.oecd.org/std/productivity-stats/2352458.pdf

4.4.3. Conclusions on productivity measures

We propose to use GO TFP as our productivity measure for the network investment expenditure category, and draw on LEMS productivity adjusted and unadjusted for capital substitution for operational activities.

4.5. Results for Comparator Sectors

In this section, we set out our preferred GO TFP and LEMS productivity measures for a set of comparators for electricity distribution businesses.

As our starting point, we calculated the productivity measures for the comparators used by Ofgem at DPCR5 and for National Grid Electricity Transmission (NGET) as part of RIIO-T1 (which comprised the same set). However, for RIIO-T1 Ofgem noted that there were concerns about the relevance of manufacturing comparators to DNOs, and hence presented composite averages including and excluding manufacturing.

In addition to the comparator sectors presented at previous reviews, we also present data for the energy, gas and water supply (EGWS) sector. However, this sector classification includes a much wider set of activities than energy network activities, i.e. it will include generation and supply. The productivity measures may overstate the prospect for future productivity improvements given the greater scope for productivity improvements following the change in ownership, regulation and structural change in the 1990s.

As per Ofgem at RIIO-T1, we also present productivity estimates for the whole economy excluding public administration, education, health, and social services, as well as real estate. We exclude these sectors because of concerns set out by the authors of the KLEMS database about the calculation of output measure for non-marketed goods (specifically the aggregation of diverse outputs for which there are no market prices), and for real estate.[64]

Table 4.1 summarises our results for comparator sectors.

[64] O' Mahony, M. and Timmer, M.P. (2009) op. cit., F391

Table 4.1
TFP GO And LEMS Productivity Estimates For Comparator sectors (1970-2007, Percent per Annum)

Industry sector	Used by Ofgem?			GO PFP (LEMS)	
	DPCR5	RIIO-(E)T1	GO TFP	Capital Substiution	Constant Capital
Manufacture of chemicals and chemical products	Y	?	1.3%	1.4%	1.4%
Manufacture of electrical and optical equipment	Y	?	1.6%	1.9%	1.8%
Manufacture of transport equipment	Y	?	1.0%	0.9%	1.0%
Construction	Y	Y	0.2%	0.4%	0.2%
Sale, maintenance and repair of motor vehicles; Retail sale of fuel	Y	Y	1.0%	1.4%	1.1%
Transport and storage	Y	Y	1.2%	1.2%	1.2%
Financial intermediation	Y	Y	-0.4%	0.3%	-0.5%
Electricity, gas and water supply	N	N	0.8%	0.6%	1.0%
Unweighted average (DPCR5 sectors)			0.8%	1.1%	0.9%
Unweighted average (DPCR5, exc. manufacturing)			0.5%	0.8%	0.5%
Whole economy (exc. non market sectors)	N	Y	0.4%	0.4%	0.4%

Source: NERA analysis of EU KLEMS data. Whole economy excl. non-market sectors excludes real estate, public administration, education, health and social work and community services.

From these results, we note the following:

- The GO TFP measure of productivity for the comparator sectors is relatively wide-ranging. It ranges from -0.4% p.a. for financial intermediation to 1.6% p.a. for manufacture of electrical and optical equipment.
- As set out in Section 4.3.4, the variation in sector productivity measure will reflect data measurement issues as well differences in productivity over time. In particular, the negative GO TFP estimate for financial intermediation (at -0.4% p.a. over the period 1970-2007) appears implausible and may reflect output measurement error
- None of the comparator sectors used by Ofgem at previous reviews appear to closely match the activities undertaken by DNOs. For example, it is not clear to us that the retail sale of fuel or financial intermediate closely represent the retail functions undertaken by DNO. Ofgem has also noted that it (and the wider industry) has concerns over the relevance of manufacturing comparators. However, it is not clear which other sectors in the KLEMS dataset, if any, would be better comparators for the DNOs.

4.6. Proposed Productivity Estimates for RIIO-ED1

For the purposes of RIIO-ED1, we report below composite or average productivity measures for comparator sectors, and for the whole economy, as averages are less prone to the theoretical and data concerns described in Section 4.3.4 than sector specific methods. For example, averaging across sectors could help address particular output measurement difficulties associated with any one sector (assuming that any measurement errors or adjustments are not systematic).

Specifically, for network activities, we recommend drawing on GO TFP sector averages and whole economy data which provides a range of 0.4% to 0.8%, and a mid-point of 0.6% p.a.

For operational activities, we propose to draw on LEMS productivity data for comparator averages, as well as the whole economy. This provides an expected improvement in productivity in the ranges:

- 0.8% to 1.1% p.a. (mid-point 0.95% p.a.) based on GO PFP (LEMS) and allowing for capital substitution, which is the relevant measure if Ofgem assumes either that the rate of capital substitution for DNOs is identical to the comparator set, or

- 0.4% to 0.9% (mid-point 0.65% p.a.) based on GO PFP for LEMS at constant capital, if Ofgem makes a separate adjustment to operating expenditure for capital substitution.

See Table 4.2.

Table 4.2
Productivity Estimates for RIIO-ED1 (Percent per Annum)

Category	Description	Lower bound	Upper bound
Network Investment	GO TFP	0.4%	0.8%
Operational Activities	GO PFP (LEMS) with capital substituion. Assumes DNO capital substitution = comparators.	0.8%	1.1%
Operational Activities	GO PFP (LEMS) at constant capital. Assumes separate adj. for capital sub.	0.4%	0.9%

Source: NERA analysis of EU KLEMS data.

4.7. Comparisons with Ofgem's Conclusions in RIIO-T1/GD1

Table 4.3 sets out our recommended range and mid-point for on-going productivity applying to network investment and operational activities, and compares these results to Ofgem's conclusions at RIIO-T1 and the Competition Commission's conclusions in the 2010 Bristol Water reference.

Our proposed mid-point estimates are lower than Ofgem's conclusions in RIIO-T1. The principal reason for Ofgem's higher estimates is that Ofgem referred to results for VA TFP as well as for GO TFP in drawing conclusions for RIIO-T1, and as set out above, VA results are systematically higher than GO results (although Ofgem noted that VA measures may not be well-suited to its intended purpose). In addition to evidence from KLEMS data, Ofgem also cited TFP and PFP estimates set out in network companies' business plans.

Table 4.3
Comparison With Regulatory Precedent

Ongoing Efficiency Estimate	Operational Activities	Network Investment
NERA Mid-Point	0.7%	0.6%
NERA Upper Bound	1.1%	0.8%
NERA Lower Bound	0.4%	0.4%
Ofgem RIIO-T1/GD1	1.0%	0.7%

Sources: NERA analysis of KLEMS data and Ofgem, RIIO-GD1 Final Proposals.

5. Conclusion and Results

In this section, we calculate the net effect of RPEs and ongoing efficiency in order to calculate the expected overall change in UKPN's unit costs.

We also compare the net results with changes in unit costs (or output prices) for relevant output price series (such as the capital output price index or COPI) and changes in unit costs for the comparator sectors we use as the basis for our estimates of TFP (as set out in section 4.5.).

5.1. Net Effect of RPEs and Ongoing Efficiency

5.1.1. Network investment

For network investment, we estimate a compound growth rate over the period of *minus* 0.1% p.a., and a range between 0.5% p.a. and *minus* 0.7% p.a. In general, we estimate a decline in unit costs in the first three years of the forecast period reflecting our short-term forecast for negative real wage growth, offset by marginally increasing unit costs over the remainder of the period. Our mid-point estimate of *minus* 0.1% p.a. is marginally below Ofgem's allowed change in unit costs for NGET of 0.1% p.a.

Table 5.1
Network Investment: RPE, Productivity and Net Effect (Percent per Annum)

	Network Investment				
FY Ending	RPE	Efficiency	Net [Mid]	High	Low
2013	-1.3%	0.6%	**-2.0%**	-1.6%	-2.4%
2014	-0.2%	0.6%	**-0.8%**	-0.3%	-1.7%
2015	0.0%	0.6%	**-0.7%**	-0.2%	-1.5%
2016	1.0%	0.6%	**0.3%**	0.9%	-0.3%
2017	1.0%	0.6%	**0.3%**	0.9%	-0.3%
2018	1.0%	0.6%	**0.3%**	0.9%	-0.3%
2019	1.0%	0.6%	**0.3%**	0.9%	-0.3%
2020	1.0%	0.6%	**0.3%**	0.9%	-0.3%
2021	1.0%	0.6%	**0.3%**	0.9%	-0.3%
2022	1.0%	0.6%	**0.3%**	0.9%	-0.3%
2023	1.0%	0.6%	**0.3%**	0.9%	-0.3%
Compound growth	0.6%	0.6%	**-0.1%**	**0.5%**	**-0.7%**
Ofgem ET1			**0.1%**	**0.1%**	**0.1%**

Source: NERA analysis. Ofgem data is for NGET TO, RIIO-T1 Final Proposals.

UKPN also requested that we calculate the change in unit costs using long term RPEs over the entire forecast period, that is, excluding short-term real wage forecasts to reflect Ofgem's approach at DPCR5. (At the time of DPCR5, Ofgem ignored strongly positive real labour wage growth.) If we were to exclude negative short-term forecasts for real wage growth, the annual average compound growth rate in unit costs would be 0.1%, and a range between *minus* 0.7% and *plus* 0.5%.

5.1.2. Operational activities

For operational activities, we estimate a compound growth rate over the period of 0.0% p.a., and a range between *minus* 0.8% and *plus* 0.6% p.a. As with network investment, we estimate a decline in unit costs in the first three years of the forecast period reflecting negative real wage growth, and a small positive increase in unit costs thereafter. Our mid-point estimate of 0.0% p.a. is higher than Ofgem's allowed change in unit costs for NGET of *minus* 0.5% p.a.

Excluding short-term real wage forecasts (consistent with Ofgem's approach at DPCR5), we estimate a mid-point of 0.2% p.a. over the forecast period, and a range between *minus* 0.8% p.a. and *plus* 0.6% p.a.

Table 5.2
Operational Activities: RPE, Productivity and Net Effect (Percent per Annum)

	Operational Activities				
FY Ending	RPE	Efficiency	Net [Mid]	High	Low
2013	-1.1%	0.7%	**-1.9%**	-1.5%	-2.3%
2014	-0.3%	0.7%	**-1.0%**	-0.4%	-2.1%
2015	-0.1%	0.7%	**-0.9%**	-0.3%	-1.8%
2016	1.2%	0.7%	**0.4%**	1.2%	-0.3%
2017	1.2%	0.7%	**0.4%**	1.2%	-0.3%
2018	1.2%	0.7%	**0.4%**	1.2%	-0.3%
2019	1.2%	0.7%	**0.4%**	1.2%	-0.3%
2020	1.2%	0.7%	**0.4%**	1.2%	-0.3%
2021	1.2%	0.7%	**0.4%**	1.2%	-0.3%
2022	1.2%	0.7%	**0.4%**	1.2%	-0.3%
2023	1.2%	0.7%	**0.4%**	1.2%	-0.3%
Compound growth	0.7%	0.7%	**0.0%**	**0.6%**	**-0.8%**
Ofgem ET1			**-0.5%**	**-0.5%**	**-0.5%**

Source: NERA analysis. Ofgem data is for NGET TO, RIIO-T1 Final Proposals.

5.2. Cross-Check With Unit Cost Data

Finally, as per Ofgem, we cross-checked our estimates of unit cost change (equal to our forecasts of RPEs *minus* forecasts of on-going productivity) against historical unit cost trends for comparator sectors.[65] The combination of RPEs and productivity growth needs to satisfy this cross-check, or else the estimates of RPEs and/or productivity growth need to be re-considered.

We compared our estimates of the long-term change in unit costs (i.e. excluding the short-term real wage forecasts) with changes in the long-term unit costs for the comparators we

65 Ofgem (2013), Strategy decisions for the RIIO-ED1 electricity distribution price control: Tools for cost assessment, p.24

used to estimate productivity improvements, i.e. from EU KLEMS, and other output price indices.

Drawing on the EU KLEMS database, we calculate the average historical growth in real unit costs for the comparator set used at DPCR5 and the whole economy, as we describe in Appendix B.4.

We also compared our estimate of the change in unit costs for network expenditure to the historical long-run average change in the capital output price index (COPI) and the infrastructure price index (IOPI). At RIIO-T1/GD1, Ofgem used COPI and IOPI as a cross-check on its estimate of the change in unit costs for network companies' capital expenditure.

As set out in Table 5.3, for network investment we estimate a change in unit costs equal to 0.3% p.a. compared to a range in unit cost changes for the three sources of comparator information (EU KLEMS, COPI and IOPI) of *minus* 2.4% p.a. to *plus* 0.8% p.a.

For operational activities, we estimate a change in unit cost of 0.4% p.a. compared to a change in unit costs for the DPCR5 comparator set of 0.2% p.a., and a range for the comparator sectors of *minus* 2.2% to *plus* 1.4% p.a..

Thus, for both operational activities and network investment, our estimates of unit cost changes based on separate estimates of RPEs and on-going productivity fall comfortably within the range of historical changes in unit costs for our comparator sectors, and thus satisfy this cross-check.

Table 5.3
Cross-Check Against Real Unit Cost Growth

	Network Investment	Operational Activities
Estimated Long Term Averages (NERA Mid-Point)		
Real Price Effect	1.0%	1.2%
Ongoing Efficiency	0.6%	0.7%
Net Effect (or change in unit cost)	0.3%	0.4%
Real Unit Cost Changes (EU KLEMS)		
DPCR5 Sub-Sectors Average (1970-2007)	-0.4%	-0.2%
Upper Bound DPCR5 Sub-Sector (1970-2007)	0.6%	1.4%
Lower Bound DPCR5 Sub-Sector (1970-2007)	-2.4%	-2.2%
Output Price Indices (BIS)		
COPI (1970-2012)	0.8%	
IOPI (1980-2012)	-1.3%	

Source: NERA analysis. Upper bound comparator sector is Construction, lower bound is Manufacture of Electrical and Optical Equipment.

Appendix A. Identifying Real Price Effects

This Appendix presents the results of our review of the historical data series for each category of inputs identified by Ofgem and identifies which series we used to calculate our final RPEs. The Appendix proceeds as follows:

- Section A.1 explains our method for selecting series;
- Section A.2 sets out our review of labour cost indices;
- Section A.3 sets out our review of materials cost indices;
- Section A.4 sets out our review of plant and equipment cost indices; and
- Section A.5 sets out our review of transport & other indices.

A.1. Overview of Method

In order to facilitate regulatory scrutiny, we reviewed data from publicly available sources or data to which we understand Ofgem has access. The best available source for publicly available historical price indices is the Office for National Statistics. We reviewed ONS series in detail. At RIIO-T1/GD1, Ofgem presented data from the British Electrotechnical and Allied Manufacturers Association (BEAMA) and the Building Cost Information Service (BCIS). We included BEAMA and BCIS data in our review.

Our first step was to review the data and methodologies available from the Office for National Statistics (ONS), BEAMA and BCIS data. From the available indices of earnings and producer price indices, we identified a longlist of possible data sources for calculating RPEs, comprising:

- Data used by Ofgem at RIIO-T1/GD1; and
- Data that related to cost items employed by an electricity distribution network (for example, wires and cables, electrical equipment and so on).

Our second step was to refine this longlist of possible data sources into a recommended set for calculating RPEs. In order to select the appropriate series from this long list, we evaluated each series in the long list according to the following criteria:

- Coverage;
- Informational value; and
- Empirical fit.

We present the results of this evaluation in the following sections.

A.2. Labour Costs

A.2.1. Relevant indices and coverage

Table A.1 shows the longlist of series we identified from the ONS, BCIS and BEAMA as potential candidates for use in calculating RPEs.

Table A.1
Relevant Labour Indices

Type	Source	Available	Index	Description
AEI	ONS	Jan 1990 - Jul 2010	Private Sector incl. Bonus	Average earnings index, discontinued by the ONS and replaced by the AWE.
AWE	ONS	Jan 2000 - Nov 2012	Private Sector incl. Bonus	"AWE is designed to produce robust estimates at whole economy level. The major strength of the MWSS is that it provides comprehensive information on earnings by industry. ONS publishes series for eight higher-level sectors and 24 lower-level industries."
AWE	ONS	Jan 2000 - Nov 2012	Construction	Includes "construction of utility projects for electricity and telecommunication", and "electrical installation".
AWE	ONS	Jan 2000 - Nov 2012	Transport	Includes "warehousing and storage" and "support activities for transportation".
AWE	ONS	Jan 2000 - Nov 2012	Manufacturing - Engineering & Allied Industries	Includes "substantial alteration, renovation or reconstruction of goods."
AWE	ONS	Jan 2000 - Nov 2012	Electricity, Gas and Water Supply	Includes "operation of distribution systems (i.e., consisting of lines, poles, meters, and wiring) that convey electric power received from the generation facility or the transmission system to the final consumer."
PAFI	BCIS	Jan 1977 - Jan 2013	Electrical Installations - Cost of Labour	Used by industry to update costs of electrical installation contracts. Index drawn from ONS data and national labour agreements.
PAFI	BEAMA	Jan 1970 - Jan 2013	Electrical Labour	Used by industry to update costs of electrical labour contracts. Average earnings in the electrical labour sector.

Source: ONS[66], BCIS[67], BEAMA.[68] AWE is "Average Weekly Earnings"; PAFI is "Price Adjustment Formula Index".

As private companies, one possible proxy for labour costs faced by distribution networks and also used by Ofgem at RIIO-T1/GD1 is the "Private Sector Average Weekly Earnings" published by the ONS. This data series clearly covers the input costs of an electricity distribution network, as it is drawn from the widest relevant sample, the private sector as a whole. We also consider the discontinued "Private Sector Average Earnings Index" to be an equally valid measure, as the difference in the mean of the two series (during the period data was available for both) is only 0.1%. This similarity is shown in Figure A.1, where we examine real changes in AWE and AEI from January 1990 to November 2012.[69] The

66 ONS, Information Paper, 18 November 2011, page 2; ONS, UK Standard Industrial Classification of Economic Activities 2007 (SIC 2007): Structure and Explanatory Notes, 2009, pages 39, 43, 71, 143.

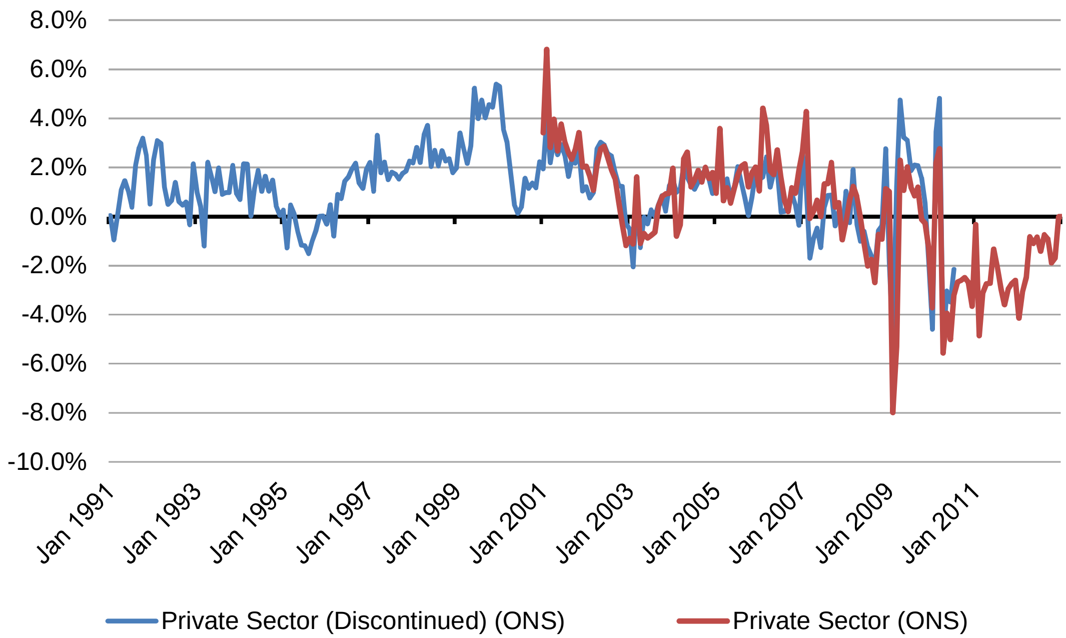
67 BCIS, Building Cost Index Models, 1997.

68 Email from Emmanuel Amoakohene, Head of Statistics, BEAMA, 5 March 2013.

69 Calculated as % change in wages y.o.y. - % change in RPI y.o.y.

average rate of real wage growth is 0.83% per annum over this period, which falls to 0.24% during the period January 2000 to November 2012.[70] Therefore, we think that by including the older AEI data, we provide a more representative view of the long term trend.

Figure A.1
Real Wage Growth (% y.o.y.) In The Private Sector

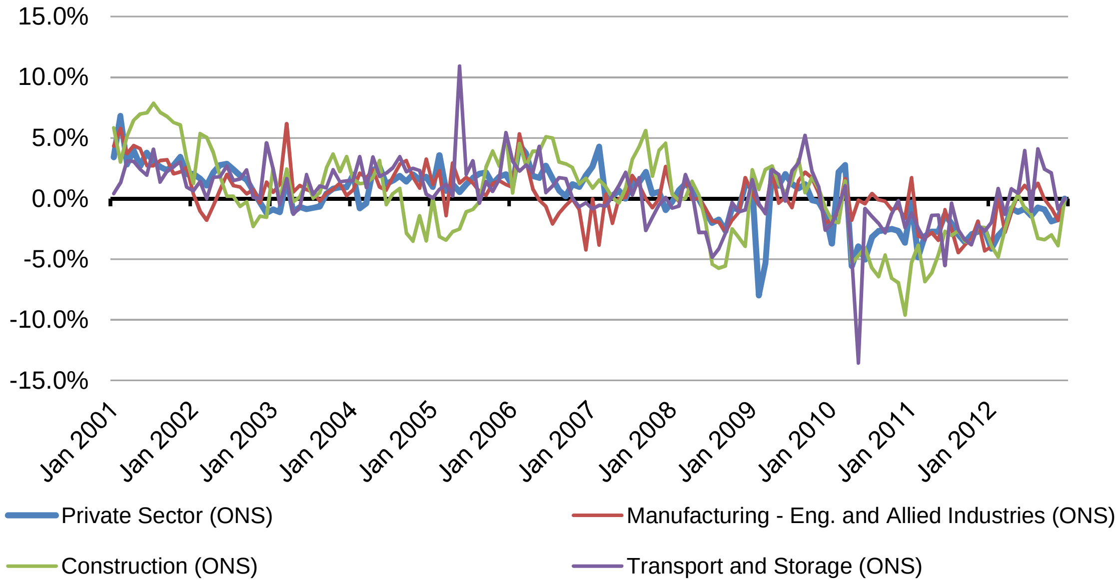


Source: NERA analysis of ONS data.

The labour costs faced by a distribution company also include factors specific to certain industrial sectors. We therefore selected the three broad industrial sectors available from the ONS AWE classification that cover operations carried out by electricity networks, such as construction of utility projects, warehousing and engineering works. The suitable indices of average weekly earnings are Construction, Transport and Storage, and Manufacturing - Engineering and Allied Industries, which we present in Figure A.2. Similar to wage growth in the private sector over the same period, these industries averaged 0.33% from January 2000 to November 2012.

70 Average of monthly data, estimated real change y.o.y..

Figure A.2
Real Wage Growth (% y.o.y.) In Broad Sub-Sectors

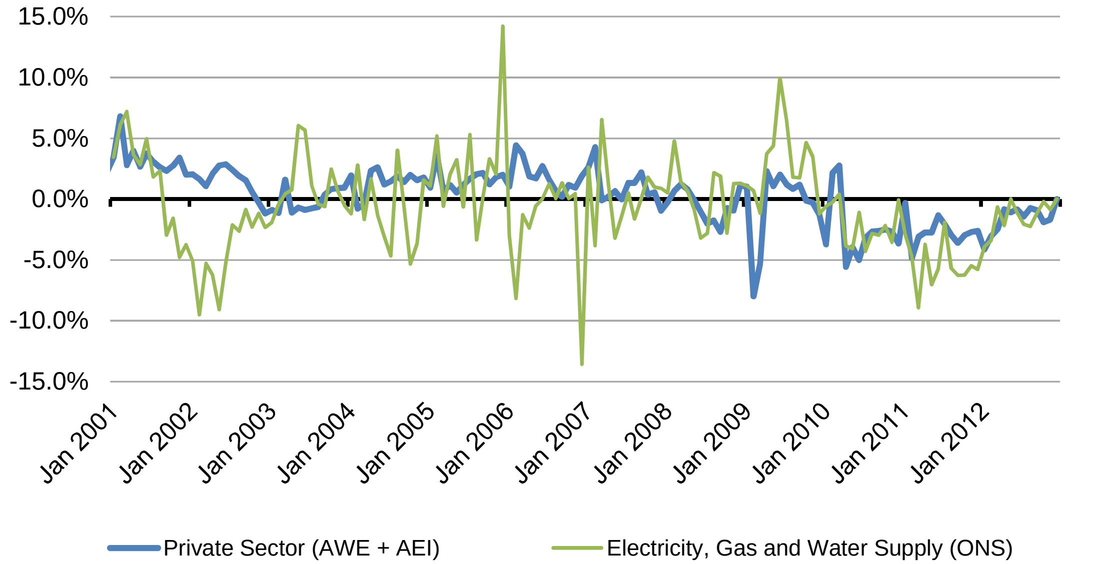


Source: NERA analysis of ONS data.

Finally, we looked at indices available from the ONS and specialist providers which provide specific coverage of the cost of labour in the electricity industry. The ONS produces an index of average weekly earnings in the electricity, water, and gas supply industries, and specialist providers BCIS and BEAMA produce indices of average earnings used to update contractually agreed wage rates. These indices are likely to provide the closest mapping to the costs of an electricity distribution network, provided the sample from which the series is estimated is sufficiently large.

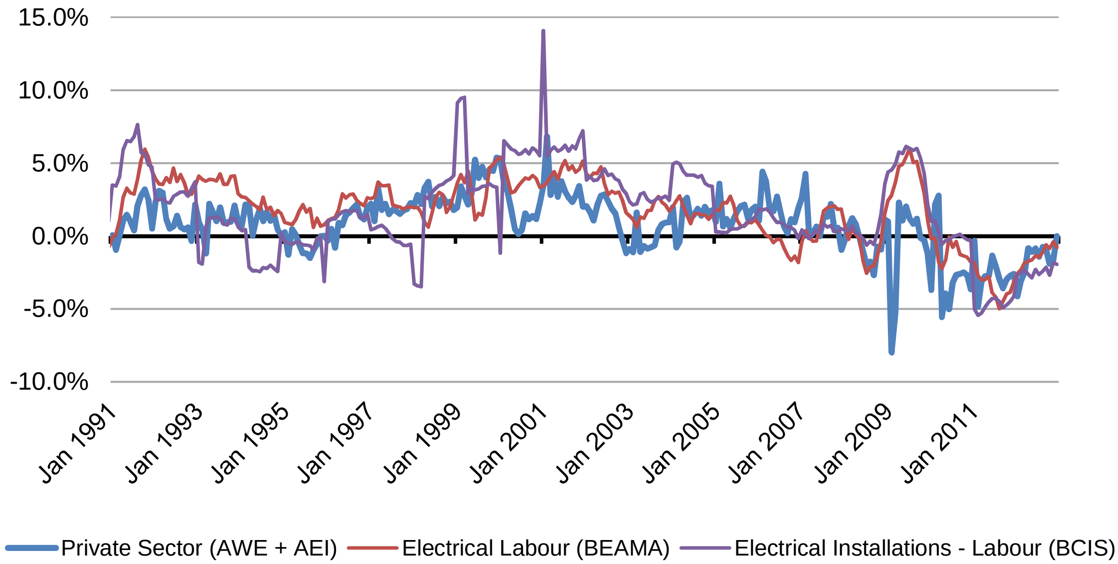
Firstly, we compared the two average weekly earnings series in Figure A.3. We note that the ONS measure shows a much higher level of volatility than the measures presented in Figure A.2. The average real wage growth in this sector was -0.61%. Secondly, we compare specialist earnings indices with data from the private sector from January 1990 (when our private sector data begins) to November 2012 in Figure A.4. The average real wage growth over that period was 2.22%.

Figure A.3
Real Wage Growth (% y.o.y.) In Electricity (ONS Data)



Source: NERA analysis of ONS data.

Figure A.4
Real Wage Growth (% y.o.y.) In Electricity Specific Sub-Sectors



Source: NERA analysis of ONS, BEAMA and BCIS data.

All of the series we examined may provide some indication of the labour costs of the electricity distribution networks. The indices published by the ONS, BCIS and BEAMA provide the best coverage of the specialist labour costs in the electricity industry. We note, however, that DNOs employ a variety of staff, not all of whom may qualify for the definitions of specific sectoral indices such as electrical labour. For example, accounting, clerical and administrative staff may not be covered by the "electrical labour" index.

A.2.2. Informational value & evidence for sectoral adjustments

Indices drawn from small samples tend to be more volatile than large samples. A small number of erroneous or anomalous data points can bias estimates drawn from small samples, especially given short sample periods. In general, therefore, broader indices with longer time series available are likely to provide a better indication of the input cost category being measured.

Figure A.1 to Figure A.4 show the possible impact of small sample sizes in the relative volatility of the different data series. Of the indices we have reviewed the Electricity, Gas and Water Supply index published by the ONS is the most volatile. By contrast, the private sector wages index is less volatile, reflecting a larger survey size.

We also note that the ONS provides comparable industry-level data on average weekly earnings no earlier than January 2000. By contract, the BCIS data series on electrical labour goes back to 1977 and the BEAMA data even further, to 1970.

Nonetheless, time series data from smaller samples over shorter periods may provide a useful indication of the costs of electricity distribution networks to the extent that these data measure the costs of electricity distribution businesses more closely and provide significantly different evidence to broader indices.

We considered whether the observable difference between the real price effect in private sector wages and different sub-sectors was evidence of a "premium" for specialist labour, or could be the result of random sampling error. We conducted a "difference of means" test to test this. We examined the mean and variance of each the AWE series over the period January 2000 to November 2012 (the period for which AWE data is available) and tested whether this was "significantly different" from the mean for the private sector. We also tested the specialist series data from January 1990 (the longest period AEI data is available) to November 2012. If a series has the same average real rate of wage growth as the private sector this would suggest that factors affecting wage growth in that sector are not significantly different to the private sector as a whole.

In Table A.2 we present the result of these tests for the four sub-sectors which we presented data on in Figure A.2 and Figure A.3. The null hypothesis of the test was that both series had an evolution over time that was not significantly different. The "p-value" indicates the confidence with which we can reject the null hypothesis. For example, a "p-value" of 0.05 indicates we can reject the null hypothesis with 95% confidence. In Table A.2, the low p-value for electricity, gas and water supply suggests that the average real rate of wage growth in that sub-sector is significantly different to the private sector. By contrast, we cannot reject the null for the other sub-sectors, which therefore do not offer additional information about the evolution of real wages.

Table A.2
Difference of Means Test (Independent Samples): Broad Sectors

Sector	Mean	Std. Deviation	Sample Size	S.e. of Sampling Distribution	Test Statistic	P-value
Private Sector (AWE)	0.24%	2.34%	143	0.28%	0.000	1.000
Construction	0.17%	3.57%	143	0.36%	-0.176	0.860
Transport & Storage	0.50%	2.58%	143	0.29%	0.900	0.370
Engineering & Allied	0.31%	2.03%	143	0.26%	0.298	0.766
Elec, Gas and Water	-0.61%	3.86%	143	0.38%	-2.233	0.027

Source: NERA analysis. Sample: January 2000 to November 2012.

In Table A.3 we present our results for the electricity specific indices shown in Figure A.4, which we tested against the AWE and AEI series of private sector earnings (forming a time series going back to January 1990). We noted above that the length of these series contributes to their lower level of volatility, which is especially true for the BEAMA index. Likewise, p-values close to zero indicate we can confidently reject the hypothesis that average real wage growth measured by these indices is equal to growth in the private sector as a whole. The results present a mixed picture:

- the wages index for Electricity, Gas and Water Supply is lower on average than the private sector as a whole; whilst
- the wages indices for electrical labour and labour for electrical installations are higher on average than the private sector as a whole.

Table A.3
Difference of Means Test (Independent Samples): Electricity Sector

Sector	Mean	Std. Deviation	Sample Size	S.e. of Sampling Distribution	Test Statistic	P-value
Private Sector (AWE + AEI)	0.83%	2.08%	263	0.18%	0.000	1.000
Elec Labour (BEAMA)	1.76%	2.22%	263	0.19%	4.971	0.000
Elec Installation (BCIS)	1.72%	3.07%	263	0.23%	3.922	0.000

Source: NERA analysis. Sample: January 1990 to November 2012.

The evidence from the ONS "Electricity, Gas and Water Supply" index may be misleading for the following reasons:

- The index of wages for electricity, gas and water supply is the most volatile (measured by its standard deviation), possibly indicating a small sample;
- The ONS also draws the index from a shorter time period (since 2000) than the other electricity sector indices; and
- Negative real wage growth suggests this measure may be capturing post-privatisation effects in reducing the wages of staff, which may not reflect the future evolution of costs.

We consider that the index of wages for electricity, gas and water supply may be a less reliable basis for calculating RPEs than alternative, sector-specific indices. Moreover, we believe that the BEAMA index, drawn from the longest period and displaying the least volatility since 1990, is likely to present the most accurate picture of the long term trend in real wage growth in the sector.

Therefore, there is evidence for a real wage premium of approximately 0.9% for electrical labour. We recommend including this premium, and accounting for non-specialist staff, by taking an unweighted average of both the Private Sector AWE and AEI and the Electrical Labour index available from BEAMA over the period January 1990 to November 2012. For consistency with our short term forecasts, a reflective premium should also be added to the HMT forecasts of near term earnings growth.

A.2.3. Empirical fit to UKPN's data

We have examined the unit labour costs that UKPN faces, insofar as this is possible from the data they have provided us with, to cross-check our conclusions in Section A.2.2. UKPN provided us with data on the pay settlements of its labour force covered by a "Collective Agreement" from 2006 -2012. Table A.4 shows that UKPN's actual costs have shown evidence of a premium above the private sector as whole. The sample of data we have available to draw this conclusion is limited, so we employ it only as a cross-check. We note that UKPN's unit labour costs have risen more quickly over the last seven years than private sector wages or electrical labour more generally.

Table A.4
Change in Unit Labour Costs (Nominal, % change y.o.y.)

	Wage Growth UKPN	Private Sector AWE ONS	Electrical Labour BEAMA
2006	4.3%	5.0%	2.6%
2007	4.6%	5.3%	5.2%
2008	4.7%	3.5%	3.4%
2009	2.5%	-1.0%	3.5%
2010	2.0%	2.0%	3.5%
2011	3.5%	2.5%	1.7%
2012	3.9%	1.4%	1.8%
Average	**3.6%**	**2.7%**	**3.1%**

Source: NERA analysis of UKPN, ONS and BEAMA data.

A.2.4. Conclusion

Our conclusions are as follows:

- **Coverage:** The index of wages in the private sector offers a broader base and a deeper sample than the more sector-specific indices. On the other hand, specialist indices exist for electrical labour which give specific coverage of DNO's costs, and demonstrate a statistically significant difference from the private sector as a whole. In practice, we recognise that DNOs employ a variety of labour types, not all of which will fall within the category of electrical labour.
- **Informational Value:** The broad sectoral indices offer similar results to the private sector as a whole. Although sector specific indices are based on smaller samples, these indices appear to offer substantially different results to the private sector as a whole. The

BEAMA Electrical Labour index is available from 1970, which may help to eliminate any small-sample bias.

- **Empirical Fit:** The data available on unit costs for labour was limited, however we note that in the recent past, UKPN's unit labour costs have risen more quickly than the private sector as a whole, or the index for electrical labour.

On the basis of this assessment, we selected the index of Private Sector Average Weekly Earnings published by the ONS and the Electrical Labour index published by BEAMA as the most suitable for calculating RPEs.

A.3. Materials Costs

A.3.1. Relevant indices and coverage

UKPN has led us to understand that the breakdown of its expenditure on materials has not changed since our review at DPCR5. These are:

- Transformers and Switchgear (25%);
- Cables (30%); and
- Other (45%).

We assembled a variety of indices covering the material costs from the ONS, BCIS, and BEAMA and including series reviewed by Ofgem at RIIO-T1/GD1. In practice, we found that a wide variety of series were available although some such as producer price indices measuring the cost of copper wire were available for only two or three years. Such series would only include the impact of the recent recession and would be unlikely to offer a reasonable estimate for RPEs over RIIO ED1. Table A.5 presents the indices that were available for longer time periods, including ONS data that is not available online.

Table A.5
Relevant Materials Indices

Type	Source	Available	Index	Description
RCI	BIS	Q1 1990 - Q2 2012	Resource Cost Index: Infrastructure Materials	"The Resource Cost Indices are w eighted averages of the [BCIS] Price Adjustment Formulae Indices", w eighted to measure the movement in material input costs.
PAFI	BCIS	Jan 1991 - Jan 2013	Pipes and Accessories: Copper	Weighted average of relevant sub-series.
PAFI	BCIS	Jan 1991 - Jan 2013	Pipes and Accessories: Aluminium	Weighted average of relevant sub-series.
PAFI	BCIS	Jan 1991 - Jan 2013	Pipes and Accessories: Steel	Weighted average of relevant sub-series.
PAFI	BEAMA	Jan 1970 - Dec 2012	Basic Electrical Equipment	Weighted average of 72 PPIs, including: 14% petroleum products, 3% imported iron and steel, 3% imported non-ferrous metals, 2% general mechanical engineering services, etc.
PPI	ONS	Jan 1996 - Jan 2013	Manufacture of Copper	Includes "the manufacture of fuse w ire or strip" and "manufacture of w ire of these metals by draw ing".
PPI	ONS	Jan 1996 - Jan 2013	Manufacture of Basic Metals	Includes "cold draw ing of w ire" and "casting of metals".
PPI	ONS	Jan 1996 - Jan 2013	Manufacture of Basic Iron, Steel and Ferro-Alloys	Sub-set of Basic Metals, includes "manufacture of tubes, pipes, hollow profiles and related fittings, of steel".
PPI	ONS	Jan 1996 - Jan 2013	Manufacture of Other Non-Ferrous Metals	Sub-set of Basic Metals, includes production of non-ferrous metals.
PPI	ONS	Jan 1996 - Jan 2013	Manufacture of Electricity Distribution and Control Apparatus	Includes "manufacture of pow er circuit breakers" and "manufacture of pow er sw itching equipment" i.e. sw itchgear.
PPI	ONS	1987-1996	Manufacture of Electricity Distribution and Control Apparatus	Older series based on SIC 1992 classification (available in print editions of Annual Abstract of Statistics).
PPI	ONS	Jan 1996 - Jan 2013	Manufacture of Electric Motors, Generators and Transformers	Includes "manufacture of all electric motors and transformers: AC, DC and AC/DC."
PPI	ONS	1987-1996	Manufacture of Electric Motors, Generators and Transformers	Older series based on SIC 1992 classification (available in print editions of Annual Abstract of Statistics).
PPI	ONS	Jan 1996 - Jan 2013	Manufacture of Other Electronics and Electric Wires	Inlcudes the manufacture of insulated w ires.
PPI	ONS	1987-1996	Manufacture of Insulated Wires and Cables	Older series based on SIC 1992 classification (available in print editions of Annual Abstract of Statistics).
PPI	ONS	Jan 1996 - Jan 2013	Manufacture of Cold Draw n Wire	Sub-set of Manufacture of Basic Metals.
PPI	ONS	1987-1996	Manufacture of Cold Draw n Products	Older series based on SIC 1992 classification (available in print editions of Annual Abstract of Statistics).

Source: BIS[71], BCIS, BEAMA[72], ONS[73].

The "RCI Infrastructure Materials" index, used by Ofgem at RIIO-T1/GD1, shown in Figure A.5, captures the broad range of materials costs faced by a distribution network. We suggest

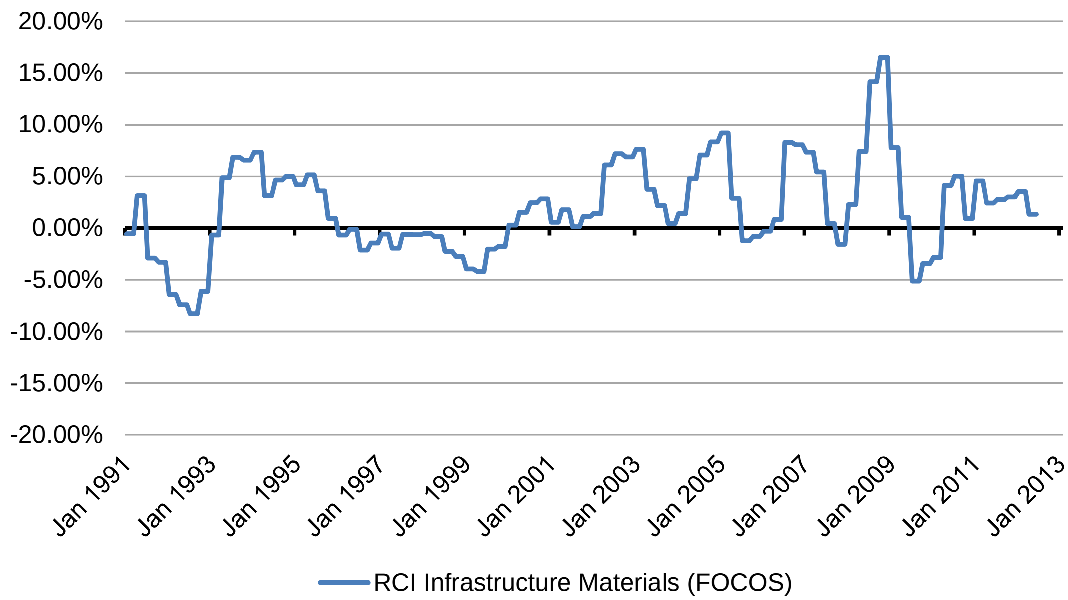
71 BIS, Construction Resource Cost Indices Notes and Definitions, page 4.

72 Email from Emmanuel Amoakohene, Head of Statistics, BEAMA, 5 March 2013.

73 ONS, UK Standard Industrial Classification of Economic Activities 2007 (SIC 2007): Structure and Explanatory Notes, 2009, pages 33, 34, 106, 117, 118; Annual Abstract of Statistics 1997, 1998: Tables 18.1 – 18.4.

that it provides a good proxy for the "Other" category of material expenditure incurred by UKPN. The average real price growth from Q1 1991 to Q2 2012 was 1.92%.

Figure A.5
Real Price Growth (% y.o.y.) In Infrastructure Materials

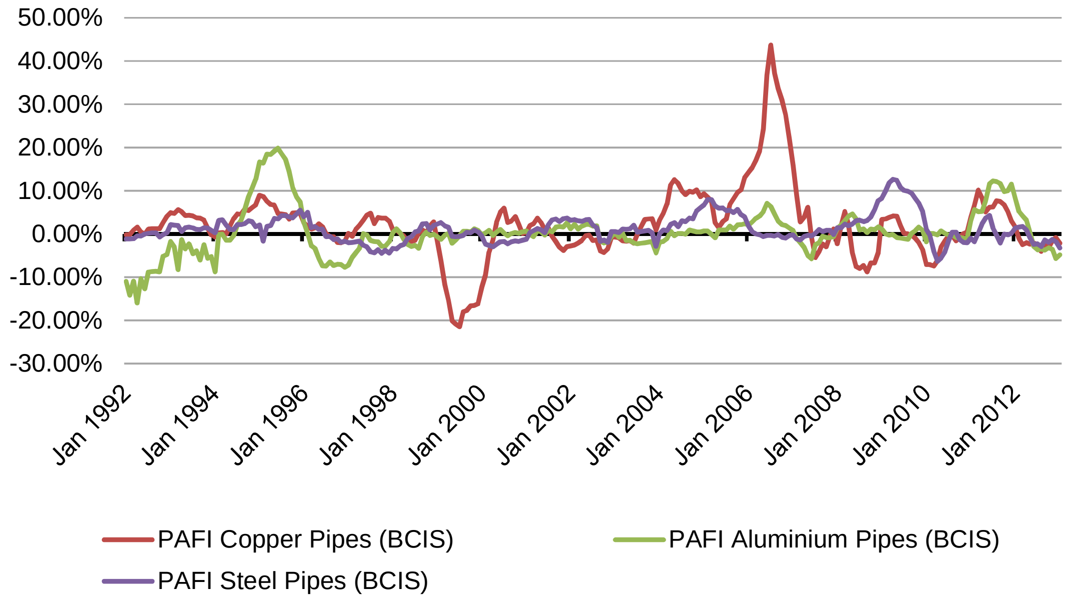


Source: NERA analysis of BIS FOCOS data. Data is quarterly.

We also examined more specific sectors that might provide coverage of the costs of a distribution network. Firstly, we looked at the PAFI indices published by the BCIS. These contain indices of the costs of metal piping. Since the input prices of metal pipes are likely to respond to the same pressures as metal products used by a DNO, such as cables and transformers, these indices could provide a good proxy for the input prices of DNOs.

We depict the evolution of real price changes of metal piping in Figure A.6. The price of piping appears to be extremely volatile, especially that of copper. However, the average picture of real price growth is broadly similar to the RCI Infrastructure index: from January 1991 to January 2013, the average real price growth measured by the PAFI indices for copper, steel and aluminium piping was 1.21%.

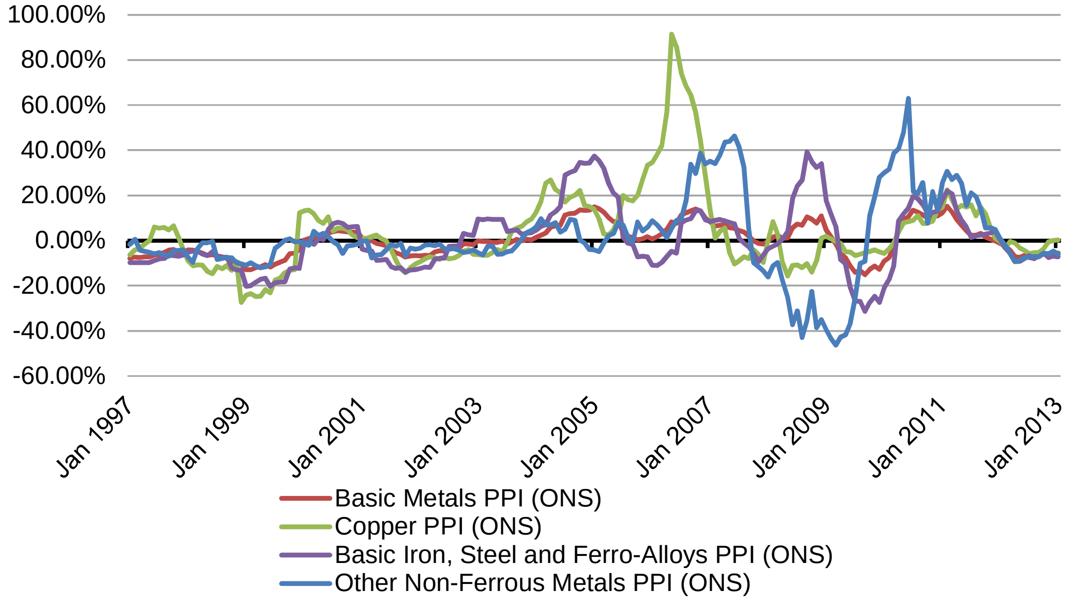
Figure A.6
Real Price Growth (% y.o.y.) In Metal Piping PAFI



Source: NERA analysis of BCIS data.

Similarly, we also considered producer price indices that would provide a reflection of the prices of manufactured materials purchased by a distribution network. We assembled the PPIs for the manufacture of basic metals, copper, iron and steel, and non-ferrous metals, as shown in Figure A.7. As indicated in Table A.5, these indices include the manufacturing cost of drawing wire. The price of these inputs is volatile, with year on year real changes in the measured price of copper as great as 90% in May 2006. These indices also present a largely consistent picture of rising real input prices over time at an average rate of 1.43% per year. We note that distribution networks do not use these basic materials directly and therefore these indices provide less direct coverage of the costs of DNOs. As inputs into the manufactured products DNOs purchase, commodities prices provide a useful indication of the trends in the prices of these products.

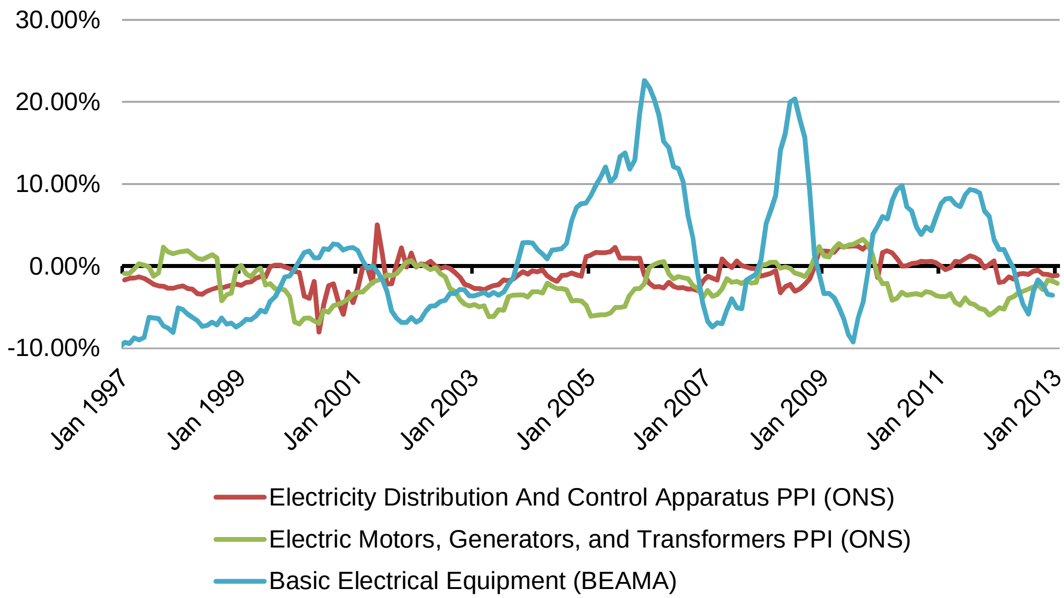
Figure A.7
Real Price Growth (% y.o.y.) In Commodities PPI



Source: NERA analysis of ONS data.

Finally, we assembled a set of indices specific to the electricity industry. These include indices published by the ONS and a measure of the price of electrical equipment published by BEAMA (which is itself a weighted average of 72 individual PPIs). We first considered those series relevant to the costs of transformers and switchgear, shown in Figure A.8. These series provide effective coverage of the costs of an electricity distribution network. The "Electricity Distribution and Control Apparatus" PPI includes the cost of manufacturing switchgear, whilst the "Electric Motors, Generators and Transformers" PPI includes distribution transformers. The average annual growth in these three series since January 1996 is negative, at -0.82%.

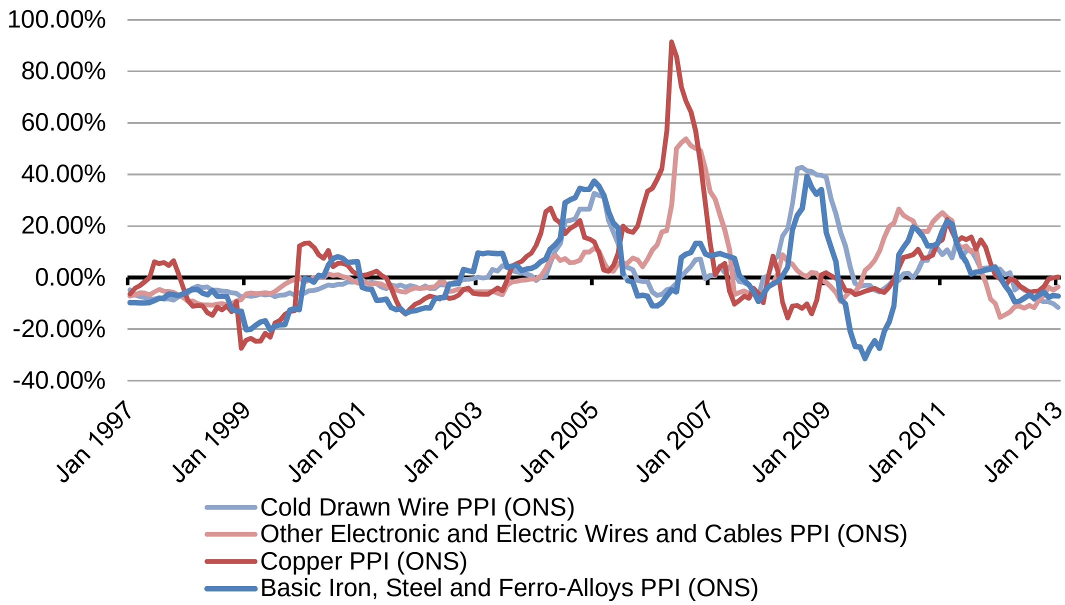
Figure A.8
Real Price Growth (% y.o.y.) In Transformers And Switchgear



Source: NERA analysis of ONS and BEAMA data.

Finally, we considered indices specifically targeted at the cost of cables. The series "Other Electronic and Electric Wires and Cables" targets the cost of manufactured insulated cables, whilst "Cold Drawn Wire" isolates another component relevant to the price of cables. The average real growth of these indices since January 1996 is 2.63%%. In Figure A.9 we illustrate how changes in each series are highly correlated with growth in commodities PPIs, with reference to copper and steel and other ferrous metals (including aluminium).

Figure A.9
Real Price Growth (% y.o.y.) In Cables and Wires



Source: NERA analysis of ONS data.

A.3.2. Informational Value

The PPI series published by the ONS only extend back to 1996, but can be supplemented with older data dating back to 1987 available in printed publications.[74] Therefore, there is less potential for bias due to a short sample period. BCIS and BIS indices, available from January 1990, are more reliable still as they encompass at least one entire business cycle. BEAMA data, available from 1970, also avoids any small sample period problems.

As for our assessment of labour indices, the evidence suggests that a combination of broader indices of materials costs and electricity sector specific series may best reflect the RPEs faced by DNOs:

- The “RCI Infrastructure Materials” index is a weighted average of a wide range of PAFI series reflecting the costs of general materials acquisition. As such, it is not clear that adding narrower PAFI series adds much informational value, unless those sub-indices evolve significantly differently over time (which copper pipes appear to have done, see Figure A.6) and reflect important categories of costs.
- Broadly speaking, commodities series are the most volatile, likely due to the underlying volatility in the prices of the products rather than sampling error. Over the sample period available commodities have experienced a similar average rate of growth to broader indices of materials costs.

---

[74] ONS, Annual Abstract of Statistics, passim.

- Electricity sector specific series are likely to rely on smaller samples, but we note that the general evolution of the costs of electricity sector materials has been, on average lower for transformers and switchgear (at around -1.0%) than cables (at around 2.6%).

A.3.3. Fit to UKPN data

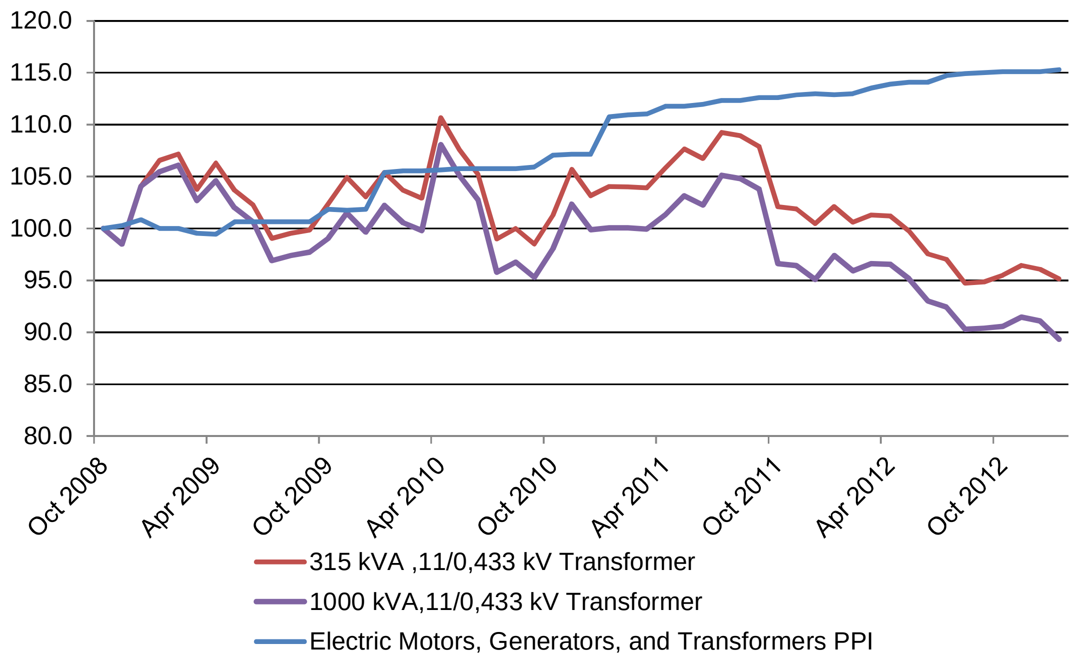
Data on materials input costs were not been available over the longer term. UKPN provided us with some data on the prices of transformers purchased under recent contracts, which were indexed to commodity prices. It has been possible to calculate the effective price that UKPN would have paid each month under these contracts to procure transformers, since September 2008.

In Figure A.10 we compare this (rebased) price to the PPI for “Electric Motors, Generators and Transformers”. The contract prices appear to be more volatile than the index of “Electric Motors, Generators and Transformers”, possibly for the following reasons:

- The PPI reflects both the evolution within contracts indexed to commodities prices and the strike price set under new contracts;
- The PPI includes a slightly wider base of products;
- UKPN’s price for transformers under the contract may not reflect market prices as a whole at any given instant, given that UKPN signed the contract with a predetermined price formula ex ante;
- Exchange rate movements may also influence the contract price, as well as commodity price fluctuations.

On the basis of this small sample it is difficult to establish whether there is an “empirical fit” between UKPN’s costs and PPIs.

Figure A.10
Evolution of Transformers Contract Cost
(Nominal Index – Rebased to 2008)



Source: NERA analysis of UKPN, ONS data.

A.3.4. Conclusion

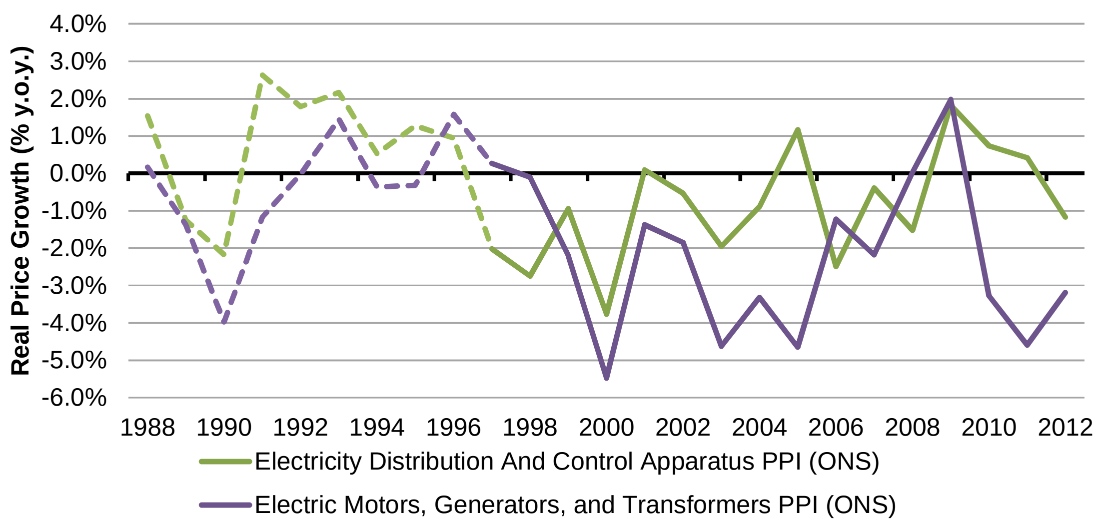
Our conclusions are as follows:

- **Coverage:** The ONS publishes PPIs covering a broad range of materials, commodities and specific electrical equipment (including separate indices for wires, transformers and control apparatus). UKPN has provided a breakdown of its materials costs into Transformers and Switchgear (25%), Cables (30%), and Other materials (45%). The separate indices for transformers and control apparatus and cables offer coverage of the first two sub-categories. "Other materials" include a broader range of materials for which a more general index might be appropriate.
- **Informational Value:** Resource cost indices are available for broad categories of costs which include the materials costs incurred by DNOs. Electricity-specific indices are available and appear to evolve differently from more general resource costs over time. The difference between electricity specific indices and resource cost indices suggests that a general resource cost index may not capture the evolution of all of a DNO's costs.
- **Empirical Fit:** The data available on unit costs was limited. Our analysis shows that the costs incurred by UKPN under its medium-term contracts do not closely follow the relevant PPIs. The differences may reflect the difference in prevailing market prices between the date of contract signature and prices of transformers at the point of purchase.

We calculated a RPE for materials using a basket of materials costs. We selected specific indices for the separately identifiable categories of materials costs on the basis that these series most closely reflect the evolution of the underlying unit costs of materials. For the remaining categories of costs we used the broadest infrastructure materials index with the longest available data series:

- **Transformers & Switchgear (25% of total materials):** we used an equal weighting of "Electric Motors, Generators and Transformers" PPI and "Electricity Distribution and Control Apparatus" PPI, because there was no objective basis for excluding either. We supplemented the ONS data available since 1996 (SIC 2007) with earlier data that dates back to 1987 (SIC 1992);
- **Wires and Cables (30% of total materials):** we used an equal weighting of the "Cold Drawn Wire" PPI and "Other Electronic and Electric Wires and Cables" PPI. We supplemented the ONS data available since 1996 (SIC 2007) with earlier data that dates back to 1987 (SIC 1992)[75]; and
- **Other materials (45% of total materials):** we used the "Infrastructure Resource Cost Index" as a broad index tracking materials costs which are not specific to DNOs. We supplemented quarterly data from 1990 onwards with annual data to make a comparable time series available from 1987.

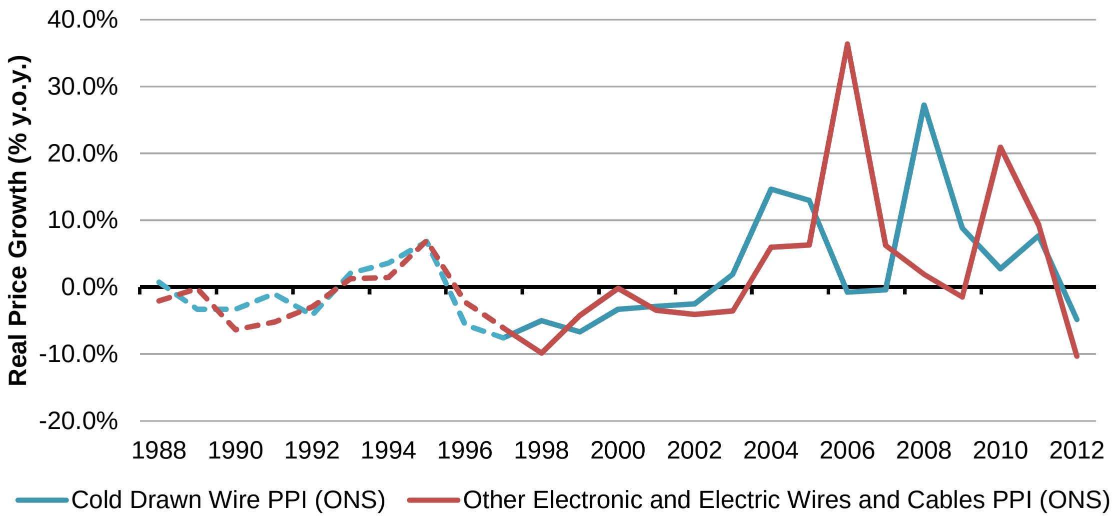
Figure A.11
Recommended Series & Averaging Period: Transformers & Switchgear
(Real % change y.o.y.)



Source: NERA analysis of ONS data.

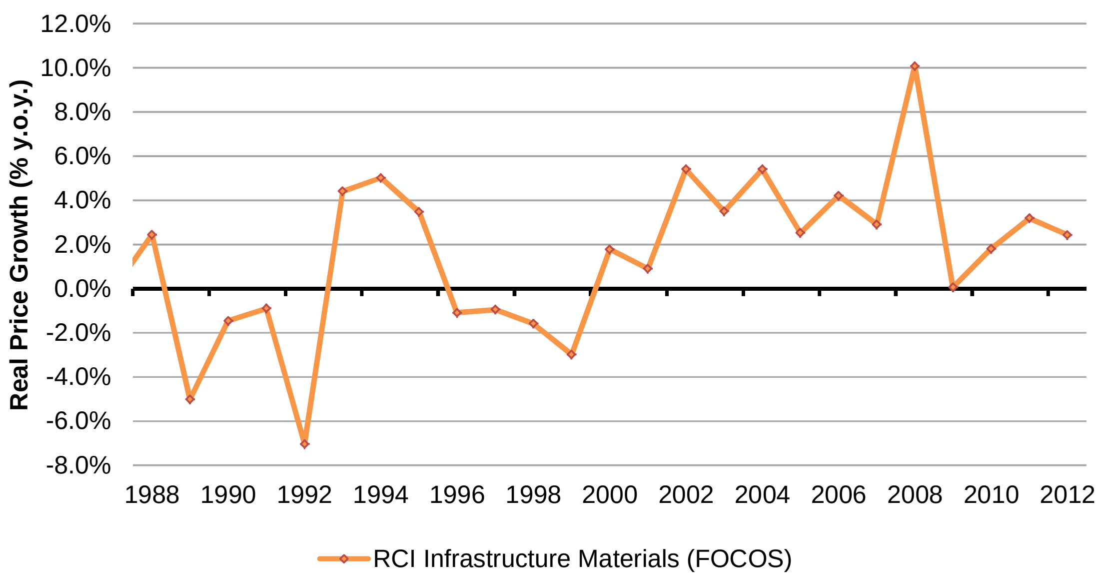
75 We used "Cold Drawn Products" (PPVY) to supplement "Cold Drawn Wire" (JV2C), and "Insulated Wires and Cables" (PQFE) to supplement "Other Electronic and Electric Wires and Cables" (K32F).

Figure A.12
Recommended Series & Averaging Period: Cables
(Real % change y.o.y.)



Source: NERA analysis of ONS data.

Figure A.13
Recommended Series & Averaging Period: Other
(Real % change y.o.y.)



Source: NERA analysis of ONS data.

A.4. Plant and Equipment Costs

A.4.1. Relevant indices and coverage

We reviewed the methodology for the ONS, BCIS and BEAMA indices that are likely to provide coverage of the costs of the plant and equipment costs of a DNO. Table A.6 contains the relevant indices.

Table A.6
Relevant Plant and Equipment Indices

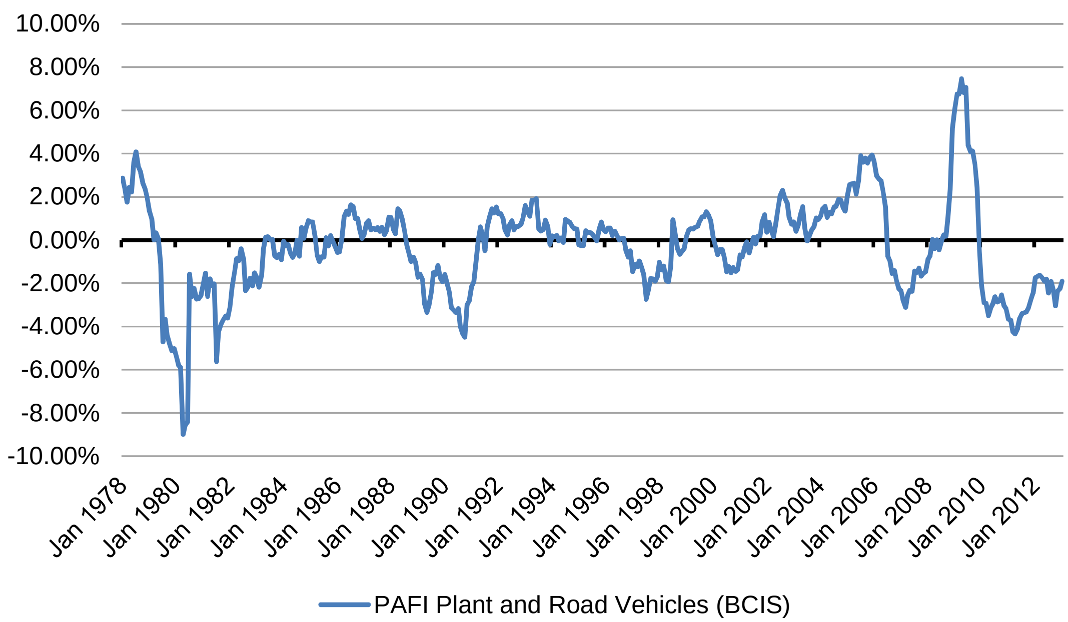
Type	Source	Available	Index	Description
PAFI	BCIS	Jan 1977 - Jan 2013	Plant and Road Vehicles	Weighted average of relevant sub-series.
PPI	ONS	Jan 1996 - Jan 2013	Machinery and Equipment Input	Includes the manufacture of general purpose machinery, excluding eletrical equipment
PPI	ONS	Jan 1996 - Jan 2013	Machinery and Equipment Output	Includes the manufacture of general purpose machinery, excluding eletrical equipment
PPI	ONS	Jan 1996 - Jan 2013	Electrical and Optical Equipment Input	Includes the manufacture of specialist machinery, such as transfomers and distribution apparatus.
PPI	ONS	Jan 1996 - Jan 2013	Electrical and Optical Equipment Output	Includes the manufacture of specialist machinery, such as transfomers and distribution apparatus.
PPI	ONS	Jan 1996 - Jan 2013	Wiring and Wiring Devices	Includes the "manufacture of current-carrying wiring devices and non current-carrying wiring devices for wiring electrical circuits regardless of material."
PPI	ONS	1987-1996	Machinery and Equipment Input	Older series based on SIC 1992 classification (available in print editions of Annual Abstract of Statistics).
PPI	ONS	1987-1996	Machinery and Equipment Output	Older series based on SIC 1992 classification (available in print editions of Annual Abstract of Statistics).
PPI	ONS	1987-1996	Electrical and Optical Equipment Input	Older series based on SIC 1992 classification (available in print editions of Annual Abstract of Statistics).
PPI	ONS	1987-1996	Electrical and Optical Equipment Output	Older series based on SIC 1992 classification (available in print editions of Annual Abstract of Statistics).

Source: BCIS, ONS[76].

[76] ONS, UK Standard Industrial Classification of Economic Activities 2007 (SIC 2007): Structure and Explanatory Notes, 2009, pages 34 – 35, 118: ONS, Annual Abstract of Statistics, 1997,1998, Tables 18.1-18.4.

The baseline for our comparison was the PAFI index of plant and roads vehicles published by the BCIS. This index has a large sample available (since 1977) and it provides coverage of the general cost of plant and equipment faced by an industrial firm The average real growth in this series over the period January 1977 to January 2013 was -0.34%.

Figure A.14
Real Price Growth (% y.o.y.) In PAFI Plant and Road Vehicles



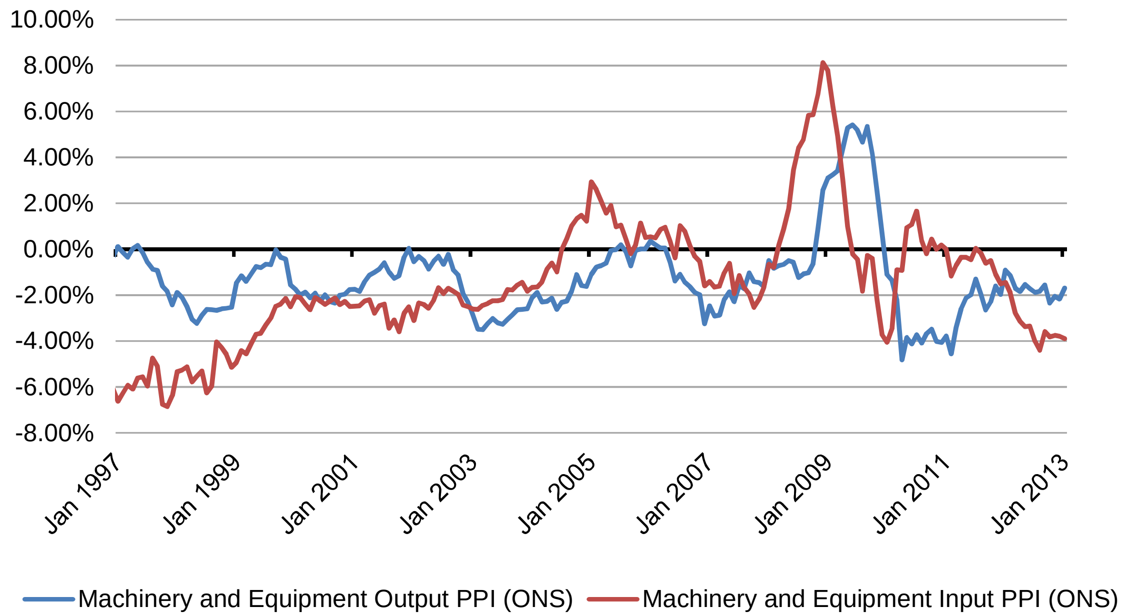
Source: NERA analysis of BCIS data.

We also examined two sets of more specific indices. The first, "Machinery and Equipment", covers the non-specialised equipment requirements that a distribution network may face. We examined both input and output PPIs, which together had a long term real average of -1.41% p.a. from January 1996 to January 2013.

These indices are likely to provide coverage of the equipment costs of a DNO as they include the prices of the "manufacture of machinery and equipment that acts independently on materials either mechanically or thermally or performs operations on materials (such as handling, spraying, weighing or packing)"[77] This includes the mobile and fixed equipment requirements of a DNO.

77 ONS, UK Standard Industrial Classification of Economic Activities 2007 (SIC 2007): Structure and Explanatory Notes, 2009, page 121.

Figure A.15
Real Price Growth (% y.o.y.) In Machinery and Equipment



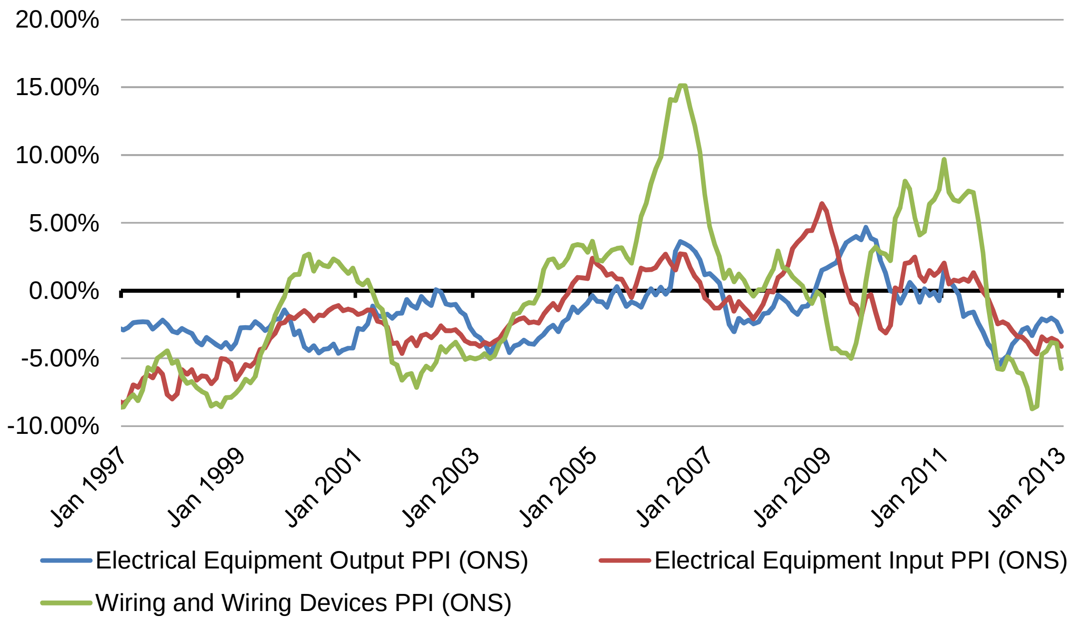
Source: NERA analysis of ONS data.

Finally, we examined the PPI of "Electrical Equipment" and its most relevant sub-sets ("Wiring and Wiring Devices" and "Other Electrical Equipment"). These indices are likely to be targeted at the input prices faced by an electricity network, but including all of them would involve double-counting certain sectors. The "Electrical Equipment" PPI, for example, includes the prices of electric transformers as well as distribution and control apparatus. In Section A.3.1. we argued that these prices are relevant to the materials cost faced by a DNO, and therefore we do not consider them to be targeted at equipment costs.

Likewise, the series "Wiring and Wiring Devices" includes items relevant to a DNO's costs, but not necessarily its equipment costs. Wiring devices include transmission pole and line and electrical conduit fittings. However, it also includes the manufacture of insulated cables, which we identified in Section A.3 as a material input.

The average real growth in all these series from January 1996 to January 2013 was -1.23% p.a..

Figure A.16
Real Price Growth (% y.o.y.) In Electrical Sector PPI



Source: NERA analysis of ONS data.

A.4.2. Informational value

The PPI series run from January 1996 to January 2013. Over the period they present a consistent picture of falling equipment prices, in the range -1.41% to -0.34%. No individual series displays unusual volatility that indicates it is drawn from a small sample.

A.4.3. Empirical Fit

UKPN were unable to provide a long series of plant and equipment costs which were comparable to the PPI series we identified.

A.4.4. Conclusion

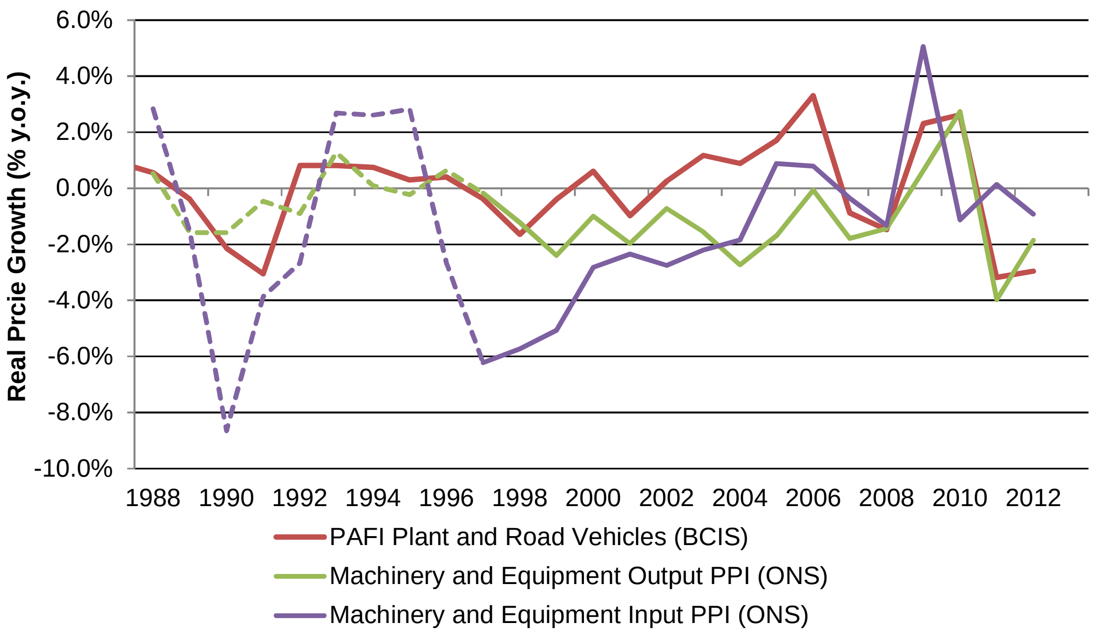
- **Coverage:** We conclude that a series of Plant and Road Vehicles, as well as the two Machinery and Equipment PPIs, effectively cover the general input prices faced by a DNO. The indices which cover the electricity industry more specifically, among them Electrical Equipment, measure the input prices of items such as transformers which we consider to be a part of materials cost;
- **Informational Value:** All the indices we assessed indicated that the real cost of plant and equipment has been falling in real terms over time. Our recommended indices agree with this trend
- **Empirical Fit:** Not applicable.

Our final RPE recommendation is an unweighted average of three series, as long term series which reflect the costs of UKPN's plant and equipment:

1. PAFI Plant and Road Vehicles;
2. Machinery and Equipment input PPI; and
3. Machinery and Equipment output PPI.

We append earlier ONS data (dashed lines in Figure A.17) to the two PPI series, increasing the averaging period to 1987-2012.

Figure A.17
Recommended Series And Averaging Period: Plant and Equipment
(Real % change y.o.y.)



Source: NERA analysis of BCIS and ONS data.

A.5. Transport & Other

We surveyed data available from ONS and specialist providers, but did not find any series which seemed particularly applicable to this area of input costs. We therefore did not have an objective basis to judge the trend in input prices relative to RPI, and as such recommend an RPI of 0%.

A.6. Indicative RPEs

In Table A.7 we present the indicative RPEs calculated using the method stated above. For 2012/13, we take the average of the monthly figures that are currently available for the financial year. For the long term average we use the periods we have described above: 1990-2012 for labour, 1988-2012 for materials, and 1988-2012 for equipment and plant.

All outturn real price effects in 2012/13 are negative, due to the prevailing macroeconomic conditions. In the long term, we assume that price growth will return to its long term trend. For labour, this is an average real increase of 1.3%, 1.1% for materials, and costs falling by

0.6% for plant and equipment. We note that our results are similar to those used by Ofgem at RIIO – ET1, also shown.

Table A.7
Indicative RPEs

RPE	2012/13	Long Term Average	Ofgem RIIO - ET1
Labour	-1.1%	1.3%	1.5%
Materials	-2.0%	1.1%	1.6%
Equipment & Plant	-2.6%	-0.6%	-0.9%
Other	0.0%	0.0%	0.0%

Source: NERA analysis, Ofgem.

Appendix B. Calculating Productivity Measures

B.1. Calculating Total Factor Productivity

We used a standard calculation of total factor productivity.[78] Using total differentiation, the identity relating gross output to factor inputs may be decomposed into its constituent parts as follows:

$$\Delta \ln GO_{jt} = s_{jt}^{X} \Delta \ln X_{jt} + s_{jt}^{K} \Delta \ln K_{jt} + s_{jt}^{L} \Delta \ln L_{jt} + \Delta \ln TFP_{jt}^{GO} \qquad (1)$$

- j is the industry sector;
- t is the time period (year);
- GO is the volume of gross output;
- X is the volume of intermediate inputs;
- K is the volume of capital inputs;
- L is the volume of labour inputs;
- TFP^{GO} is total factor productivity; and
- s_{jt}^{X} is the two period average share of input *i*'s compensation (current prices) in the nominal value of gross output ($s_{jt}^{X} + s_{jt}^{K} + s_{jt}^{L} = 1$).

This equation states that growth in the (log) volume of output is identical to the weighted sum of growth in the (log) volume of each factor of production (capital, labour, intermediate goods), plus growth in the (log) productivity of all factors. Hence, since all variables except *TFP* are observable, by rearranging the equation in terms of $\Delta \ln TFP_{jt}$ we have an equation which identifies growth in total factor productivity. We implemented this calculation using the EU KLEMS by using the mapping shown in Table B.1.

To calculate TFP using value added data, we performed an extremely similar calculation, dropping intermediate inputs *X* and redefining output as the volume of value added, as shown below. Since value added growth does not include the compensation due to intermediate inputs, the factor shares are $v_{jt}^{K} + v_{jt}^{L} = 1$.[79]

$$\Delta \ln VA_{jt} = v_{jt}^{K} \Delta \ln K_{jt} + v_{jt}^{L} \Delta \ln L_{jt} + \Delta \ln TFP_{jt}^{VA} \qquad (2)$$

---

[78] Timmer, M.P., O'Mahony, M. and van Ark, B., "EU KLEMS Growth and Productivity Accounts: An Overview", March 2007, page 4. Available at http://www.euklems.net/data/overview_07i.pdf

[79] TFP estimated from value added data will always be greater than TFP estimated from gross output data. This is because, rearranging equations (1) and (2), TFP(VA) = TFP(GO) x 1/Share of VA in GO.

Table B.1
EU KLEMS Data Used

Term	Source Variable(s)	Description
GO	GO_QI	Gross output, volume indices, 1995 = 100
VA	VA_QI	Gross value added, volume indices, 1995 = 100
X	II_QI	Intermediate inputs, volume indices, 1995 = 100
K	CAP_QI	Capital services, volume indices, 1995 = 100
L	LAB_QI	Labour services, volume indices, 1995 = 100
s^X	II ÷ GO	Intermediate inputs at current purchasers' prices ÷ Gross output at current basic prices (in millions of British Pounds)
s^K	CAP ÷ GO	Labour compensation ÷ Gross output at current basic prices (in millions of British Pounds)
s^L	LAB ÷ GO	Capital compensation ÷ Gross output at current basic prices (in millions of British Pounds)
v^K	CAP ÷ VA	Labour compensation ÷ Gross value added at current basic prices (in millions of British Pounds)
v^L	LAB ÷ VA	Capital compensation ÷ Gross value added at current basic prices (in millions of British Pounds)
w^X	II ÷ (LAB + II)	Intermediate inputs at current purchasers' prices ÷ Labour compensation + intermediate inputs at current prices (in millions of British Pounds)
w^L	LAB ÷ (LAB + II)	Labour compensation ÷ Labour compensation + intermediate inputs at current prices (in millions of British Pounds)
LP	LAB / LAB_QI	Labour, wages index (calculated)
XP	II_P	Intermediate inputs, price indices, 1995 = 100

Source: NERA analysis of EU KLEMS data.

B.2. Calculating Partial Factor Productivity (Constant Capital)

We are also interested in the productivity attributable to single factors, for instance labour. We can examine this by assuming that the change in capital employed per unit of output is constant from one period to the next. Therefore, the growth rates of capital and value added output in equation (2) are equal, $\Delta \ln VA_{jt} = \Delta \ln K_{jt}$. This allows us to substitute this in to equation (2) as follows:

$$\Delta \ln VA_{jt} = v_{jt}^{K} \Delta \ln VA_{jt} + v_{jt}^{L} \Delta \ln L_{jt} + \Delta \ln TFP_{jt}^{VA} \quad (3)$$

Rearranging:

$$(1 - v_{jt}^{K}) \Delta \ln VA_{jt} = v_{jt}^{L} \Delta \ln L_{jt} + \Delta \ln TFP_{jt}^{VA} \quad (4)$$

Since $v_{jt}^{K} + v_{jt}^{L} = 1$:

$$v_{jt}^{L}(\Delta \ln VA_{jt} - \Delta \ln L_{jt}) = \Delta \ln TFP_{jt}^{VA} \quad (5)$$

We can therefore state the equation in terms of the difference between growth in value added output and growth in labour inputs. This difference is the contribution of improvements in labour productivity. Therefore, we can derive the growth in labour productivity from equation (5) as shown:

$$(\Delta \ln VA_{jt} - \Delta \ln L_{jt}) = \frac{\Delta \ln TFP_{jt}^{VA}}{v_{jt}^{L}} = \Delta \ln PFP_{jt}^{L} \quad (6)$$

By an analogous argument, we can calculate the total productivity improvements due to growth in the productivity of labour, energy and materials (LEMS). We can state the LEMS partial factor productivity measure as:

$$\Delta \ln PFP_{jt}^{LEMS} = \frac{\Delta \ln TFP_{jt}^{GO}}{s_{jt}^{X} + s_{jt}^{L}} \quad (7)$$

B.3. Calculating Partial Factor Productivity (Capital Substitution)

To calculate the LEMS productivity measure, allowing for substitution between capital and labour or intermediate goods, we used:

$$\Delta \ln PFP_{jt}^{LEMSadj} = \Delta \ln GO_{jt} - w^{L}\Delta \ln L_{jt} - w^{X}\Delta \ln X_{jt} \quad (8)$$

- w^{i} is input *i*'s share of total compensation paid to LEMS, in current prices.

B.4. Calculating Unit Cost Measures

The change in cost per unit of output is the change in the price paid per unit *minus* change in productivity (at constant capital). We use the KLEMS data base to calculate the changing unit cost of labour as follows:

$$\Delta \ln COST_{jt}^{L} = \Delta \ln LP_{jt} - \Delta \ln PFP_{jt}^{L} \quad (9)$$

Similarly, we calculate the change in unit cost for the LEMS measure as:

$$\Delta \ln COST_{jt}^{LEMS} = w^{L}\Delta \ln LP_{jt} + w^{X}\Delta \ln XP_{jt} - \Delta \ln PFP_{jt}^{LEMS} \quad (10)$$

Finally, we calculate output price growth from the series *GO_P* in the KLEMS database. To convert these measures into real terms, we subtract the logarithmic growth of the retail price index year by year.

B.5. Sensitivity To Time Period

We examined whether our estimates of productivity were sensitive to the time frame which we examined, as shown in Table B.2. Most estimates were consistent across time, with the exception of Financial Intermediation (which turns from negative to positive). Likewise, our whole economy and DPCR5 averages were not very sensitive to changes in timeframe.

Table B.2
Sensitivity Of TFP To Timeframe

Industry Sector	TFP from following period start dates to 2007:		
	1970	1990	1997
Manufacture of chemicals and chemical products	1.3%	1.3%	1.1%
Manufacture of electrical and optical equipment	1.6%	1.7%	2.2%
Manufacture of transport equipment	1.0%	0.7%	0.7%
Construction	0.2%	0.2%	-0.2%
Sale, maintenance and repair of motor vehicles; Retail sale of fuel	1.0%	1.3%	2.0%
Transport and storage	1.2%	0.7%	0.6%
Financial intermediation	-0.4%	0.6%	0.5%
Electricity, gas and water supply	0.8%	0.3%	0.2%
Unweighted average (DPCR5 sub-sectors)	0.8%	0.9%	1.0%
Unweighted ave. excl. manufacturing (ET1 sub-sectors)	0.5%	0.7%	0.7%
Whole economy (exc. non market sectors)	0.4%	0.7%	0.7%

Source: NERA analysis of EU KLEMS data.

B.6. Converting From Logarithms Into Percentage Terms

As all our results were estimated in logarithms we converted our estimates into percentage terms, using the formula *exp{x} -1*.

Appendix C. Commodities Price Forecasts

We examined whether a robust link between traded commodity prices and input prices for a DNO could be established, to assess whether commodity prices could form the basis of a forecast of future input price changes. To examine this link, we took the ONS PPI series that we judged to be:

- most relevant to the material input prices faced by an electricity network; and
- most sensitive to traded commodity prices.

We selected eight candidate PPI series using these criteria (shown in Table C.1), available from 1996. We converted these series into real terms by subtracting growth in the RPI over the same period. We compared these to three traded commodities: crude oil, copper, and aluminium.[80] We converted these prices into sterling using the prevailing spot exchange rate, and controlled for growth in RPI to produce a series of real prices, stated in 1996 pounds.

To examine the relationship between the commodity prices and input prices, we used ordinary least squares regression. In each regression, the dependent variable was the month on month change in real input prices. The independent variables were lagged changes in commodity prices. For example, in Table C.1, the independent variables are the changes in the real price of Brent crude oil from one month previously, three months previously, six month previously, and so forth.

Our results indicate that lagged changes in commodity prices (up to six months) have a significant effect on some PPIs, principally "Basic Metals" and "Electricity Production and Distribution". However, the proportion of variation explained by these independent variables (the "R-squared") is generally low. Whilst this is not a reason for rejecting a regression model, it indicates that its predictive power will be limited.

Therefore, in line with our recommendations made at DPCR5, we do not think that there is strong enough evidence to forecast a distribution network's real input prices using commodity prices.

[80] We downloaded data from the Bloomberg information service on closing prices at the London Metal Exchange for Copper and Aluminium and ICE Brent Crude Oil 1 month futures.

Table C.1
Regression of PPIs on Crude Oil

PPI	Basic Metals	Machinery and Equipment	Electricity Distribution and Control	Electricity Production and Distribution	Electric Motors, Generators, & Transformers	Cold Drawn Wire	Wire Products, Chain and Springs	Other Electronic and Electric Wires and Cables
Code	K385	K389	JV72	K696	K62B	JV2C	K2ZO	K32F
Δ Brent	0.128**	-0.016	-0.043	-0.456**	0.017	0.193*	0.151*	0.095
	(0.04)	(0.02)	(0.04)	(0.15)	(0.02)	(0.08)	(0.07)	(0.09)
Δ Brent M3	0.168***	-0.024	-0.045	0.12	0.014	0.244**	0.157*	0.127
	(0.04)	(0.02)	(0.04)	(0.15)	(0.02)	(0.08)	(0.07)	(0.09)
Δ Brent M6	0.116**	0.027	0.001	0.457**	0.069***	0.149	0.08	0.003
	(0.04)	(0.02)	(0.04)	(0.15)	(0.02)	(0.08)	(0.07)	(0.09)
Δ Brent M9	0.032	0.026	0.014	0.101	0.040*	0.069	-0.053	-0.06
	(0.05)	(0.02)	(0.04)	(0.16)	(0.02)	(0.08)	(0.07)	(0.09)
Δ Brent M12	0.027	0.015	0.047	-0.11	0.013	0.139	-0.052	-0.052
	(0.05)	(0.02)	(0.04)	(0.16)	(0.02)	(0.09)	(0.07)	(0.09)
Δ Brent M15	0.053	0.022	0.002	0.098	0.013	0.128	-0.099	0.049
	(0.05)	(0.02)	(0.04)	(0.16)	(0.02)	(0.08)	(0.07)	(0.09)
Δ Brent M18	-0.104*	0.034	0.016	0.052	0.005	-0.195*	-0.206**	-0.239*
	(0.05)	(0.02)	(0.04)	(0.16)	(0.02)	(0.09)	(0.07)	(0.09)
Constant	-0.062	-0.104**	-0.062	0.209	-0.146***	0.078	-0.078	0.202
	(0.08)	(0.03)	(0.07)	(0.27)	(0.03)	(0.15)	(0.12)	(0.16)
R^2	0.18	0.07	0.03	0.13	0.10	0.14	0.13	0.06
Observations	185	185	185	185	185	185	185	185

* p<0.05,** p<0.01,*** p<0.001

Source: NERA analysis of ONS and Bloomberg data.

Table C.2
Regression of PPIs on Copper

PPI	Basic Metals	Machinery and Equipment	Electricity Distribution and Control	Electricity Production and Distribution	Electric motors, generators, & transformers	Cold Drawn Wire	Wire Products, Chain and Springs	Other electronic and electric wires and cables
Code	K385	K389	JV72	K696	K62B	JV2C	K2ZO	K32F
Δ Copper	0.002***	0.000	0.000	-0.007***	0.000	0.002	0.001	0.003*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Δ Copper M3	0.003***	-0.000*	0.000	0.001	0.00	0.001	0.002*	0.004***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Δ Copper M6	0.003***	0.000	0.000	0.004*	0.001**	0.004***	0.001	0.002
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Δ Copper M9	0.001	0.000	0.001	0.002	0.000*	0.000	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Δ Copper M12	0.001*	0.000	0.000	-0.003	0.000	0.003**	0.00	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Δ Copper M15	0.001*	0.000	0.000	-0.001	0.000	0.002*	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Δ Copper M18	-0.002**	0.000	0.000	0.002	0.00	-0.002*	-0.003***	-0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	-0.07	-0.095**	-0.073	0.252	-0.137***	0.117	-0.09	0.116
	(0.07)	(0.03)	(0.06)	(0.27)	(0.03)	(0.14)	(0.12)	(0.16)
R^2	0.32	0.06	0.02	0.13	0.08	0.15	0.11	0.11
Observations	185	185	185	185	185	185	185	185

* p<0.05,** p<0.01,*** p<0.001

Source: NERA analysis of ONS and London Metal Exchange data.

Table C.3
Regression of PPIs on Aluminium

PPI	Basic Metals	Machinery and Equipment	Electricity Distribution and Control	Electricity Production and Distribution	Electric motors, generators, & transformers	Cold Drawn Wire	Wire Products, Chain and Springs	Other electronic and electric wires and cables
Code	K385	K389	JV72	K696	K62B	JV2C	K2ZO	K32F
Δ Aluminium	0.007***	0.000	0.000	0.003	0.002	0.006	0.004	0.001
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Δ Aluminium M3	0.008***	-0.002*	-0.002	0.001	0.000	0.002	0.005	0.006
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Δ Aluminium M6	0.008***	0.002*	0.004*	0.003	0.003***	0.011**	0.003	0.007
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Δ Aluminium M9	0.000	0.000	-0.001	0.009	0.000	-0.001	-0.004	-0.001
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Δ Aluminium M12	0.000	0.001	0.002	0.006	0.001	-0.001	-0.008**	-0.004
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Δ Aluminium M15	0.000	0.000	-0.001	-0.01	-0.001	0.003	-0.003	0.004
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Δ Aluminium M18	0.000	0.001	0.001	-0.008	0.001	0.003	0.004	0.000
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	0.021	-0.089**	-0.061	0.24	-0.115***	0.21	-0.083	0.198
	(0.07)	(0.03)	(0.06)	(0.27)	(0.03)	(0.15)	(0.12)	(0.16)
R^2	0.25	0.07	0.05	0.04	0.11	0.07	0.10	0.05
Observations	185	185	185	185	185	185	185	185

* p<0.05,** p<0.01,*** p<0.001

Source: NERA analysis of ONS and London Metal Exchange data.