Regional factors for RIIO-GD3: sparsity

Prepared for Wales & West Utilities

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Contents

Figures and Tables

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Executive summary

Ofgem's recent RIIO-3 Sector Specific Methodology Decision (SSMD) indicates that it will broadly take the same general approach to pre-model adjustments for regional factors as it did in RIIO-GD2. However, Ofgem is also testing a density (and density squared) variable within-model to account for both urbanity and sparsity effects.[1] We note that a within-model solution for both sparsity and urbanity effects appears unlikely due to practical limitations (discussed below).

Currently, a sparsity adjustment applies to emergency and repair costs. Evidence submitted by WWU to Ofgem and the CMA during RIIO-GD2 demonstrated a similarly strong operational rationale for extending these adjustments to other cost categories, particularly REPEX and maintenance costs, due to the similarities in day-to-day activities.[2]

Activities in sparsely populated regions incur higher costs due to factors outside of management control, including:

- **increased number of local depots** required;
- **higher travel costs** resulting from longer distances and less-developed road infrastructure or challenging topographies;
- **greater distances to quarries and mines** for tipping and materials;
- **elevated labour costs**, for both direct labour and third-party contractors (e.g. a greater number of engineers are required per customer for emergency and related costs[3]).

During the GD2 appeals, the CMA stated that WWU needed (but at the time failed) to show 'to what extent firms with sparser regions should have structurally higher costs than those with more densely populated

[1] Ofgem (2024), 'RIIO-3 Sector Specific Methodology Decision – GD Annex', 18 July, paras. 5.30–5.35, 5.54, 5.67, 5.80–5.81.
[2] Wales & West Utilities (2021), 'Notice of appeal Energy Licence modification RIIO-GD2 Price Control (2021-2026)', section C4. See also Oxera (2019), 'Regional factors in the cost assessment for GD2', 29 November, section 3.2; Oxera (2020), 'A review of Ofgem's cost assessment approach in the RIIO-GD2 Draft Determination', 4 September, paras 4.1–4.18.
[3] For emergency costs, a minimum number of engineers per area are required to be on standby (or carrying out alternative work, such as repairs, when possible), so that they are able to attend escapes within the time standard required. We understand that these same engineers are employed to conduct related repairs, REPEX and maintenance activities.

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regions, or to what extent we should expect an increase in costs, as WWU's profile of work moves from urban to rural areas'.[4]

This report addresses these concerns by:

- assessing top-down evidence for structurally higher costs in sparsely populated regions for emergency, repair, maintenance, and REPEX activities;[5]
- analysing WWU's granular mains replacement data to evaluate whether costs rise as similar workloads shift to sparser areas.

Results

We find strong empirical evidence to support a sparsity claim for all four activities (emergency, repair, maintenance and REPEX). The results, shown in the figures below, are also robust to a range of sensitivities.

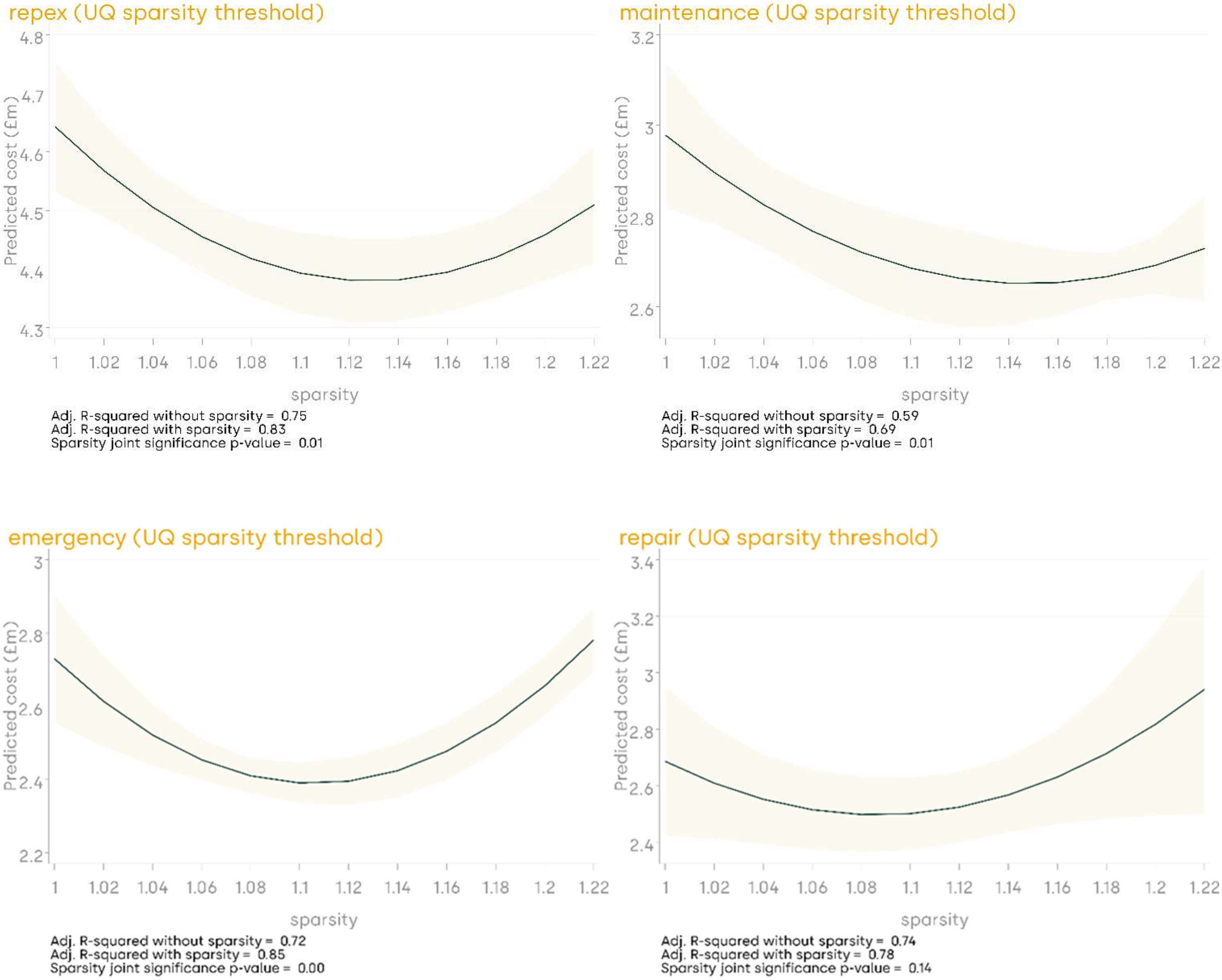
- **Our top-down analysis** illustrates the positive U-shaped relationship between sparsity and costs for an average GDN, using Ofgem's current cost drivers and an upper quartile (UQ) sparsity metric.
- **A bottom-up analysis** of WWU's REPEX data demonstrates rising unit costs as workloads shift to increasingly sparse areas.

At GD2, Ofgem's sparsity index classified all areas below average Great Britain population density as sparse. However, the average threshold was not based on operational insight and, in practice, the costs associated with sparsity only begin to manifest at higher levels (as other GDNs have noted[6]).

We therefore use a more stringent upper quartile (UQ) threshold to capture the effect of workloads in truly sparse and more remote areas. Among the various sparsity and density metrics tested, UQ sparsity performs best from both an operational and statistical perspective (discussed in section 4.1).

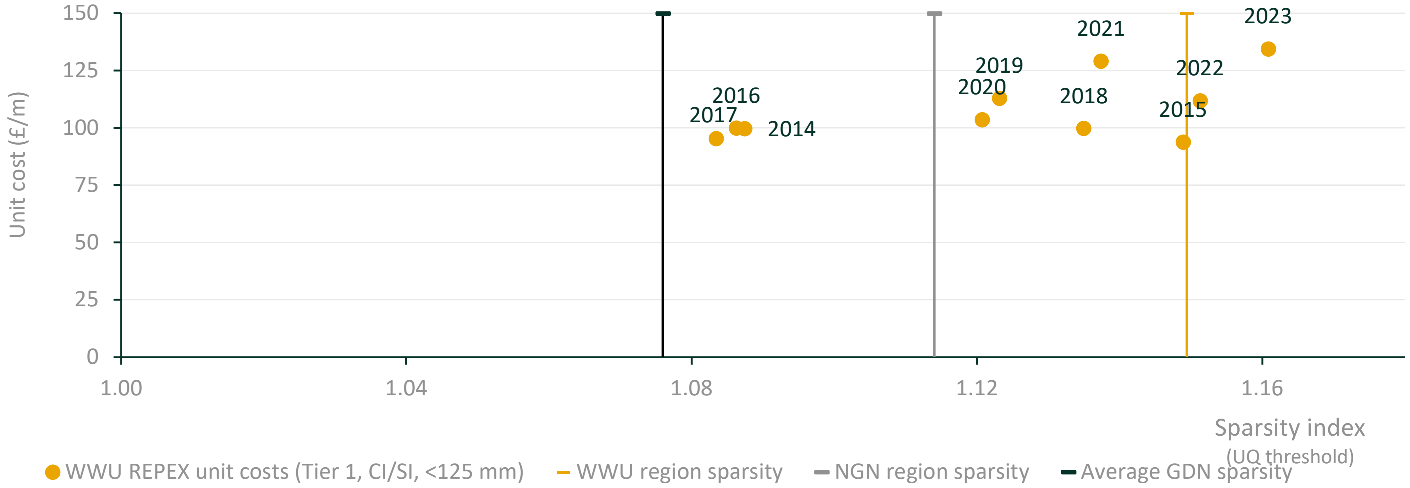
[4] Competition and Markets Authority (2021), 'Cadent Gas Limited, National Grid Electricity Transmission plc, National Grid Gas plc, Northern Gas Networks Limited, Scottish Hydro Electric Transmission plc, Southern Gas Networks plc and Scotland Gas Networks plc, SP Transmission plc, Wales & West Utilities Limited vs the Gas and Electricity Markets Authority. Final determination. Volume 3: Individual grounds', 28 October, para. 15.67.
[5] We do so for the main areas of cost where this effect can be modelled robustly: emergency, repair, maintenance and REPEX.
[6] Northern Gas Networks (2024), 'RIIO-3 Sector Specific Methodology Consultation Overview & GD annex - NGN Response', pp. 65–66. This is also parallel to the 'high density' metric proposed by Cadent at CAWG 15—see Cadent (2024), 'GD3 proposals for cost exclusions and regional/company-specific factors', 12 November, slide 23.

Top-down modelled impact of sparsity on select costs



Note: Top down analysis based on 2014–23 outturn period; shaded areas represent the 95% confidence intervals; outturn models include a single time trend.
Sources: Oxera top-down analysis based on Ofgem updated cost assessment dataset (November 2023).

WWU's high-volume, Tier 1 REPEX unit costs by sparsity



Notes: Bottom-up analysis based on gross unit costs for relevant mains.
Sources: Oxera bottom-up analysis based on WWU workload data (metres replaced) and Ofgem's REPEX cost and volume data (as at November 2023).

Implications for Ofgem's approach

Our analysis suggests that REPEX and maintenance costs require additional sparsity adjustments, alongside existing adjustments for emergency and repairs. It also highlights the following key implications for Ofgem's approach.

- **Pre-model adjustments are still required:** while within-model adjustments for sparsity and urbanity would be ideal in theory, this is not possible given the practical limitations of the current framework (e.g. small sample size, London-specific bias, and the risk of double-counting regional wage impacts). Bottom-up evidence and pre-modelling adjustments thus remain the most reliable approach.
- **An UQ sparsity metric is more appropriate:** it more precisely captures the effect of workloads in truly sparse and more remote areas, and performs the best among alternative metrics.
- **More granular data needed**: more detailed workload distribution data should be considered to refine sparsity cost assessments during RIIO-GD3—especially for REPEX. Proxy measures are too imprecise to capture the underlying workload impacts.
- **Cost model specification affects adjustments**: the extent of pre-modelling adjustments eventually required will depend on Ofgem's final GD3 cost model suite. For example, alternative scale drivers to MEAV, such as customer numbers or throughput, would necessitate larger sparsity adjustments for GDNs with sparser workloads.

1 Introduction

In the cost assessment for RIIO-GD3, Ofgem will need to benchmark the costs of the gas distribution networks (GDNs) against each other. In order to ensure a like-for-like comparison, any regional- or company-specific factors that result in material cost differences between the GDNs should be captured, either within the cost drivers in the model or using pre-modelling adjustments.

Ofgem's recent RIIO-3 Sector Specific Methodology Decision (SSMD) for gas distribution (GD) summarises Ofgem's intended modelling approach for GD3. While Ofgem has not made any definitive decisions, it has indicated that the GD2 framework will largely form the basis for the GD3 approach and the specific model testing and alterations that it is considering. For regional factors, Ofgem highlights two specific considerations and potential changes for GD3.

- **Regional wages recalibration**, revaluating the activities covered and noting that London wages have increased more slowly than the rest of the UK.
- **Testing within-model density controls**, testing a density (and density squared) variable within-model to account for both urbanity and sparsity effects.[7]

We agree that regional wage convergence and sparsity/urbanity effects are the two main categories of regional factors that that should be re-examined and potentially changed, as we consider that both are unlikely to be either sufficiently or correctly captured in Ofgem's existing cost drivers.[8] This report focuses on sparsity and urbanity, specifically sparsity,[9] and is structured as follows:

- section 2 provides the historical context and continued operational rationale for WWU's sparsity factor claim;
- section 3 summarises our approach and methodology;
- section 4 summarises the main results;
- section 5 concludes with implications for Ofgem's approach to regional factor adjustments for sparsity (and urbanity) at GD3.

[7] Ofgem (2024), 'RIIO-3 Sector Specific Methodology Decision – GD Annex', 18 July, paras. 5.46–5.47.
[8] As the final GD3 models are not yet known, this would need to be re-evaluated when Ofgem has published these models.
[9] See also accompanying report discussing regional wage adjustments: Oxera (2024), 'Regional factors for RIIO-GD3: Regional wages', November, Report prepared for Wales & West Utilities.

2 Context

At GD2, Ofgem applied a regional cost pre-modelling adjustment for sparsity to WWU's emergency and repairs costs. However, it did not accept evidence presented by WWU that similar regional adjustments are required for other cost categories—most notably REPEX (subsequently appealed at the CMA[10]) where a similar or the same workforce is used, as well as other areas (such as maintenance, connections and property management costs[11]).

The operational rationale for the claim is that activities undertaken in sparse regions are more costly for geographical and topographical reasons outside of management control. This is because of:

- the need for more local depots;
- greater travel costs (as sparser areas also have less-developed road infrastructure and/or difficult topographies);
- larger distances to quarries and mines (for tipping and materials);
- increased labour costs, for both direct labour and third-party contractors (e.g. a greater number of engineers are required per customer for emergency and closely related activities[12]).

WWU appealed Ofgem's decision not to allow a sparsity adjustment to its REPEX costs.[13] In its final decision, the CMA acknowledged that the evidence provided by WWU illustrated a U-shaped impact of sparsity and urbanity on *its own* REPEX costs (that is, relatively high costs in both WWU's sparse and dense regions).[14] However, the CMA stated that WWU did not provide the appropriate evidence to illustrate 'how the overall

[10] Competition and Markets Authority (2021), 'Cadent Gas Limited, National Grid Electricity Transmission plc, National Grid Gas plc, Northern Gas Networks Limited, Scottish Hydro Electric Transmission plc, Southern Gas Networks plc and Scotland Gas Networks plc, SP Transmission plc, Wales & West Utilities Limited vs the Gas and Electricity Markets Authority. Final determination. Volume 3: Individual grounds' [the 'GD2 appeals final determination'], 28 October, section 15.
[11] For a full list, see Oxera (2019), 'Regional factors in the cost assessment for GD2', 29 November, Table 3.3, reiterated in Oxera (2020), 'A review of Ofgem's cost assessment approach in the RIIO-GD2 Draft Determination', 4 September, paras 4.1–4.18.
[12] For emergency costs, a minimum number of engineers per area are required to be on standby (or carrying out alternative work, such as repairs, when possible), so that they are able to attend escapes within the time standard required. In Ofgem's current TOTEX modelling suite, the number of customers is assumed to be the greatest cost driver for emergency costs, reaffirming the need for a sparsity adjustment in a sparse region such as Wales and the South West of England. We understand that these same engineers are employed to conduct related repairs, REPEX and maintenance activities.
[13] Wales & West Utilities (2021), 'Notice of appeal Energy Licence modification RIIO-GD2 Price Control (2021-2026)', section C4.
[14] Competition and Markets Authority (2021), 'GD2 appeals final determination', paras 15.56, 15.65, 15.67–68.

costs of a network in a sparse region would compare with one in a densely populated region'.[15] In particular, the CMA stated that WWU needed (but failed) to show:

- the extent to which GDNs in sparser regions have structurally higher costs than those with denser regions;
- the extent to which one should expect an increase in REPEX costs as WWU's profile of work moves from more urban to rural areas (in effect, whether WWU's workload moves from a lower to a higher point in the U shape).[16]

We address these two points in this report.

[15] Ibid., para. 15.68.
[16] Ibid., para. 15.67.

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3 Methodology

Given the evidential bar set by the CMA, we assess two types of evidence (where the data and models are sufficiently robust to do so).

- **Top down**: whether there is structural evidence of a U-shaped impact of sparsity across GDNs for emergency, repair, maintenance and REPEX activities (the former two represent existing adjustments made by Ofgem, the latter two areas where Ofgem currently makes no adjustments);
- **Bottom up**: for REPEX, given the granularity of data available from WWU, we assess whether the costs of WWU's current and expected workload distribution would suggest that it is moving from a lower to a higher point on the U curve.

The top-down approach entails remodelling the relevant disaggregated cost categories, but without prior regional factor adjustments (for labour, sparsity and urbanity), and adding the relevant sparsity/density metrics directly to the models as a cost driver instead. An improved model performance and U-shaped sign on the sparsity/density coefficient thus provides structural evidence of a need for an adjustment. We model outturn performance over 2014–23.[17]

We also conduct the following sensitivities in the top-down approach:

- we assess the impact of sparsity/density drivers with Ofgem's regional wage index added (though, given the potential collinearity between density and wages, we expect more precise sparsity estimates without the wages variable);
- we assess results with several sparsity/density metrics, and the characteristics of each metric (to select a preferred metric);
- we assess the sensitivity of results to potential outliers and influential observations.

Given the sample size and lack of granularity of the top-down models[18] (and related overfitting/influential observation concerns), we also consider bottom-up evidence for WWU's REPEX costs. WWU's internal REPEX cost models are detailed and contain highly disaggregated information. This enables us to plot WWU's REPEX unit costs for (roughly)

[17] Based on the latest available outturn data from Ofgem, as shared with WWU in November 2023.
[18] That is, company-level aggregate measures of sparsity/urbanity are, at best, proxies for where GDNs' respective emergency, repairs, mains replacement, etc., workloads occur in practice (and how the sparsity or urbanity of these areas affects relative cost).

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the equivalent mains replacement work and estimate the impact on driving times, as REPEX workloads have moved from urban to sparser areas over time.[19]

Such a movement is outside of WWU's control as the location of WWU's REPEX programme is determined by Health and Safety Executive (HSE) policy (and changes therein). Specifically, the sequencing of workloads is determined by the current three-tier, risk-based approach of the Iron Mains Risk Reduction Programme, which has been refined/adjusted by the HSE on a regular basis.[20]

We also note the need for a more stringent sparsity threshold. We have tested an array of potential sparsity/density metrics, drawing on those previously considered by Ofgem and Ofwat.[21] However, as discussed below, a sparsity index with a higher upper-quartile (UQ) sparsity threshold across local authorities (LAs) performs the best from both an operational and statistical perspective.

At GD2, Ofgem's sparsity index classified all areas below Great Britain's (GB) average population density as sparse. However, the GB average threshold chosen at GD2 was not based on operational insight. In practice, costs associated with sparsity only begin to manifest at higher levels of sparsity (as other GDNs have noted,[22] and parallel to the 'high density' metric proposed[23]).

We have thus chosen a more stringent upper-quartile (UQ) threshold, to capture more appropriately the operational dynamic underlying the adjustment. Because the sparsity metric acts as a proxy for the workloads in the more remote areas of GB—those rural areas that are

[19] Both analyses will need to be updated with more recent forecast data for the remainder of GD2 and GD3, once available.

[20] As explained by WWU in its engagements with Ofgem. See, for example, Wales & West Utilities (2023), 'BPDT & RRP feedback, CAWG meeting 2', 16 November; Wales & West Utilities (2024), 'Repex', CAWG meeting 5, 27 February.

[21] We focus on those metrics that could be appropriate in the context of a sparsity adjustment: (i) Ofgem's GD2 sparsity index (with a GB average-level threshold); (ii) an updated sparsity index with a tighter threshold (with LAs classified as sparse if they are below the UQ sparsity level, instead of the GB average); (iii) an aggregate network density metric (measured as a GDN's total customers per length of main, a metric also assessed by Ofgem in the GD3 cost assessment working groups, CAWGs); (iv) a weighted average area density metric (defined as people per km^2 in a given LA, weighted by LA population, the density metric used by Ofwat in its base cost modelling suite).

[22] Northern Gas Networks (2024), 'RIIO-3 Sector Specific Methodology Consultation Overview & GD annex - NGN Response', pp. 65–66.

[23] At CAWG 15, Cadent proposed three potential density metrics that it considers appropriate for their proposed within-model density adjustment, one of which is 'high density'. This metric is based on a weighted average density per LA, similar to the WAD metric discussed in section 4.1 below, but only considers LAs with a population concentration greater than 2,000 people per square kilometre. Cadent (2024), 'GD3 proposals for cost exclusions and regional/company-specific factors', 12 November, slide 23.

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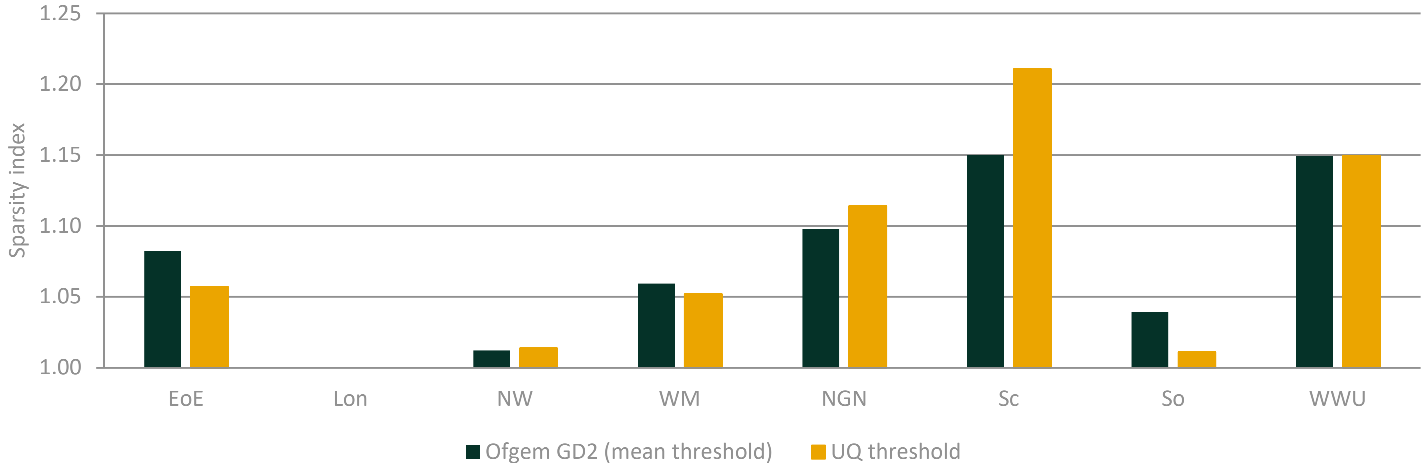
more distant from depots, tipping points and quarries, require significant travel times to reach and/or more employees—the sparsity index should also only capture workloads in these truly sparse, more remote areas.

Figure 3.1 below shows that certain networks (e.g. Sc, NGN) have a greater proportion of very sparse areas than suggested by the GD2/mean threshold index.[24] Conversely, others (e.g. So, WM) have fewer areas that are very sparse. Overall, the relative rankings of the UQ metric aligns with where general intuition would suggest the truly remote, rural, areas in GB are (reaffirmed in the weighted average population/region density metrics in Figure 4.4 below).

Figure 3.1 GDNs' average sparsity index with mean and UQ thresholds



Note: Average index over GD1 and GD2.
Source: Oxera based on Ofgem's regional adjustment indices dataset (November 2023).

[24] At least when measured on the basis of the regions weighted average populations density across LAs (as opposed to the sparsity of actual workloads).

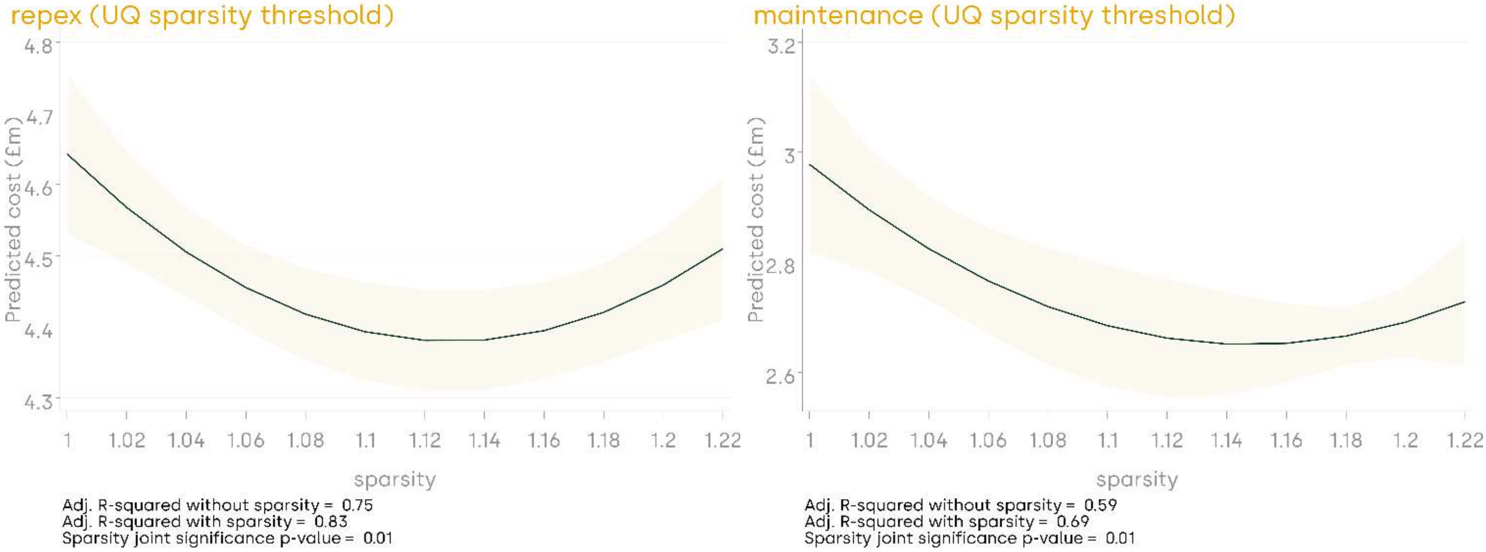
4 Results

Section 4.1 summarises the main results from top down modelling and Section 4.2 presents bottom-up evidence on REPEX unit costs, as similar workloads have moved to sparser areas over time.

4.1 Top-down modelling

We find structural evidence of a U-shaped sparsity impact on REPEX and maintenance, supporting new claims. This is based on disaggregated regression modelling using Ofgem's current GD2 cost drivers (corresponding to the respective cost areas[25]), and using the UQ sparsity metric (as the metric with both the best statistical fit and operational justification). The curve in Figure 4.1 shows the estimated relationship between sparsity and costs for the notional average GDN across the period,[26] with levels of sparsity increasing from left to right.

Figure 4.1 Impact of sparsity on REPEX and maintenance costs



Notes: Analysis on 2014–23 outturn period; shaded area = 95% confidence interval; outturn models include a single time trend.
Source: Oxera based on Ofgem's updated cost assessment dataset (November 2023).

[25] The corresponding composite scale variable (CSV) cost drivers for each of the following cost categories are: (i) emergency CSV—customer numbers (80% weighting) and external condition reports (20% weighting); (ii) repairs CSV—external condition reports; (iii) maintenance CSV—'maintenance' modern equivalent asset value (i.e. the asset value of above-ground assets); (iv) REPEX CSV—a synthetic cost of REPEX workload (in effect, a composite unit cost, accounting for different types of mains replaced and related services).
[26] That is, using the 'margins' function in Stata, plotting the predicted costs over sparsity at the mean of Ofgem's standard cost drivers in the respective model (the corresponding CSV and time trends in Ofgem's modelling).

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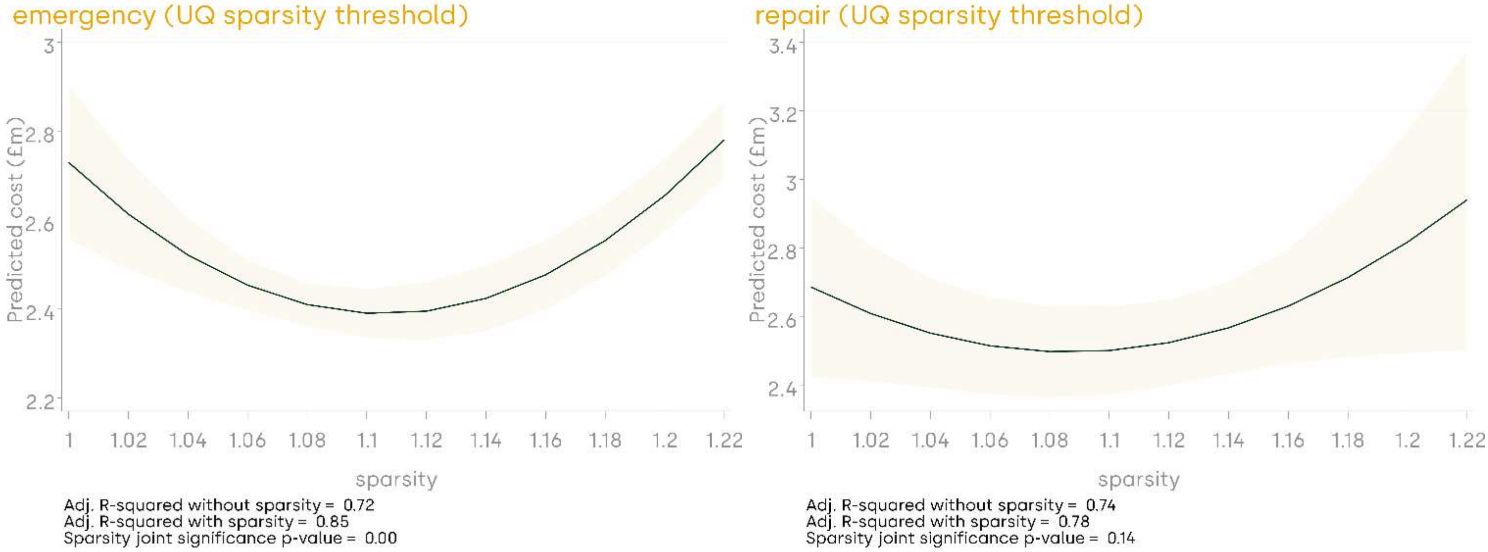
Top-down modelling also reaffirms that the current emergency and repairs claims should be retained. Figure 4.2 shows the U-shape sparsity estimates on each of these respective costs.

Figure 4.2 Impact of sparsity on emergency and repair costs



Notes: Analysis on 2014–23 outturn period; shaded area = 95% confidence interval; outturn models include a single time trend.
Source: Oxera based on Ofgem's updated cost assessment dataset (November 2023).

In all the cases above, the inclusion of a quadratic sparsity term improves the models in all respects: the model fit improves,[27] the sparsity term is of the expected sign and it is precisely estimated.[28]

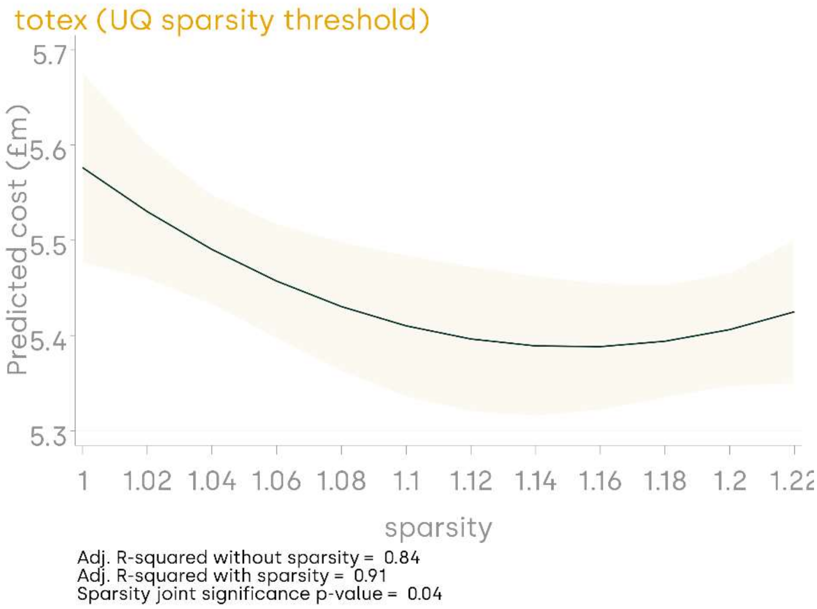
The estimates are robust across the sensitivities tested. The U-shaped estimates also hold when Ofgem's GD2 regional wages index is added to the models—as shown in appendix 5A1. However, the regional wage and sparsity coefficients are in some cases less precisely estimated when included simultaneously.[29] This is due to the multicollinearity between the UQ sparsity and regional wage indices: GDNs London (Lon) and Southern (So) are the two least-sparse regions (see Figure 3.1) and also

[27] Model fit also improves relative to including sparsity linearly, where the adjusted R-squared values are 0.73, 0.75, 0.79 and 0.66 for the emergency, repairs, REPEX and maintenance respectively.
[28] As shown in the note to Figure 3.1, the coefficients on the sparsity and sparsity-squared terms are jointly significant at the $p < 0.01$ level for emergency, REPEX and maintenance, and at the $p = 0.15$ level for repairs.
[29] This is most notable in the REPEX, maintenance and repairs models. For example, when Ofgem's GD2 regional wage index is added (alone) as an explanatory model to unadjusted REPEX costs, its coefficient is significant at the $p < 0.01$ level. Similarly, (UQ) sparsity and sparsity-squared are individually and jointly highly significant ($p < 0.01$ and 0.05, respectively). However, when the regional wage and sparsity indices are added simultaneously, both the sparsity and wage coefficient estimates become insignificant. For maintenance, the regional wage coefficient becomes negative and thus unintuitive when included alongside sparsity.

have the highest regional wage indices. The results are also robust to the exclusion of a potentially influential observation: the same U-shaped sparsity impact holds when either the least- or the most-sparse regions (Lon and Sc, respectively) are excluded.

We note that further top-down assessment of other cost categories for which WWU has provided operational rational would be required once more forecast data and/or robust bottom-up models are available.[30] These categories include connections, property management and elements of work management.[31] For example, as shown in Figure 4.3, a similar U-shaped relationship is evident at the TOTEX level—which suggests that sparsity may affect other areas of GDN's cost base.

Figure 4.3 Impact of sparsity at the TOTEX level



Notes: Analysis on 2014–23 outturn period; shaded area = 95% confidence interval; outturn models include a single time trend.
Source: Oxera based on Ofgem's updated cost assessment dataset (November 2023).

[30] A lack of robust bottom-up models (potentially due to cost allocation and changing capitalisation rule issues) precludes us from providing robust estimates for other categories for which WWU has previously provided a strong operational rationale, reiterated in their GD3 business plan. See Oxera (2019), 'Regional factors in the cost assessment for GD2', 29 November, Table 3.3; Oxera (2020), 'A review of Ofgem's cost assessment approach in the RIIO-GD2 Draft Determination', 4 September, paras 4.1–4.18.
[31] As discussed in WWU's GD3 business plan chapter on cost assessment and benchmarking approach.

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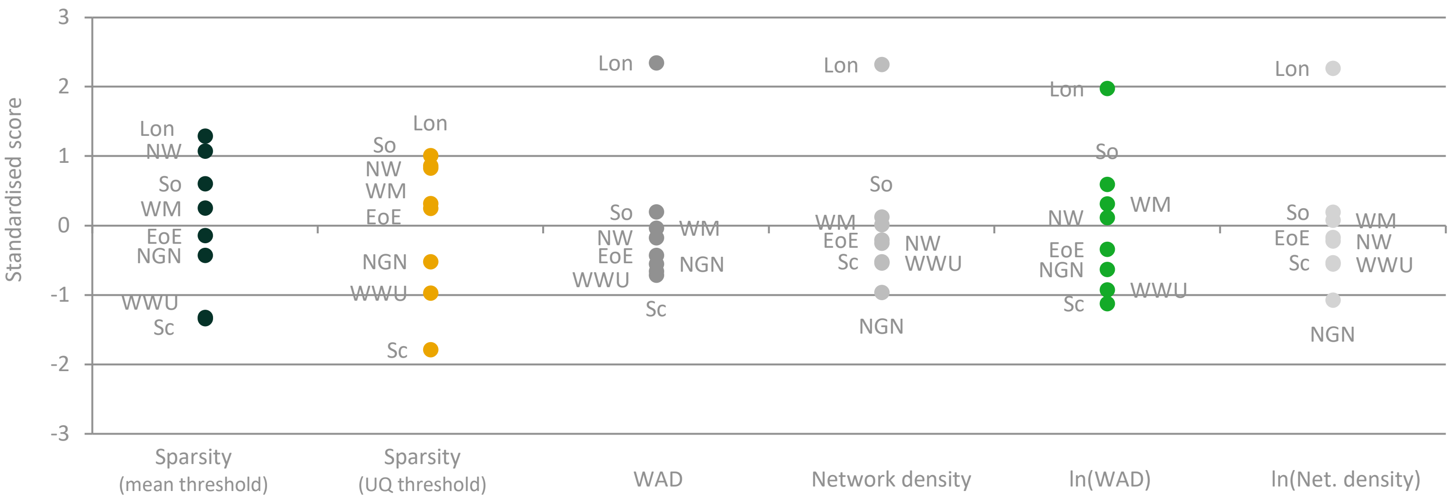
While alternative sparsity/urbanity proxy variables serve as a useful sensitivity check, they are less appropriate from both an operational and statistical perspective (given outlier/overfitting concerns).

Figure 4.4 shows the distribution of the various potential sparsity and density drivers on a comparable scale (with each GDNs score standardised). It shows that for both network density (customers per length of main) and the weighted average density (WAD, or population per area) metrics, London is a significant outlier and there is a lack of variation among the other GDNs. This causes overfitting concerns for models using these density metrics as the proxy for sparsity/urbanity. Using these density metrics instead of sparsity yields unintuitive, inverted U-shaped results (similar to Ofgem's findings during the 2021 GD2 appeals[32]).

Figure 4.4 Standardised distribution across proxy metrics assessed



Note: All values are standardised, i.e. centred around the mean across GDNs with a unit standard deviation (based on each GDN's average score over GD1 and GD2). 'Ln': natural log transformed versions of the respective density variables.
Source: Oxera based on Ofgem's regional adjustment indices dataset (November 2023).

Of the alternative variables with more appropriate distributions from a modelling perspective (GD2 mean sparsity and the log transformed WAD), we find that these proxy variables yield estimates that are generally consistent with the U-shape estimates on UQ sparsity—as shown in appendix 5A2. However, these metrics perform worse from a statistical perspective as they result in sparsity/density estimates that

32 Competition and Markets Authority (2021), 'GD2 Appeals final determination', paras 10.249–10.250.

are less precise and explain less of the residual variation in the unadjusted costs.

This highlights the importance of tailoring any sparsity/urbanity metrics to the exact left (sparsity) or right (urbanity) tail dynamic that one wishes to capture. The analysis above indicates that a sparsity metric with a more stringent threshold is required, and that average density measures do not capture the relevant tail dynamics (because local-level extremes average out at the aggregate level). For example, a WAD metric would suggest medium sparsity levels for a GDN that has significant amounts of workload in both very rural and urban areas within its network region. This also suggests that a mirroring urbanity metric, with a more stringent threshold, may also be required for corresponding urbanity adjustments.[33]

4.2 Bottom-up evidence

Trends in WWU's own REPEX unit costs for roughly equivalent work reaffirm the relationship estimated at the industry level: costs increase as the workload moves to sparser areas. Figure 4.5 shows the increasing trend in WWU's unit costs for its most routine work (the smallest, <125mm diameter, Tier 1, cast- and spun-iron mains), as a greater share of its workload has moved to sparser regions from 2013 to 2023 (based on the same UQ threshold sparsity index). Figure 4.5 thus plots WWU actual workload sparsity relative to the average population sparsity level across GDNs and two of the sparsest regions (NGN and WWU) over the period.

We focus on this specific subset of mains replacement activity as we understand it to be the most like-for-like on a historical basis (keeping diameter, replacement urgency/tier and material type constant), and so attempt to isolate the impact of sparsity on costs on an 'all else equal' basis.[34] This subset represents 62% of WWU's Tier 1 REPEX costs over 2013–23, and is consistent with Ofgem's assessment of where REPEX unit costs were most reliable at the GD2 draft determinations. As the report commissioned by Ofgem for GD2 noted on the matter:

unit cost assessments tend to work well for high volume, standardised, routine activities associated with mains installation and replacement. As

[33] We note that such a 'high density' metric has been proposed by Cadent—see Cadent (2024), 'GD3 proposals for cost exclusions and regional/company-specific factors', 12 November, slide 23.
[34] We thus control for all the cost drivers of REPEX activities for which data is readily available: (i) pipe diameter; (ii) material type; (iii) geography (or at least, sparsity). The most important remaining cost drivers that we are unable to control for are: (i) replacement technique (whether dead main insertion or open cut); (ii) ground surface, as data for these is not collected at the workload/site level.

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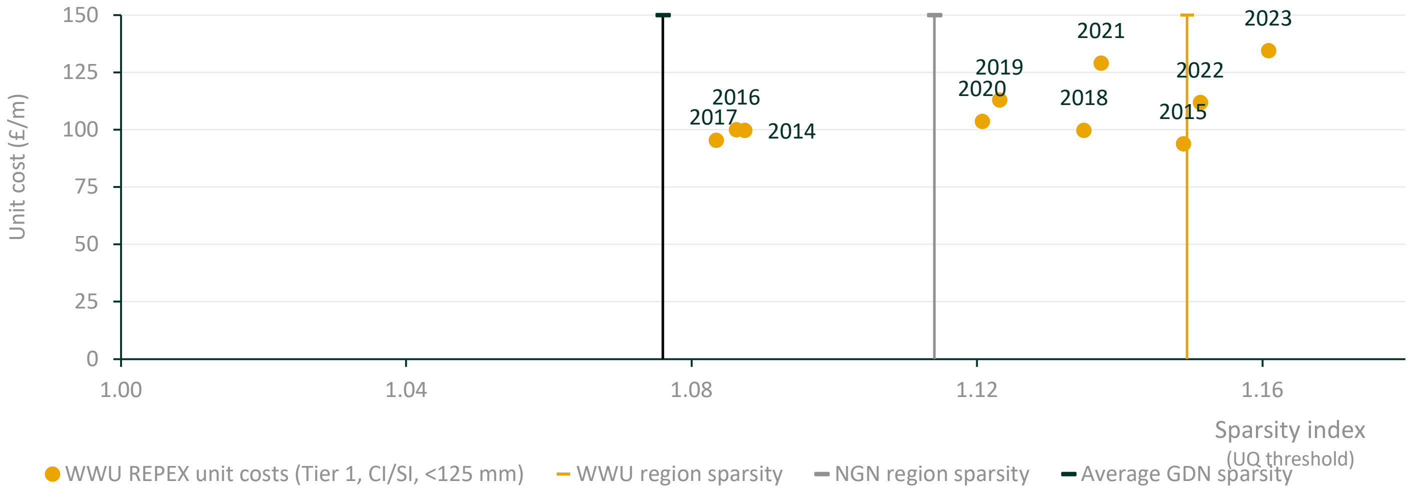
a result, unit cost benchmarking can work well for smaller pipe diameters as this replacement tends to be relatively high volume and standardised across companies. [35]

As shown in Figure 4.5, for these mains gross unit costs increased from £99.74/metre in 2014 to £134.45/metre (or 35%) by 2023 (a trend similar to that noted by the CMA in relation to WWU's aggregate workload over GD1[36]). This rise occurred as the sparsity of WWU's workload increased from between the GDN average and NGN levels, to that surpassing the WWU region's aggregate population/area sparsity level.

Figure 4.5 WWU's high-volume, Tier 1 REPEX unit costs by sparsity

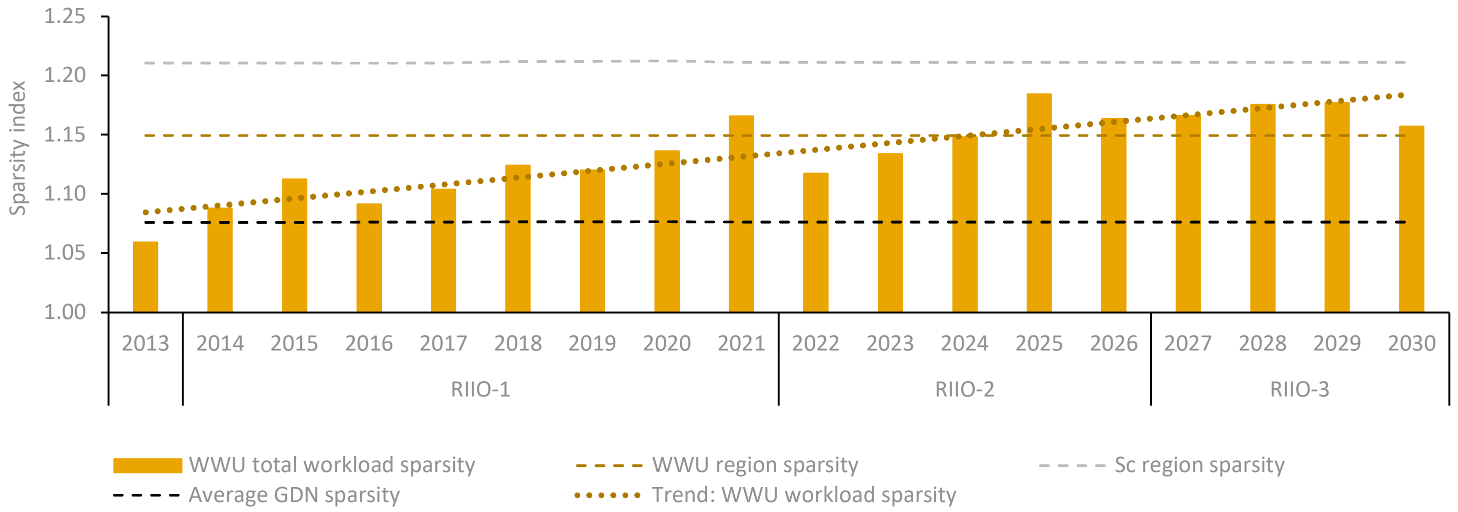


Note: Gross unit costs for relevant mains.
Source: Oxera based on WWU workload data (metres replaced per LA) and Ofgem's REPEX cost and volume data for WWU (as at November 2023).

WWU's workload sparsity has increased over time, with the remaining work (driven by HSE policy) in the sparsest areas. Figure 4.6 compares the (UQ) sparsity level of WWU's historic and forecast total workload with the sparsity of the two sparsest GDN areas and all GDNs on average. WWU's remaining workload will be more sparsely distributed than its GD1–GD2 workloads to date and its population density.

[35] Cambridge Economic Policy Associates (2020), 'RIIO-GD2: Synthetic Unit Costs Update', A report prepared for Ofgem, 27 February, pp. 9–10.
[36] Competition and Markets Authority (2021), 'GD2 Appeals final determination', figure 15-1.

Figure 4.6 Increased sparsity of WWU's forecast total REPEX workload



Note: Outturn workload sparsity up to 2023, forecast from 2024. Based on UQ threshold.
Source: Oxera based on WWU REPEX workload data (metres replaced per LA).

In turn, this will increase driving distances, times and costs. The average driving distance between sites and depots increases by 13.8% between GD2 to GD3 (from 17.1 to 19.5 miles on average). Thus, in addition to the increased drivetimes due to the speed limit in residential areas in Wales reducing from 30mph to 20mph, this would add another c.6 mins per trip based on current speed limits.

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5 Implications for Ofgem's approach

The top-down modelling results and a bottom-up assessment of WWU's REPEX costs by workload distribution clearly illustrate the need for: (i) a continued sparsity adjustment for emergency and repair expenditure; and (ii) a new adjustment for at least REPEX and maintenance.

The most appropriate approach to estimate the exact level of the sparsity adjustments required remains bottom-up evidence and pre-modelling cost adjustments. In theory, a within-model approach that symmetrically and simultaneously captures the relative cost impacts of sparse and urban regions would be ideal. However, Ofgem's current modelling approach and data availability limits the ability to make robust determinations by simply adding regional factor drivers directly to the modelling. There are several reasons for this:

- a TOTEX modelling approach is preferred, given cost allocation- and changing capitalisation rates concerns;[37]
- a small sample and aggregated data mask workload dynamics;
- separate sparsity/urbanity tail drivers are required;
- London overfitting concerns on density metrics;[38]
- double-counting concerns, specifically for GDNs Lon and So (given the collinearity between sparsity and regional wages).[39]

A UQ sparsity metric should be considered to more precisely capture the effect of workloads in truly sparse and more remote areas. As the sparsity metric acts as a proxy for the workloads in the more remote areas—those rural areas that are more distant from depots, tipping points and quarries, require significant travel times to reach and/or more employees—the sparsity index should also only capture workloads in these truly sparse, more remote areas.

[37] GDNs' SSMC responses noted that different cost allocation and capitalisation rules (often within company, over time) make disaggregated models less reliable for cost determination (and thus regional adjustment) purposes. See, for example, WWU (2024) 'RIIO-3 Sector Specific Methodology Consultation (SSMC) – Wales & West Utilities (WWU) response', pp. 66 and 72.

[38] For both the density drivers traditionally considered by Ofgem (network density) and Ofwat (WAD), London is a significant outlier and high-leverage observation. As both Ofgem and the CMA noted during the GD2 appeals, using such a driver would bias the estimates to the extent that London's costs are different from the model-predicted costs for any reason other than its relative density (e.g. inefficiency). Competition and Markets Authority (2021), 'GD2 Appeals final determination', paras 10.249–10.251 and 10.268–10.270.

[39] That is, moving to a within-modelling adjustment approach would require Ofgem to add a regional wage variable to the models alongside the sparsity/urbanity variable(s). The collinearity observed between the UQ sparsity and regional wage indices (driven by So and Lon) suggests that this would result in less-precise estimates (if both factors were added to the models simultaneously), or double-counting concerns (if each regional factor were modelled separately).

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The REPEX bottom-up analysis highlights the need for Ofgem to collect more granular workload distribution data across GDNs, including over the forecast period. This would allow Ofgem to conduct a more precise assessment of the impact of sparsity on costs over the GD3 period, based on actual and forecast workloads (instead of proxy measures).

Last, Ofgem's final suite of GD3 cost determinations models will also affect the extent to which pre-modelling adjustments are required. There are two specific areas where Ofgem's modelling decisions would clearly affect the level of compensating sparsity adjustment required.

- **REPEX synthetic cost driver construction**: as discussed in the accompanying Oxera (2024)[40] cost assessment report, the GD2 REPEX synthetic cost driver only accounts for a subset of the elements that contribute to workload complexity—and thus mains replacement costs.[41] Given the interaction between workload complexity and sparsity, either the REPEX drivers ability to capture these complexity drivers should be improved, or a greater weight should be placed on more recent REPEX outturn and/or forecast data. Without correcting for workload complexity, the greater the weight placed on historical GD1 data, the greater the required compensating sparsity adjustment will likely need to be.
- **Alternative scale drivers included**: the greater the weighting given to customer numbers or throughput as a cost driver, the greater the compensating sparsity adjustment required for GDNs with sparser workloads will need to be (given that customers and demand are spread across larger areas).

For example, the latter would be required if Ofgem chooses to triangulate across several TOTEX models at the GD3 determinations, including an alternative 'top down' CSV such as that which it has considered in the CAWG process ('CSV1', with 50%–25%–25% weighting to network length, customer numbers and throughput, respectively[42]). This could also be required if Ofgem considers alternative cost pools and cost drivers, such as the 'Pool2a' middle-up model with

[40] Oxera (2024), 'Review of Ofgem's proposed approach to cost assessment at GD3', November, Report prepared for Wales & West Utilities.
[41] For example, the GD2 REPEX synthetic driver does not account for cost difference between ductile iron and spun or cast iron, different ground surfaces, techniques required, or the sparsity of remaining workloads.
[42] Ofgem (2024), 'RIIO-GD3 Cost Assessment Working Group 7. Totex modelling and BPDT development', 10 April, slide 14. Currently, the customer number TOTEX CSV weight is 3.8% (and throughput 0%), given that customer numbers contribute 80% of the emergency CSV (which in turn contributes 4.7% weight to the status quo TOTEX CSV). See Ofgem (2021), 'RIIO-2 Final Determinations – GD Sector Annex (REVISED)', 3 February, table 17, p. 103.

corresponding ‘CSV3’ presented during the same CAWG (which similarly increases the relative weight to customer numbers as a cost driver).

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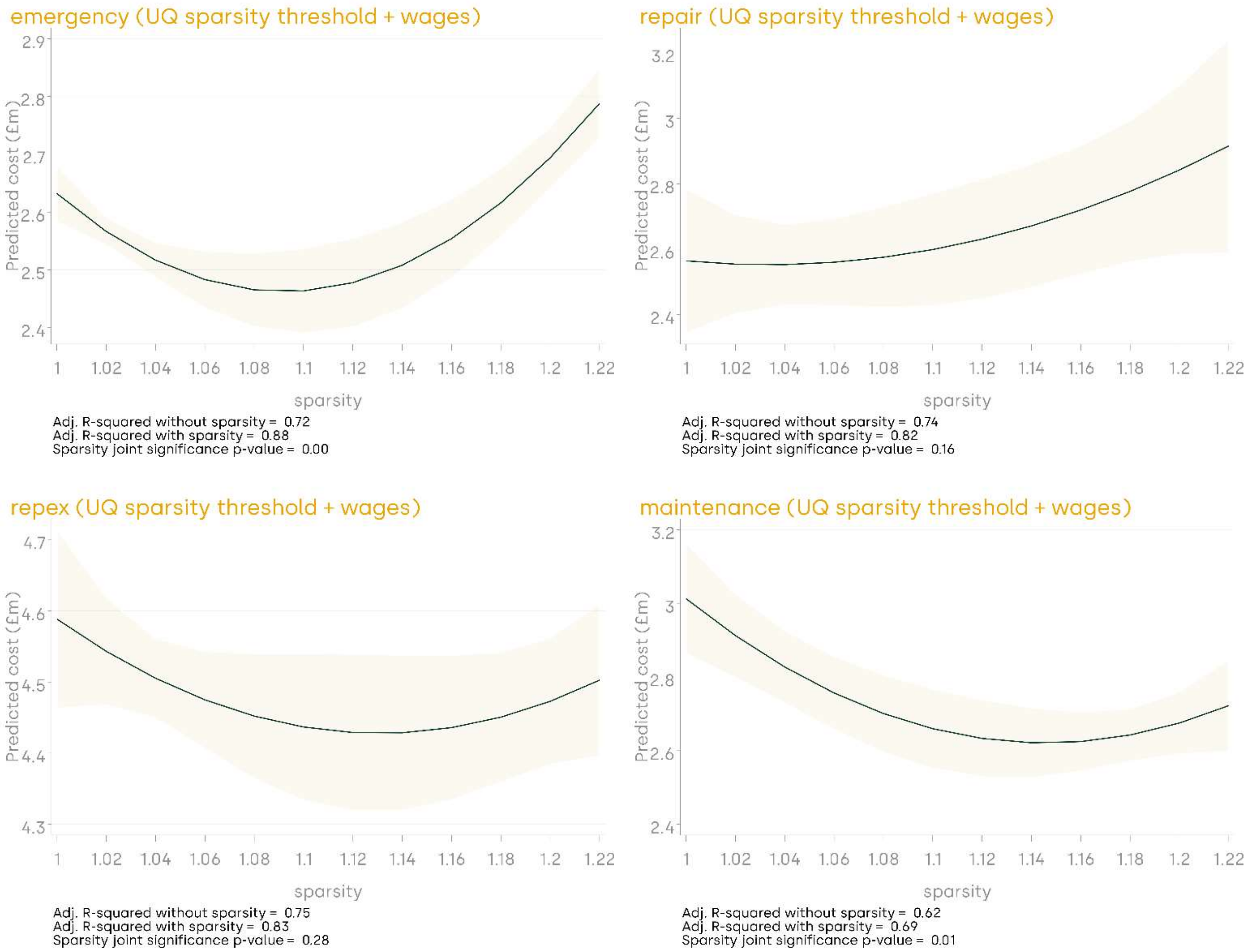
Appendix (sensitivities)

We have tested the robustness of the main results presented in-text against several sensitivities, including: (i) modelling the impact of both regional wages and sparsity simultaneously; (ii) testing alternative sparsity/density metrics. We present the results from these sensitivities below.

A1 Top-down results with regional wages

As discussed in section 4.1, the U-shaped estimates also hold when Ofgem's GD2 regional wages index is added to the models (though the regional wage and sparsity coefficients are in some cases less precisely estimated due to the correlation between the two metrics).

Figure A1.1 Impact of sparsity when included alongside regional wages



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Notes: Analysis on 2014–23 outturn period; shaded areas represent 95% confidence intervals; outturn models include a single time trend.
Source: Oxera based on Ofgem's updated cost assessment dataset (November 2023).

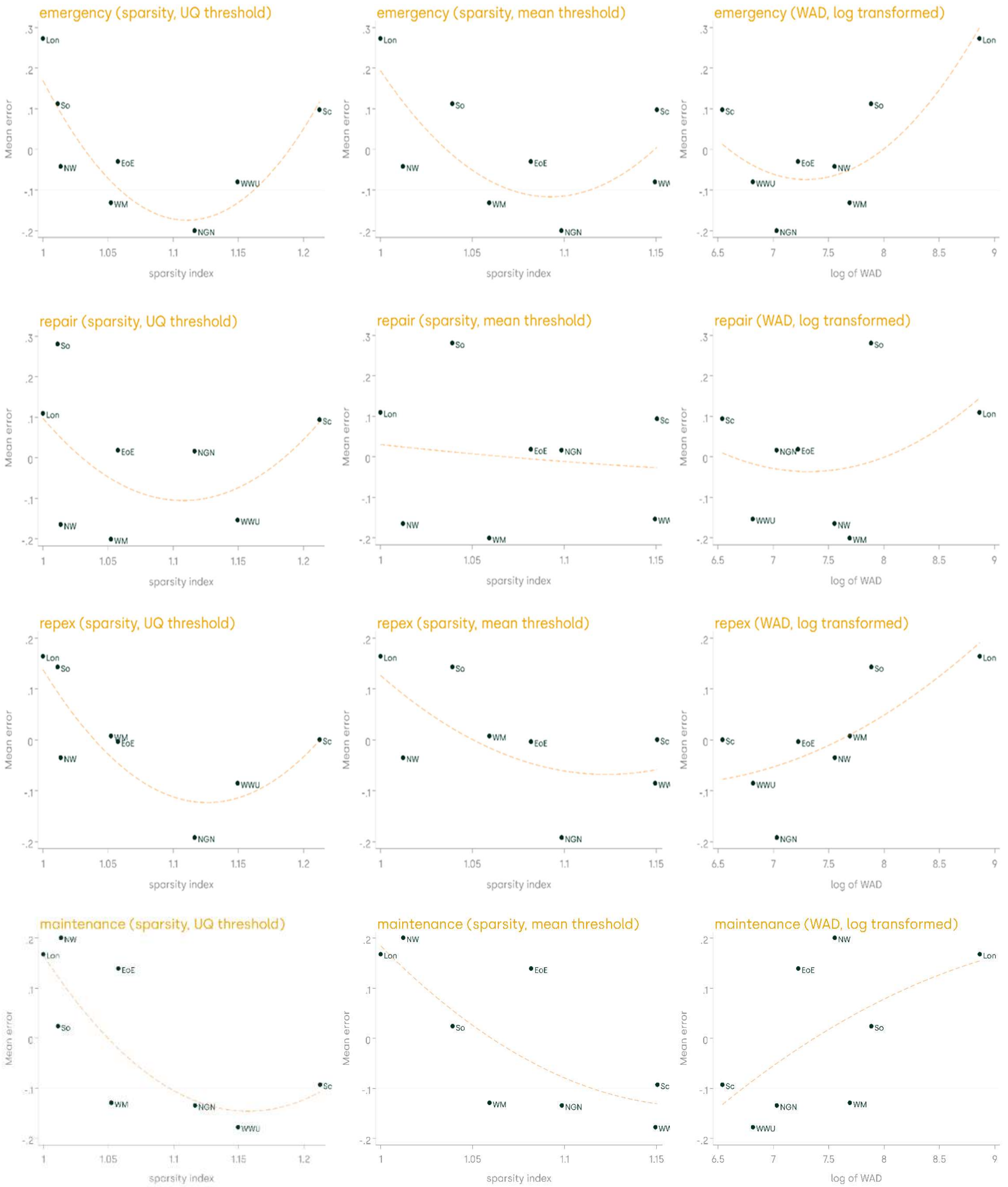
A2 Top-down results using alternative metrics

Figure A2.1 shows the average residual value per GDN for each relevant disaggregate regression of unadjusted costs (using the status quo cost drivers), graphed over the three respective sparsity/density metrics. As discussed in sections 2 and 4.1, the UQ sparsity metric aligns more closely with operational rationale and is the least likely to be biased by overfitting due to influential observations. The shape implied by the coefficient estimates on these alternative sparsity and density metrics indicate a relationship that is either consistent with, or at least not inconsistent with, the UQ sparsity index.

Where there are differences, this is clearly driven by influential (outlier and/or high leverage) observations on the two metrics that less-accurately capture the share of workloads in truly sparse areas.[43] Further, because we model the average residual across GDNs, there are only eight observations, which affects the precision of the estimates (recall the general caveats around modelling with a small sample of highly aggregated data, discussed in section 5 above).

[43] For example, focusing on the mean sparsity metric, in practice one would expect So to have little-to-no workloads in sparse areas, and for Sc to have a greater workload in sparse areas than WWU (as also suggested in the WAD metric). Similarly, as noted above, Lon is an extreme outlier on the WAD metric, with significant leverage on the presumed U-shape estimate. Both of these observations are supported by standard statistical tests for observations with significant leverage and influence on the regression estimates. For example, Lon has the highest leverage statistic in all models with density drivers (be it WAD or customers per length of main). Standard Cook's D and DFIT statistics (measuring observation influence) also show that Sc, So and London generally become more influential observations in repairs and REPEX models using density (as opposed to sparsity) metrics as the additional cost driver. Note, however, that care needs to be taken when interpreting such measures—as to not conflate between inefficiency and modelling error.

Figure A2.1 Residual from status quo models against sparsity/density



Note: Y-axis shows mean residual and X-axis the mean sparsity/density over 2013–23, with a quadratic line of best fit.
Source: Oxera based on Ofgem's regional adjustment indices dataset (November 2023).

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