NERA
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Review of Indepen report recommendations on beta estimation

Prepared for National Grid

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National Grid plc (National Grid) commissioned NERA Economic Consulting (NERA) to review the recommendations for estimating betas for UK regulated companies presented in the report by Indepen Ltd ("Indepen report"), commissioned by Ofgem as part of its recent RIIO-2 sector consultation.[1]

The Indepen report makes several recommendations which contrast with a report prepared under the umbrella of the UK Regulators Network from Wright et al ("UKRN report"), which was also commissioned by Ofgem. These recommendations are the use of high frequency data (specifically daily data), the acknowledgement of structural breaks and support for the use of OLS models in a regulatory context. In these specific instances, we agree with Indepen.

Indepen also makes a further set of recommendations, with which we have concerns: i) the conceptual questions supporting the beta decomposition; ii) a proposed adjustment to the notional gearing level; iii) a debt beta range of 0.1 to 0.15; iv) the non-reliability of international comparators; and v) the use of alternative models for estimating betas.

On this basis, Indepen estimates an equity beta range for UK energy companies of **0.55 to 0.7**, by relying on daily data estimates for United Utilities, National Grid, SSE, Pennon and Severn Trent, over three different windows (2000 to 2018, 2008 to 2018 and 2013 to 2018) and using OLS, GARCH and LAD models. It further restricts this range to **0.57 to 0.65**, with a central estimate of **0.6** by placing more weight in the 2008 to 2018 window, as it captures the period from the last general structural break.[2]

In this report we explain our concerns with Indepen's and Ofgem's analysis in more detail. We show that correcting for the issues identified results in higher asset betas and cost of equity estimates.

There is strong theoretical and practical support for decomposing NG's beta. By ignoring this evidence, Indepen understates National Grid's beta

NG plc's composite beta reflects the combined systematic riskiness of NG plc's UK and US operations.

In an earlier report for National Grid, we showed US regulatory regimes impose lower risks on investors due to a number of factors, including some assets are regulated under cost-plus rather than incentive regulation; and, greater investor security offered by court based proceedings which have enshrined property rights and "prudence standards" which imposes a high evidentiary bar for the disallowance of costs. Our empirical analysis of comparable US networks betas confirm this: the asset betas for a large sample of US networks are systematically lower than for networks operating under incentive based regulation.

Indepen acknowledges that National Grid's composite beta can be decomposed to reflect the risks associated with UK and US networks, but raises three conceptual questions that it considers need to be addressed before it can rely on such evidence. These conceptual issues

[1] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final.

[2] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 5, pp.45 and 46.

(*as repeated in italics*) can be addressed drawing on established finance theory and regulatory practice:

- *Should it [the decomposition] be applied to equity or asset betas?* If we are drawing on comparator firms to inform elements of a business risk, we must compare these on a common financial leverage, otherwise we introduce firm specific financing effects into our estimates. Using asset betas is the correct way to compare the pure business risk of different comparators and thus, the decomposition should be applied to asset betas;
- *If applied to asset betas, should a group average, group actual or industry specific gearing be used?* In terms of the gearing used to de-leverage the comparators equity betas (in National Grid's case, US comparator networks), the estimated equity betas depend on the capital structure of the comparator and must be de-leveraged using that comparator's actual gearing. For the gearing used to re-leverage, finance theory states that this should be a measure of the expected future gearing of the company over the relevant period; in our view, this can be proxied by a notionally efficient gearing level, e.g. Ofgem assumes 60 per cent in its sector consultation; and
- *Are net assets the right way of measuring the weights?* In finance theory, the weights should reflect the present value of future cash flows of each business segment. In the case of regulated firms, the RAB provides a good estimate of the expected value of future cash-flows. Thus, weights based on the proportion of regulated assets is consistent with finance theory.

The beta decomposition approach that results from the analysis above is also consistent with regulatory precedent, namely Ofcom's approach to estimating the beta for BT's business segments, and the then Competition Commission ("CC") approach to BAA airports.[3]

Indepen provides an example calculation for the decomposition of National Grid's beta. We find Indepen's methodology to be flawed, as it assumes that the equity betas obtained from US comparators can be used directly to inform National Grid's US equity beta. This is not correct because, as explained above, the elements of business risk should be compared on a common financial leverage, as equity betas depend on the specific capital structure of the comparator. Correcting for its errors, we conclude that Indepen should consider the results from the decomposition of National Grid's asset beta in its derivation of the recommended equity beta range, which indicate a higher beta for National Grid's UK operations.

Indepen's "adjusted" notional gearing measure implies a lower cost of equity with a higher weight, has no precedent in UK regulation and is based on flawed MAR estimates

Indepen provides an equity beta range based on the direct estimation of equity betas, arguing that as core comparators have gearing levels close to the notional levels, de-leveraging and re-leveraging is not justified. We show that for 3 out of the 5 comparators this is not the case and that not de-leveraging and re-leveraging leads to an understatement of its recommended equity beta range.

While not de-leveraging and re-leveraging, Indepen argues that it is inconsistent to de-leverage the observed equity betas using their actual gearing value (based on an enterprise

[3] Ofcom (28 03 2018): Wholesale Local Access Market Review: Statement, Annexes 17-27, pp.76 and 115-136; Competition Commission (28 September 2007), BAA Ltd, A report on the economic regulation of the London airport companies (Heathrow Airport Ltd and Gatwick Airport Ltd), Appendix F, pp.F-7, F-8 and F-28 to F-31.

value gearing) and then re-leveraging them using a RAB-based notional gearing estimate. Indepen recommends the use of a notional enterprise value level of gearing which is calculated as D/(RAB*MAR), where MAR is assumed to be 1.1.

In this report we show that, if Ofgem were to apply Indepen's adjustment, it would have to adjust the corresponding weights used in the Weighted Average Cost of Capital (WACC) calculation, to reflect the "adjusted" notional gearing, which would increase the weight on the cost of equity component and leave the overall cost of capital largely unaffected relative to an approach that does not incorporates its MAR adjustment.[4]

There is also no precedent in UK regulation for adjusting the notional gearing level. Regulators such as Ofwat, Ofcom and the Civil Aviation Authority ("CAA") use a notional gearing measure without any adjustment.[5] Finally we also show that , after adjusting non-regulated/non-UK activities, there is no strong evidence that the resulting adjusted MARs are different from 1 for National Grid, Severn Trent and United Utilities.

Ofgem's fails to apply Indepen's approach in practice, and its own approach materially understates the asset beta by around 0.02 to 0.03

Ofgem does not apply Indepen's MAR adjustment to notional gearing, but instead applies it to the average actual gearing for a set of comparators used to de-leverage raw equity betas (implicitly assuming that the same equity betas apply at different levels of gearing). By using a higher gearing assumption (adjusted upwards by a factor of 1.1), Ofgem derives assets betas that around 0.02 to 0.03 lower than would otherwise be the case (see Table 4.3). We disagree with the adjustment: equity betas reflect the effects of firm specific gearing (i.e. depend on gearing) and must be de-leveraged using the actual gearing of these firms, and not an adjusted measure.

Ofgem also uses a gearing estimate to de-gear the comparators equity betas based on a specific point in time. By contrast, the correct approach is to use the average gearing that corresponds to the beta estimation period.

Indepen's assumed debt beta range of 0.1 to 0.15 is out of line with academic evidence and UK regulators' decisions on debt beta

Indepen proposes a debt beta range of 0.1 to 0.15. We note that the debt beta assumption will only affect the notional equity betas if the actual gearing of the comparators differs from the notional gearing assumed. If the actual gearing is below the notional gearing, then an increase in the debt beta results in a decrease in the notional equity beta. We show that for Ofgem's assumptions around notional and actual (and for which we have serious concerns about its MAR adjustment to the actual gearing), an increase in the debt beta of c.0.05 results in a decrease of c.0.01 in the notional equity beta.

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4 Arguably, if Ofgem is to apply a MAR of 1.1, it is suggesting that the regulated company will be expected to outperform throughout the duration of the regulatory period. If Ofgem makes that assumption, it should then be clear on what allowance parameter would allow for this outperformance.

5 Ofwat (December 2014), Setting price controls for 2015-20 Final price control determination notice: policy chapter A7 – risk and reward, pp.41-42; Ofwat (January 2014), Setting price controls for 2015-20 – risk and reward guidance, Appendix 1, pp.8-9; Ofcom (28 03 2018): Wholesale Local Access Market Review: Statement, Annexes 17-27, pp.75, 111 and 112; CAA (2013), Economic regulation at Heathrow from April 2014: final proposals – WACC appendix, pp.35-37 and 52.

In addition, we show that recent academic evidence supports a lower range than Indepen of between 0 and 0.1. We therefore consider that Indepen's range overstates the debt beta, and therefore understates the equity beta given the lower actual relative to notional gearing.

Using Italian and Spanish networks provides a reasonable cross-check on the betas of UK networks, potentially more so than the use of UK water companies

Indepen argues that the use of international comparators is not helpful given issues such as the comparability of regulatory regimes and instead focusses on UK listed water companies.

In relation to UK water company evidence, we show that, while the regulatory regimes of energy and water are closely aligned, there are a number of TO specific risks that are not faced by water companies – such as capex complexity; asset stranding, and competition risks – that suggests energy networks are higher risk. Our conclusions for the relative risk analysis are in line with the empirical evidence for betas for NG and SSE which are higher than for water companies.

For European comparators, we show that regulatory regimes of Italian and Spanish networks are broadly comparable to that of UK networks. Given that the companies operating in the same sector face similar business risks and the regulatory regimes are increasingly well-aligned, we recommend the use of these European comparators as a cross-check for the asset beta of UK networks.

Indepen addresses some of our concerns with the estimation model from the UKRN report, but still places some weight on evidence going as far back as 2000

As discussed in our previous report for National Grid, we had identified a number of areas of disagreement with the UKRN report. Indepen addresses some of these, including the use of high frequency data, the acknowledgement of structural breaks and a more detailed discussion of the modelling choice (through the testing of several GARCH-type models).

However, Indepen, in its recommended equity beta range, places some weight on evidence going as far back as 2000, which is not consistent with its own recommendation of using data since the most recent structural break, 2013.

We also provide a discussion on the estimation model to be used in a regulatory context. While we do not object to the use of GARCH models for the purpose of estimating betas, we note that GARCH-type models are complex and difficult to implement and reproduce by stakeholders, which may introduce arbitrariness in regulatory decision making and increase perceptions of regulatory risk. We conclude that a rolling-window OLS may be the most suitable model in a regulatory context, which is consistent with Indepen's conclusion that OLS can continue to be used as the estimation model in a regulatory context.

We conclude that correcting for Indepen's and Ofgem's issues leads to a higher cost of equity

We provide an updated cost of equity range by correcting for the methodology issues identified above. While we do not agree with Ofgem's estimates, we retain the estimates of Actual gearing, Total Market Return and Risk-free Rate.

As a first step, we correct for Ofgem's misconstrued MAR adjustment used to de-gear the raw equity betas, and also assume a debt beta of zero, in line with regulators approaches in most recent network decisions.

As a second step, we draw on wider set of evidence disregarded by Indepen: namely decomposition of National Grid's asset beta and European network beta evidence, which supports an asset beta range of 0.4 to 0.45.[6] The lower bound is consistent with evidence from European comparators and National Grid's own beta. The upper bound is slightly lower than the mid-point between National Grid's asset beta (which is 0.39), and the decomposition of National Grid's beta, which supports a value of around 0.55 for its UK operations.

We present our updated estimates in Table 1. Adjusting for the debt beta and leverage issues identified above, leads to a cost of equity estimate that is 0.47 to 0.73 percentage points higher, compared to Ofgem's estimate. If we use an asset beta range that accounts for National Grid's beta decomposition and European energy comparators, we estimate a cost of equity that is 2.43 to 2.67 percentage points higher than Ofgem's estimate.

Table 1: Correcting Indepen/Ofgem's Methodology Issues Leads to a Higher Cost of Equity

	Ofgem application of Indepen		**Correcting for debt beta and leverage**		**Decomposition and other evidence**	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Raw equity beta	0.6	0.7	0.6	0.7	n.a.	n.a.
Actual gearing	50.80%	50.80%	50.80%	50.80%	n.a.	n.a.
EV/RAV	1.1	1.1	n.a.	n.a.	n.a.	n.a.
Adjusted gearing	56%	56%	50.80%	50.80%	n.a.	n.a.
Debt beta	0.15	0.10	0.10	0	0	0
Asset beta	**0.35**	**0.36**	**0.35**	**0.34**	**0.40**	**0.45**
Notional gearing	60%	60%	60%	60%	60%	60%
Notional equity beta	**0.65**	**0.76**	**0.72**	**0.86**	**1.00**	**1.13**
Risk-free rate	-1.68%	-1.68%	-1.68%	-1.68%	-1.68%	-1.68%
Equity risk premium	6.9%	7.4%	6.9%	7.4%	6.9%	7.4%
Cost of equity (real post-tax, RPI)	**2.76%**	**3.93%**	**3.23%**	**4.66%**	**5.19%**	**6.60%**

Source: NERA calculations based on Ofgem's data (without adjusting for Actual gearing, Risk-free rate and Equity risk premium parameters, with which we do not fully agree with Ofgem).

[6] Based on a debt beta of zero.

1. Introduction

National Grid plc (National Grid) commissioned NERA Economic Consulting (NERA) to review the recommendations on estimating betas for UK regulated companies presented in the report by Indepen Ltd ("Indepen report").[7]

Indepen was asked by Ofgem, while working with other UK regulators (via the UK regulators Network (UKRN)) to investigate issues linked to the measurement and estimation of beta, as part of the Capital Asset Pricing Model (CAPM) approach to estimating the cost of equity.[8] The Indepen report provides a view on several common issues associated with the estimation of beta, including data frequency, regression models, gearing assumptions, appropriate comparators and beta decomposition.

In its RIIO-2 sector specific methodology Consultation, Ofgem introduces the Indepen report with the objective of supplementing Dr Donald Robertson's report[9] and addressing outstanding issues.[10] Dr Donald Robertson's report, which covers different methodologies for estimating equity betas, was commissioned to address issues raised by stakeholders following the Framework Consultation and Decision.[11]

This report has been prepared to support National Grid's response to Ofgem's RIIO-2 sector specific methodology Consultation on the appropriate methodology for estimating betas at RIIO-2.

This report is structured as follows:

- Section 2 presents the key recommendations of the Indepen report in relation to beta estimation;
- Section 3 assesses academic and regulatory precedent for beta decomposition and addresses Indepen's conceptual concerns;
- Section 4 provides our view on the gearing approach proposed by Indepen and its application by Ofgem;
- Section 5 presents regulatory and academic evidence on estimate of a debt beta;
- Section 6 sets our view on the relevance of international comparators and provides a relative risk assessment between UK regulated networks and European networks;
- Section 7 discusses the use of GARCH models for estimating betas in a regulatory context.

7 Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final.

8 Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 1, p.1.

9 Donald Robertson (19 April 2018), Estimating β.

10 Ofgem (18 December 2018), RIIO-2 Sector Specific Methodology Annex: Finance, Section 3, p.35.

11 Ofgem (18 December 2018), RIIO-2 Sector Specific Methodology Annex: Finance, Section 3, p.34.

2. Key Recommendations on Beta Estimation Presented in the Indepen Report

The Indepen report reviews a number of issues in the estimation of betas for setting an allowed cost of equity, and provides recommendations on its preferred approach.

Along with the Indepen report, Ofgem also commissioned a report from Robertson, as well as a report under the umbrella of the UK Regulators' Network from Wright et al ("UKRN report") that also both covered beta estimation issues.[12] The Indepen report makes a number of recommendations some of which contrast with these two other reports, as we identify below. In a separate report for National Grid, we discuss in greater detail the differences between the three sets of recommendations.

The Indepen report makes the following recommendations which we broadly agree with:

- **Use of high frequency data**: Indepen argues that when choosing the data frequency, there is a trade-off between obtaining more data points (and making inference possible) and the noise introduced from the use of more data (breaching OLS's statistical assumptions).[13] Its recommendation is to use higher frequency data (daily or weekly returns) over longer windows and its recommended beta range is informed by estimates using daily data.[14] By contrast, the UKRN report employed low frequency data when setting out its indicative beta estimates for SVT and UU.[15]
- **Existence of structural breaks**: Indepen acknowledges the existence of structural breaks in the data (presenting its beta estimates for three windows: 2000 to 2018, 2008 to 2018 and 2013 to 2018) and recommends the use of the period since the most recent structural break as the estimation window (which implies the use of a five-year estimation window).[16] Again, this contrasts with UKRN report which employed the longest time frames possible back to 2000 to estimate betas. [17]
- **Other measures of beta**: Indepen considers two additional measures of beta: accounting beta (regressing beta of listed stocks on various accounting measures) and use of returns on debt as an indicator of the market's view on the company's riskiness. However, Indepen concludes that the methods are either unreliable (in the case of the accounting beta) or not viable (in the case of the return on debt);[18]
- **Ordinary Least Squares (OLS) as the estimation model**: While Indepen presents its recommended beta range taking into account Generalised Autoregressive Conditional

[12] Donald Robertson (19 April 2018), Estimating β; Wright, S, Burns, P, Mason, R, and Pickford, D (2018), Estimating the cost of capital for implementation of price controls by UK Regulators, An update of Mason, Miles and Wright (2003).

[13] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 2, p.8.

[14] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 2 and Section 5, pp.18, 19 and 45.

[15] Wright, S, Burns, P, Mason, R, and Pickford, D (2018), Estimating the cost of capital for implementation of price controls by UK Regulators, An update of Mason, Miles and Wright (2003), p.53 and Appendix G.

[16] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 2 and Section 5, pp.6,7 and 45.

[17] Wright, S, Burns, P, Mason, R, and Pickford, D (2018), Estimating the cost of capital for implementation of price controls by UK Regulators, An update of Mason, Miles and Wright (2003), p.G-139

[18] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 3, pp.20 to 24.

Heteroscedasticity (GARCH), OLS and Least Absolute Deviation (LAD) models, it recognises that the results are not widely divergent and OLS can continue to be used as the estimation model, provided that the time window and appropriate corrections to standard errors are considered.[19] By contrast, the UKRN report recommends the use of GARCH models.[20]

Indepen makes a further set of recommendations with which we have concerns. These are:

- **Beta decomposition**: Indepen acknowledges that a case can be made for a decomposition of the beta for some listed UK networks, including National Grid. However, it raises three conceptual issues that it argues need to be addressed before we can draw on decomposition data:
    a. Should it [the decomposition] be applied to equity or asset betas?
    b. If applied to asset betas, should a group average, group actual or industry specific gearing be used?
    c. Are net assets the right way of measuring the weights?[21]

  We consider that these conceptual issues can (and have) been addressed based on finance theory and regulatory determinations (as shown Section 3), and therefore Indepen should place weight on the decomposition analysis in in its beta recommendations. By not using this evidence, its conclusions understate National Grid's beta.
- **Beta leveraging and de-leveraging**: Indepen argues that it is inconsistent to de-lever the comparator's equity beta using Debt/Enterprise Value (D/EV), where EV= net debt + market cap, and re-lever using notional gearing which is based on Debt/Regulatory Asset Base (D/RAB). Indepen acknowledges that this would not be an issue if the Market to Asset Ratio (MAR) is close to one.[22] However, given that it believes MAR is greater than 1, the standard method overstates the asset beta. To correct for the high MARs, Indepen proposes to generate a notional EV gearing by adjusting D/RAB using MAR =1.1 as a starting point, adjusting D/RAB to D/(RAB*1.1), which reduces the gearing ratio, and gives a lower re-leveraged equity beta.[23] By contrast, we do not consider that such adjustments are required in principle, and in practice we provide evidence which shows that MARs are around 1.
- **Debt beta**: Indepen recommends the use of a debt beta in the range of 0.1 to 0.15, drawing on empirical analysis and a review of regulatory precedent.[24] We believe regulatory precedent and recent academic evidence point to values below those recommended by Indepen for the debt beta.

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19 Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Executive Summary and Section 5, pp. xi, 45 and 46.

20 Wright, S, Burns, P, Mason, R, and Pickford, D (2018), Estimating the cost of capital for implementation of price controls by UK Regulators, An update of Mason, Miles and Wright (2003), Appendix G

21 Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 4, pp.36 to 39.

22 Market to Asset ratio is defined as Market Value of the company over the RAB.

23 Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 3, pp.31 to 34.

24 Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 3, pp.26-29; Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Appendices D-H, Appendix E, pp.4-10.

- **International comparators**: Indepen considers that, while these might be helpful in a context of beta decomposition, they are probably not helpful for estimating betas for UK companies due to concerns over different economies, regulatory and tax regimes.[25] By contrast, we consider that European energy betas are relevant to National Grid, and potentially more indicative of the risk faced by UK energy networks than UK water, which Indepen draws on.
- **Alternative models for estimating beta**: In presenting its recommend beta range, Indepen draws on evidence from GARCH, OLS and LAD models, acknowledging that the results are not widely different. The use of GARCH models is intended to correct for the potential conditional heteroscedasticity in returns (making it possible to estimate time variation in beta), while the LAD model is used as a cross-check against the impact of outliers.[26] We consider that the use of OLS provides the best trade-off between regulatory objectives, namely in terms of accuracy, complexity and transparency.

Overall, Indepen estimates an equity beta range for UK energy companies of **0.55 to 0.7**, by relying on daily data estimates for United Utilities, National Grid, SSE, Pennon and Severn Trent, over three different windows (2000 to 2018, 2008 to 2018 and 2013 to 2018) and using OLS, GARCH and LAD models. It further restricts this range to **0.57 to 0.65**, with a central estimate of **0.6** by placing more weight in the 2008 to 2018 window, as it captures the period from the last general structural break.[27]

We explain our concerns with Ofgem and Indepen's analysis in more detail in the following sections, and derive range for the asset and equity beta for National Grid for RIIO-2 correcting for errors.

[25] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 3 and Section 5, pp.23, 24 and 42.

[26] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Executive Summary and Section 2, pp. xi and 10.

[27] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 5, pp.45 and 46.

3. Beta Decomposition

In this section, we start by summarising the differences in the regulatory regime for National Grid's UK and US operations. We then set out the conceptual questions raised by Indepen and answer these based on finance theory and regulatory precedent. We show that there is a basis for decomposing beta to account for different risks in businesses within the same company and conclude that performing the decomposition for National Grid supports a higher beta for its UK operations.

3.1. Relative Risk Analysis of National Grid's US Operations

Indepen acknowledges that a case can be made for the beta decomposition of some listed UK networks, including National Grid, which has sizeable US operations. Moreover, it also agrees in principle with our decomposition of National Grid's asset beta, provided adequate comparators are used and assumptions explained. To investigate the impact that National Grid's non-UK regulated businesses have on the asset beta estimated, we present a comparison of the differences in regulatory regimes faced by National Grid in the US and UK drawing on previous NERA reports explaining the decomposition of National Grid's asset beta, as submitted to Ofgem.[28]

In 2017/18, National Grid's UK non-regulated activities accounted for 5 per cent of the group's revenues and about 6 per cent of the group's fixed assets.[29] US regulated operations accounted for 41 per cent of the group's combined regulated asset base.[30]

In the US, National Grid's operations are subject to various regulatory regimes, depending on the state in which they operate and the business activity in question. The majority of these businesses are subject to incentive regulation (about 90 per cent of regulated assets), albeit a lower-powered incentive regime than the UK. However, around 8 per cent of assets are subject to rate of return regulation, which exposes the company to less risk in terms of potential over or underperformance. In addition, National Grid Generation, which comprises around 2 per cent of the business' regulated assets, operates under a long-term power supply agreement with the Long Island Power Authority, with very low systematic risk.[31]

Although National Grid's US businesses that are regulated under incentive based regimes are subject to revenue caps similar to the UK regulated business, i.e. do not bear material demand or revenue risk, there are some key differences that mean the US incentive based regimes are less risky than RIIO-2:

- Greater objectivity in setting allowed costs: in most cases, cost allowances are set based on outturn costs for a base year and projected forwarded, without explicit efficiency factors that reduce allowances over time. Some are also based on historical costs (especially in Massachusetts). The prudency standard for permissible costs sets a high

[28] NERA (30 April 2018), RIIO-T2 Beta and Risk Assessment, for National Grid.

[29] These activities included National Grid Ventures, UK property development and insurance and corporate activities in the UK and US. See National Grid Annual Report 2017/18, p.108-110.

[30] National Grid (17 May 2018), 2017/18 Full Year Results, p.13-15. This calculation only takes into account National Grid's remaining 39% stake in its former gas distribution business, whose regulated asset base is reported by Cadent Annual Report 2017/2018, p.1.

[31] See National Grid US Databook for 2017/18, p.7.

evidentiary bar for the disallowance of incurred costs. By contrast, RIIO draws on more subjective comparative efficiency analysis and technical review of costs;

- US regimes provide a true-up for pension and other post-employment liabilities, whereas National Grid bears the risk on its post-2012 liabilities in the UK;
- US companies generally have less stringent output and quality of service incentives (they focus mainly on reducing and preventing gas leakage and some efficiency incentives);
- The US regimes incorporate greater use of cost pass-through or true-ups, e.g. for commodity prices, commodity related bad debt, some mandated capex, and environmental remediation costs. By contrast, the true-ups or pass-through provisions for National Grid are more limited, e.g. relating to security, network development, infrastructure enhancement, strategic wider works, and some environmental costs.[32]

Overall, US regulatory regimes are determined with reference to case law which has been tested in the courts. The nature of the proceedings offers greater investor security relative to the more subjective approach, and weaker appeals mechanisms, associated with GB price controls. For example, the rate cases have enshrined principles in relation to the protection of property rights, and notions of prudency standards in relation to permissible costs.[33]

Based on the analysis presented above, our view is that investors would perceive that US networks face lower equity risk than the UK networks. In Appendix B we provide evidence that backs this view. By decomposing the asset beta of National Grid, we are able to estimate a measure of risk that is more relevant for the UK-regulated part of the business, which is precisely the relevant part for RIIO-2.

3.2. Indepen Conceptual Questions on Beta Decomposition

Indepen considers that, while a strong case can be made for decomposing the asset betas of some listed UK networks (including National Grid), there is still uncertainty around the assumptions required and thus it does not recommend relying on results obtained through a beta decomposition until these issues are resolved. Indepen's concerns are centred around three issues:

a. Should it [the decomposition] be applied to equity or asset betas?

b. If applied to asset betas, should a group average, group actual or industry specific gearing be used?

c. Are net assets the right way of measuring the weights? [34]

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[32] Ofgem (2012), RIIO-T1: Final proposals for National Grid Electricity Transmission and National Grid Gas – Finance support document, pp.89 and 90.

[33] The regulation of utilities in North America faces a special kind of constraint that most other nations do not exhibit. Particularly in the United States, major regulatory statutes do not become settled methods of government control over private businesses until they are tested in the courts. There are established principles in relation to property rights, and prudency standards. See for example: NERA (2015) Half a century of estimating the cost of capital, Link: http://www.nera.com/content/dam/nera/publications/2015/PUB_Cost_of_Capital_1115.pdf

[34] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 4, pp.36 to 39.

We address these questions in the following sections by relying on finance theory and presenting regulatory precedent as a cross-check.

3.3. Beta Decomposition is Established in Financial Theory

Beta decomposition is a practice that is widely applied in finance literature, commonly used in the "bottom-up beta" approach. This approach calculates the beta of a company by calculating individual betas for each business segment based on specific industry comparators. The comparator equity betas are de-leveraged using their actual gearing to obtain comparable asset betas, which are then used to estimate an asset beta for each segment of the company. Given that a portfolio beta is the weighted average beta of the securities in the portfolio,[35] we can calculate a company asset beta by taking a weighted average of the specific business segments asset betas. These weights should be reflective of the proportion of firm value derived from each business segment. Equation (1) shows the formula for this composite asset beta:

$$(1)\ Composite\ Asset\ Beta = \sum_{i=1}^{N} W_i \times Asset\ \beta_i$$

where N = total number of business segments and W = weight given to each business segment

Finally, the weighted average asset beta (composite asset beta) is re-leveraged at the current gearing of the company or a forward-looking measure.[36]

Note that the property relating to the weighted average beta of securities in a portfolio being the portfolio beta is usually considered in the context of the estimation of equity betas, i.e. the equity beta of a portfolio is the weighted average equity beta of the securities in the portfolio. Nonetheless, it is commonly accepted that the asset beta is linear in the equity and debt betas,[37] which means the property can also be applied to asset betas, as described in the approach above. While Indepen casts doubt on this linear relationship,[38] it provides no evidence to move away from established practice and financial theory.

The approach set out above, commonly used in finance literature, provides the answers to Indepen's questions set out in the previous section.

First, the decomposition should be applied to asset betas. This is because if we are drawing on comparator firms to inform elements of a business risk (for example, drawing on comparable US networks to decompose National Grid's beta), we must compare these elements on a common financial leverage. By using equity betas, we would be distorting the estimated betas by including the riskiness derived from financing decisions, i.e. a firm that has a higher leverage could be perceived as riskier and this would affect the estimated beta. This is what Indepen does when presenting an equity beta for a business segment by relying on comparators equity beta without adjusting for financing effects.[39] The use of an asset beta

[35] See for example Berk, J. and DeMarzo, P. (2014), Corporate Finance, Third Edition, Chapter 11, p.385.

[36] See for example Damodaran, A (2012), Investment Valuation: tools and techniques for determining the value of any asset, Chapter 8, p.197.

[37] See for example Berk, J. and DeMarzo, P. (2014), Corporate Finance, Third Edition, Chapter 12, p.416.

[38] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 4, pp.29 and 30.

[39] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 4, pp.36.

removes these effects and is a sensible way to compare the pure business risk of different comparators.

On the question of which gearing level to use, there are implicitly two questions: the gearing level to use when de-leveraging equity betas and the gearing level to use when re-leveraging the asset betas. Indepen uses the same gearing level for both and presents three alternatives to calculate the gearing: actual gearing of the group, actual gearing of each business segment and industry gearing of each business segment. As it pertains to the gearing used to de-leverage equity betas, finance theory is clear: this should be the actual gearing of each comparator, as this removes the specific effects of financing included in the equity beta of each company.

To re-leverage the asset beta, an estimate of the future gearing level of the company over the relevant regulatory period should be used. In a regulatory context, this expected level could be proxied by a notional gearing level, which is the assumed level of gearing an efficiently financed company would choose.

Finally, regarding the weights used, these should reflect the value of each business segment, which is measured as the present value of future cash flows. In the case of regulated firms, such as National Grid, this present value is already calculated in the form of the RAB. Thus, our preferred approach of using the proportion of regulated assets as relative weights, set out in our previous report, is supported by financial theory.

3.4. There is Regulatory Precedent in Beta Decomposition

The option of decomposing a company's beta to account for the different business lines' exposure to systematic risk is not without precedent in the UK. For example, Ofcom, the UK communications regulator, applies an asset beta decomposition when setting the asset beta for BT Group plc ("BT") to account for the different exposure to systematic risk in BT's different business segments. This approach has been maintained in its more recent determination (2018 Wholesale local access market review[40]) and consultation (2018 Consultation: Business connectivity market review[41]).

Ofcom disaggregates BT's group asset beta (estimated using BT's returns and de-leveraged using BT's actual average gearing) into three different business segments (Openreach copper access, Other UK Telecoms and Rest of BT), as these have different exposures to systematic risk. The weights of each segment are determined by Ofcom, which relies on EBITDA and the ratio of net replacement cost to enterprise value for each segment as a proportion of BT group. To estimate the asset beta for each business segment, Ofcom relies on comparator asset betas, which are de-leveraged using their actual gearing. Finally, Ofcom re-leverages the asset betas for each business segment using the same estimate of notional gearing across all three segments.[42] Therefore, Ofcom's approach is consistent with our approach, proposed in the previous section.

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40 Ofcom (28 03 2018): Wholesale Local Access Market Review: Statement, Annexes 17-27, p. 115.

41 Ofcom (19 December 2018), Business connectivity market review, Annexes 1-22, pp.228 and 229.

42 Ofcom (28 03 2018): Wholesale Local Access Market Review: Statement, Annexes 17-27, pp.76 and 115-136.

There is also precedent for beta disaggregation in the UK aviation sector. In 2007, when BAA Ltd still operated several UK airports (including Heathrow and Gatwick), the then Competition Commission ("CC"), now Competition and Markets Authority or (" CMA), prepared a report on the economic regulation of the London airports.[43] In its report, the CC disaggregated the asset beta of BAA into three business segments: Heathrow, Gatwick and Other, weighting them by the value of assets in proportion to BAA's total assets. In determining the beta for each business segment, the CC considered factors such as demand risk, riskiness of airline customers and operational leverage, estimating a different beta for each segment, which were further cross-checked against other international airports. The asset betas estimated for Heathrow and Gatwick were then re-leveraged using a notional gearing value.[44] As was the case with Ofcom, the CC's approach is consistent with our proposed approach.

3.5. Indepen's Beta Decomposition Example is Flawed but Supports an Higher Asset Beta for National Grid's UK Operations

As mentioned in the previous sections, Indepen agrees in principle that National Grid's beta could be decomposed to account for the differences in risk of its US and UK businesses. Furthermore, Indepen provides an illustrative example, calculating betas for the UK and US businesses for different gearing assumptions.

We understand that in calculating the beta for National Grid's UK operations, Indepen assumes fixed equity betas for National Grid as whole and for National Grid's US operations. It then de-leverages these betas using specific gearing measures for each segment, but it is not clear to us how these gearing values are calculated. Indepen then calculates the UK asset betas through an asset beta decomposition using the formula below, where the weights are based on RAB values.

(2) $\beta_{National\ Grid} = W_{UK} * \beta_{UK} + W_{US} * \beta_{US}$

Finally, Indepen then re-leverages the UK asset beta using a measure of gearing, whose derivation is unclear to us.

In our view, Indepen's approach is incorrect based on the finance theory presented above. Indepen assumes that the equity betas obtained from US comparators can be used directly to inform National Grid's US equity beta. This is not correct because, as explained above, directly estimated equity betas are influenced by each comparator's financing decisions (i.e. the chosen D/E structure) and does not simply reflect business risk. When performing a beta decomposition, the comparators' betas are used to inform the risk of a specific segment, regardless of the financing decisions and thus it is necessary to use comparators' betas de-leveraged using the company's own financial structure.

Despite the flawed methodology, Indepen arrives at an asset beta for National Grid's UK operations which is higher than the beta for National Grid as a whole.[45] This is supported by

[43] Competition Commission (28 September 2007), BAA Ltd, A report on the economic regulation of the London airport companies (Heathrow Airport Ltd and Gatwick Airport Ltd).

[44] Competition Commission (28 September 2007), BAA Ltd, A report on the economic regulation of the London airport companies (Heathrow Airport Ltd and Gatwick Airport Ltd), Appendix F, pp.F-7, F-8 and F-28 to F-31.

[45] Indepen's NG UK asset beta value using data from the last two years, 0.44, is close our estimated range of 0.40 to 0.45 (presented in Section 8)

our relative risk analysis summarised in section 3.1 and presented more in depth in our previous report for National Grid, where we conclude that the UK operations were likely to face greater systematic risk than US operations. Correcting for the errors we have identified, Indepen should take into account evidence from decomposing NG plc's beta, which we show provides for a higher asset beta for National Grid to reflect the higher risk of its UK operations compared to the US.

3.6. Conclusion on Beta Decomposition for National Grid

In summary, Indepen should draw on National Grid's beta decomposition in the estimation of betas for RIIO-2. As discussed in section 3.3, there is support in finance theory to decompose the asset beta of a company as method of differentiating the risks faced by different business segments of the same company. The evidence from finance theory allows us to answer Indepen's three conceptual questions. First, the decomposition should be done using asset betas because these capture the segment's business risk, as asset beta estimates are unaffected by financial leverage decisions. Second, the gearing used for de-leveraging the comparators' equity betas must reflect the actual gearing of the comparators', while the gearing used for re-leveraging the estimated asset beta should be a notional gearing level. Finally, the weights used should be based on the present value of future cash-flows, which, can be proxied by the proportion of regulated assets out of total regulated assets. We also show that there is a regulatory precedent in the UK for decomposing asset betas, which is consistent with the presented finance theory.

While Indepen acknowledges the case for decomposing the beta of National Grid, it presents a flawed methodology for doing so, as it relies on directly estimated equity betas of US comparators to inform the equity beta of National Grid's US operations, which then introduces a capital structure bias in the asset beta estimated for this segment. Correcting for the errors we have identified, we conclude Indepen should take into account evidence from decomposing NG plc's beta.

4. The Inconsistency in Leveraging/De-Leveraging Betas

In this section, we set out our concerns with Indepen's proposed approach to leveraging and de-leveraging, and Ofgem's application. We start by showing that Indepen's adjustment understates equity betas for Ofgem's notional gearing and is inconsistent with regulatory precedent. We also provide evidence that adjusted MARs are not significantly different from 1 and so, even if one applies Indepen's correction, the correct "normal" MAR should be 1, which would keep the notional gearing level unchanged. Finally, we show that Ofgem appears to mis-interpret Indepen's recommendation and uses an approach that is not correct according to standard financial theory.

4.1. Indepen's Approach to Leveraging/De-Leveraging

Indepen provides an equity beta range based on the direct estimation of equity betas, unlike the common approach of de-leveraging the estimated equity betas and then re-leveraging them using a notional gearing level. Indepen argues that, as the core comparators have gearing levels close to the notional gearing assumption, the impact of de-leveraging and re-leveraging would be small and does not justify the assumptions that would have to be made.[46]

Despite the reasoning above, Indepen believes there is a potential inconsistency in the leveraging process: if observed equity betas are de-leveraged using their actual gearing value (based on an enterprise value gearing), it is inconsistent to then re-leverage them using a RAB-based notional gearing estimate.

Indepen acknowledges that this would not be an issue if MAR is close to 1, i.e. enterprise value and RAB gearing are close. However, for the cases where MAR is different from 1, Indepen recommends the use of a notional enterprise value level of gearing which is calculated as D/(RAB*MAR).

Having set the formula for calculating a notional enterprise value level of gearing, Indepen also considers the MAR value to use. Given the issues surrounding the use of the actual MAR, Indepen opts for using a "normal" MAR of 1.1 as a starting point, based on evidence from the UKRN report, including the fact that recent MAR's for water pure-plays are around 1.1 and the average MARs for energy and water networks over the past 20 years is close to 1.2. The choice of a MAR above 1 implies that the new notional gearing measure will be lower, which will be reflected in lower re-leveraged equity betas.

4.2. Indepen does not Provide a Strong Argument for not Estimating Re-Leveraged Equity Betas

Indepen provides a recommended equity beta range, not de-leveraging and re-leveraging equity betas as they consider that core comparators have gearing levels sufficiently close to the notional gearing assumption. Indepen considers that due to this, the leveraging impact would be small and would not justify the numerous assumptions required.[47]

This view is not consistent with the measures of gearing provided by Indepen. As shown in Table 4.1, the enterprise value gearing levels are substantially different from Ofgem's

[46] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Main Report, Final, Section 5, p.46.

[47] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Main Report, Final, Section 5, p.46.

notional gearing assumption of 60 per cent for all but one comparator. Even using Indepen's "adjusted" notional gearing measure, which is calculated using a "normal" MAR of 1.1 to adjust the RAB-based notional gearing of 60 per cent, we still observe considerable differences for 3 out of the 5 comparators, as shown in Table 4.1.

Table 4.1: Enterprise Value and Adjusted Notional Gearing are not Close

	NG	UU	SSE	PNN	SVT
Enterprise Value Gearing	44.90%	58.50%	41.70%	50.10%	54.60%
Ofgem's notional gearing	60%	60%	60%	60%	60%
Indepen "Adjusted" Notional Gearing	54.55%	54.55%	54.55%	54.55%	54.55%

Note: Adjusted notional gearing calculated as Ofgem's notional gearing divided by 1.1
Source: NERA analysis of Indepen's data.

The fact that the companies' actual gearing levels are below both Ofgem's notional gearing level and the Indepen's "adjusted" notional gearing level means that by not de-leveraging and re-leveraging, Indepen's recommended range is understating the equity betas. For example, taking Ofgem's equity beta range and the average gearing of comparators, we calculate re-leveraged equity betas using Indepen's "adjusted" notional gearing level. As shown in Table 4.2, by de-leveraging and re-leveraging the betas, we obtain a range that is c.0.04 to 0.05 higher than using raw estimates of equity betas. Moreover, if we re-leverage the asset betas without using Indepen's "adjusted" notional gearing, we obtain an equity beta range that is c.0.1 to 0.14 higher than using raw estimates of equity betas.

Table 4.2: Re-Leveraged Equity Betas are Higher than Raw Equity Betas

Re-leveraging based on:	**Indepen's adjusted notional gearing**		**Unadjusted notional gearing**	
	Lower Bound	**Upper Bound**	**Lower Bound**	**Upper Bound**
Raw equity beta	**0.60**	**0.70**	0.60	0.70
Average gearing	50.80%	50.80%	50.80%	50.80%
Debt beta	0.15	0.10	0.15	0.10
Asset beta	0.37	0.40	0.37	0.40
Adjusted notional gearing	54.55%	54.55%	60%	60%
Re-leveraged equity beta	**0.64**	**0.75**	**0.70**	**0.84**
Increase on raw equity beta	0.04	0.05	0.1	0.14

Source: NERA analysis of Ofgem's data.

Indepen also recommends that regulators estimate re-leveraged equity betas but provided they investigate issues surrounding debt betas and gearing levels.[48] However, in providing a recommended beta range, Indepen does not estimate re-leveraged equity betas, but only raw equity betas.

[48] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Main Report, Final, Section 4, p.34.

Ofgem, on the other hand, while stating that further research into de-leveraged and re-leveraged asset betas is recommended, continues to calculate equity betas resulting from re-leveraging asset betas with a notional gearing level.[49] We note that if Ofgem used the raw equity betas estimated directly by Indepen without de-leveraging and re-leveraging, this would be problematic as it would mean the notional gearing structure would be tied to the gearing decisions of relatively few comparators. It would also mean that Ofgem would have to adopt a common notional gearing across all sectors, in contrast with its approach at RIIO-1.

One of the UKRN report authors, Burns, while acknowledging that regulators must carefully consider the specific methods for re-leveraging, agrees with the conversion of raw equity beta values from actual to notional gearing levels. The reasoning is that doing so avoids setting the cost of equity for a regulated business by using the capital structure of a comparator as a reference.[50] This would be even more problematic in the case of unlisted companies, where their cost of equity would be directly influence by another company's capital structure, which may be from another sector or jurisdiction.[51]

As pointed out by Burns, the use of re-leveraged equity betas allows the regulator to assess what the equity beta of a company with similar risk would be, at a notional gearing level, leaving financing decisions and responsibilities to the companies.[52]

In our view, Indepen does not provide any rationale to move from the regulatory practice of estimating re-leveraged equity betas.

4.3. Indepen's Adjustment Implies WACC Weights Must be Re-Set to be Consistent

When calculating the baseline allowed returns, Ofgem relies on the WACC formula (as set out in the equation below), which provides a weighted average between the cost of equity and cost of debt, where the weights are based on the notional gearing level.[53]

$$(3)\ Weighted\ Average\ Cost\ of\ Capital\ (WACC) = CoE * (1 - g) + CoD * g$$

where CoE = cost of equity, g = notional gearing and CoD = cost of debt.

Ofgem, by re-leveraging the equity betas using a notional gearing, is setting a cost of equity for a firm assuming a given notional capital structure. If then a WACC for the same notional firm is estimated, the weights should be based on the same notional capital structure assumed in the cost of equity calculation. The use of the same notional gearing assumption to re-

[49] Ofgem (18 December 2018), RIIO-2 Sector Specific Methodology, Section 10, p.104, para 10.48; Ofgem (18 December 2018), RIIO-2 Sector Specific Methodology Annex: Finance, Section 3, pp.39 and 40.

[50] Wright, S, Burns, P, Mason, R, and Pickford, D (2018), Estimating the cost of capital for implementation of price controls by UK Regulators, An update of Mason, Miles and Wright (2003), Introduction, p.10.

[51] Wright, S, Burns, P, Mason, R, and Pickford, D (2018), Estimating the cost of capital for implementation of price controls by UK Regulators, An update of Mason, Miles and Wright (2003), section, pp.57-58.

[52] Wright, S, Burns, P, Mason, R, and Pickford, D (2018), Estimating the cost of capital for implementation of price controls by UK Regulators, An update of Mason, Miles and Wright (2003), Introduction, p.10.

[53] Ofgem (18 December 2018), RIIO-2 Sector Specific Methodology, Section 10, Table 7, p.107.

leverage asset betas and estimate WACC weights is the theoretically correct approach, and the standard practice followed by regulators (such as Ofwat and Ofcom) and the Competition and Markets Authority (CMA).[54]

By re-leveraging equity betas to a lower notional gearing (i.e. D/RAV*1.1.), under Indepen's approach the same lower notional leverage assumption must be used in the WACC calculation. Indepen's adjustment, which would therefore amount to setting a lower gearing level, would have two effects on a firm's cost of capital, which counter each other and combine to leave the WACC relatively unchanged:

- Lower cost of equity resulting in lower WACC: A lower gearing means that the firm's equity capital is less risky. This is because debt holders have the prior claim on a firm's cash flows and hence a decrease in the gearing increases the likelihood that equity holders will receive a return on their investment. The consequence of this is the firm's cost of equity decreases, through a lower re-leveraged equity beta;
- Higher weight placed on cost of equity resulting in higher WACC: A lower gearing also means that a higher weight is placed on the cost of equity when calculating the WACC. Since the cost of equity is higher than the cost of debt (because debt holders have the prior claim on cash flows), by placing more weight on the cost of equity, the WACC increases.

The CMA has also noted at previous price controls that changes to the notional gearing leaves the WACC relatively unchanged. [55]

4.4. There is no Precedent in the UK for Adjusting Notional Gearing

Even if we were to accept that MARs were higher than 1 (which we do not, as we set out below), Indepen's proposed adjustment to notional gearing does not have any precedent in UK regulation. Other UK regulators have opted for the use of a notional gearing without any adjustment in their previous determinations:

- Ofwat, in their PR14 determination, proposed a notional gearing level based on actual gearing (enterprise value gearing) and other factors such as credit rating and used it to re-leverage the estimated asset beta; [56]
- Ofcom determined re-leveraged equity betas based on notional gearing informed by evidence including actual gearing (enterprise value gearing), in their 2018 Wholesale local access determination;[57]

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[54] Ofwat (December 2014), Setting price controls for 2015-20 Final price control determination notice: policy chapter A7 – risk and reward, pp.41-42; Ofcom (28 03 2018): Wholesale Local Access Market Review: Statement, Annexes 17-27, pp.75-76; CMA (October 2015) Bristol Water plc report, pp. 333 and 335.

[55] *"However, after taking into account the tax shield from more debt, the WACC is not very sensitive to the level of gearing."* Source: CMA (October 2015) Bristol Water plc report, p. 300.

[56] Ofwat (December 2014), Setting price controls for 2015-20 Final price control determination notice: policy chapter A7 – risk and reward, pp.41-42; Ofwat (January 2014), Setting price controls for 2015-20 – risk and reward guidance, Appendix 1, pp.8-9

[57] Ofcom (28 03 2018): Wholesale Local Access Market Review: Statement, Annexes 17-27, pp.75, 111 and 112.

- The Civil Aviation Authority (CAA) re-leverages asset betas using a notional gearing measure and presents no further adjustments.[58]

CEPA, in a report published alongside Ofgem's framework consultation, assumed a notional gearing estimate informed by regulatory precedent and actual gearing, which it used to re-leverage the asset betas estimates.[59]

In none of the cases above was the estimate of a notional gearing level adjusted to reflect the differences between the RAB and enterprise value.

4.5. There is no Strong Evidence that MARs are Different from 1

Indepen argues for the use of a "normal" MAR of 1.1 on the basis of evidence from water and energy network comparators, pointing to an average MAR of 1.1 and 1.2, respectively. In Appendix A we present our analysis on MAR evidence for National Grid and two water companies (United Utilities and Severn Trent). We find that after adjusting for non-UK/non-regulated activities, the estimated values do not provide strong enough evidence to move away from a MAR of 1, given the recent trends and the relatively wide intervals obtained.

We note that our analysis shows that it is necessary to make sizeable and uncertain adjustments to convert the raw MARs to a MAR that reflects only the UK regulated part of the businesses. This is recognised by Indepen, which cites circularity and valuation issues as reasons for not setting the MAR equal to the actual MAR.[60]

4.6. Conclusion on Indepen's Adjustment

In summary, Indepen understates the equity beta values in its recommended range because it fails to take account of the difference between the comparator and notional gearing levels. Regarding Indepen's "adjusted" notional gearing measure, there is no precedent in UK regulation. Moreover, even if we were to accept Indepen's recommendation of adjusting notional gearing by a "normal" MAR value, this would imply that the WACC weights would have to be set accordingly, resulting in a greater weight being applied to the cost of equity in the WACC to reflect the lower level of leverage.[61] Finally, there is no evidence that the "normal" MAR value isdifferent from 1, which means the adjustment would have no effect on the notional gearing level.

[58] CAA (2013), Economic regulation at Heathrow from April 2014: final proposals – WACC appendix, pp.35-37 and 52.

[59] CEPA (February 2018), Review of Cost of Capital Ranges for Ofgem's RIIO-2 for Onshore Networks, pp.62-64 and 71.

[60] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Main Report, Final, Section 4, p.33.

[61] Arguably, if Ofgem is to apply a MAR of 1.1, it is suggesting that the regulated company will be expected to outperform throughout the duration of the regulatory period. If Ofgem makes that assumption, it should then be clear on what allowance parameter would allow for this outperformance.

4.7. Ofgem's Approach to Beta Estimation

In its sector methodology consultation, Ofgem proposes to de-leverage and re-leverage betas, but takes into account the inconsistency issue raised by Indepen, although does not follow Indepen's proposed approach.[62]

Ofgem starts from a raw equity beta range of 0.6 to 0.7, consistent with Indepen's recommendations. It then de-leverages these values using an adjusted gearing value, which it calculates by applying Indepen's MAR adjustment to the average of the gearing of 5 utility companies. In calculating the asset betas, Ofgem adopts a debt beta range of 0.1 to 0.15.

To re-leverage the asset betas, Ofgem uses its notional gearing estimate of 60 per cent, without applying Indepen's MAR adjustment. It estimates a notional equity beta of 0.65 to 0.76.[63]

4.8. Ofgem's Approach is Inconsistent with Finance Theory and Indepen's Approach

In our view, Ofgem's approach is not in line with Indepen's approach. Ofgem applies the MAR "correction" proposed by Indepen to the actual gearing (enterprise value gearing), instead of applying it to the RAB-based gearing, as proposed by Indepen.

While Indepen's argument was that the inconsistency of re-leveraging and de-leveraging using different gearing basis (RAB-based and enterprise-based) should be corrected, it does so by adjusting the notional gearing from a RAB-basis to an enterprise-basis using the MAR. Ofgem applies the same adjustment but to the actual gearing level used to de-leverage the equity betas estimated, thereby overstating the actual gearing level.

In standard financial theory, as explained in section 3.3, the de-leveraging of equity betas is done with the purpose of removing the financing decisions effects from the beta, to get a measure of business risk. When estimating the equity beta of a company, this will take into account the capital structure of the firm being analysed and so, the equity beta will depend on gearing. Thus, Ofgem's approach of de-leveraging the raw equity betas using an average "adjusted" gearing is flawed for two reasons.

First, by adjusting the actual gearing used to de-leverage raw equity betas, Ofgem is implicitly assuming that the same raw equity betas would apply at different levels of gearing. Equation (4) shows the standard Miller formula for calculating asset betas, while Equation (5) rewrites it in terms of the equity beta.

$$(4)\,\beta_{asset} = \beta_{equity} * (1 - gearing) + \beta_{debt} * gearing$$

$$(5)\,\beta_{equity} = \frac{\beta_{asset} - gearing * \beta_{debt}}{(1 - gearing)}$$

[62] Ofgem (18 December 2018), RIIO-2 Sector Specific Methodology, Section 10, p.104, para 10.48.

[63] Ofgem (18 December 2018), RIIO-2 Sector Specific Methodology, Annex: Finance, Section 3, pp. 39 and 40.

As shown in Equation (5), it is clear that the equity beta depends on the gearing level, and a change in gearing would result in a new equity beta.[64] Therefore, as explained above, since the equity betas incorporate the effects of financing from specific firms, they should be de-leveraged using a gearing reflecting the specific decisions of those firms and not a measure adjusted to reflect a notional level.[65] By adjusting the actual gearing, Ofgem is introducing a bias into the asset betas estimated, as these now also reflect a factor accounting for outperformance (derived from the MAR above 1), and not just the business risk, as they should.

Our second issue with Ofgem's gearing measure, is that it uses a specific date to inform the level of gearing. This is problematic, as it does not capture the variation of the gearing level over the period where the beta was estimated.[66]

Instead, Ofgem should estimate an asset beta range drawing on equity betas from comparators, de-leveraged using their specific capital structure and not an average gearing. This is the approach followed by most regulators, including Ofwat.[67]

4.9. Ofgem's Adjustment Punishes Outperformance

As presented in Appendix A, the MAR is defined as the ratio of enterprise value to RAB. After adjusting for the non-regulated and non-UK activities, an adjusted MAR above 1 reflects the market's view of expected outperformance.

The existence of outperformance, for some companies at least, is expected as part of an incentive regulation framework and should not be clawed back in the asset beta estimation.

Ofgem's approach of adjusting the gearing level used to de-leverage equity betas, overstates the actual gearing level. This gearing overstatement leads to an understatement of asset betas and, by extension, the cost of equity, thereby punishing outperformance. In Table 4.3, we show that Ofgem's approach of adjusting the gearing level used to de-leverage raw equity betas, leads to an understatement of asset betas by c.0.02 to 0.03 and of the cost of equity by 0.39 to 0.56 percentage points. To calculate these values, we use the same assumptions as Ofgem, aside from the adjustment to the actual gearing levels.

64 Assuming the asset and debt betas remain unchanged.

65 See for example Berk, J. and DeMarzo, P. (2014), Corporate Finance, Third Edition, Chapter 12, pp.415-416; Damodaran, A (2012), Investment Valuation: tools and techniques for determining the value of any asset, Chapter 8, p.197.

66 We address this issue in more detail in a separate report.

67 Ofwat (December 2014), Setting price controls for 2015-20 Final price control determination notice: policy chapter A7 – risk and reward, pp.34-36.

Table 4.3: Ofgem's Approach Understates Asset Betas and Cost of Equity

	Ofgem Lower Bound	Ofgem Upper Bound	NERA Lower Bound	NERA Upper Bound
Raw equity beta	0.6	0.7	0.6	0.7
Actual gearing	50.80%	50.80%	50.80%	50.80%
EV/RAV	1.1	1.1	n.a.	n.a.
Adjusted gearing	56%	56%	50.80%	50.80%
Debt beta	0.15	0.1	0.15	0.10
Asset beta	**0.35**	**0.36**	**0.37**	**0.40**
Notional gearing	60%	60%	60%	60%
Notional equity beta	**0.65**	**0.76**	**0.70**	**0.84**
Risk-free rate	-1.68%	-1.68%	-1.68%	-1.68%
Equity risk premium	6.9%	7.4%	6.9%	7.4%
Cost of equity (real post-tax, RPI)	**2.76%**	**3.93%**	**3.15%** (+39 bps relative to Ofgem lower bound)	**4.49%** (+ 56 bps relative to Ofgem upper bound)

Note: Adjusted gearing for NERA's range does not contain any adjustment to the actual gearing and serves only for a comparison with Ofgem's gearing used to de-leverage raw equity betas.
Source: NERA calculations based on Ofgem's data.

4.10. Conclusion on Ofgem's Approach

In summary, Ofgem's adjustment to gearing levels is not only inconsistent with Indepen's approach, but it is also inconsistent with standard finance theory. By overstating the actual gearing levels when de-leveraging the raw equity betas, Ofgem is not correctly estimating a measure of business risk and understates the asset betas. We conclude that this issue leads to an understatement of the asset betas by 0.02 to 0.03 and of the cost of equity by 0.39 to 0.56 percentage points.

5. Debt Beta

In this section, we consider the evidence on debt betas and whether a debt beta of 0.1 to 0.15, as suggested by Indepen, is justified. We show that choosing higher debt betas results in a reduction of the re-leveraged equity beta in this instance. Overall, we do not consider that Indepen's assumed range of 0.1 to 0.15 is supported by the evidence.

5.1. An Increase in the Debt Beta Assumption Results in a Reduction of the Re-Leveraged Equity Beta

Unlevered asset betas are estimated as the weighted average of empirical equity betas and a debt beta (as per Equation (4)). The asset beta is then re-leveraged back to notional gearing to derive an equity beta for setting the cost of equity for notional financial structure. The assumed debt beta affects the notional cost of equity only to the extent that leverage for the comparators differs from the notional assumption. If empirical leverage is the same as notional and consistent debt betas are used for un-leveraging and re-leveraging, there is no impact on the re-leveraged cost of equity.

Essentially, if the actual gearing (used to de-leverage equity betas) is below the notional gearing (used to re-leverage asset betas), then an increase in the debt beta results in a decrease in the notional equity beta. To show this impact, we have conducted a sensitivity analysis to Ofgem's proposed equity beta range, where we retained Ofgem's notional gearing assumption of 60 per cent, comparator gearing of 50.8 per cent, and raw equity beta range of 0.6 to 0.7.[68,69] The results are shown in Table 5.1.

Table 5.1: Higher Debt Beta Results in Lower Notional Equity Betas (Given Comparators' Gearing is Below Notional)

Debt Beta	Lower Bound	Upper Bound
0	0.74	0.86
0.05	0.73	0.85
0.1	0.72	0.84
0.15	0.70	0.83
0.2	0.69	0.82

Note: Shaded rows represent the debt beta assumptions adopted by Ofgem in the sector methodology consultation.
Source: NERA analysis based on Ofgem's data

As shown in Table 5.1, an increase in debt beta of c.0.05 results in a decrease of approximately 0.01 in the re-leveraged equity beta.

[68] Ofgem (18 December 2018), RIIO-2 Sector Specific Methodology Annex: Finance, Section 3, pp.39 and 40.

[69] As explained in Section 4, our view is that Ofgem does not apply correctly Indepen's correction of gearing to account for MAR. As such, we use Ofgem's actual gearing estimate prior to the MAR adjustment.

5.2. UK Regulators Have Consistently Used Low Values for Debt Beta

In general, UK regulators have assumed a zero debt beta for networks with some exceptions, yet the CAA has assumed positive debt betas for airports:

- Ofwat and Ofgem used a zero debt beta in estimating cost of equity at PR14 and the recent RIIO reviews;[70]
- In contrast, Ofcom as well as the CAA used a non-zero debt beta at recent determinations, with the CAA assuming a 0.1 debt beta for Heathrow at Q6 and NATS at RP2 and Ofcom assuming a debt beta of 0.1 for WLA controls;[71]
- The Competition and Market Authority (CMA) has taken varying approaches to the debt beta assumptions, estimating a debt beta of 0.1 for Heathrow at Q5, a 0.05 debt beta for NIE in 2014 and a zero debt beta in its most recent determination for Bristol in 2015.[72]

The regulatory precedent on debt beta determinations is summarised in Table 5.2 below.

Table 5.2: UK Regulators Have Consistently Used Low Values for Debt Beta

Decision	Date	Debt Beta
Ofgem RIIO-T1/GD1	2012	n/a – determines equity beta directly
Ofgem RIIO-ED1	2014	n/a – determines equity beta directly
Ofwat PR14	2014	0
Ofcom WLA	2018	0.1
CAA Heathrow/Gatwick	2014	0.1
CAA NATS (RP2)	2014	0.1
CMA Heathrow	2007	0.1
CMA NIE	2014	0.05
CMA Bristol	2015	0

Source: Regulatory decisions; Competition Commission (28 September 2007), BAA Ltd, A report on the economic regulation of the London airport companies (Heathrow Airport Ltd and Gatwick Airport Ltd), Appendix F, p.F-26; Competition Commission (26 March 2014), Northern Ireland Electricity Limited price determination A reference under Article 15 of the Electricity (Northern Ireland) Order 1992 Final determination, p.13-36; CMA (6 October 2015), Bristol Water plc A reference under section 12(3)(a) of the Water Industry Act 1991 Report, p. 325.

[70] Ofgem (December 2012), RIIO-T1: Final Proposals for National Grid Electricity Transmission and National Grid Gas - Finance and uncertainty supporting document; Ofgem (December 2012), RIIO-GD1: Final Proposals - Finance and uncertainty supporting document; Ofgem (July 2014), RIIO-ED1: Draft determinations for the slow-track electricity distribution companies – Financial Issues; Ofwat (December 2014), Setting price controls for 2015-20 Final price control determination notice: policy chapter A7 – risk and reward, pp. 41 and 42.

[71] Ofcom (28 03 2018): Wholesale Local Access Market Review: Statement, Annexes 17-27, pp.113-114; CAA (2013), Economic regulation at Heathrow from April 2014: final proposals – WACC appendix, p.75; CAA (June 2014), UK-Ireland FAB RP2 Performance Plan – Supporting Document, p.274.

[72] Competition Commission (2007), BAA airports market investigation, Appendix F – Cost of capital, p.F-26; Competition Commission (26 March 2014), Northern Ireland Electricity Limited price determination A reference under Article 15 of the Electricity (Northern Ireland) Order 1992 Final determination, p. 13-36; CMA (6 October 2015), Bristol Water plc A reference under section 12(3)(a) of the Water Industry Act 1991 Report, p. 325.

5.3. Academic Studies Estimate Debt Betas in Range 0 to 20 bps

As recognised by Indepen, there are two main approaches for estimating the debt beta: i) the regression method and ii) the credit spread decomposition method.

The regression method consists of regressing corporate bond returns against the stock market index returns to estimate the debt beta directly (similarly to estimating the equity beta). The credit spread decomposition method assumes that bondholders require compensation not only for bearing liquidity and default risks, but also for systematic risk, and decomposes the credit spread into the constituent elements compensating for these risks (as shown in the below formula).

$$Debt\ premium = Liquidity\ Premium + Default\ Premium + \boldsymbol{Debt\ Beta} * Market\ Risk\ Premium$$

Our review of the literature suggests evidence on debt betas is mixed. We summarise the most recent evidence in Table 5.3 below.

Table 5.3: Academics and Other Evidence on Debt Beta

Authors	Date	Rating	Debt Beta
Fama & French	2002	BBB	0.22
		A	0.21
		AA	0.20
Schaefer & Strebulaev	2008	-	0.04
Damodaran	2012	A	0.125
Brealey & Myers	2013	-	0.00 - 0.20
Brattle Group	2016	BBB+ to BBB-	0.10
		AAA to A-	0.05

Source: Fama, E and French, K (1993): "Common risk factors in the returns on stocks and bonds", Journal of Financial Economics, Vol. 33, No.1, pp. 3-56; Schaefer, S and Strebulaev, I (2008): "Structural models of credit risk are useful: Evidence from hedge ratios on corporate bonds", Journal of Financial Economics, Vol. 90, No.1, pp. 1-19; Damodaran, A (2012): "Investment Valuation – Tools and Techniques for Determining the Value of any Asset", p411; Allen F., Brealey R., Myers S. (2013): Principles of Corporate Finance 11th Edition, page 436; Brattle Group (2016) report for the European Commission: Review of approaches to estimate a reasonable rate of return for investments in telecoms networks in regulatory proceedings and options for EU harmonization, Section VI.G, page 88.

In theory, debt betas can be estimated in the same way as equity betas by regressing bond returns against a relevant reference market index, but in practice, the low trading frequency for many bonds leads to illiquidity issues that make the estimation of a debt beta particularly difficult and subject to distortions that do not provide robust estimates.

This may explain why we see a relatively wide range of values in Table 5.3. Whereas in 2002, Fama & French suggested that a debt beta assumption around 0.2 may be appropriate (regardless of the credit rating), more recent estimates are lower and largely support the range of 0 to 0.1.

Some authors recommend a simple rule of thumb that sets the debt beta based on the company's credit rating, without relying on empirical estimates. For example, Brattle suggests a range of 0.05 to 0.1 based on a simple rule.

While some UK regulators such as Ofcom have also relied on evidence from regression analysis when setting debt betas,[73] in general regulators do not rely on such evidence, possibly due to the difficulties in the estimation of debt betas empirically, as pointed out by Indepen.[74]

5.4. Conclusion on Debt Beta Estimate

Overall, we consider that Indepen's range of 0.1 to 0.15 is above the evidence presented above. In general, regulators in setting the cost of capital for networks have assumed a zero debt beta, although CAA has generally assumed a higher asset beta for higher risk airports. The market evidence is wide-ranging, potentially reflecting estimation difficulties. However, more recent market evidence supports a range of 0 to 0.1 which implies that Indepen's range of 0.1 to 0.15 overstates debt betas and understates the re-levered equity beta and cost of equity.

[73] In their latest determination, Ofcom relied on evidence from Brealey and Meyers (2013) and the Brattle Group, as well as regulatory precedent, when setting their debt beta of 0.1. Source: Ofcom (28 03 2018): Wholesale Local Access Market Review: Statement, Annexes 17-27, pp.113-114.

[74] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Appendices D-H, Appendix E, p.10.

6. The Use of International Comparators

In this section we show that European energy networks provide reasonable comparators to inform the beta estimation of UK networks by way of a relative risk analysis, by contrast Indepen's discards such evidence.

6.1. Risk Assessment Relative to UK Comparators

As stated by Indepen, a good starting point for estimating betas for RIIO-2 are the beta estimates for listed UK examples.[75] We agree, although we recommend performing a relative risk analysis of these UK companies so that we understand whether the risk exposure is comparable.

We have compared the risks faced by UK energy networks, and specifically by National Grid's regulated activities in the UK, i.e. electricity transmission (NGET) and gas transmission (NGGT), relative to other UK networks against a range of risk factors.

In general the regulatory regimes in energy and water are closely aligned, and are expected to converge in the future price controls, namely with Ofwat's introduction of a cost of debt indexation mechanism, albeit for new debt only, at PR19[76] and Ofgem setting the default length of the price control period at 5 years, a reduction from the previous length of 8 years.[77] Water companies potentially face greater risk from the treatment of pensions relative to energy networks, where water companies can recover 50 per cent of deficits as at PR09.[78] By contrast, energy networks can recover the established deficit as at 2013 with triennial revaluation to allow for changes in the value of the deficit, but face risk on post-establishment deficits.[79]

Despite the convergence in the regulatory framework, the water and energy sectors are still affected by fundamentally different risk factors which imply greater risk for energy networks. In a previous report for NG, we identified the following factors:[80]

- *Complexity of the capex programmes:* At RIIO-T1, Ofgem considered both the scale and complexity of investment as risk factors. Ofgem took into account factors such as the size of the project, the number of projects, interlinkages with other projects and the projects'

[75] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 3, pp.23 and 24.

[76] Ofwat (December 2017) Delivering Water 2020: Our final methodology for the 2019 price review, Link: https://064f1d25f5a6fb0868ac-0df48efcb31bcf2ed0366d316cab9ab8.ssl.cf3.rackcdn.com/wp-content/uploads/2017/12/Final-methodology-1.pdf

[77] Ofgem (July 2018), RIIO-2 Framework Decision, page 17.

[78] At PR09, Ofwat determined the price control allowance for pension deficit repair costs associated with companies defined benefit pension schemes assuming a 10- to 15-year deficit repair period starting in 2009 or 2010. Ofwat allowed companies to recover about 50 per cent of pension deficit repair costs from customers from PR09, with the rest dealt with by management action or shareholder contributions. Source: Ofwat (October 2013), IN 13/17: Treatment of companies' pension deficit repair costs at the 2014 price review. Link: https://0980a19b0bb02fe4a86d-0df48efcb31bcf2ed0366d316cab9ab8.ssl.cf3.rackcdn.com/wp-content/uploads/2015/11/prs_in1317pr14pension.pdf

[79] Ofgem (17 December 2012), RIIO-T1: Final Proposals for National Grid Electricity Transmission and National Grid Gas - Finance Supporting Document, Appendix 5.

[80] NERA (April 2018) RIIO-T2 Beta and Risk Assessment

bespoke nature when assessing the complexity of networks' investments.[81] Investments in transmission can be far larger and more bespoke compared to smaller and more routine projects for water.

- *Asset stranding risk:* Energy networks such as NGGT and NGET have greater exposure to the government's decarbonisation agenda, which is driving significant changes in the energy supply market with traditional sources of energy supply being replaced with a divergent mix, thus creating uncertainty over the future role of these networks.
- *Cyber security risks*: NGET and NGGT face greater cyber security risks and potential costs than other networks, given the nature and systemic importance of energy transmission. Energy transmission is the most critical system within the UK. Transmission assets cover the whole of the UK, compared with the localised nature of the distribution networks. As a result, energy transmission is a single point of failure for mainland UK with a critical effect on all other sectors.

In addition to these risks, TO's also face far greater competition risks under the government's proposed competitive tendering regime for on-shore TOs (or CATO), [82] and Ofgem's competition proxy model (CPM) and special purpose vehicle (SPV) models designed to introduce competition ahead of the legislative change required for CATO.[83] These models expose TOs to greater uncertainty over future capex and funding allowances, and greater regulatory risk, with Ofgem excluding projects that were to be undertaken within RIIO price control framework.

[81] Ofgem (2012), RIIO-T1: Final proposals for National Grid Electricity Transmission and National Grid Gas – Finance support document, Table 3.3 and Table 3.4

[82] DECC (January 2016), Extending competitive tendering in the GB electricity transmission network, IA No: DECC 3088(1)

[83] Ofgem (2018), Impact Assessment on applying the PSV and CPM to future new, separable and high value projects, p. 14

6.2. Risk Assessment Relative to European Comparators

Indepen argues that the use of international comparators is not helpful given issues such as the comparability of regulatory regimes.[84] While we agree that companies from different countries may not be the most comparable evidence, it is also the case that some of these can be useful as benchmarks, provided a relative risk analysis is conducted. For example, if a Spanish company operating in the same sector is exposed to a lower systematic risk, then the beta of that company may be used to inform a lower bound. Thus, we recommend considering additional international evidence.

Given the above, we present in Table 6.1 a summary of our risk assessment of National Grid's UK regulated networks (NGET and NGGT) relative to listed European comparators, specifically Italian and Spanish networks. In general, our assessment is that NGET and NGGT face similar risks to Italian and Spanish networks. We note that we do not include US comparators here since, as shown in Section 3.1, these are exposed to a regulatory regime with lower risk.

In principle, companies operating in the same sector (i.e. energy networks in the UK, Italy and Spain) would be broadly exposed to similar fundamental/sector risks such as capex complexity, even if operating in another country. If, in addition, the companies are exposed to similar risks in terms of the regulatory regime, then Italian and Spanish networks should provide a good benchmark for the risks faced by energy networks in the UK. We provide a brief comparison of the regulatory regimes below and in Table 6.1

In Italy, networks are regulated under a hybrid of a price cap (on opex) and a rate of return regime (on capex). Due to a periodic true-up, only a very small share of opex is subject to volume risk (around 5 per cent).[85] Moreover, opex cost risk is partially mitigated through a 50 per cent sharing factor. Italian networks face very little capex risk given that capex is effectively passed through.

Whereas the Italian networks face relatively low risk based on volume and cost risk considerations, the regulator has announced its intention to introduce a RIIO-like incentive based framework, which will increase the systematic risk of these networks. Given the expected change to the regime, we consider the Italian networks face a similar risk to National Grid.

In Spain, transmission networks are regulated under revenue caps, as are NGET and NGGT. On the cost side, they are subject to a 50 per cent sharing factor on capex, but bear the full cost risk on opex. Naturgy (Gas Distribution)[86] is subject to a revenue cap, based on opex and capex volume drivers. There is no sharing of opex and capex out or underperformance which indicates that it faces greater cost risk than UK networks, although this is mitigated by annual updates to the allowance in line with volume drivers and unit costs.[87] As with the

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84 Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 3 and Section 5, pp.23, 24 and 42.

85 See for example Aeegsi, Decision 514/2013/R/gas (Tariff regulation for gas transport for RP4), Article 13.

86 Formerly Gas Natural.

87 **Gas**: Ley 18/2014, https://www.boe.es/boe/dias/2014/10/17/pdfs/BOE-A-2014-10517.pdf; **Electricity**: Ley 24/2013 (https://www.boe.es/boe/dias/2013/12/27/pdfs/BOE-A-2013-13645.pdf), Royal Decree 1047/2013 (https://www.boe.es/boe/dias/2013/12/30/pdfs/BOE-A-2013-13766.pdf) and Royal Decree 1048/2013 (https://www.boe.es/boe/dias/2013/12/30/pdfs/BOE-A-2013-13767.pdf).

Italian regime, we consider that investors in NGET and NGGT face a similar degree of risk as investors in Spanish networks.

Table 6.1: Relative Risk Assessment Shows that National Grid Bears Similar Risks as Listed European Comparators

	GB		Italy	Spain	
	NGET	NGGT	Snam (GT),Terna (ET), Acea (ED)	Enagas (GT), Red Electrica (ET)	Naturgy (GD)
Form / length of revenue period	• Revenue-cap • 8 years [5 years in RIIO-2]		• Hybrid of price cap (opex) and cost plus/pass through (capex), but virtually no volume risk on opex as a result of true up • 4 years (8 years under discussion)	• Revenue-cap • 6 years • Volume drivers for GT revenues based on outturn demand	• Revenue-cap (s.t. volume drivers) • Volume drivers/unit costs can be updated every 6 years
Setting cost allowances	• Expert review of totex • DB pension deficit recovery over 15yrs with 3Y re-valuation (but risk on post-2012 liabilities) • Re-openers for some costs • COD update = 10Y trailing average iBoxx		• Based on actual opex in base year, updated annually according to CPI-X formula.	• Allowances set based on "standard" costs for capex and opex (review of historical data & technical input) • Standard costs revised at the start of every regulatory period and every 3 years for GT	• Revenues not linked to RAB but based on base year costs (2002) rolled forward with volume drivers (demand and customer number growth)
Outturn cost risk & incentives	• TIM • Uncertainty/pass-through of non-controllables • Disapplication of price control		• Opex: 50% sharing factor, limited volume risk • Ex-post recognition of actual capex spent • Additional WACC for some investments (e.g. security of supply)	• Opex: no sharing factor • Capex: 50% sharing factor; profit from underspend capped at 12.5% of costs (ET only)	• No explicit sharing of out or underperformance
Quality of Service/Output incentives	• Performance incentives : +0.6/ -1.4% of RORE	• Performance incentives : +1.7/ -1.4% of RORE	• Quality of service premiums/penalties (mainly technical, e.g. interruptions)	• ET: Availability incentive (of minor importance, capped)	
Other	• Uncertainty over future role of system from distributed generation	• Uncertainty over future role given uncertainty about energy mix, and decarbonisation of heat	• Risks from prospective regulatory reforms (longer controls, outputs based regime)		• Higher unit remuneration for some assets

*Source: **Italy**: Aeegsi, Decision 514/2013/R/gas (Tariff regulation for gas transport for RP4), Aeegsi, Decision 654/2015/R/EEL (Tariff regulation for electricity transmission); **Spain**: Gas: Ley 18/2014, https://www.boe.es/boe/dias/2014/10/17/pdfs/BOE-A-2014-10517.pdf; Electricity: Ley 24/2013 (https://www.boe.es/boe/dias/2013/12/27/pdfs/BOE-A-2013-13645.pdf), Royal Decree 1047/2013 (https://www.boe.es/boe/dias/2013/12/30/pdfs/BOE-A-2013-13766.pdf) and Royal Decree 1048/2013 (https://www.boe.es/boe/dias/2013/12/30/pdfs/BOE-A-2013-13767.pdf)*

6.3. Conclusion on Value of International Comparators

To estimate beta risk for National Grid, we focus on its own beta estimate. However, we agree with Indepen's proposal to consider other evidence for other listed comparators, as long as this is based on a thorough assessment of relative risk.

We recommend comparing energy networks to other UK regulated sectors to understand how risk might be perceived by investors. As discussed in Section 6.1, our view is that, while the water and energy regulatory regimes are expected to converge in the future, there are other risks (such as capex complexity and asset stranding risks) that need to be taken into account and neither Ofgem nor Indepen have considered these, implicitly assuming that water and energy companies are exposed to the same risks without a thorough relative risk analysis. As set out in the previous section, we identified a number of factors which broadly support a higher risk for energy networks, when compared to the water sector.

Contrary to Indepen, we consider that there is value in estimating betas for international comparators, provided that a relative risk analysis is conducted. Based on the analysis in Section 6.2, we recommend estimating Italian and Spanish networks betas, which we concluded faced broadly comparable risks to energy networks in the UK, specifically NGET and NGGT and can thus be used as a further cross-check. Moreover, we note that other UK and European regulators have used betas from other countries in their determinations. For example, the CAA in its 2014 price review for Heathrow and Gatwick estimated an asset beta by reviewing evidence from airports from countries such as Germany (Fraport) and France (ADP).[88] Indeed, European energy regulators draw on a wide range of international comparators in forming beta estimates at price control review.[89]

[88] CAA (2014), Estimating the cost of capital: technical appendix for the economic regulation of Heathrow and Gatwick from April 2014: Notices granting the licenses, pp.39-43

[89] See for example, Commission de regulation d'energie (CRE) in France, which draws on European and global energy networks to inform beta estimates . See for example, a report commissioned by CRE from Frontier (2015) Évaluation du taux de remuneration des gestionnaires de réseaux d'électricité et de gaz naturel en France, p. 90

7. The Estimation Models Chosen

In this section we analyse the equity beta estimates obtained using the different estimation methods proposed by Indepen and discuss their use in a regulatory context.

In summary, we find that Indepen addresses several of our previous concerns with the UKRN report, namely by using high frequency data (specifically daily data), acknowledging the existence of structural breaks and providing further details regarding the choice of a specific GARCH model. Regarding the model to use in a regulatory context, OLS is the most appropriate model to use given the lower degree of complexity and similarity of its estimates obtained with other techniques.

7.1. Indepen's Approach to GARCH Estimation

Indepen's first considers the issue of data frequency. Indepen raises the concern of heteroscedasticity, i.e. conditional volatility is not constant over time, and tests for its presence using the Engle test.[90,91]

Having found evidence of heteroscedasticity, Indepen argues for the use of a GARCH (1,1) model and tests for different specifications of the model using the Bayesian Information Criterion (BIC)[92]. Based on these results, Indepen selects a preferred model for each company using 2000-2018 data, with these being the T-BEKK (Triangular BEKK) and Full VECH (Half-vectorisation) models.[93]

As a cross-check, Indepen also tests whether the order of the GARCH model or the estimation window chosen affects the choice of the preferred model. For the GARCH order, Indepen tests whether extending the options to GARCH (2,2) models changes the choice of the preferred model using the BIC criterion and concludes that in most cases the same GARCH (1,1) specification is still preferred.[94] Finally, Indepen also tests whether the choice of estimation window affects the preferred model choice using the BIC criterion and finds that while some variation exists, there is some evidence of stability across different time horizons.[95] For the cases where the model differed based on the estimation window, new betas were estimated to reflect the new preferred model.[96]

Indepen provides equity beta estimates relying on daily data for three estimation periods (2000-2018, 2008-2018 and 2013-2018) and using the preferred GARCH specifications for each company. Indepen calculates two types of GARCH-based betas (similarly to Dr

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90 Engle, R.F. (1982), Autoregression Conditional heteroscedasticity with Estimates of the Variance of United Kingdom Inflation, Econometrica, 50, pp. 987-1007.

91 Indepen (December 2018), Ofgem Beta Study – RIIO-2 Main Report, Final, Section 2, pp.8-9.

92 Schwarz, G. (1978), Estimating the Dimension of a Model, Ann. Statist, 6, pp.461-464.

93 Indepen (December 2018), Ofgem Beta Study – RIIO-2, Appendices A-C, Final, Appendix C, pp.55-59.

94 Indepen finds that for two companies, the preferred model changes. Nonetheless, it argues that there are issues with the estimation of these higher order models and opts for maintaining the model selected under GARCH (1,1). Source: Indepen (December 2018), Ofgem Beta Study – RIIO-2, Appendices A-C, Final, Annex C1, pp.67-82.

95 Indepen (December 2018), Ofgem Beta Study – RIIO-2, Appendices A-C, Final, Annex C2, pp.84-87.

96 Indepen (December 2018), Ofgem Beta Study – RIIO-2 Main Report, Final, Section 2, footnote 20, p.11.

Robertson[97]): average of daily betas from estimated daily variances and covariances and beta calculated from average of individual variances and covariances.[98]

7.2. Indepen Addresses UKRN Issues

In our report for National Grid reviewing the recommendations of the UKRN report for the estimation of betas,[99,100] we pointed out several areas where we did not agree with the authors, namely the use of low frequency (e.g. quarterly) data, the long estimation window (since 2000) and the non-discussion of the modelling choice (given the existence of several GARCH models).

Indepen partially addresses these concerns in their recommended process for estimating betas. We present these views and our thoughts below.

Use of low frequency data

Three of the UKRN report authors, Mason, Pickford and Wright ("MPW"), recommend the use of low frequency data for estimating beta.[101] This would require extending the estimation period to ensure sufficient observations, leading to the inclusion of periods that are not relevant in terms of risk profile. Even when all the data available is used (in MPW's case, data from 2000 to 2017), the number of observations is still considerably smaller compared to the common practice of using daily data, leading to less precise beta estimates as measured by standard errors. A preference for the use of high frequency data over low frequency data, provided there is sufficient variation between observations, is also supported by the academic literature.[102]

Moreover, MPW propose to use GARCH models for estimating betas to reflect time-varying properties of asset returns (such as time-varying volatility) but at the same time they also propose to remove those very properties that GARCH models are designed to deal with from the data by aggregating returns. Therefore, we find the simultaneous recommendation for the use of GARCH-type models and the aggregation of returns inconsistent.

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97 Donald Robertson (19 April 2018), Estimating β, Section 4, p.16.

98 Indepen (December 2018), Ofgem Beta Study – RIIO-2, Appendices A-C, Final, Annex C3, pp.88-87.

99 NERA (2018), Review of UKRN report recommendations on beta estimation, Prepared for National Grid.

100 Wright, S, Burns, P, Mason, R, and Pickford, D (2018), Estimating the cost of capital for implementation of price controls by UK Regulators, An update of Mason, Miles and Wright (2003).

101 Wright, S, Burns, P, Mason, R, and Pickford, D (2018), Estimating the cost of capital for implementation of price controls by UK Regulators, An update of Mason, Miles and Wright (2003), p.53, and appendix G.

102 Daves et al (2000) say: "First, given identical return periods, shorter return intervals are associated with smaller Si [standard errors] or greater precision in estimating beta. Again, financial managers should use daily data to estimate beta." (Source: Daves, P., Ehrhardt, M. and Kunkel, R.D. (2000), Estimating Systematic Risk: The Choice of Return Interval and Estimation Period, Journal of Financial and Strategic Decisions, volume 13 number 1, p.10.
Morse (1984) says: "The most powerful estimate of mean abnormal returns is generated by the return series that minimizes bias and maximizes efficiency. The results generally support the use of daily return data to estimate information effects, with the possible exception of cases in which there is uncertainty about the date of the information release. Even with this uncertainty, however, daily returns may still be preferred to monthly returns in some situations." (Source: Morse, D. (1984), An Econometric Analysis of the Choice of Daily Versus Monthly Returns in Tests of Information Content, Journal of Accounting Research, vol. 22(2), p. 606)

Indepen provides a different view on the frequency of data, arguing against the use of low frequency data in the form of monthly data given its lower number of observations and the existence of structural breaks and does not mention the possibility of using quarterly data.[103]

For its equity beta range, Indepen provides betas estimated with high frequency-data, specifically daily data, which addresses our points above.[104]

Use of long estimation windows

MPW recommend estimating betas over long horizons going back to 2000. We had argued that doing so would ignore material changes in UK (and other comparator) companies' business and financial risk, changes in market conditions as well as changes in the regulatory regime and risk.[105]

This is still a concern in the Indepen report, which estimates an equity beta range based on three estimation windows, one of those going as far back as 2000. Indepen argues that it is important to take a longer view and longer windows to address issues surrounding noise in the estimation process.[106]

However, in the same report, Indepen argues for the use of data since the most recent structural break, which in this case, would be the last five years (since 2013).[107] This is then not reflected in Indepen's "narrower range", which is estimated by placing lower weight in the data from the 2013-2018 estimation window and more weight in the 2008-2018 estimation window. The argument presented for choosing a lower weight for the most recent estimation period is the spike occurring around the 2017 election, which has since reversed according to Indepen. This seems inconsistent with then placing weight on data from 2000 to 2018, which includes other clear structural breaks as Indepen identify themselves.[108]

We agree with Indepen's move towards using more recent data, but still have concerns that weight is being placed in data going as far back as 2000, which biases beta with risks that are not as relevant going forward, as explained above.

Discussion of the modelling choice

GARCH models address the issue of conditional heteroscedasticity of returns, making it possible to estimate time variation in beta. There is a wide range of GARCH models including the one used by MPW (BEKK-MGARCH). Given the possibilities around introducing a GARCH model for estimating betas, it is important that several alternatives are tested against each other using an appropriate selection criterion to justify the eventual use of one particular model. Examples of these criteria include the Bayesian Information Criterion (BIC), the Akaike Information Criterion (AIC) and the Hannan-Quinn Information Criterion

103 Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 2, p.19.

104 Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 5, p.45.

105 For a more detailed discussion, see NERA (2018), Review of UKRN report recommendations on beta estimation, Prepared for National Grid, Section 3.

106 Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 2, p.18.

107 Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 2, p.7.

108 Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Section 5, p.46.

(HQIC). In the case of MPW, no discussion surrounding the choice of the modeling choice is provided.

Indepen presents a significant improvement in this aspect, providing a detailed explanation on the choice of the GARCH model. The choice is based on the BIC, which is calculated using daily data for each company over the period 2000-2018. The equity betas are then estimated using the preferred GARCH model for each company (Triangular BEKK and Full VECH (Half-vectorisation)), as determined by the BIC.[109] Indepen also performs a sensitivity analysis considering higher order GARCH models, but finds that for most cases this does not change the choice of the preferred model and order.[110]

We present further thoughts on the use of GARCH instead of OLS in regulatory determinations in Section 7.3. However, if GARCH is to be used for the estimation of betas, we would recommend an approach similar to that of Indepen, where different models are measured against each other using the appropriate criteria.

7.3. Use of GARCH in a Regulatory Context

We consider that in the future more advanced time series models may prove useful insight for beta estimation in the regulatory context. In particular, they may help understand and assess variation in betas over time.

Beta is defined as the covariance between returns on the asset and returns on the market portfolio, divided by the variance of returns of the market portfolio. In academic literature, there are several econometric methods available for estimating the CAPM beta.

The earliest and possibly the most widely used method to date is the standard linear regression model, estimated by ordinary least squares (OLS). One of the potential restrictions of the OLS model is that it assumes the beta is constant over time. However, there is a body of empirical evidence showcasing that betas may vary over time.[111]

There are a number of models which allow analysing time variation in beta. Variants from the GARCH family provide a framework to explicitly model how the variance and covariance of stock returns changes over time. State-space models relying on the Kalman filter (KF) represent another class of models besides GARCH which also accommodate time-varying betas. The KF is widely employed in academic literature, but also in engineering technical applications where results can be tested experimentally. The OLS model using a rolling window (RW) estimation approach is a much simpler model that may incorporate time variation in beta as well.

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[109] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Appendices A-C, Appendix C, pp.55-59.

[110] Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Appendices A-C, Annex C1, pp.82.

[111] For example, Engle and Patton (2001) survey the most important stylized facts about the volatility of asset returns.[111] They present evidence of so called volatility clustering, which means that large moves in returns (of either direction) are typically followed by large moves and small moves are typically followed by small moves, creating persistence in volatility. They also show that volatility is mean reverting, i.e. a period of high volatility will eventually give way to a more normal level of volatility and conversely a period of exceptionally low volatility will eventually reverse, too. These stylised observations about asset returns' volatility imply that beta may vary over time. (Source: Engle, R.F., Patton, A.J., 2001. "What good is a volatility model?" Quantitative Finance, vol(1), pp. 237-245)

Hollstein and Prokopczuk (2016) provide a comprehensive survey of market beta estimation techniques comparing a broad range of models, including GARCH, Kalman Filter and even more advanced, option-based models.[112] They find that:

> *"estimators using historical information perform well only if they do not make too strong structural assumptions, like the simple historical beta and the Kalman filter approach with a random walk parametrization. In contrast, models that make strong assumptions on the volatility and correlation processes (like the GARCH-based DCC) are shown to produce very large errors."*[113,114]

Indepen, while estimating betas using GARCH and LAD processes, acknowledges that the different approaches give relatively similar numbers.[115] The differences in equity betas estimated from all the different approaches considered by Indepen are on average 0.04, 0.07 and 0.07 for the estimation periods 2000-2018, 2008-2018 and 2013-2018, respectively. If we consider the differences using only GARCH and OLS specifications, the values drop to 0.04, 0.06 and 0.05, respectively.[116] These values are consistent with our previous conclusions on the report for NG, which concluded that once consistent time periods and data frequencies are used, the results from standard OLS estimation and the MGARCH model proposed by MPW become very similar.[117]

The use of GARCH implies a certain degree of subjectivity in the model selection. Indepen, even testing for various specifications, only tests for 10 GARCH specifications. It also admits that higher GARCH orders are possible (although it only tests for a GARCH (2,2) in comparison with GARCH (1,1)).[118]

We believe the rolling-window OLS approach may potentially provide the most suitable method for analysing time-varying properties of betas in the regulatory context, as it offers the best trade-off between various regulatory objectives. It i) is easy to implement and well understood, ii) incorporates time-varying betas, and iii) is transparent and so minimises the scope for regulatory discretion/arbitrariness. Moreover, as discussed above, given that GARCH and OLS models produce consistent results, we consider the benefits from implementing a more complex model (GARCH) relative to OLS appear questionable in a regulatory context.

7.4. Conclusion on the Estimation Model to be Used

The choice of an estimation model for the purposes of regulation is a task that requires the balancing of several regulatory objectives.

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112 Hollstein, F. and Prokopczuk, M. (2016), Estimating Beta, Journal of Financial and Quantitative Analysis, vol. 51(4), pp. 1437-1466.

113 Hollstein, F. and Prokopczuk, M. (2016), op. cit., p. 1464.

114 By simple historical beta the authors refer to an OLS regression with a rolling window of one year.

115 Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Main Report, Executive Summary, p. xi.

116 Based on Indepen's reported equity beta estimates. Source: Indepen (December 2018), Ofgem Beta Study – RIIO-2 Final, Section 5, p.45.

117 NERA (2018), Review of UKRN report recommendations on beta estimation, Prepared for National Grid, Section 5, p.23.

118 Indepen (December 2018), Ofgem Beta Study – RIIO-2, Appendices A-C, Final, Appendix C, pp.55-58.

When estimating betas using the GARCH model, Indepen address some of the issues we identified with MPW's approach, namely the use of high frequency data and the testing of different specifications, but still places some weight on evidence going back to 2000.

We conclude that a rolling-window OLS is the approach that provides the best trade-off between the regulatory objectives. We noted that there is a degree of subjectivity in the selection of the GARCH model, which affects the transparency of the estimates. Moreover, the similarity in estimates provided in our report for National Grid and the Indepen report between betas estimated using a GARCH or a OLS model is evidence that the use of an OLS model is not leading to under/overstated betas.

8. Conclusion on Indepen's Recommendation

In this report, we have set out issues on beta estimation where we do not fully agree with Indepen's recommendation. Moreover, we have also identified a further issue with the approach adopted by Ofgem, where it did not fully follow Indepen's recommendation. We set out our findings below:

- **Beta decomposition**: There is a strong theoretical basis and practical application to support decomposition of National Grid's beta to estimate the beta for its UK network operations. Indepen should have taken into account the higher risk of National Grid's UK operations relative to US operations, and adjusted the beta estimated to reflect this fact. This would have lead to higher estimates in Indepen's recommend equity beta range;
- **Beta leveraging and de-leveraging**: We consider that a correct application of Indepen's proposed adjustment would mean that Ofgem would have to set the WACC weights based on the "adjusted" notional gearing, which would mean that the WACC would not change significantly. We note that Indepen's proposed adjustment has no precedent in UK regulation and, even if we were to accept this, there is no strong evidence that adjusted MARs are significantly different from 1. Moreover, Ofgem fails to correctly apply Indepen's method, and instead applies an adjustment to actual gearing (with which we also have issues in terms of using the average gearing at one specific date), leading to an understatement of asset betas and cost of equity;
- **Debt beta**: We find that Indepen's debt beta range of 0.1 to 0.15 is higher than regulatory practice for network operators where most decisions are based on a zero debt beta, and higher than recent academic evidence;
- **International comparators**: While Indepen considers that there are concerns in using international comparators, we find that European energy companies face similar business and regulatory risks and therefore are relevant comparators for National Grid, and more relevant than UK water companies, which Indepen draws on; and
- **GARCH models**: Indepen corrects some of the issues identified in our previous report on the UKRN recommendations, namely the use of low frequency data and the discussion of the model chosen. However, we consider that the OLS method provides the best trade-off between regulatory objectives, in terms of accuracy, complexity and transparency.

To assess the impact of our corrections in Ofgem's estimates, we update the cost of equity estimate presented by Ofgem in their sector specific methodology. We estimate corrected notional equity beta ranges by retaining Ofgem's Actual gearing, Total Market Return and Risk-free Rate assumptions, although as pointed out in this and previous reports, we do not agree with these estimates.[119] We first present an updated cost of equity range by adjusting Ofgem's estimates of debt beta and gearing level used to de-leverage raw equity betas.

[119] We explained in a previous report that we did not agree with Ofgem's view that the TMR had fallen (Source: NERA (2017), Total Market Return for Determining the Cost of Equity at RIIO-2). In reports for the Energy Networks Association, we have set out further issues with evidence on which Ofgem relies (NERA (2018), Review of UKRN Report Recommendations on TMR and NERA (2018), Further evidence on the TMR).

We perform a second adjustment where we estimate an asset beta range that includes evidence from European comparators and National Grid's beta decomposition, as set out in our previous report for National Grid.[120] We find that the evidence supports an asset beta range of 0.40 to 0.45,[121] where the lower bound is consistent with evidence from European comparators and National Grid's own asset beta. For our upper bound, we determine a value of 0.45 which slightly lower than the mid-point between NG plc's asset beta (which is 0.39), and the decomposition of NG's plc's beta to isolate UK energy risk, which supports a value of around 0.55 (two-year asset betas). We do not adopt the higher value of 0.55 given the absence of wider evidence to support this assumption (e.g. from European networks), and the scope for statistical error in decomposing composite betas into their constituent elements. We present these estimates in Appendix B.

We present our updated estimates in Table 8.1. We note that, adjusting for the debt beta and leverage issues identified above, leads to a cost of equity estimate that is 0.47 to 0.73 percentage points higher, compared to Ofgem's estimate. If we use an asset beta range that accounts for National Grid's beta decomposition and international comparators, we estimate a cost of equity that is 2.43 to 2.67 percentage points higher than Ofgem's estimate.

[120] NERA (2018), RIIO-T2 Beta and Risk Assessment, for National Grid.

[121] These values are calculated based on a debt beta of zero.

Table 8.1: Correcting Indepen/Ofgem's Methodology Issues Leads to a Higher Cost of Equity

	Ofgem application of Indepen		Correcting for debt beta and leverage		Decomposition and other evidence	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Raw equity beta	0.6	0.7	0.6	0.7	n.a.	n.a.
Actual gearing	50.80%	50.80%	50.80%	50.80%	n.a.	n.a.
EV/RAV	1.1	1.1	n.a.	n.a.	n.a.	n.a.
Adjusted gearing	56%	56%	50.80%	50.80%	n.a.	n.a.
Debt beta	0.15	0.10	0.10	0	0	0
Asset beta	**0.35**	**0.36**	**0.35**	**0.34**	**0.40**	**0.45**
Notional gearing	60%	60%	60%	60%	60%	60%
Notional equity beta	**0.65**	**0.76**	**0.72**	**0.86**	**1.00**	**1.13**
Risk-free rate	-1.68%	-1.68%	-1.68%	-1.68%	-1.68%	-1.68%
Equity risk premium	6.9%	7.4%	6.9%	7.4%	6.9%	7.4%
Cost of equity (real post-tax, RPI)	**2.76%**	**3.93%**	**3.23%**	**4.66%**	**5.19%**	**6.60%**

Source: NERA calculations based on Ofgem's data (without adjusting for Actual gearing, Risk-free rate and Equity risk premium parameters, with which we do not agree with Ofgem).

Appendix A. MAR Evidence

In this appendix we present evidence on raw and adjusted MARs for National Grid, United Utilities and Severn Trent over time.

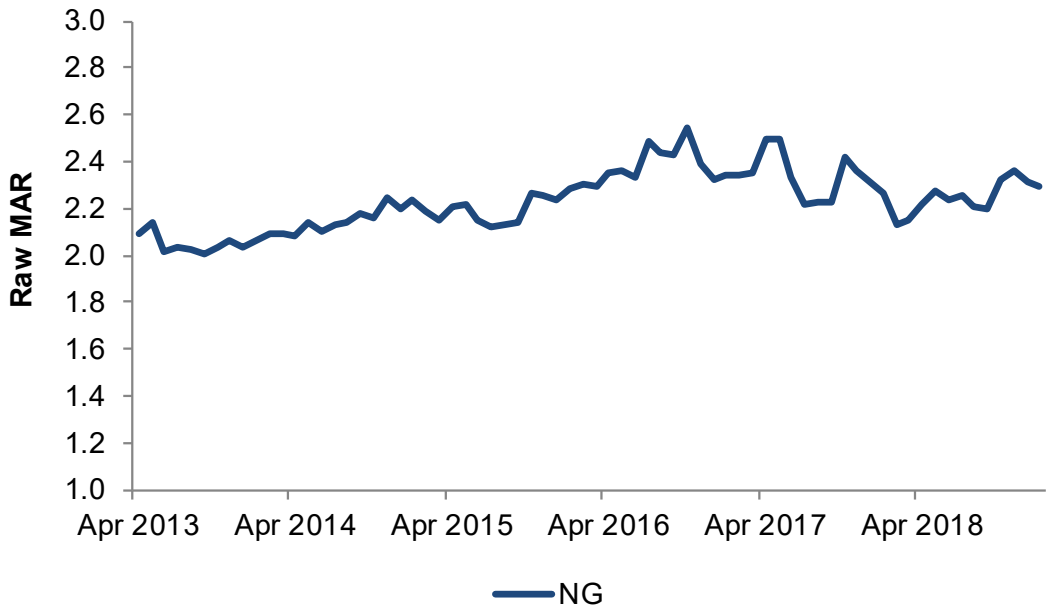
A.1. Raw MARs

MARs measure the ratio of the market value (MV) of the regulated business to the value of the RAV,[122] as shown in Equation (6).

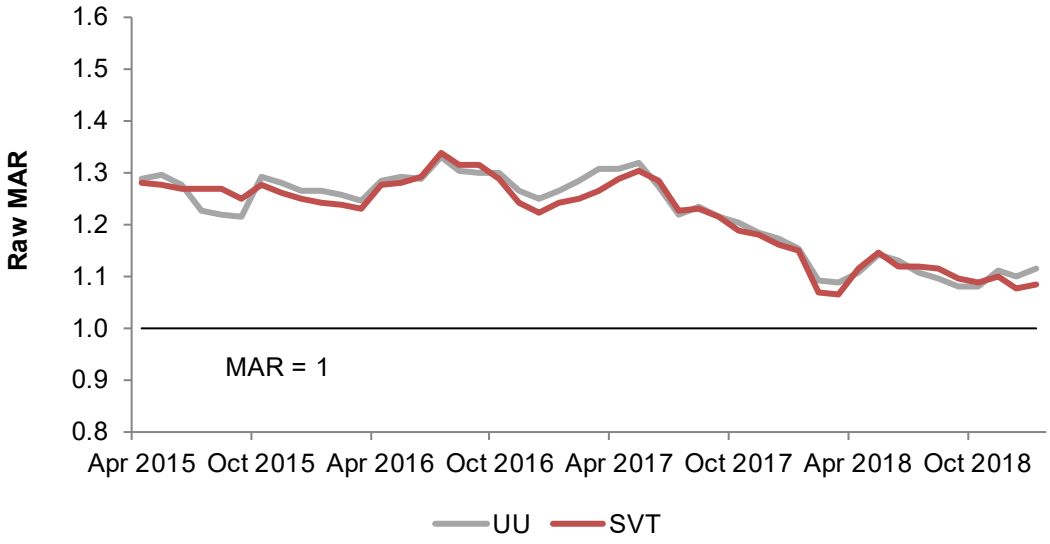
$$(6)\ MAR = \frac{MV\ of\ regulated\ business\ (debt+equity)}{RAV}$$

We calculate raw MARs as enterprise value for each of the companies (as reported by Bloomberg), divided by the regulatory asset base for the UK regulated business. In Figure A.1 below, we show the raw MARs for National Grid and listed UK water companies (United Utilities and Severn Trent) since the start of RIIO-T1/GD1 and PR14 respectively.

Figure A.1: Raw MAR for National Grid has been around 2.2 since the start of the RIIO-T1/GD1 and around 1.2 for Water Companies since the start of the PR14



[122] Throughout the report, we consistently refer to the value of regulated assets for UK networks as the Regulatory Asset Base (RAB). We note that different regulators use different terminology, e.g. Ofgem refers to the asset base as the RAV (Regulated Asset Value) while Ofwat uses the term RCV (Regulated Capital Value).



Note: We calculate raw MARs as enterprise value for each of the companies (as reported by Bloomberg), divided by the regulatory asset base for the UK regulated business. For NG, we take the value of the RAB for UK T&D activities as per NG published annual Factsheets (available at .https://investors.nationalgrid.com/news-and-reports/factsheets/2018). For the value of the share in Cadent we use Cadent's annual reports. For water companies, we use the Ofwat annual updates of the RAB (available at: https://www.ofwat.gov.uk/publications/regulatory-capital-value-updates/).
Source: NERA calculations based on Bloomberg, NG, Cadent, Ofwat and ONS data.

As shown in Figure A.1, the raw MAR for National Grid has been around 2.2 the since start of RIIO-T1/GD1. The relatively large raw MAR for National Grid is driven by the fact that around half of National Grid's market value relates to non-UK regulated activities, which are not reflected in the denominator, the UK RAB. The raw MAR for water companies has been around 1.2 since the start of PR14, but similarly to National Grid, this is before any adjustments for non-regulated activities.

We calculate so-called *adjusted MARs* for listed UK networks, to remove the effects of non-regulated/non-UK activities, which can form a substantial portion of the overall market value of the company. These activities are not included in the RAV values, the denominator in the above equation, and thus should not be included in the numerator, to calculate a MAR for regulated UK activities.

The value of the adjustments for these factors is inherently uncertain, which represents one of the key practical difficulties with estimating adjusted MARs. Nevertheless, to assess the likely value impact of the above adjustments on National Grid, Severn Trent and United Utilities' valuation and MAR, we collected estimates for each of the above factors from independent equity analyst reports, which we present in Table A.1 to Table A.4.

One other possible adjustment would be for outperformance of regulatory assumptions, e.g. outperformance on costs under the totex incentive mechanism. For the purposes of estimating a notional gearing, as proposed by Indepen, we do not consider that we should adjust the MARs for outperformance, given that this outperformance is a reason why the enterprise value could be different from RAB in the UK-regulated business segment. We

note that if we adjusted for outperformance, this would result in lower adjusted MARs than those presented in the following sections.[123]

A.2. Adjustments to MARs for NG are volatile, but consistent with an adjusted MAR of 1 for UK-regulated business

The enterprise value of NG is driven by a number of factors which are unrelated to the cost of capital for UK regulated networks and which need to be removed from the raw MAR estimates to calculate an adjusted MAR for NG's UK transmission and distribution business. The factors for which we adjust the MAR are:

- **US regulated business**: The NG enterprise value includes the company's assets and operations in the United States, which include electricity transmission and distribution facilities, as well as gas distribution networks;[124]
- **Non-regulated activities**: The NG enterprise value also includes the impact of the company's non-regulated activities, such as interconnectors, LNG operations, UK gas metering, UK property management, and US non-regulated businesses.[125]

As explained in the previous section, we collected analyst reports to assess the weight of these activities as a proportion of the UK RAB. We present separate estimates for the value of the adjustments for the period prior to, and post, NG's partial sale of its gas distribution business in March 2017. The partial sale of its gas distribution businesses resulted in a reduction of the UK transmission and distribution RAB and in turn increased the relative size of the adjustments for the non-regulated businesses. Table A.1 and Table A.2 show the analyst report valuations considered.

[123] In a previous report for National Grid we have estimated adjusted MARs accounting for outperformance on regulatory assumptions. Source: NERA (2017), Implications of Observed Market-to-Asset Ratios for Cost of Equity at RIIO-T2.

[124] National Grid, Annual Report and Accounts 2017/18, p.3.

[125] National Grid, Annual Report and Accounts 2017/18, p.3.

Table A.1: Analyst Estimates of Value of US Business and Non-Regulated Activities as Percentage of UK RAB (Pre-NGGD Transaction)

Analyst	Report date	US Activities	Non-regulated activities
JPMorgan	30-Jan-13	50%	15%
RBC	25-Mar-13	62%	17%
RBC	20-May-14	70%	18%
Deutsche Bank	12-Jun-14	50%	12%
RBC	11-Sep-14	66%	17%
Societe Generale	09-Oct-14	59%	12%
Societe Generale	12-Nov-14	59%	13%
Deutsche Bank	19-Nov-14	53%	14%
Edison	12-Jan-15	59%	15%
Investec	10-Mar-15	54%	16%
RBC	29-May-15	72%	16%
JPMorgan	04-May-16	75%	16%
Investec	27-May-16	74%	19%
Range of Estimates		50% - 75%	12% - 19%

Source: JPMorgan (January 2013), p.14; RBC (March 2013), p.11; RBC (May 2014), p.8; Deutsche Bank (June 2014), p.6; RBC (September 2014), p.7; Societe Generale (Oct 2014), p.94; Societe Generale (November 2014), p.5; Deutsche Bank (November 2014), p.8; Edison (January 2015), p.14; Investec (March 2015), p.25; RBC (May 2015), p.9; JPMorgan (May 2016), p.7; Investec (May 2016), p.2.

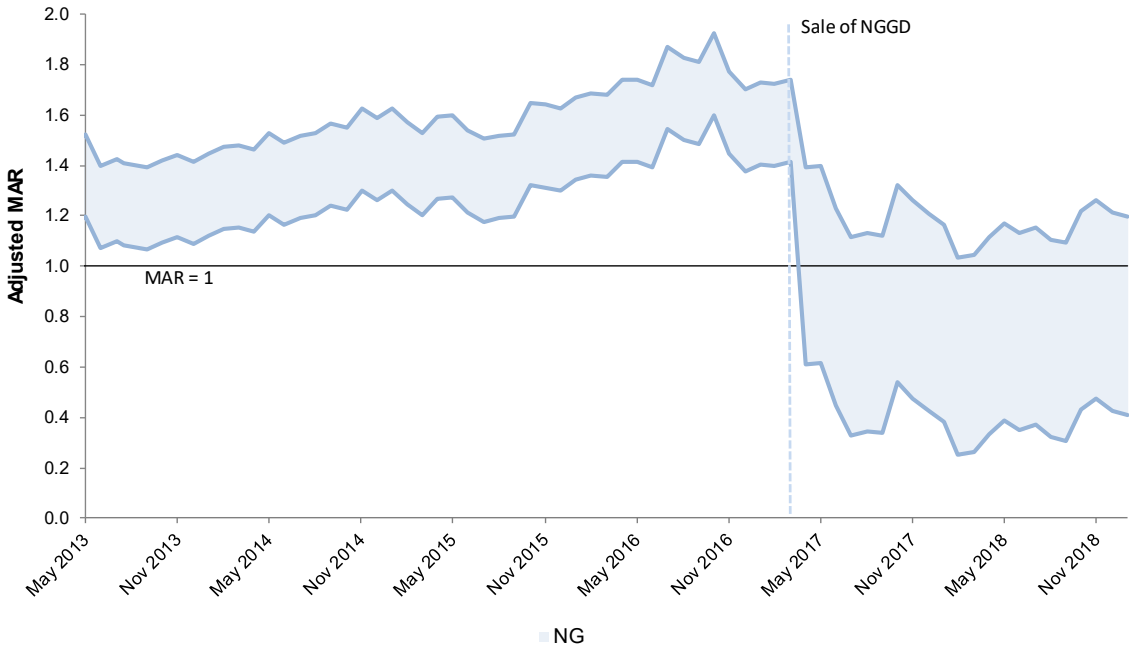
Table A.2: Analyst Estimates of Value of US Business and Non-Regulated Activities as Percentage of UK RAB (Post-NGGD Transaction)

Analyst	Report date	US activities	Non-regulated activities
JPMorgan	31-Mar-17	112%	19%
Edison	28-Apr-17	93%	26%
Edison	04-May-17	93%	26%
JPMorgan	18-Aug-17	129%	22%
JPMorgan	14-Nov-17	129%	22%
RBC	11-Dec-17	128%	27%
JPMorgan	22-Jan-18	141%	19%
JPMorgan	23-Jan-18	141%	19%
JPMorgan	02-Mar-18	133%	17%
Societe Generale	18-May-18	98%	24%
JPMorgan	31-May-18	126%	18%
RBC	03-Aug-18	143%	29%
JPMorgan	08-Nov-18	126%	18%
Societe Generale	08-Nov-18	109%	25%
JPMorgan	11-Dec-18	159%	20%
Range of Estimates		**93% - 159%**	**17% - 29%**

Source: JPMorgan (March 2017), p.4; Edison (April 2017), p.11; Edison (May 2017), p.11; JPMorgan (August 2017), p.4; JPMorgan (November 2017), p.4; RBC (December 2017), p.9; JPMorgan (January 2018), p.2; JPMorgan (January 2018), p.2; JPMorgan (March 2018), p.15; Societe Generale (May 2018), p.6; JPMorgan (May 2018), p.12; RBC (August 2018), p.9; JPMorgan (November 2018), p.3; Societe Generale (November 2018), p.6; JPMorgan (December 2018), p.25.

Based on the analyst reports collected, we estimated a range for each of the adjustments: US activities and non-regulated activities. To calculate the adjusted MAR, we then removed these values from the raw MAR. We present our estimates of National Grid's adjusted MAR in Figure A.2.

Figure A.2: National Grid's Adjusted RAB Estimates are Consistent with a MAR of 1



Note: Ranges for adjustments are calculated based on min and max of all analyst estimates. We apply two sets of adjustments: one pre-sale of National Grid Gas Distribution (NGGD and one post-sale. We assume that the ranges estimated for each period can be applied throughout the duration of the same period.
Source: Equity analyst reports.

As shown in Figure A.2, analysts' estimates of the value of the adjustments are subject to a large degree of uncertainty. In the period since the start of RIIO-T1/GD1 until the sale of NGGD, we estimate National Grid's adjusted MAR lies in a wide interval of approximately c.1 to 1.9. More recently, after the sale of NGGD, we estimate a range of c.0.3 to 1.2.

In summary, we consider that the MAR evidence for National Grid does not support a value different from 1, i.e. no RAB premium. While evidence prior to the sale of NGGD pointed towards higher MARs, recent evidence points to ratios much closer to 1 and possibly lower.

A.3. Adjustments to Water Comparators provides us with MARs consistent with 1

Similar to National Grid, the enterprise value of water companies is driven by factors which are unrelated to the regulated UK business and which need to be removed from the raw MAR

estimates to calculate an adjusted MAR for the wholesale business (for which the water RAB is measured). As with National Grid, one of the factors we must adjust for is the non-regulated activities, as these are not taken into account in the RAB.

In the case of water companies, one additional factor is non-wholesale regulated activities. In PR14, Ofwat introduced separate wholesale and retail controls, with the RAB going forward only relating to wholesale controls. As a result, the value of all other non-wholesale regulated activities[126] needs to be removed to arrive at a market value for the wholesale regulated business only, which can be compared to the wholesale RAB. Table A.3 and Table A.4 show the analyst report valuations considered.

Table A.3: Analyst Estimates of Value of Non-Regulated Activities as Percentage of UK RAB

Analyst	Report Date	Severn Trent	United Utilities
Societe Generale	29-Mar-16	3%	1%
RBC	05-Oct-16	4%	2%
Societe Generale	13-Oct-16	7%	3%
RBC	30-Jan-17	n/a	2%
JPMorgan	23 & 25 May 2017	2%	1%
RBC	31-Jul-17	5%	2%
JPMorgan	09-Mar-18	2%	1%
Deutsche Bank	01-Jun-18	3%	1%
RBC	26-Nov-18	5%	1%
Range of Estimates		**2% - 7%**	**1% - 3%**

Source: Societe Generale (March 2016), United Utilities, p.6; Societe Generale (March 2016), Severn Trent, p.2; RBC (October 2016), UK Water: RORE and valuations, p.12; Societe Generale (October 2016), United Utilities, p.11; RBC (January 2017), United Utilities Group, PLC, p.3; JPMorgan (May 2017), Severn Trent, p.2; JP Morgan (May 2017), United Utilities, p.2; RBC (July 2017), United Utilities Group PLC, p.4; RBC (July 2017), Severn Trent PLC, p.4; JPMorgan (March 2018), United Utilities, p.19; JPMorgan (March 2018), Severn Trent, p.23; Deutsche Bank (June 2018), p.15; RBC (November 2018), United Utilities, p.3; RBC (November 2018), Severn Trent, p.3.

Table A.4: Analyst Estimates of Non-Wholesale Regulated Activities as Percentage of UK RAB

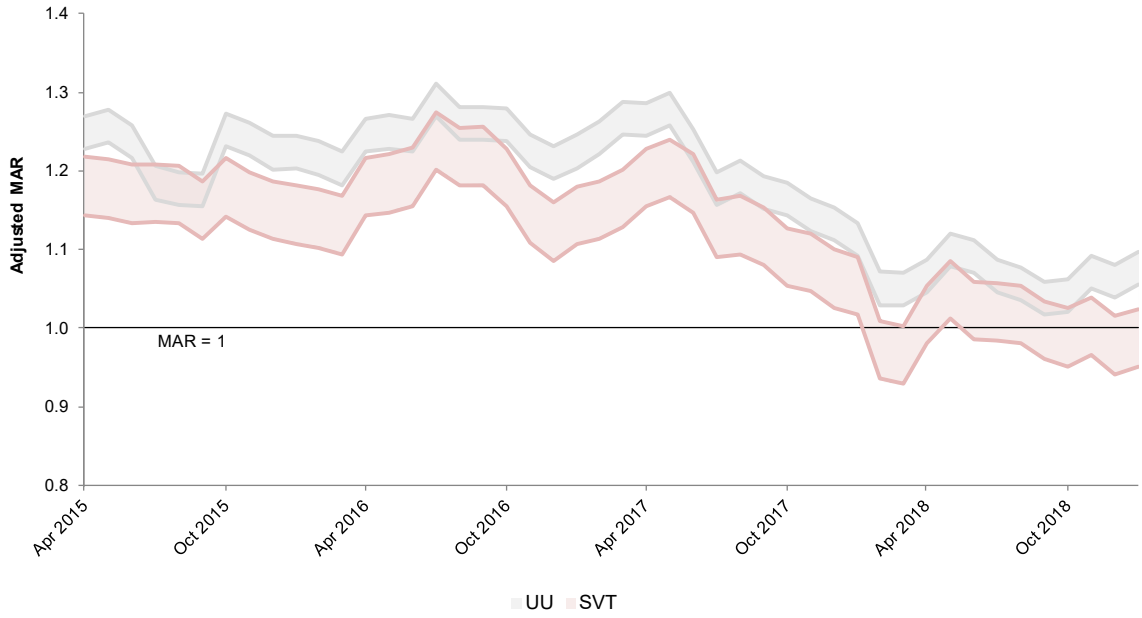
Analyst	Report date	Severn Trent	United Utilities
RBC	05-Oct-16	6%	1%
RBC	30-Jan-17	n/a	1%
RBC	31-Jul-17	7%	3%
RBC	26-Nov-18	4%	2%
Range of estimates		**4% - 7%**	**1% - 3%**

Source: RBC (October 2016), UK Water: RORE and valuations, p.12; RBC (January 2017), United Utilities Group, PLC, p.3; RBC (July 2017), United Utilities Group PLC, p.4; RBC (July 2017), Severn Trent PLC, p.4; RBC (November 2018), United Utilities, p.3; RBC (November 2018), Severn Trent, p.3.

[126] Most notably household retail, as non-household retail is typically classified by analysts as a non-regulated activity following recent market opening.

We estimate the adjusted MAR for water companies using the same method as for National Grid described above. We present our estimates of Severn Trent and United Utilities adjusted MARs in Figure A.3.

Figure A.3: Severn Trent and United Utilities Adjusted MARs are Consistent with a MAR of 1



Note: Ranges for adjustments are calculated based on min and max of all analyst estimates. We assume that the ranges estimated for each company can be applied throughout the duration of the estimation window.
Source: Equity analyst reports.

While still providing relatively wide estimates, the adjusted MAR intervals are narrower than National Grid's ranges, given the smaller share of non-UK regulated activities for these companies compared to National Grid. Recent drops in the adjusted MARs, coinciding with the publication of Ofwat's PR19 consultation, resulted in ranges of approximately 0.9 to 1.2 for Severn Trent and 1 to 1.2 for United Utilities, since April 2018 (after which adjusted MARs became relatively more stable).

As with National Grid, we conclude that there is no conclusive evidence that the adjusted MARs for water wholesale businesses are different from 1.

Appendix B. European Comparator's and National Grid's Beta Decomposition Evidence

In this appendix, we present the evidence used to support our asset beta range for National Grid. This includes the estimation of asset betas for international comparators, as well as the estimation of betas of US comparators for the purposes of decomposing National Grid's asset beta.

B.1. European Comparators Evidence

In Section 6, we presented arguments on why international comparators should be used to inform the asset beta of a UK energy company. We have focused on Spanish and Italian networks betas as these provide a reasonable benchmark for the risk faced by UK energy networks, as can be seen from the relative risk analysis in Section 6.2. We note that there are other listed European network companies (e.g. Elia, Fluxys), but their stocks have generally been illiquid and hence are not included in this analysis.

Table B.1 below provides the most recent asset beta estimates for these comparators, for a range of estimation windows. This evidence supports an asset beta of around 0.4 over the most recent 2-year period.

Table B.1: Empirical Asset Beta Estimates for Listed European Utilities

	Country	1Y	2Y	5Y
Snam (GT)	Italy	0.38	0.45	0.44
Terna (ET)	Italy	0.35	0.43	0.43
Acea (ED)	Italy	0.35	0.44	0.36
Enagas (GT)	Spain	0.30	0.35	0.36
Red Electrica (ET)	Spain	0.23	0.34	0.39
Naturgy (GD)	Spain	0.42	0.43	0.47
Average		**0.34**	**0.40**	**0.41**

Source: Bloomberg, NERA analysis, cut-off: 8 February 2019, daily data, reference index: Eurostoxx. assumed debt beta of 0.

B.2. National Grid's Beta Decomposition Evidence

In Section 3, we presented our view on why a beta decomposition for National Grid, separating the risk faced by its UK and US businesses, is warranted and supported it based on finance theory and regulatory precedent.

In order to obtain a measure of the systematic riskiness of National Grid's UK regulated business, we decompose its group asset beta into a UK and US asset beta, based on the equation below.[127]

[127] National Grid (17 May 2018), 2017/18 Full Year Results, p.13-15. This calculation only takes into account National Grid's remaining 39% stake in its former gas distribution business, whose regulated asset base is reported by Cadent Annual Report 2017/2018, p.1.

(7) $$\beta_{National\ Grid} = \frac{Regulated\ assets\ in\ UK}{Total\ regulated\ assets} * \beta_{UK} + \frac{Regulated\ assets\ in\ US}{Total\ regulated\ assets} * \beta_{US}$$

$$\beta_{National\ Grid} = 59\% * \beta_{UK} + 41\% * \beta_{US}$$

In order to estimate the beta associated with National Grid's US regulated businesses (β_{US}), we have identified a preliminary sample of twenty network comparators in the US. This is the same set of comparators as those identified in our previous report for National Grid.[128] We selected these comparators based on networks operating exclusively in the US, and principally engaged in regulated energy network, retail, or generation activities, as well as ensuring that the stocks met standard liquidity thresholds.[129] Of this initial set of comparators, three comparators operate in the same states, and hence similar regulatory regimes, as National Grid. In particular, Consolidated Edison operates in New York (where National Grid USA has about 56 per cent of its regulated assets), and Unitil Corp and Eversource Energy have significant operations in Massachusetts, New Hampshire (and Maine), where about 30 per cent of National Grid USA's regulated assets are located.

Table B.2 and Table B.3 summarise the asset betas of the three companies mentioned and the full set of comparators, over different estimation windows. We start by estimating the asset beta for National Grid without any adjustment for different business segments. We then estimate an asset beta for its US operations based on the average asset beta of US comparators (in Table B.2 this beta is based on the three most comparable firms, while in Table B.3 it is based on the full set of comparators). In both cases, and over both estimation windows, the average asset betas for US operations are below that of National Grid's group. Finally, to derive an asset beta for UK operations, we apply the formula above in Equation (7).

Table B.2: National Grid's UK Beta Ranges from 0.49 to 0.57 Based on the Three Most Direct Comparators

	National Grid overall	US	UK
Share of regulated assets		41%	59%
2Y asset beta	0.39	0.13	**0.57**
5Y asset beta	0.38	0.21	**0.49**

Source: Bloomberg, NERA analysis; cut-off: 8 February 2019, daily data, reference index: FTSE All Share for National Grid overall and S&P500 for US comparators; assumed debt beta of 0.

[128] NERA (April 2018), RIIO-T2 Beta and Risk Assessment, For National Grid, p.15. Out of these 22 comparators, we removed Great Plains Energy and WGL Holdings, as these companies were acquired in June and July 2018, respectively.

[129] We look at bid-ask spreads as a proxy for the liquidity of the listing. We consider stocks with bid-ask spreads above 1 per cent to meet liquidity threshold, based on UK and European regulatory approaches. See for example, NERA (2016) Update of the Equity Beta and Asset Beta for BT, A report for Ofcom. Section A4, pp 58-59. Link: https://www.ofcom.org.uk/__data/assets/pdf_file/0028/97039/annex_31.pdf

Table B.3: National Grid's UK Beta Ranges from 0.46 to 0.55 Based on the Full Set of Comparators

	National Grid overall	US	UK
Share of regulated assets		41%	59%
2Y asset beta	0.39	0.16	**0.55**
5Y asset beta	0.38	0.26	**0.46**

Source: Bloomberg, NERA analysis; cut-off: 8 February 2019, daily data, reference index: FTSE All Share for National Grid overall and S&P500 for US comparators; assumed debt beta of 0.

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