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UK 900 MHz, 1800 MHz & 2100 MHz Annual Licence Fees

A NERA report prepared on behalf of Virgin Media O2

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Project Team

Richard Marsden, Senior Managing Director
Dr Soren Sorensen, Managing Director
Julien Martin, Consultant
Benjamin Tello, Analyst

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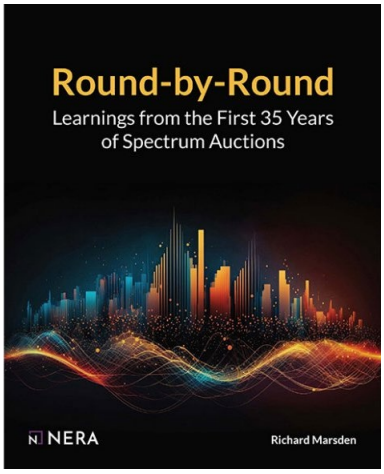

In 2024, NERA published a new book, *Round-by-Round: Learnings from the First 35 Years of Spectrum Auctions*. Round-by-Round charts the rise of spectrum auctions worldwide across five generations of mobile technology and anticipates their further evolution in the 6G era. It includes detailed statistics on the global adoption of different auction formats and the evolution of prices paid for radio spectrum since the 1990s, as well as case studies of spectrum award "successes" and "failures" from around the world.

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NERA (USA)
1166 Avenue of the Americas
New York, NY 10036
United States

NERA (UK)
138 Houndsditch
London EC3A 7AW
United Kingdom

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Executive Summary

UK mobile operators pay annual licence fees (ALF) to use mobile spectrum once the initial licence term has expired. There are currently three bands subject to ALF: 900 MHz, 1800 MHz and 2100 MHz. In July 2024, Ofcom announced that it will undertake a review of ALF charges for all three bands. It also invited stakeholders to submit evidence as part of a pre-consultation phase of the review.

NERA Economic Consulting has been asked by Virgin Media O2 to prepare this report for the purposes of submission to Ofcom as relevant evidence for reviewing ALFs. We were tasked with reviewing Ofcom's methodology for setting ALFs and updating annual payments, and estimating the current lump sum market value of spectrum in all three bands. Virgin Media O2 also asked that we consider the implications of the 5G era decline and convergence in prices paid for spectrum worldwide, a trend that we identified and analysed in NERA's 2024 book, *Round-by-Round: Learnings from the First 35 Years of Spectrum Auctions*. We were not asked at this time to consider Ofcom's approach for converting lump sum values to annual fees, but we may address this in a later submission.

Prices paid for mobile spectrum bands worldwide are declining and converging

The period since 2018, when ALFs for 900 MHz and 1800 MHz were set, has seen huge change in the prices paid for mobile spectrum. We identify an overall decline in spectrum prices in the 5G awards era and a convergence in prices paid for all mobile bands below 4 GHz. This convergence has resulted from a significant decline in the value of low-band spectrum (sub-1 GHz) and lower mid-band spectrum (1800 and 2100 MHz), whereas higher bands have tended to retain their value, albeit from a much lower base. Although mobile operators worldwide typically still pay more per MHz in auctions for lower frequencies than higher ones, the premium paid (in both absolute and percentage terms) has declined significantly.

On the supply side, the critical factor bringing down overall prices has been a huge rise in the supply of spectrum suitable for deployment at standard base stations. Ofcom is a global leader in bringing mobile spectrum to market. As of end-2023, it had made available 1,159 MHz spectrum below 4 GHz for mobile use, ahead of other leading European economies, such as Germany (1,124 MHz), Italy (984 MHz) and France (923 MHz).

On the demand side, three factors have driven the decline and convergence in prices. Firstly, densification of urban networks and improvements in antenna technology (specifically massive MIMO) have diminished the propagation value premium associated with lower frequencies below 4 GHz. Secondly, the slowdown in the growth in mobile traffic has eased 4G-era concerns that operators could face near-term network capacity constraints. And thirdly, MNOs worldwide are struggling with low profitability, and this is putting downward pressure on competition and valuations for spectrum.

Given that Ofcom set ALFs for 900 MHz and 1800 MHz in 2018, only a few years after the 4G era peak in prices, and drew primarily on evidence from 4G era awards, it is logical to expect that the current annual fees will overstate today's market value and should be reduced. On the same basis, it is to be

expected that 2100 MHz ALF will be too high, but the extent of overstatement should be smaller, as the price was set later and that review considered more recent price evidence.

Ofcom's approach should be adapted to the new benchmark landscape

Ofcom first consulted on setting ALFs for 900 MHz and 1800 MHz in 2013, and new prices were introduced in 2018. Ofcom subsequently set ALFs for 3500 MHz in 2019 (later converted to lump sum payments) and for 2100 MHz in 2021. For each band, it has maintained a consistent methodology based on benchmarking, relying primarily on UK auction prices and secondarily on European award prices. The current review provides an opportunity to revisit this methodology, considering both industry trends and the evolution of the available spectrum price data.

We find that the existing methodology is broadly fit for purpose subject to three adaptations:

1. Ofcom should focus on benchmarks from the last 10 years, which loosely corresponds to the 5G awards era. It should retire earlier 4G era price points as they are no longer reflective of today's market value for spectrum.
2. Ofcom should analyse and price similar spectrum bands together, consistent with their role in modern 5G networks. This would result in a common price for the 700, 800 and 900 MHz bands, and a common price for the 1800 and 2100 MHz bands.
3. Ofcom should use historic nominal prices rather than inflation-adjusted prices for the current review, given that relevant price levels have been falling and inflation adjustment will therefore contribute to a further overstatement of market value, at odds with the most recent observed data.

Evidence supports a reduction in ALF for all three bands

We analyse evidence relating to the 2024 full market value of 900 MHz. We first discuss UK evidence, where we identify the 700 MHz auction price of £14.0m per MHz as the best available proxy for the value of 900 MHz. We then consider the relative value of the three sub-1 GHz bands, concluding that the evidence supports the hypothesis that there is no longer any value difference between them. Finally, we examine European absolute value benchmarks, and find no evidence to contradict our conclusion that setting UK 900 MHz ALF based on the 2018 price of 700 MHz is reasonable.

We also analyse evidence relating to the 2024 full market value of 1800 MHz and 2100 MHz. Again, we start with UK evidence, which we use to identify a range of £8.0m - £10.6m per MHz within which the value of 1800 MHz and 2100 MHz likely lies. We then consider the relative value of 1800 MHz and 2100 MHz, concluding that the evidence supports the hypothesis that there is no longer sufficient difference between the bands to justify valuing them independently. Next, we apply the distance value method to European benchmarks, and find that the average implied value for UK lower mid-band spectrum of £9.3m per MHz is within our range. Finally, we examine European absolute value benchmarks for 1800 MHz and 2100 MHz; we find no evidence to contradict our conclusion that setting a common ALF for the two bands within our proposed range is reasonable.

As a cross check on these values, we consider the relative values of 900 MHz and 1800 / 2100 MHz. We identify evidence that a reasonable premium for low-band over lower-mid band spectrum is around 25%.

On this basis, Ofcom may consider setting ALF lump sum values at the following levels:

- 900 MHz: The lower of the unadjusted 700 MHz UK benchmark of £14.0m per MHz and 25% above the 1800 / 2100 MHz lump sum value; and
- 1800 and 2100 MHz: A value of around £9.3m per MHz.

Our analysis supporting these prices incorporates the methodological changes set out above. Even with these changes, we recognise that our approach is vulnerable to overstatement: as spectrum prices have been falling in nominal terms, our zero-inflation adjustment is insufficient to address an upward value bias in older benchmarks within our ten-year sample. It is also more likely than not that the market value of ALF spectrum will fall further in coming years. Ofcom may address this risk by exercising its discretion to determine a conservative estimate of full market value.

Annual ALFs should be adjusted using CPI-CPI

Ofcom adjusts ALF each year based on UK consumer price inflation (CPI). In recent years, this has led to significant increases in ALF at a time when the value of the relevant spectrum bands worldwide has been falling. We present data that demonstrates these adjustments have contributed to a material misalignment in prices, with current ALFs for all three bands being too high.

Looking forward, the appropriate annual adjustment approach depends on the future path of spectrum prices and general inflation. If spectrum prices were projected to rise, then a CPI adjustment may be appropriate. However, the greater likelihood is that spectrum prices will continue to fall in the period to the next ALF review (which may be 5 years away), albeit with less room to decline than before. Meanwhile, the Bank of England is pursuing a 2% per annum inflation target. In this context, a zero annual adjustment of a conservatively set ALF is appropriate for the near future. Within the context of Ofcom's methodology, a zero annual adjustment could be realised by applying a CPI-X adjustment, with X set equal to CPI.

1. Prices paid for mobile spectrum bands worldwide are declining and converging

The period since 2018, when ALFs for 900 MHz and 1800 MHz were set, has seen huge change in the prices paid for mobile spectrum. NERA's 2024 book, *Round-by-Round: Learnings from the First 35 Years of Spectrum Auctions*, includes a chapter on spectrum award prices across the mobile eras.[1] We identify an overall decline in spectrum prices in the 5G awards era and a convergence in prices paid for all mobile bands below 4 GHz. This convergence has resulted from a significant decline in the value of low-band spectrum (sub-1 GHz) and lower mid-band spectrum (1800 MHz and 2100 MHz), whereas higher bands have tended to retain their value, albeit from a much lower base. Although mobile network operators (MNOs) worldwide typically still pay more per MHz in auctions for lower frequencies than higher ones, the premium paid (in both absolute and percentage terms) has declined significantly.

In this section, we present evidence of the decline in prices paid for mobile spectrum and the convergence of prices below 4 GHz. We then identify the factors that underpin these price movements and explain why they are likely to endure in the near term. We conclude with a discussion of the implications for the review of UK ALFs.

Given that Ofcom set ALFs for 900 MHz and 1800 MHz in 2018, only a few years after the 4G era peak in prices and drawing primarily on evidence from 4G era awards, it is logical to expect that the current annual fees will overstate market value in 2025 and should be reduced. Given the scale of global price declines, this expectation would apply even if Ofcom had maintained ALFs at the same nominal prices every year. In fact, ALFs have been increased every year based on the UK consumer price index (CPI) and, owing to high inflation from 2021-23, annual payments have increased significantly. Accordingly, a large downward reduction in ALFs for both 900 MHz and 1800 MHz may be anticipated.

On the same basis, it should be expected that the price set for 2100 MHz in 2021 will also be too high. In this case, the overstatement should be smaller given that the price was set later and considered more recent price evidence. The 2100 MHz price has also seen fewer inflation adjustments but was set before the high inflation period from 2021-23.

1.1. Prices paid for mobile spectrum have declined

In Figure 1, we present a three-year moving average of unit and per capita prices in USD paid for mobile spectrum worldwide from 1999-2023, as reported in Marsden (2024). It is based on observed prices in 351 band awards across 51 major economies worldwide, effectively a superset of the European evidence that Ofcom relies on to set ALFs. A three-year moving average was applied to smooth trends over time.

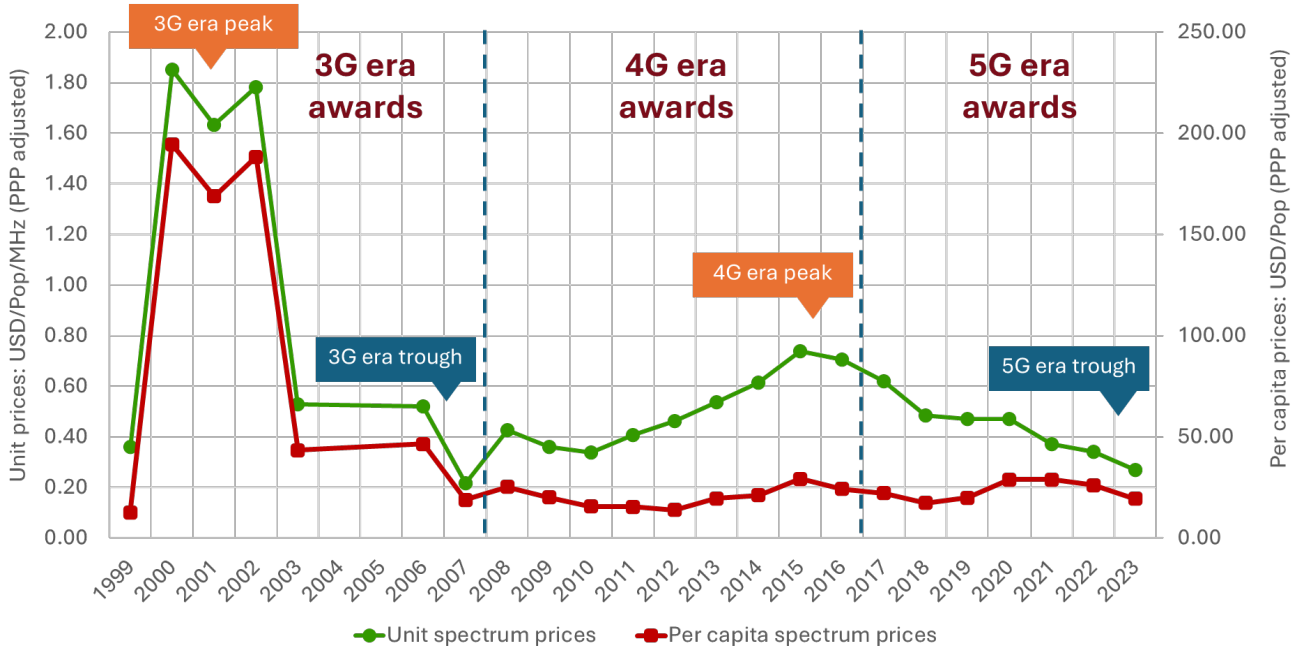
[1] Marsden, Richard (2024), Round-by-Round: Learnings from the First 35 Years of Spectrum Auctions, NERA, Chapter 10
Hard copy available from Amazon.com and Amazon.co.uk;
Electronic version free download available from https://www.nera.com/insights/publications/2024/round-by-round-

Across the period, Marsden (2024) identified a series of pronounced peaks and troughs in unit spectrum prices (price paid per MHz pop), as highlighted on the chart:

- The first peak occurs in 2000, the year that the UK and German 3G auctions realized record revenues, driven by intense competition to enter fast-growing national mobile markets.
- The first trough follows in the mid-late 2000s, a period of (relative) disillusionment in the industry, when 3G technology was seen as failing to deliver on its early hype and MNOs in many countries, including the UK, were perceived as having overpaid for 3G spectrum licenses.
- Market perceptions changed in the 4G era owing to the take-off in mobile data usage, encapsulated by the success of the iPhone. Prices climb to a second peak in around 2015-16.
- Since then, during the period of 5G awards, average unit prices have more than halved and have now entered a second trough of unknown duration.

The graph plots nominal prices (i.e. prices converted to USD using PPP exchange rates at the time of award), with no adjustment for inflation. If we had rebased everything in 2024 prices, adjusting for inflation, the 3G and 4G peaks and the 5G era decline would look even more pronounced.

Figure 1: Three-year moving average of unit and per capita prices (USD) for mobile spectrum



Source: Figure 30 (p. 107) of Marsden (2024), with peak and trough highlights added.
Notes: Data derived from survey of prices for all usable mobile spectrum sold in bands between 600 MHz and 4 GHz in 351 awards across 51 countries from 1997-2023. Spectrum prices include award revenues and the net present value of associated annual fees. They are converted to US dollars using PPP exchange rates from the World Bank for year of award and adjusted pro rata for a common license duration of 15 years.

During the 4G era, unit prices grew at a much faster rate than per capita prices, indicating that operators were not just spending more on spectrum but also investing heavily in terms of the price paid per unit of capacity. This was a period when mobile data use was growing rapidly and there were concerns in the industry that the identification and release of new mobile bands would not keep pace with the industry's capacity requirements.

In contrast, in the 5G era, the decline in unit prices has not been matched by a similar decline in per capita prices. This indicates that operators are continuing to invest heavily in spectrum, but money is being spread over a much larger volume of MHz. This is consistent with the release of larger volumes of new spectrum in the 5G era than in previous eras, most notably the award in many countries of up to 400MHz in the 3500 MHz band.

Prices paid in UK auctions have broadly tracked the international trend. The UK 3G, which raised an astounding £22.5 bn, was a key contributor to the 3G era price peak in 2000. The UK 4G auction took place in 2013, when prices were on an upward trajectory – it was very competitive, producing high value bids and substantial revenues of £2.3 bn (albeit less than expected). The two UK 5G auctions, in 2018 and 2021 respectively, occurred when prices were in decline. Both auctions were competitive but the intensity of bid competition was lower in the second auction; each raised about £1.4 bn but the 2021 auction generated fewer price increments.

In conclusion, global spectrum prices have evolved in cycles which (in our book) we link to long-run industry trends in supply of and demand for spectrum. UK prices appear to have evolved in line with this trend, as is to be expected given the global nature of the mobile industry. We are currently in a period of historically low values per MHz for mobile spectrum.

1.2. Prices paid for mobile bands below 4 GHz have converged

The era of 5G spectrum awards has also seen a convergence in the prices paid for all types of mobile spectrum below 4 GHz.

Using a global sample of awards, Figure 2 [also from Marsden (2024)] tracks the evolution of unit (per MHz-pop) prices for three categories of mobile spectrum bands from 2010 to 2023:

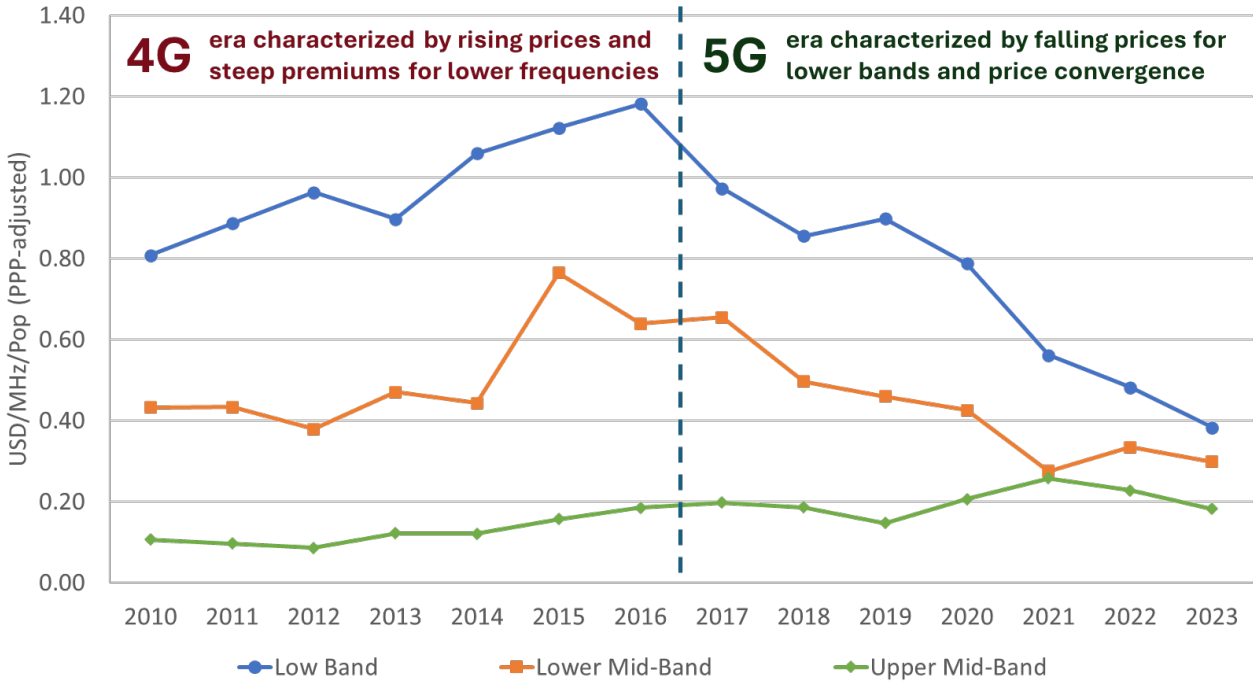
1. **Low-band (600, 700, 800, 850 and 900 MHz): blue line**. These bands are recognised as having the highest value per MHz, owing to limited supply and superior propagation: signals travel further and penetrate buildings more easily. They provide both capacity and broad geographic coverage.

2. **Lower-mid band (1800, 2100, PCS and AWS): orange line**. These bands are not as effective for wide-area geographic coverage as low-band spectrum, owing to weaker signal penetration. However, they collectively offer greater size and capacity, which made them ideal for 3G and 4G deployment, especially in urban areas where signal propagation is less of a concern owing to the need to re-use frequencies in increasingly dense cell site networks.

3. **Upper-mid band (2300, 2500 and 3500 MHz): green line**. These bands were added later, providing operators with significant additional capacity for 4G and 5G deployment. Advances

in mobile technology and densification of urban networks have made these bands more attractive over time.

Figure 2: Three-year moving average of unit prices (USD) for categories of mobile spectrum



Source: Figure 31 (p. 110) of Marsden (2024).
Notes: Same sample and adjustments as Figure 1.

Unit prices paid for low-band and lower-mid band spectrum exhibit the same upward trend in the 4G era and downward trend in the 5G era that we observe for the aggregate data in Figure 1. However, prices paid for upper-mid band spectrum have evolved differently. In the 4G era, prices also rose but at a more modest pace than lower frequencies. This upward trend continued through the first five years of the 5G award era, although prices have moved downwards since 2021.

Comparing prices paid across spectrum band categories in the 4G awards era, it is evident that bidders worldwide were willing to pay a steep premium for lower frequency spectrum. In most years between 2010 and 2016, low-band sold at a 2X (100%) premium over lower-mid band spectrum, which in turn sold at a circa 3X premium over upper-mid band. However, in the 5G era, these premiums have eroded, as illustrated by the convergence of the three lines in Figure 2. In 2023, the three-year moving average of prices for low-band spectrum was only 30% higher than lower mid-band, which in turn was only 62% higher than upper-mid band. As we explain below, we attribute price convergence to a combination of data growth and technological progress which has led to an increasing emphasis on the high-capacity 2300, 2500 and 3500 MHz bands in 5G network rollout.

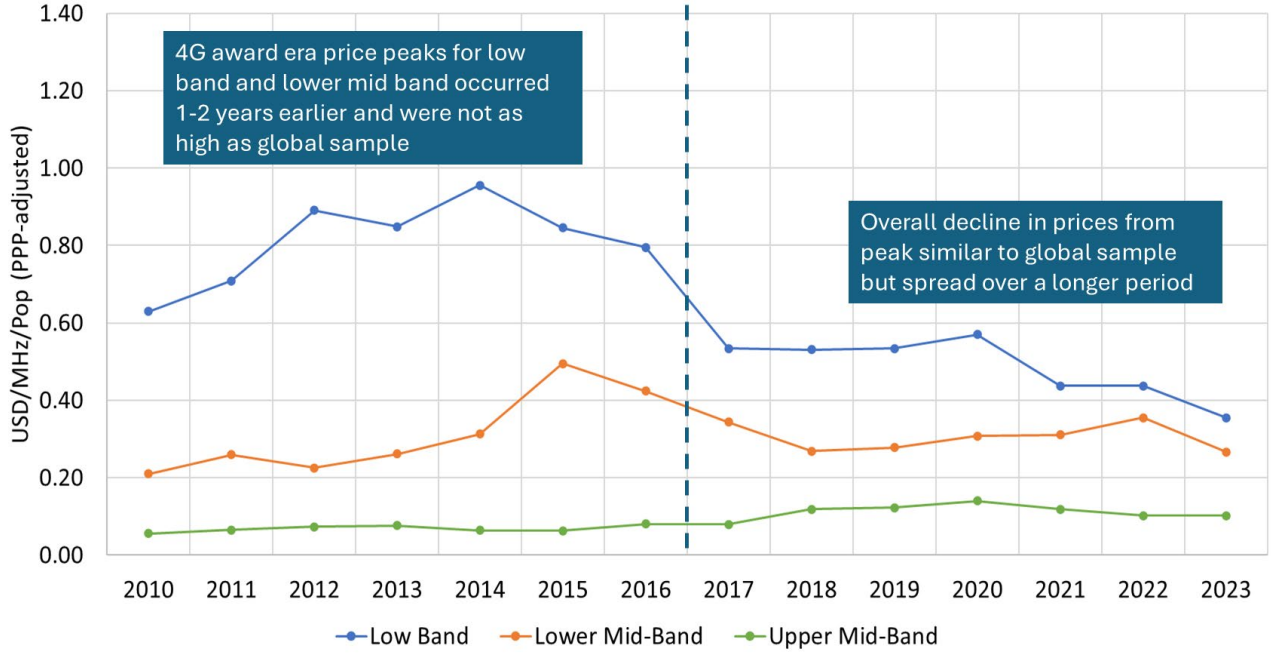
In Figure 3, we undertake the same analysis for European awards only, a subset of the global data broadly consistent with Ofcom's approach when setting ALFs of relying on benchmark evidence from EU member states plus Iceland, Norway, Switzerland and the United Kingdom. We observe the same

upward price trend in the 4G awards era, downward price trend in the 5G awards era, and a similar convergence in the prices paid for all mobile bands from around 2015. As of 2023, the premium for low-band over lower-mid band was 20%, which is similar to the 30% premium observed for the global sample.

There are some notable differences from the global trend:

- Peak prices for low-band and lower mid-band spectrum are lower for the European sample than the global sample. This may reflect the fact many non-European countries in the economy had brighter economic and demographic growth outlooks than Europe over this period.
- Prices paid for low-band and lower-mid band spectrum appear to have peaked 1-2 years earlier than in the global sample. This may be explained by European countries generally having relatively advanced 4G development compared to the broader sample.
- The overall decline in prices from peak levels in Europe appears similar to the global sample, but because prices peaked earlier, the decline is spread over a longer period.

Figure 3: Three-year moving average of unit prices (USD) for categories of mobile spectrum – restricted sample of European countries



Source: NERA, using same methodology as Figure 31 (p. 110) of Marsden (2024).
Notes: Same adjustments as Figure 2. Sample restricted to 204 awards across 29 European countries (EU member states plus Iceland, Norway, Switzerland & the United Kingdom), consistent with Ofcom ALF methodology.

The results of the UK 5G auctions appear consistent with the price convergence story observed both in Europe and worldwide. The 2018 auction, which only featured upper mid-band spectrum attracted more bid competition and produced robust prices. Notably, the price for 3400 MHz spectrum was

£7.9m per MHz, which exceeded the implied price for 2.6 GHz FDD in the 2013 auction of £5.5m. This may also be linked to the limited supply of 3.5 GHz spectrum and uncertainly over the timing of further releases. The 2021 auction was competitive but there were fewer bidding rounds. The UK 700 MHz spectrum in 2021 sold for £14.0m per MHz, less than 40% of the implied price for 800 MHz in the 2013 auction of £29.9m per MHz. And the price paid for 3600 MHz of £4.2m was significantly below the 2018 price for 3400 MHz.

1.3. Understanding why 5G era prices are declining and converging

In Marsden (2024), we attributed the decline and convergence of mobile prices in the 5G era to a combination of supply side and demand side factors. On the supply side, the critical factor bringing down overall prices is the huge rise in the overall supply of spectrum suitable for deployment at standard base stations.

In many leading economies, spectrum supply has nearly doubled in the 5G era, facilitated by the release of C-band spectrum around 3.5 GHz. This increase appears to have alleviated 4G-era concerns that spectrum supply might not keep track with rising demand for data. It is notable that, in the 5G era, high prices observed for a minority of awards can often be linked to bottlenecks in supply. For example, Myers (2023) observes that limited supply and asymmetric packaging of lots led to high prices in the Italy 5G auction (2018).[2] Similarly, Marsden (2004) links high unit prices unit prices paid for 3.5 GHz in Italy (2018), Taiwan (2020) and Canada (2021) to restricted supply.[3] It is also noteworthy that the average price paid for (non-set aside) 3.5 GHz in Canada in a second auction in 2023 was 93% lower than equivalent spectrum in the first auction, after the supply was hugely increased from 200 MHz to 450 MHz. While the Canadian price differential is extreme, directionally this is consistent with what happened in the two UK auctions, with the price of 3400 MHz potentially overstated owing to reduced supply and the price of additional 3600 MHz being much lower.

It is also important to remember that market prices for spectrum should reflect the marginal value of the spectrum, not the absolute value. Mobile operators may place very high value on their overall spectrum portfolio but place much lower value on adding an incremental block of MHz. In recent years, with the release of additional low-band and mid-band spectrum, the number of blocks of spectrum owned by an operator has increased, and consequently operator values have shifted down the value curve. In this way, the price of spectrum can fall significantly even though the total stock of value associated with all mobile spectrum is still growing. This valuation structure may explain why UK operators won 3600 MHz spectrum at a lower price in 2021 than they paid for 3400 MHz in 2018.

Ofcom has been a global leader in bringing mobile spectrum to market. As of end-2023, it had made available 1,159 MHz spectrum below 4 GHz for mobile use, with supply up 90% since 2016 through a combination of new releases and liberalisation of legacy bands. This is more than other leading

[2] Myers, G. (2023), 'Spectrum Auctions: Designing Markets to Benefit the Public, Industry and the Economy', London: LSE Press (open access), p.121.

[3] Marsden (2024), p. 114.

European economies, such as Germany (1,124 MHz), Italy (984 MHz) and France (923 MHz).[4] One wrinkle in this UK success story was the bifurcated release of 3500 MHz spectrum. This contributed to a much higher price per MHz for the first auction (£7.9m per MHz), when the timing of future supply was uncertain, than the second auction (£4.2m per MHz), when the full supply was delivered.

On the demand side, three factors have driven the decline and convergence in prices:

1. *Technological advances and network densification*. With denser networks in urban areas, the premium value of lower frequencies is reduced, as the advantage of signals that propagate further is diminished. In recent years, this trend has been accentuated by improvements in antenna technology (specifically massive MIMO) which has increased spectral efficiency as well as the coverage of mid-band spectrum from 1800 MHz through 3800 MHz.

2. *Slowdown in data growth*. In recent years, growth in mobile traffic has slowed, a significant change from much of the 2010s, when data growth was exponential and some industry forecasts anticipated that this would continue indefinitely.[5] As operators have become more confident about the limits of future capacity requirements, it follows that their incremental value for spectrum will fall.

3. *Industry weakness*. In countries worldwide, MNOs are struggling with low profitability coupled with high capital intensity to deliver 5G networks. This may be attributed to a combination of revenue stagnation, owing to intense price competition in mobile services and an absence of new revenue streams, and high build-out costs owing to intense government and competitive pressure to maintain investments in next generation networks. These factors tend to directly decrease operator valuations for spectrum based on discounted cash flow (DCF) modelling, which in turn lowers the competitive intensity of auctions as incumbents reduce their valuations or factor in budget constraints, and potential entrants are deterred from participation.

Another relevant development is the integration of all mobile bands into a common 5G ecosystem. Across the 2010s, mobile bands often had specific roles supporting either 2G, 3G or 4G technology, with certain bands favoured for legacy networks and others for transition to new ones. As a result, bands with similar propagation characteristics, such as 800 MHz and 900 MHz, and 1800 MHz and 2100 MHz, had different use cases, and this could drive significant differences in value to operators. In the 2020s, technology is eliminating these differences. New devices have wide band RF capabilities that can group like bands into a single RF chain and then use tuning techniques to optimise the performance for the bands being used. Today's technology enables the 700/800/900 MHz bands to be deployed using a common radio hardware platform. Similarly, 2100/1800 MHz can be deployed using common radio hardware platforms. Therefore, bands with groups are increasingly interchangeable.

4 Marsden (2024), p. 113.

5 See Ihle, Marsden & Frizlen (2024), Evolution of Prices for Mobile Spectrum and Possible Explanations (available at: https://www.nera.com/insights/publications/2024/evolution-of-prices-for-mobile-spectrum-and-possible-explanation), for an analysis of recent forecast data and review of sources.

None of the above factors are expected to change much before the end of the 2020s. Spectrum supply is likely to increase gently through the late 2020s with potential for larger releases from around 2030. In the United Kingdom, Ofcom plans to release mmWave and additional 1500 MHz soon and is expected to explore other releases for the future , such as 600 MHz and upper 6 GHz. Elsewhere in Europe, many countries lag the United Kingdom in mobile spectrum supply and may be expected to catch up over time. Meanwhile, mobile data consumption is still increasing, but at a slowing rate, so mobile operators are not projected to require access to more spectrum (other than mmWave for traffic hot spots) to address capacity constraints until around 2030. Deployment of 5G networks will also improve the efficiency of existing spectrum capacity. Finally, mobile industry weakness is expected to persist for some time with no significant new revenue streams on the horizon. Accordingly, it is more likely than not that global prices paid for spectrum will decline further over the next few years, and prices for different types of spectrum may continue to converge.

1.4. Implications of price decline and convergence for UK ALFs

ALFs for 900 and 1800 MHz were set in 2018. ALF for 2100 MHz was set in 2021. Prices in each band were based on evidence from preceding years, and annual fees have subsequently been increased in line with inflation, which has been unusually high. Given that spectrum prices in the period since these decisions have been trending downwards, it is therefore to be expected that a downward revision of all ALFs will be necessary. International evidence also suggests that Ofcom should maintain a price premium for 900 MHz over 1800 MHz and 2100 MHz.

With regards to setting ALFs in the UK, it is relevant that the international trend for declining and converging prices, and the factors driving them, are largely a new story not previously accounted for in Ofcom's analysis. Some of these developments were foreshadowed in consultation responses on setting 900 MHz and 1800 MHz prices, but it was too early in the 5G awards cycle for Ofcom to determine that a significant revision of prices was underway. The separate determinations of ALFs for 2100 MHz and 3500 MHz did benefit from new 5G-era benchmark data but the single band focus did not afford an opportunity for a broader re-evaluation of prices across all mobile bands.

In the June 2018 consultation, stakeholders anticipated many of the factors that have reduced spectrum prices but Ofcom argued that to the extent these points were material, it had already addressed them[6]:

- Operators argued that the "*supply of spectrum had increased more than was expected in 2013*", and as a result UK 2013 auction values likely overstated current value. Ofcom pointed out that it factored this point into its rationale in 2015 for taking "*a conservative approach*" to setting prices. It was broadly of the opinion that subsequent developments were too limited to have "*materially affected operators' forward-looking values for additional 900 MHz spectrum.*" It did acknowledge that greater certainty over availability of 3500 MHz might have reduced the value of 1800 MHz spectrum.

[6] Ofcom (2018), Section A3.

We now have clear evidence that MNO values worldwide for both 900 MHz and 1800 MHz have declined significantly since 2015, as illustrated in Figure 2 and Figure 3. And we know that low-band has lost the most value. In hindsight, it is reasonable to conclude that Ofcom's 2018 decision did not anticipate the extent to which increased supply of spectrum would erode spectrum values over time.

- "*Respondents highlighted the use of massive MIMO and beamforming in higher frequency bands, which they said make them better substitutes for lower frequencies*." Ofcom recognized that these technologies might erode the value of 1800 MHz over time but thought they would have negligible impact on 900 MHz. However, it is now apparent that these technologies have substantially eroded the value of all lower frequency bands, as the extension in the capabilities of higher frequencies has eroded the coverage premium associated with lower bands. In hindsight, it is reasonable to conclude that Ofcom's 2018 did not fully anticipate the transformational impact that these technologies would have on mobile network design and on spectrum values.
- "*Telefónica also said that there has been a convergence in the value of all spectrum bands below 4 GHz over time, and that there is no longer any meaningful premium for the marginal value of 900 MHz over 1800 MHz spectrum*." Ofcom accepted that there had been some convergence but said that this was reflected in its reduction of the premium for 900 MHz ALFs over 1800 MHz ALFs to 36%, down from 67% when it first consulted in 2013.

  The international evidence suggests that Ofcom was roughly right: its 36% premium is only slightly above the 30% and 20% premiums observed for the 2023 moving averages in Figures 2 and 3 respectively. However, international evidence tell us that the absolute premium between the two bands has fallen significantly, because the absolute values of both bands have fallen. Meanwhile, because Ofcom has been inflating ALFs with CPI, the absolute GBP price premium between 900 MHz and 1800 MHz ALFs has been widening.

The graphs we have presented tracking trends in global spectrum values show nominal prices. The 5G era price decline we highlight would have been even more pronounced if we had shown prices for all years in today's prices. This suggests that there is a problem with Ofcom's methodology of inflating prices based on CPI. When Ofcom first developed its approach in 2013, inflation was low and spectrum prices were still rising, so an upwards CPI adjustment seemed reasonable as a tool to reduce understatement in aging benchmarks and prevent the real value of annual ALF payments eroding unduly. However, as we have moved into an era of declining spectrum prices, the CPI adjustment looks increasingly anomalous, having the contrarian effect of inflating payments and widening the absolute payment gap between bands, whereas market values have been declining and converging. We conclude from this that Ofcom needs to look again at its methodology for adjusting both historic benchmarks and future ALF payments for inflation.

2. Ofcom's approach should be adapted to the new benchmark landscape

Ofcom first consulted on setting ALFs for 900 MHz and 1800 MHz in 2013, and new prices were set in 2018. It subsequently set ALFs for 3500 MHz in 2019 (later converted to lump sum payments) and for 2100 MHz in 2021. For each band, it has maintained a consistent methodology based on benchmarking, relying primarily on UK auction prices and secondarily on European award prices. In this section, we consider the case for adaptations to Ofcom's methodology, considering both industry trends and the evolution of the available spectrum price data.

After briefly recapping Ofcom's methodology, we make three recommendations. First, we propose that Ofcom focus on benchmarks from the last 10 years, which loosely corresponds to the 5G awards era, and retire earlier 4G era price points. Second, we recommend that Ofcom analyse and price similar spectrum bands together, consistent with their role in modern 5G networks. This would result in a common price for the 700, 800 and 900 MHz bands, and a common price for the 1800 and 2100 MHz bands. Third, we propose that Ofcom use historic nominal prices rather than inflation-adjusted prices for the current review, given that relevant price levels have been falling and inflation adjustment will therefore contribute to an overstatement of market value.

2.1. Overview of Ofcom's approach to setting ALFs

Ofcom most recently described its approach to determining lump sum values for ALFs for mobile bands as follows:

> "*… our starting point when calculating the appropriate fee for a spectrum band is to first determine the market value (based on its opportunity cost to that next highest use or user) of the spectrum concerned. For mobile spectrum, we considered the evidence on the market value of mobile spectrum bands which have been auctioned in the UK alongside other evidence (where available).*"[7]

This is a benchmarking methodology. Within this methodology, there is an established hierarchy of preferred benchmarks:

1. **UK benchmarks.** The best possible benchmarks come from "*directly relevant UK auction evidence*." These are recent awards of the same or similar spectrum. For example, when setting the ALF for 3.4 GHz and 3.6 GHz spectrum already held by UK Broadband Ltd (UKB) in 2019, Ofcom based its estimate of market value on the results of the 2018 auction of 3.4 GHz spectrum. If there have been no awards of spectrum in the same frequency band, then Ofcom may look to similar bands and consider appropriate adjustments. For example, Ofcom used UK 800 MHz values to infer the value of 900 MHz, and both UK 800 MHz and 2600 MHz values to infer the value of 1800 MHz.

[7] Ofcom (2021), Annual licence fees for 2100 MHz spectrum, Statement, 13 Dec 2021, para 3.17.

2. **Other European benchmarks.** Where there is insufficient directly relevant UK auction evidence, Ofcom supplements this with price evidence from other European awards:
    a. **Relative value benchmarks.** It primarily relies on European benchmarks to make inferences about the relative value of bands when assessing the value of one UK band based on the value of another. Here, Ofcom relies on the ratio of values between two or three band observations in other countries, and then applies the same ratios to UK observations to infer the value of UK bands. For the 1800 MHz and 2100 MHz, where there have been no UK auctions of similar bands, it uses an interpolation technique, known as the "distance method", to estimate where the value of these bands lies between observed values for low-band and upper mid-band frequencies.
    b. **Absolute value benchmarks.** This is the more usual form of benchmarking, where you infer the value for a UK band directly from an observed price for the same spectrum in another country. Ofcom has placed less weight on absolute value benchmarks, owing to concern that they may be distorted by country and award specific factors. Nevertheless, it recognises absolute values as a helpful cross-check on the reasonableness of UK-based value estimates.

We anticipate that Ofcom will continue with this broad methodology for the current review. This seems a reasonable approach, given the abundance of benchmark evidence and the well-understood challenges of alternative approaches, such as building valuation models for UK operators. We also understand that there is unlikely to be another review of all bands together for at least five years. Therefore, this is an appropriate time to consider whether the methodology needs to be adapted and updated, considering the industry price trends identified in Section 1 and evolution in the available benchmarks. We set out our recommendations below.

2.2. Recommendation I: Ofcom should focus on 5G era awards

Over time, new benchmarks become available and older ones become less relevant. Here, we discuss how the relevant benchmark sample has evolved, and which benchmarks should carry more weight going forward. Our core recommendation is that Ofcom focus on awards in the last ten years and retire older benchmarks. Even within the last ten years, qualitative analysis should attach greater weight to more recent benchmarks, as later awards will be the most reflective both of market conditions and the impact at the margin of the increased supply in the earlier years of the last decade.

A tally of potentially relevant benchmarks (one per band per award) is set out in Figure 4. We have surveyed the full set of UK and European awards for mobile bands from 700 MHz up to 3800 MHz across the 4G (2010 to 2016) and 5G (2017 to present) award eras. We restrict the sample to EU member states plus Iceland, Norway, Switzerland and the UK, as these are the countries that Ofcom has previously identified as the most relevant comparators for the UK. We treat each award of a band as a separate benchmark, so if a country sells three distinct frequency bands in the same auction, this produces three benchmarks, and if a country sells spectrum from the same band in two auctions, this produces two benchmarks.

The actual number of usable benchmarks will be a large subset of this count. A complication is that some regulators do not report band-specific prices, for example because lots were allocated in a package bid auction or bundled with discounts for taking on coverage obligations. In some situations, it is possible to estimate missing values, as Ofcom did for some legacy awards (e.g. applying linear reference pricing to CCA results in Austria and Ireland). However, this is not always possible.

Figure 4: Count of potentially relevant benchmark awards by band

	# UK awards		# European awards	
Band	**4G era (2010-16)**	**5G era (2017-24)**	**4G era (2010-16)**	**5G era (2017-24)**
700 MHz FDD	-	1	3	21
800 MHz FDD	1	-	22	3
900 MHz FDD	-	-	12	8
1800 MHz FDD	-	-	22	5
2100 MHz FDD	-	-	5	15
2300 MHz TDD	-	1	1	4
2600 MHz FDD	1	-	18	4
2600 MHz TDD	1	-	14	3
3500 MHz TDD	-	2	1	27

Source: NERA; Notes: Sample comprises the full set of UK and European awards for mobile bands from 700 MHz up to 3800 MHz across the 4G (2010 to 2016) and 5G (2017 to present) award eras. We restrict the sample to EU member states plus Iceland, Norway, Switzerland and the UK. Not all awards included in the above award counts are used for benchmarking owing to data challenges associated with factors such as attachment of onerous coverage obligations or use of package bidding.

We have the following observations regarding the updated benchmark sample:

- **New UK benchmarks should be preferred evidence.** Since the ALF decision on 900 MHz and 1800 MHz, there have been two UK auctions producing four directly relevant UK benchmarks: 700 MHz, 2300 MHz, 3400 MHz and 3600 MHz.[8] Precedent for using these benchmarks has already been established in ALF decisions relating to the 2100 MHz and 3500 MHz bands. Consistent with Ofcom's policy of placing greater weight on UK evidence, we presume these should be considered as the highest tier of new evidence.

  The potentially relevant auction benchmarks for UK 4G and 5G award are set out in Figure 5, where they are compared to lump sum ALFs. We show lump sum values at the time of award or ALF decision and, after CPI adjustment, in 2024 equivalent prices. We observe that the price paid for 700 MHz is much lower than both the original 800 MHz price and original 900 MHz ALF value. This is consistent with the global observation that the value of low-band spectrum

[8] We use "3500 MHz band" to refer to the full 3400-3800 MHz 5G band, and we use 3400 MHz and 3600 MHz respectively to refer to the lower and upper parts of the 3500 MHz band.

has declined in the 5G era. The 700 MHz price is also below the 1800 MHz ALF value, which is compelling evidence that this price is also too high.

Figure 5: UK auction prices and lump-sum ALFs by frequency band

Band	Type	Auction / ALF decision date	Lump sum price (per MHz)	
			Year of award/decision	2024 prices
700 MHz FDD	Auction	March 2021	£14.0m	£17.1m
800 MHz FDD	Auction	March 2013	£29.9m	£40.9m
900 MHz FDD	ALF decision	December 2018	£19.0m	£24.2m
1800 MHz FDD	ALF decision	December 2018	£14.0m	£17.8m
2100 MHz FDD	ALF decision	December 2021	£10.5m	£12.7m
2300 MHz TDD	Auction	April 2018	£5.1m	£6.5m
2600 MHz FDD	Auction	March 2013	£5.5m	£7.5m
3400 MHz TDD	Auction	April 2018	£7.6m	£9.5m
3400 & 3600 MHz TDD	ALF decision	June 2019	£7.6m	£9.5m
3600 MHz TDD	Auction	March 2021	£4.2m	£5.2m

Source: Ofcom; Notes: ALF values taken from Ofcom ALF decisions. Auction values from Table 4.1 in Ofcom (2021). We have omitted 700 MHz SDL and 2600 MHz TDD as values were impacted by poor ecosystem development, making them unsuitable for purposes of setting ALFs.

- **Original UK benchmarks should be retired.** When determining the 2100 MHz ALF in 2021, Ofcom continued to place significant weight on the UK 4G auction benchmarks from 2013. However, by the time the current review is concluded, this award will be 12-years old. Our view is that 2013 auction benchmarks should now be retired on the basis that prices were determined in a different awards era when market conditions and expectations were different from today. As discussed in Section 1, we have ample evidence that both price levels and relative values across bands have changed significantly since these awards, and they are therefore unlikely to be reflective of market value in 2024.

  When Ofcom first consulted on ALFs in 2013, it commissioned a study from DotEcon that explored spectrum auction price data as far back as 1994, incorporating 2G and 3G era awards.[9] Ofcom considered all this evidence but ultimately opted to focus its analysis "*on 4G auctions in EU countries from 2010 onwards*".[10] Notably, it disregarded the 2000 UK 3G auction price. For the same reasons, it follows that it should now focus on UK 5G awards and disregard the UK 4G auction prices.

9 DotEcon (2013), International benchmarking of 900MHz and 1800MHz spectrum value, Final Report for Ofcom.

10 Ofcom (2013), para 4.27.

- **There are many new European awards which provide relevant evidence.** We now have a near complete set of 5G era awards from European countries. This is a rich dataset. For the purposes of determining both relative and absolute value benchmarks, Ofcom no longer needs to rely on legacy 4G era awards. As above, retiring 4G era benchmarks would be consistent with Ofcom's approach of ignoring 3G era benchmarks when it first set ALFs for 900 MHz and 1800 MHz.

  We recognize that the cut-off date between 4G and 5G awards is less distinct than that between 3G and 4G era awards, as the two era ran into each other and band release timetables varied across Europe. While we generally refer to 2017 as a start date for 5G era awards, there were some European awards of 700 MHz as early as 2015. Accordingly, we suggest that Ofcom focus its analysis on awards from 2015 onwards, a period of ten years that roughly corresponds with the observed price declines in Europe in Figure 3. Within this period, we suggest that greater weight be placed on more recent observations as they are more likely to reflect current values.

- **The composition of benchmarks has shifted, and Ofcom's approach should adapt to reflect this.** Whereas in the 4G era, most awards involved 800 MHz and 2600 MHz spectrum, most 5G era awards have focused on 700 MHz and 3600 MHz. Some countries have also released spectrum at 1500 MHz and 2300 MHz. And some European awards have included spectrum from expiring licences at 900, 1800 and 2100 MHz. There have been very few new awards of 800 MHz and 2600 MHz, as licenses for these bands are typically still in their original term.

  Collectively, these benchmarks cover the full range of low-band, lower mid-band and upper mid-band frequencies, providing a rich range of potential relative and absolute value benchmarks. As Ofcom recognizes, its approach should adapt to reflect this change in benchmark composition. There is already precedent for Ofcom adapting its distance method to incorporate 700 MHz and 3500 MHz awards when inferring the UK value of 2100 MHz, and we assume these will similarly be used as reference points for 1800 MHz and 2100 MHz.

Ofcom's approach relies on a mixture of quantitative and qualitative analysis. When considering a large sample of awards across a ten-year period, it is informative to identify statistical means and medians, excluding outliers where appropriate. However, such averages come with significant error bars, as spectrum price data is noisy (in part owing to the impact of local factors) and mobile spectrum prices have generally been declining and converging over the last ten years. Consequently, it makes sense to overlay quantitative analysis with qualitative assessments that put more weight on individual observations deemed more relevant to UK value in 2024. Ofcom already does this through a process of tiering evidence points. If it continues this approach, we recommend it factor the timing of awards into this tiering, with higher weight given to more recent awards within the last ten years.

2.3. Recommendation II: Similar spectrum bands should be analysed and priced together

When we analysed global price trends in our book, Round-by-Round, we aggregated values for similar bands (see, for example, Figure 2). Notably, we aggregated 700, 800 and 900 MHz spectrum into a common "low-band' category, and we aggregated 1800 and 2100 MHz spectrum into a common 'lower mid-band" category. This reflects the interchangeable way these bands are deployed in a modern 5G network. Aggregation is also helpful from a statistical perspective, as it increases sample size, making it possible to more reliably delineate global trends in spectrum prices.

In other contexts, we have also undertaken statistical tests on differences between bands within our categories to test whether they have similar values. These tests confirmed that bands within the above sets are close substitutes. (We also found that the picture is more complex for bands between 2300 MHz and 3800 MHz, an observation that may be explained by the wider frequency range and still developing ecosystems for some of these bands).

In Ofcom's prior ALF work, it has generally looked at bands individually, in part relying on benchmark evidence about relative values between similar bands (e.g. 800 MHz and 900 MHz) to draw inferences about UK values. We are sceptical that this approach is sustainable given the convergence in how similar frequency bands are used. Instead, we recommend that Ofcom aggregate analysis and pricing of bands as we have done, adopting a common approach for categories of similar bands rather than individual bands. It could then either set the same price for bands within the category or apply small discounts to higher bands within the category to reflect minor value differences based on propagation.

2.4. Recommendation III: Ofcom should use nominal prices rather than inflation-adjusted prices for the current review

Ofcom adopted a detailed benchmark methodology with adjustments for a series of factors, including PPP exchange rates, licence duration and inflation. Of these, a key aspect that deserves scrutiny is the application of inflation to UK and European benchmarks to adjust them to current year prices. As previously discussed, this methodology was first developed in 2013, when spectrum prices were rising. At the time, it was a reasonable concern that historic nominal prices might understate value and adjusting for inflation would help to offset this risk. However, in the current era of declining spectrum prices, historic nominal prices on average are likely to overstate current values, so adjusting for inflation increases the overstatement. In recent years, this has become a bigger issue, as UK inflation has significantly increased, meaning the overstatement has got larger.

A partial fix to this problem is to revert to nominal prices, making no adjustment to historic benchmarks for inflation. Recalculating new and old benchmarks on this basis eliminates the overstatement bias associated with inflation adjustment. However, as nominal prices have been trending downwards, this change reduces but does not eliminate broader concerns about overstatement. This methodology change is most applicable for observations from around 2014, when prices for low-band and lower mid-band peaked in Europe. It is less obvious how prices pre-2014

might be adjusted, given spectrum prices were still increasing at that time, but we suggest that Ofcom ignore these benchmarks given the likelihood that they are no longer informative regarding today's market value and the difficulty of adjusting them.

An issue with simply reverting to nominal rather than current year pricing is that the methodology might need to be revised again in the future if spectrum prices start to rise. To address this, Ofcom may consider applying a CPI-X methodology, with CPI set equal to CPI. Applying a CPI-CPI (i.e. zero) adjustment to historic prices for all years up to 2024 addresses the overstatement problem but leaves open an option to restore inflation adjustments in the future by adopting a new value for X below CPI.

3. Evidence supports a reduction in ALF for 900 MHz

In this section, we analyse evidence relating to the 2024 full market value of 900 MHz. We first discuss UK evidence, where we identify the 700 MHz auction price as the best available proxy for the value of 900 MHz. We then consider the relative value of the three sub-1 GHz bands, concluding that the evidence supports the hypothesis that there is no longer any value difference between them. Finally, we examine European absolute value benchmarks, and find no evidence to contradict our conclusion that setting UK 900 MHz ALF based on the 2018 price of 700 MHz is reasonable.

3.1. 900 MHz ALF: UK evidence

The lump sum value for 900 MHz was set at £19.0m per MHz in 2018. This value was set with reference to an estimated price for 800 MHz in the 2013 UK 4G auction of £29.9m. The lower price for 900 MHz reflected benchmark evidence that the value of 800 MHz at the time overstated the value of 900 MHz and early evidence that the general value of sub-1 GHz had declined since 2013.

The UK 4G auction took place over ten years ago, in a different mobile technology era at a time when the supply of mobile spectrum was much lower and the outlook for future releases of spectrum uncertain. For the reasons discussed in Sections 1 and 2 of this report, it is no longer a good reference point for assessing the current value of 900 MHz spectrum in the UK.

In 2021, Ofcom awarded 700 MHz spectrum by auction. In a modern 5G network, 700 MHz and 900 MHz spectrum are broadly interchangeable, offering similar propagation and playing the same role with regards to coverage and capacity. Accordingly, the auction price of 700 MHz in the UK should be an excellent benchmark for the value of 900 MHz.

The 700 MHz price was set in a competitive process, which Ofcom has identified as a relevant criterion for identifying high quality benchmarks. All four UK operators competed for 700 MHz spectrum, with excess demand of four 2x5 MHz lots in round 1. Competition continued for 10 rounds, with three of four bidders dropping demand; the price ultimately being determined by Vodafone's decision to stop bidding for 700 MHz at a price 40% above the reserve level. A relevant consideration is that Vodafone walked away with no 700 MHz spectrum, which may imply that its decision was driven by valuation rather than demand reduction, given that it did not directly benefit from setting the 700 MHz price.

700 MHz spectrum sold at a price of £14.0m per MHz, a significant discount relative to the 2018 ALF price for 900 MHz of £19.0m (which is 36% higher) and the lump sum equivalent value for 2021 ALF of £19.7m (41% higher). This is robust evidence that the UK value of 900 MHz has declined significantly since ALF was set in 2018. This finding is not a surprise, given international context. As illustrated in Figures 2 and 3, the three-year moving average of low-band prices in 2021, both worldwide and in Europe, was about 50% down from its peak in 2014-16. And European prices in 2021 were around 20-25% down from 2018.

Since 2021, Global and European prices paid for sub-1 GHz spectrum have continued to fall. This implies that a 2021 UK benchmark should be an upper bound for 2024 value, and the actual market value may be lower. However, under Ofcom's current methodology, the 700 MHz benchmark would

rise from £14.0m to £17.1m after adjusting for CPI between 2021 and 2024. This seems perverse. Given the context of declining global values, we recommend that Ofcom instead applies a CPI-CPI adjustment to the 700 MHz value in 2021 and recognizes that the resulting value of £14.0m carries a risk of overstatement.

3.2. 900 MHz ALF: European sub-1 GHz relative value evidence

Ofcom's original ALF methodology relied heavily on European observations regarding the relative value of 800 MHz and 900 MHz spectrum. The general finding was that the market value of 900 MHz was rather less valuable than 800 MHz. This may be attributed to ecosystem differences. Operators placed relatively high value on marginal 800 MHz because incremental blocks brought them closer to filling an LTE carrier, thereby offering a valuable capacity boost to a 4G network. In contrast, marginal 900 MHz was less valuable owing to the small quantities available for 4G after the legacy needs of 2G and 3G networks had been addressed. In a 5G world, where 2G and 3G networks have been shut down and all spectrum is being migrated to a single network, such differences are no longer relevant. Accordingly, it no longer seems reasonable for Ofcom to rely on legacy ratios between 800 MHz and 900 MHz to value 900 MHz spectrum in 2024.

European auctions of 700 MHz spectrum began in 2015, producing benchmarks that Ofcom also considered when setting ALF for 900 MHz. In theory, the observed value ratio between 700 MHz and 900 MHz spectrum in European auctions provides an alternative to the legacy 800 / 900 MHz ratio for valuing 900 MHz.

In practice, we do not recommend using the 700/900 MHz price ratio for the purposes of setting ALFs, for two reasons:

1. Technical evidence suggests that going forward 700, 800 and 900 MHz bands should be considered to have identical value.
2. The benchmark evidence, set out below, is consistent with the hypothesis that 700 MHz and 900 MHz have the same value, implying a ratio is redundant.

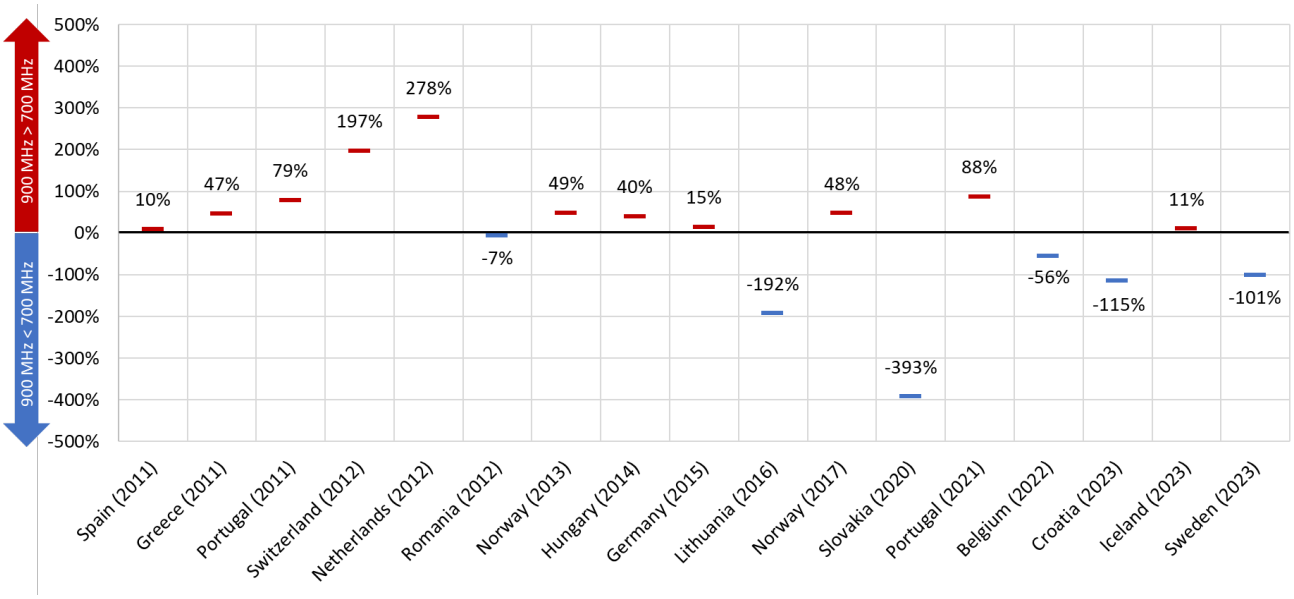
In Figure 6, we identify 17 European countries that have released both 700 MHz and 900 MHz spectrum in the period 2010-2024. We report the ratio of the price paid per MHz for 700 MHz versus 900 MHz for each of these sets of awards. A majority of benchmarks (11 of 17) produce a higher value for 900 MHz. However, 6 award pairs report the opposite ratio, with 700 MHz valued more highly than 900 MHz.

Most of the awards that value 900 MHz more highly are comparing an earlier auction of 900 MHz with a later auction of 700 MHz, and eight of them are comparing a 900 MHz award that took place more than 10 years ago with a more recent 5G-era award of 700 MHz. The premium for 900 MHz may therefore be entirely explained by the decline in value of low-band spectrum over time and uninformative regarding the relative values of the two bands. In support of this hypothesis, we observe that in two countries where 900 MHz was sold later than 700 MHz – Croatia (2023 and 2021 awards respectively) and Sweden (2023 and 2018) – 700 MHz sold for a premium over 900 MHz. We

also note that in Belgium, where 700 MHz and 900 MHz were awarded in the same 2022 auction, 700 MHz also sold for a higher price than 900 MHz.

There are only two examples of countries that have sold both 800 MHz and 900 MHz in recent awards: Croatia and Iceland. In both countries, spectrum in the two bands sold for similar prices. The price levels were at or close to reserve, which implies that the regulators perceived the bands as having similar value and that bidders had no incentive to challenge this through their bids.

Figure 6: Value ratios for 700 MHz / 900 MHz for European auctions (2010-2024)



Source: NERA. Notes: Sample consists of countries that have held both 900 MHz and 700 MHz awards since 2010. The year of award in parentheses corresponds to the year of the 900 MHz award. Data points above the 0% line represent the premium for 900 MHz relative to 700 MHz in percentage terms (i.e. 900 MHz Price/700 MHz Price – 1). Data points below the 0% line represent the negative of the premium for 700 MHz relative to 900 MHz in percentage terms (i.e. –[700 MHz Price/900 MHz Price – 1]).

In summary, while the benchmark evidence is not definitive, we think it broadly supports the hypothesis that there is no longer a meaningful value difference between any of the three sub-1 GHz bands. Where there have been observed price differences, we believe they can be attributed to local competition factors not relevant to setting UK ALFs. Accordingly, we recommend that Ofcom abandons the approach of looking at the ratio of values between sub-1 GHz bands to value UK 900 MHz, and instead sets 900 MHz value directly based on the UK 700 MHz auction price.

3.3. 900 MHz ALF: European absolute value evidence

Ofcom uses absolute values from auctions of similar bands in European countries as a cross check on the value of UK 900 MHz spectrum. There is no expectation that UK value will correspond to the mean or median of European values, as local factors might cause bidders in particular European auctions to value equivalent spectrum above or below UK value. Notwithstanding this point, there is an

expectation that Ofcom's estimate of full market value will not be an outlier within the observed benchmark set, as that could be a red flag that the process was flawed in some way.

Our view is that all sub-1 GHz bands can now be treated as having equivalent value. This is a change from the 4G era, where there were real ecosystem differences between the bands that could explain the observed higher value of 800 MHz over 900 MHz. Given this change, going forwards it seems appropriate to look at all absolute value benchmarks for 700, 800 and 900 MHz together when assessing the reasonableness of the UK 900 MHz lump sum value.

In Figure 7, we show the absolute benchmark values in GBP for all European sub-1 GHz awards in the last ten years. We have applied the Ofcom benchmark methodology with the exception that we show values at the time of award, i.e. we have not adjusted values upwards based on inflation between the year of award and now. We make no adjustment for inflation because we know that prices for sub-1 GHz bands have been falling in nominal terms, so we would expect older benchmarks within this sample to (on average) overstate 2024 value, and adjusting for inflation would only serve to exaggerate the overstatement. The benchmarks are presented in chronological order.

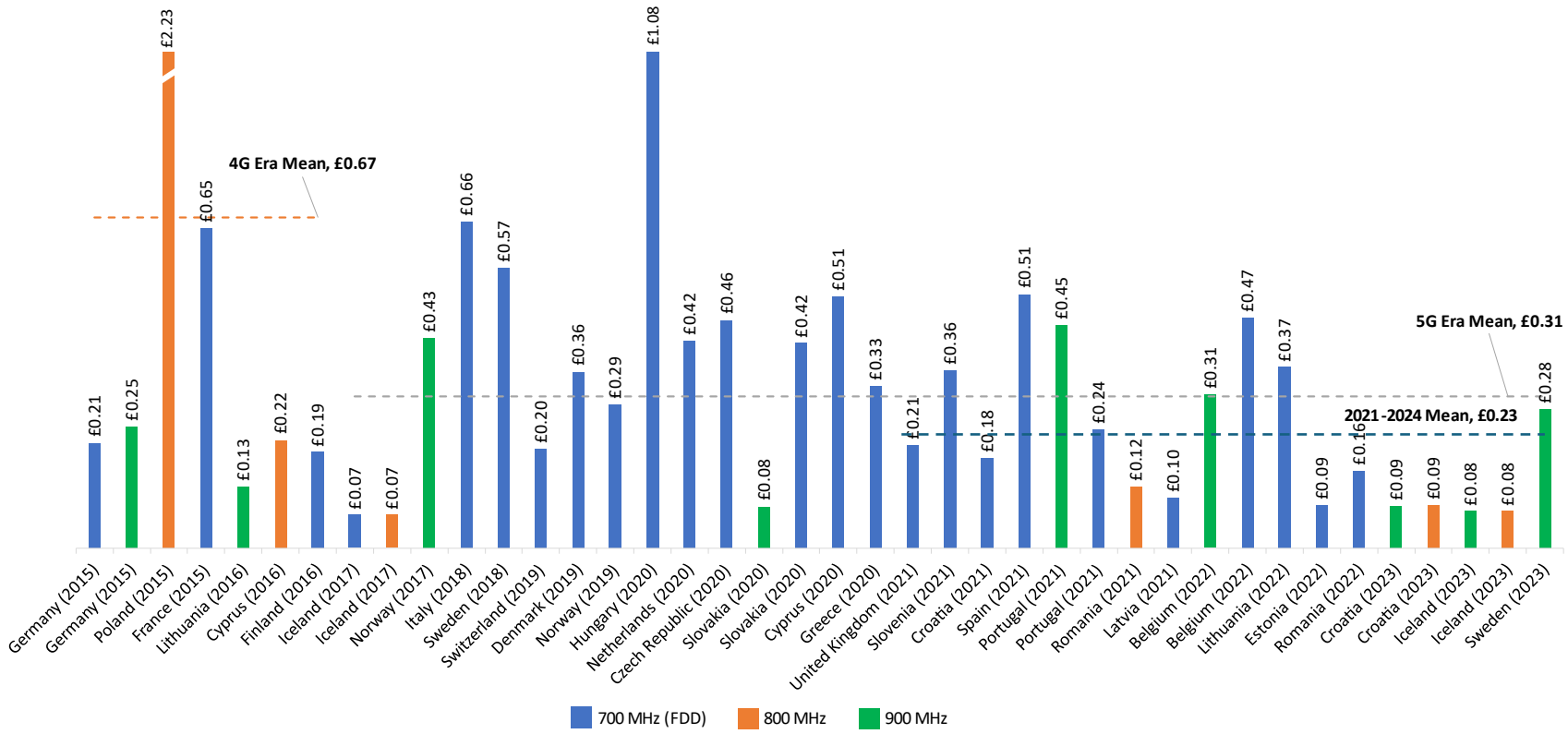
The sample includes the UK 700 MHz award price of £0.21 per MHz/pop (£14.0m per MHz), which we identified above as a preferred benchmark for the value of UK 900 MHz. A key question is whether this value falls within a reasonable range of observed benchmarks.

We conclude that the absolute benchmark evidence supports our view that the 700 MHz UK benchmark is a reasonable benchmark for the value of sub-1 GHz spectrum, for the following reasons:

- The UK benchmark lies joint 23rd out of 39 benchmarks across the ten-year period. While it is in below the mode, it is not an outlier.
- Low-band prices have fallen significantly from the 4G awards era, when they averaged £0.67 per MHz/pop, to the 5G era, when they averaged £0.30. The UK benchmark occurs in 2021, well into the 5G era, so it is to be expected that it will be at the lower end of the sample range.
- Over the last three years, 2021-23, the mean value of 18 benchmarks is £0.23. The UK value of £0.21, which is the 9th highest in this group, is very similar.
- Some recent awards which may be perceived as higher quality ones, such as Belgium and Sweden, have produced higher values than the UK. However, differences between countries are common. There may be good reasons why the marginal value of sub-1GHz spectrum in the UK is lower than in these countries, for example because spectrum distribution across UK operators is more asymmetric. The marginal value for 700 MHz expressed by Vodafone UK in 2018 is much more likely to be reflective of this aspect of spectrum value than the observed value in another country where distributions were more even between operators (and all else equal would give rise to a somewhat higher marginal value).

UK operators in 2024 are due to pay ALF of £24.2m per MHz or £0.36 per MHz/pop. This amount is above the 5G awards era average, and well above the average of the last three years. This is further evidence that current UK ALF price can no longer be considered a conservative estimate of UK value and needs to be reduced.

Figure 7: European sub-1 GHz absolute value benchmarks (2015-2024) for UK 900 MHz ALF lump sum value



Source: NERA. Notes: Sample consists of relevant awards for 700 MHz (FDD), 800 MHz and 900 MHz spectrum held in EU member states plus Iceland, Norway, Switzerland and the United Kingdom since 2015. Spectrum prices are reported in GBP/MHz/Pop and include award revenues and the net present value of associated annual fees. They are converted to GBP using PPP exchange rates from the World Bank and adjusted for a common license duration of 20 years. Prices are reported in nominal terms. The 4G Era Mean value is computed on the full 4G Era sample from 2010-2016.

4. Evidence also supports a reduction in ALF for 1800 MHz & 2100 MHz

In this section, we analyse evidence relating to the 2024 full market value of 1800 and 2100 MHz. We first discuss UK evidence, which we use to identify a range of £8.0m - £10.6m per MHz within which the value of 1800 MHz and 2100 MHz likely lies. We then consider the relative value of 1800 MHz and 2100 MHz, concluding that the evidence supports the hypothesis that there is no longer sufficient difference between the bands to justify valuing them independently. Next, we apply the distance value method to European benchmarks, and identify an average implied value for UK lower mid-band spectrum of £9.3m per MHz, which is within our range. Finally, we examine European absolute value benchmarks for 1800 MHz and 2100 MHz; we find no evidence to contradict our conclusion that setting a common ALF for the two bands within our proposed range is reasonable.

4.1. 1800 MHz & 2100 MHz ALF: UK evidence

A challenge when pricing spectrum in the 1800 MHz and 2100 MHz bands is the absence of any direct UK benchmarks for lower mid-band spectrum. There have been UK awards of bands in spectrum categories below (700 MHz) and above (2300, 3400 and 3600 MHz) the two bands. These benchmarks are informative regarding lower and upper boundaries for the value of 1800 / 2100 MHz but cannot by themselves provide a point estimate for market value.

Looking first at UK low-band spectrum, it is reasonable to expect that 700 MHz – which sold at £14.0m per MHz in 2021 – will have a higher value than 1800 and 2100 MHz. Although we have presented evidence indicating that the value of low-band and lower mid-band spectrum has converged over the 5G era, a plurality of awards have priced low-band spectrum at a higher level. As illustrated in Figure 2 and Figure 3, the 3-year moving average of global and European spectrum prices in 2023 reveals a value premium for low-band over lower mid-band of 30% and 20% respectively. And in 2018, the UK ALF for 900 MHz was set at a 36% premium over 1800 MHz.

Looking next at upper-mid band spectrum, it is reasonable to expect that 2300, 3400 and 3500 MHz will all have a lower value than 1800 and 2100 MHz:

- The closest band in frequency terms is 2300 MHz, which sold for at £5.1m per MHz in 2018. In a modern 5G network, 2300 MHz is a good substitute for 1800 MHz and 2100 MHz, having modestly inferior propagation and a TDD ecosystem which allows for higher downlink capacity versus FDD. However, the 2300 MHz ecosystem in Europe was not well-established as of the 2018 auction (and many countries have still not released this band). All 40 MHz available in the UK was won by Telefonica UK at a price per MHz lower than 3400 MHz, even though the frequency is significantly lower. A plausible explanation for this lower price is that all bidders prioritized 3400 MHz, owing to its primary role in the global 5G ecosystem, whereas Vodafone, EE and H3G (which unlike Telefonica UK already had significant mid-band holdings) were less interested in 2300 MHz. This implies that the UK 2300 MHz price may understate full market value for upper-mid band spectrum.

- The 3400 MHz and 3600 MHz bands, though highly prized for 5G, are at significantly higher frequencies than the other bands analysed. These sub-bands sold at £7.6m per MHz and £4.2m per MHz respectively. The 3400 MHz price potentially overstates full market value owing to the initial scarcity of the spectrum for operators other than H3G. Meanwhile, the 3600 MHz carries a potential risk of understatement, given that the three winning bidders in the 2021 auction quickly found a settlement that divided the spectrum equally between them under circumstances that may have discouraged them from expressing their full marginal value for incremental spectrum.

For our analysis, we prefer 3500 MHz over 2300 MHz as a baseline for the value of higher mid-band spectrum. Give the opposing risks of overstatement and understatement associated with the 3400 MHz and 3600 MHz benchmarks, we have adopted a simple average of the two award prices of £5.9m per MHz as a proxy for the UK value of 3500 MHz. (We recognize that this may merit deeper analysis.) On this basis, we identify £5.9m per MHz as a lower bound for the value of 1800 and 2100 MHz.

As illustrated in Figure 2 and Figure 3, the 3-year moving average of global and European spectrum prices in 2023 revealed a value discount for upper-mid band versus lower mid-band of 38% and 64% respectively. And in 2019, the UK ALF for 3500 MHz was set at £7.6m per MHz, a discount of 46% versus the 2018 ALF for 1800 MHz and a 28% discount versus the 2021 ALF for 2100 MHz. Given the general trend of convergence in lower- and upper mid band prices, we would not expect these differentials to have increased since ALFs were first set.

In summary, direct evidence tells us that the value of 1800 MHz and 2100 MHz lies somewhere between £5.9m and £14.0m per MHz. A common ALF might reasonably be set at least 25% below 900 MHz ALF and at least 35% above the value of 3500 MHz. Taking the average price across the two UK 3500 MHz awards of 5.9m, this implies a range of £8.0m - £10.6m for the full market value of UK lower mid-band spectrum.

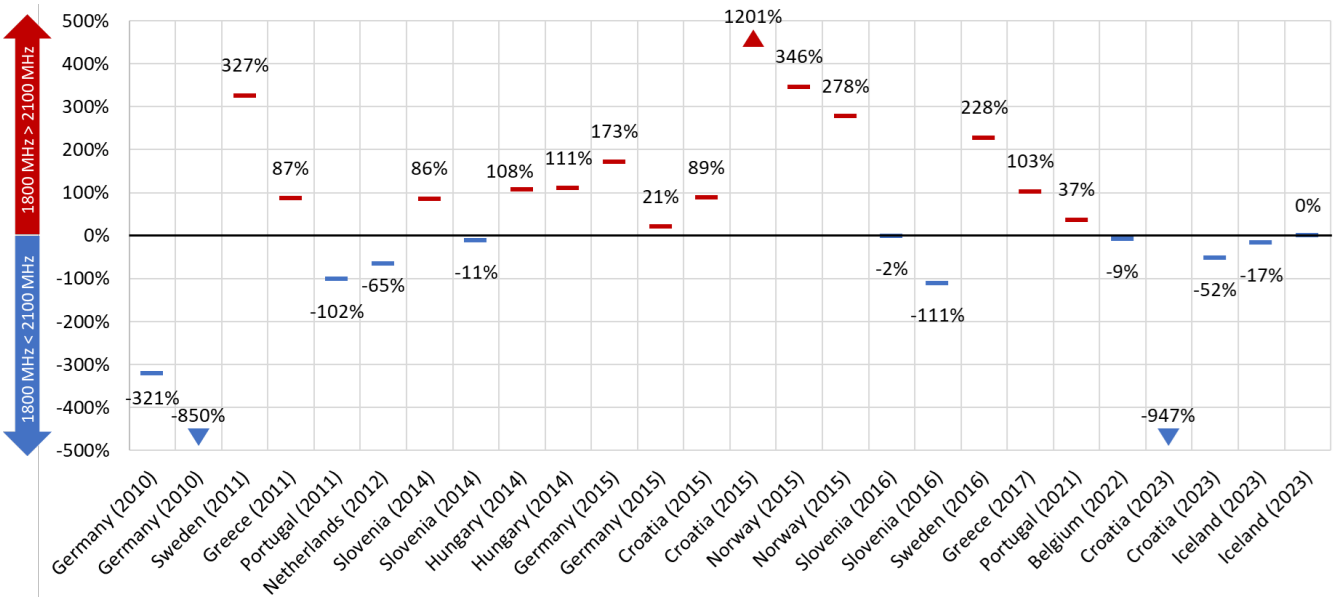
4.2. 1800 MHz & 2100 MHz ALF: European relative value evidence

Currently, there is a substantial difference in the ALFs levied on 1800 MHz and 2100 MHz spectrum licences, with 1800 MHz ALFs being 54% higher than 2100 MHz ALFs (after inflation adjustments). The two bands are functionally equivalent and serve the same purpose within an operator's network. Rather than reflecting a relevant difference in the market value of the two spectrum bands, the difference is likely an artefact stemming from the 2100 MHz ALFs being set more recently, and therefore reflecting the decline in the value of spectrum during the 5G Era. To establish whether there is a material difference in the value of 1800 MHz and 2100 MHz spectrum, we examine the relative value of these bands in countries that have held awards for both.

Figure 8 displays the relative value differences between 26 pairs of 1800 MHz and 2100 MHz prices in countries that have held awards for both bands. There are a similar number of data points above the 0% parity line as there are below, implying no systematic difference in the price of 1800 MHz and 2100 MHz spectrum. Of the 26 award pairs, 14 have a positive value (implying a premium for 1800 MHz), while 11 have a negative value (implying a premium for 2100 MHz). One pair of band prices, in

Iceland, sits on the parity line owing to the spectrum selling at reserve price, which was set equal for the two bands.

Figure 8: Relative value differences between 1800 MHz and 2100 MHz (FDD)



Source: NERA. Notes: Sample consists of countries that have held both 1800 MHz and 2100 MHz awards since 2010. The year of award in parentheses corresponds to the year of the 1800 MHz award. Data points above the 0% line represent the premium for 1800 MHz relative to 2100 MHz in percentage terms (i.e. 1800 MHz Price/2100 MHz Price – 1). Data points below the 0% line represent the negative of the premium for 2100 MHz relative to 1800 MHz in percentage terms (i.e. –[2100 MHz Price/1800 MHz Price – 1]).

Most of the awards that value 1800 MHz more highly are comparing an earlier auction of 1800 MHz with a later auction of 2100 MHz. The premium for 1800 MHz may largely be explained by a decline in the value of lower mid-band spectrum over time and is uninformative regarding the relative values of the two bands. This hypothesis is supported by the observation that during the 5G Era, where countries have sold the two bands in the same award process, the average ratio of the value differences between the two bands collapses to a mere -5%.[11]

In summary, we believe the benchmark evidence supports the observation that the current 54% difference in ALFs for 1800 MHz and 2100 MHz licences is much too high. Given the equivalent function the two bands serve in a modern 5G mobile network, and recent evidence suggesting they have similar market value, we recommend that Ofcom sets the ALFs for the 1800 MHz and 2100 MHz bands at the same level.

[11] These awards are: Slovenia 2016, Portugal 2021, Belgium 2022, Croatia 2023, and Iceland 2023.

4.3. 1800 MHz & 2100 MHz ALF: Distance value evidence

Ofcom's methodology for setting 1800 MHz and 2100 MHz ALFs relied heavily on European distance method benchmarks. Given the lack of suitable UK benchmarks for 1800 MHz and 2100 MHz spectrum, Ofcom inferred a UK benchmark price for the 1800 MHz and 2100 MHz bands by examining ratios of differences between the value of this spectrum and a low-band benchmark and an upper mid-band benchmark in European awards.

There are many European countries that have awarded 1800 MHz or 2100 MHz. As these countries have generally also awarded 700, 800, 2600 and 3500 MHz bands, and some have awarded 900 and 2300 MHz bands, there is a significant increase in the number of 'benchmark triplets' where the distance method could be applied. However, a complication is that many of these triplets include at least one observation before 2015 and/or feature observations from awards many years apart. These include many triplets that Ofcom has previously categorized as Tier 1 benchmarks, but now need to be retired.

For example, when Ofcom calculated the 2100 MHz ALF in 2021, it identified 20 benchmark triplets from European awards, but half of these now include awards that are more than 10 years old, and some include awards that are 15 years old. Fortunately, there are new benchmarks – for example from Belgium and the Netherlands – that can replace these aging, less relevant benchmarks.

For the 1800 MHz ALF process, Ofcom used the UK 800 MHz and 2600 MHz auction prices as the UK reference values, as these were the most recently available UK data points. However, the UK 800 MHz and 2600 MHz benchmarks are now over ten years old and no longer good proxies for the value of UK spectrum. Fortunately, they can be replaced by the new UK auction benchmarks. For 2100 MHz ALF, Ofcom also considered UK 2300 and 3400 MHz prices from the 2018 5G market for the upper benchmarks. And Ofcom now has available UK benchmarks for 700 MHz and 3600 MHz from the 2021 auction.

Looking forward, we recommend that Ofcom substitute UK 700 MHz for 800 MHz, and UK 3500 MHz for 2600 MHz. This will have the positive effect of limiting benchmarks to the last ten years. Separately, we have argued that for benchmarking purposes, the values of 700, 800 and 900 MHz are now identical, so in principle European benchmark prices for any of these bands might be used. However, given the preponderance of recent European releases of 700 MHz and 3500 MHz, it seems sensible to rely primarily on benchmarks from these bands. We have also argued that 1800 MHz and 2100 MHz should have the same value, so the distance method for the two bands may be merged.

Figure 9 displays distance method benchmarks for all relevant 1800 / 2100 MHz awards based on distance from 700 MHz and 3500 MHz prices. For each country triplet of low-band, lower mid-band and upper mid-band benchmarks, we compute the ratio of the difference between the lower mid-band and upper mid-band benchmarks and the low-band and the upper mid-band benchmarks, which Ofcom refers to as the "Y/X ratio". We then solve for the UK value of the lower mid-band spectrum using the UK 700 MHz value of £14.0m per MHz and the average of the prices for UK 3400 MHz and 3600 MHz of £5.9m (see discussion in Section 4.1 for rationale).

The observed range of UK lower mid-band distance method benchmarks span a wide range of prices. We have excluded results that show a value below GBP 0/MHz, on the basis that such results are nonsensical. We further expect that observations should normally show that the low-band spectrum is worth more than lower mid-band spectrum, which in turn is worth more than upper mid-band spectrum. If this value order is observed in the data, the associated Y/X ratio should lie between 0 and 1. This is the case for 22 out of 32 observations, but there are 10 exceptions which we highlight in red in Figure 9. Such exceptions may reflect differences in the timing of awards (older awards often have higher values) or local factors that precipitated higher competition for select bands.

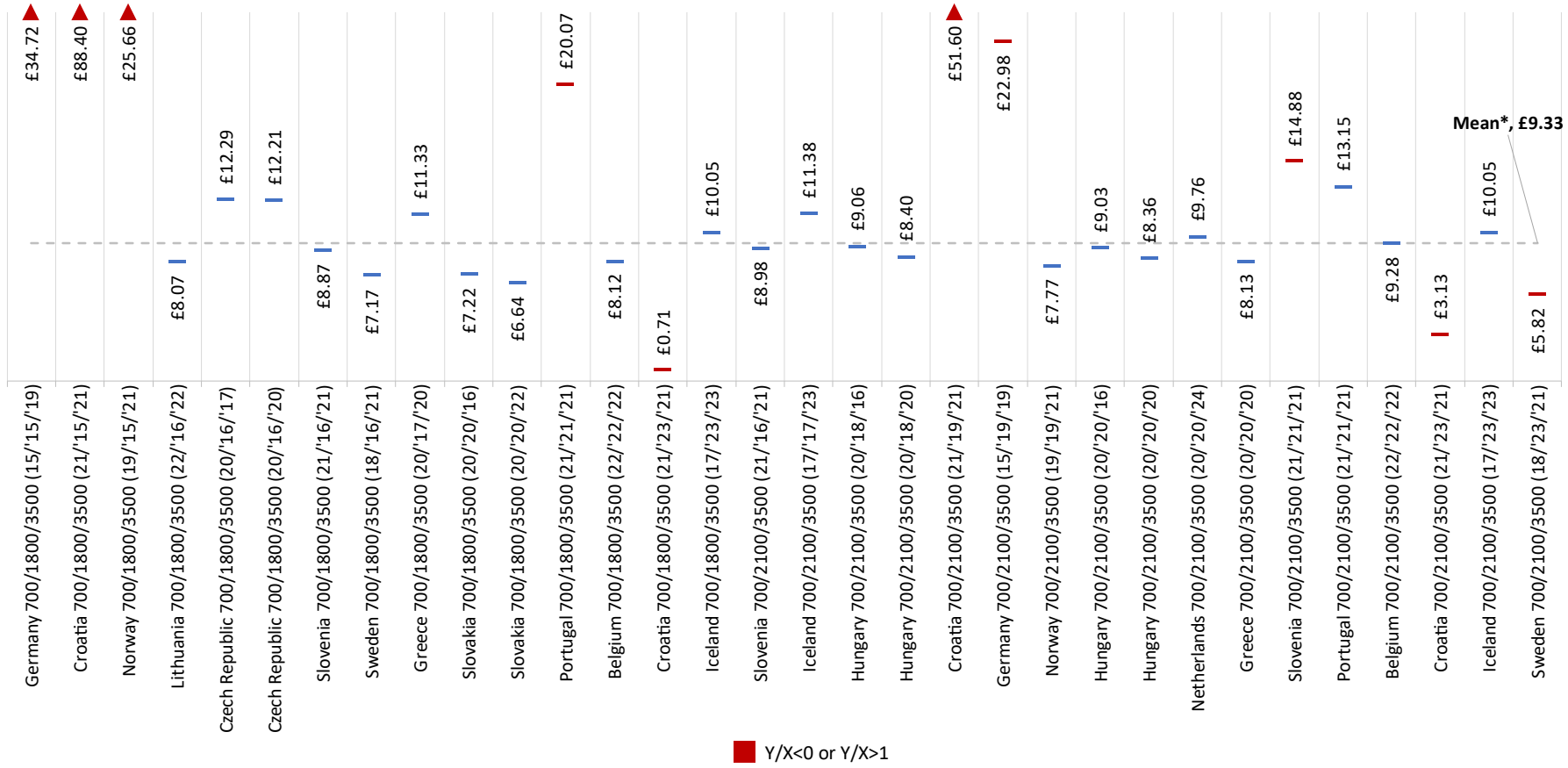
Restricting the sample to the 22 observations with a Y/X ratio between 0 and 1 produces a value range from £6.6m per MHz up to £13.2 per MHz, with an average value of £9.3m per MHz. We observe that this value coincidentally lies at the mid-point of the value range of £8.0m - £10.6m per MHz for 1800 / 2100 MHz spectrum that we identified in Section 4.1, based on UK benchmark evidence. We therefore identify this as a reasonable point estimate for the current value of 1800 MHz and 2100 MHz.

Separately, we also considered a larger set of distance method observations incorporating other bands as proxies for low-band (800 or 900 MHz) and upper mid-band spectrum (2300 MHz or 2600 MHz). This super set of distance benchmarks is shown in Figure 10 (for space reasons we only show observations with a Y/X ratio between 0 and 1). In this case, 72 of 106 observations have a Y/X ratio between 0 and 1, with an average value of £9.0m per MHz. We put less weight on this average, as we observe that the sample is weighted towards a minority of countries that have released many bands since 2015 and so produce multiple distance benchmarks. Nevertheless, it is reassuring that the average value is not hugely different.

A general concern with the distance methodology is that each observation relies on three different European benchmarks, and a distortion in any one of them (owing to local factors) could skew the result. An approach of averaging across what is now a broad sample may help to reduce the impact of such biases, but we would nevertheless apply a non-trivial margin for error to our preferred average of £9.3m per MHz.

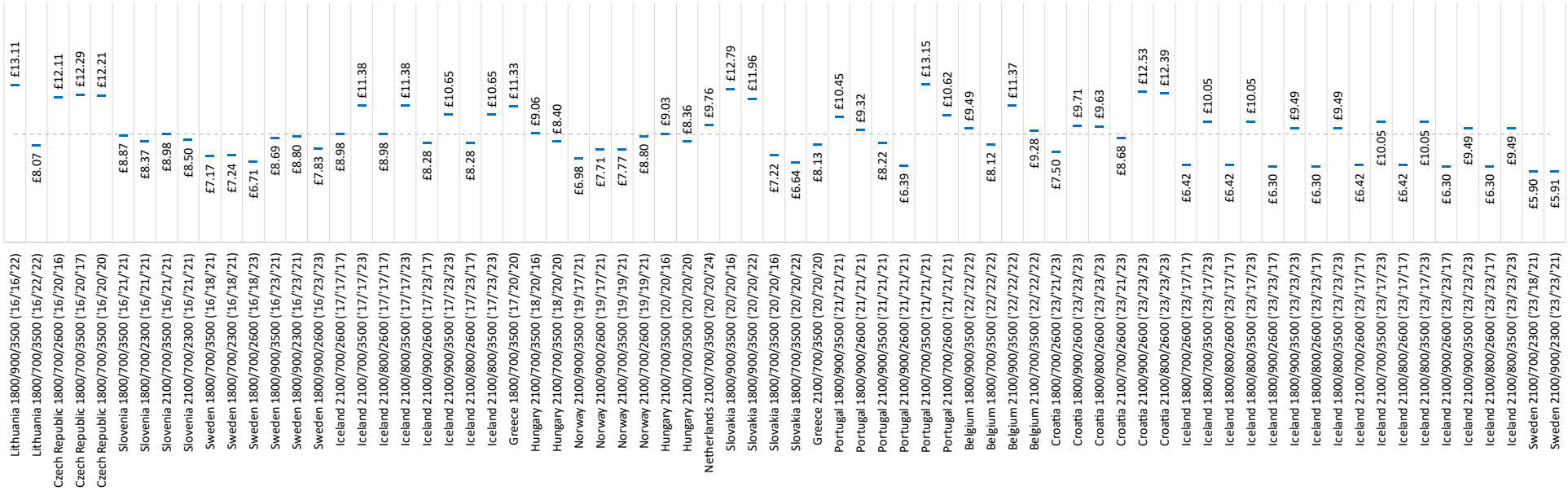
In the past, Ofcom has attempted to address noise in the sample by placing greater weight on selected distance benchmarks that it identified as Tier 1 evidence. We have not attempted to tier our observations, but we recognize that this could provide a cross check on or alternative to adopting a simple average. One reason why a qualitative approach was necessary for 1800 MHz in the original ALF analysis was that the number of observations was small, so a simple average was unduly vulnerable to distortion from individual results. This is less true now owing to the much larger sample of relevant triplets available in the 5G awards era. We also note that the qualitative approach was contentious with stakeholders because tiering decisions can have a significant impact on final prices. Therefore, where the data sample is large enough, there may be an advantage to basing prices off the observed average price.

Figure 9: Distance method benchmarks (£/MHz) for 1800 and 2100 MHz, restricting sample to triplets with 700 MHz and 3500 MHz awards



Source: NERA. Figure displays the implied UK 1800 MHz and 2100 MHz prices in GBP/MHz based on a sample of countries that have held 700 MHz, 1800 MHz / 2100 MHz and 3500 MHz awards since 2015. Data markers in red indicate that the Y/X ratio lies outside the range 0-1. The 1800 and 2100 MHz UK benchmark prices are computed using the 2021 UK auction price for 700 MHz (FDD) of £14.0m per MHz and the average of the 2018 and 2021 UK prices for 3400 MHz and 3600 MHz prices respectively of £5.9m. The Mean line displays the average implied price of 1800 and 2100 MHz in the UK for triplets of awards whose Y/X ratio of price differences is between 0 and 1.*

Figure 10: Distance method benchmarks (£/MHz) for 1800 and 2100 MHz, superset of previous figure incorporating 800, 900, 2300 and 2600 MHz awards



Source: NERA. Figure displays the implied UK 1800 MHz and 2100 MHz prices in GBP/MHz based on a sample of countries that have held 700 / 800 / 900 MHz awards, 1800 MHz / 2100 MHz awards and 2300 / 2600 / 3500 MHz awards since 2015. Data markers in red indicate that the Y/X ratio lies outside the range 0-1. The 1800 and 2100 MHz UK benchmark prices are computed using the 2021 UK auction price for 700 MHz (FDD) of £14.0m per MHz and the average of the 2018 and 2021 UK prices for 3400 MHz and 3600 MHz prices respectively of £5.9m. The Mean line displays the average implied price of 1800 and 2100 MHz in the UK for triplets of awards whose Y/X ratio of price differences is between 0 and 1.*

4.4. 1800 MHz & 2100 MHz ALF: European absolute value evidence

Ofcom uses absolute values from auctions of similar bands in European countries as a cross check on the value of UK 1800 and 2100 MHz spectrum. As with 900 MHz, there is no expectation that UK value will correspond to the mean or median of European values, as there are many local factors that might cause bidders in particular European auctions to value equivalent spectrum above or below UK value. Notwithstanding this point, there is an expectation that Ofcom's final conservative estimate of full market value should not be an outlier.

Our view is that 1800 MHz and 2100 MHz can now be treated as having equivalent value in a 5G network. This is a change from the 4G era, when operators displayed a clear preference for 1800 MHz, owing to its role as a primary 4G band (whereas 2100 MHz was associated with legacy 3G). Given this change, going forwards it seems appropriate to look at all absolute value benchmarks for 1800 and 2100 MHz together when assessing the reasonableness of current ALF charges.

In Figure 11, we show the absolute benchmark values in GBP for all 24 European awards of 1800 MHz and 2100 MHz in the last ten years. We have applied the Ofcom benchmark methodology with the exception that we show values at the time of award, as we believe that applying inflation would unduly overstate value (same reasoning as for 900 MHz in Section 3.3). The benchmarks are presented in chronological order.

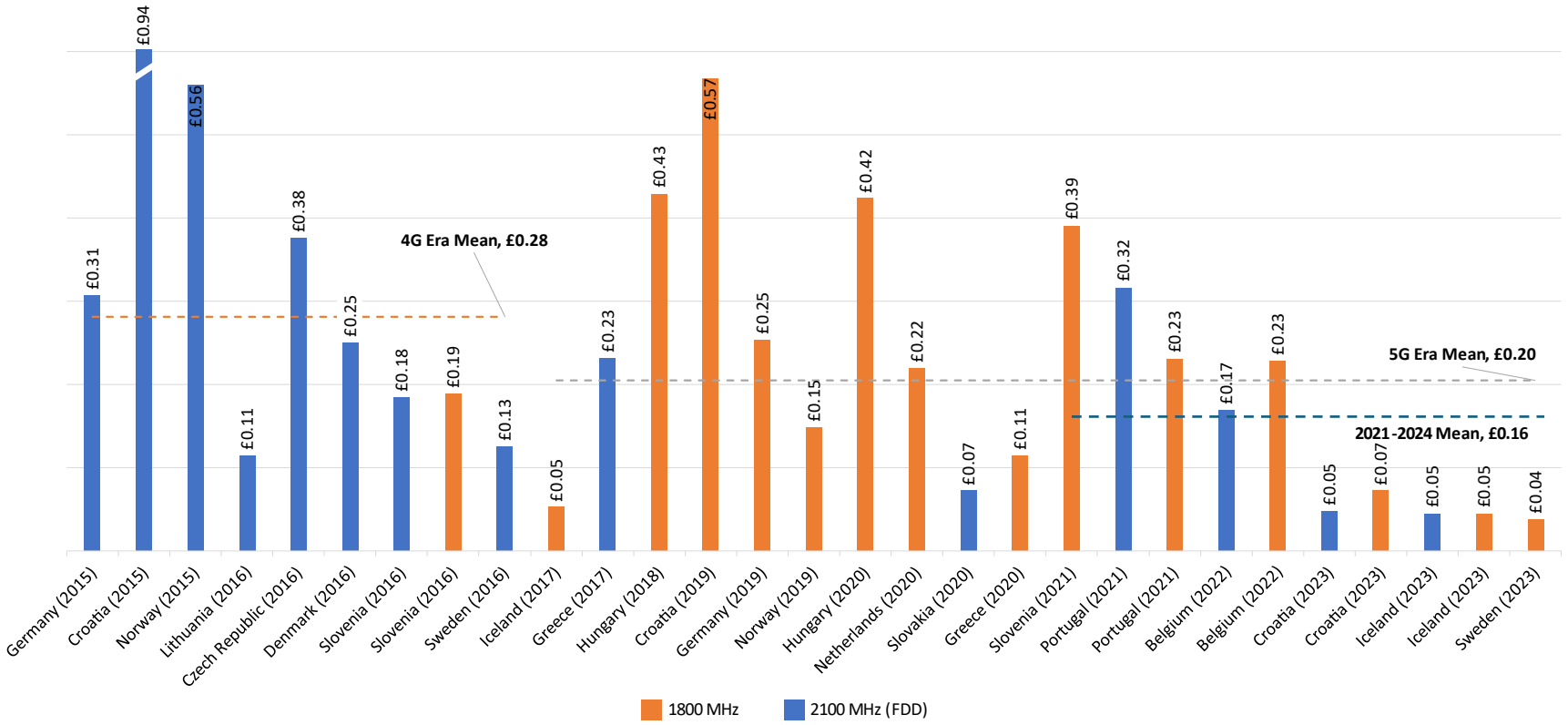
In Section 4.1, we identified a range of £8.0m - £10.6m for the current full market value of UK lower mid-band spectrum. This translates to a range of £0.12-£0.16 on a per MHz/pop basis. A key question is whether this value range is reasonable given the range of observed absolute benchmarks.

We conclude that the absolute benchmark evidence supports our view that this is a reasonable range, for the following reasons:

- Across 24 benchmarks, 14 are above this range, 2 within the range, and 8 below. On this basis, a UK ALF set in this range would not be an outlier.
- Prices paid for European lower-mid band spectrum have fallen from the 4G awards era, when they averaged £0.28 per MHz/pop, to the 5G awards era, when they averaged £0.20. The average value in the last three years, 2021-23, fell further to £0.16. Our proposed range is immediately below the current level of the three-year moving European average, which seems reasonable as an estimate of UK full market value.
- Two recent awards which may be perceived as higher quality ones have produced both higher and lower values than the proposed range: Belgium was slightly higher and Sweden significantly lower.

UK operators in 2024 are due to pay ALF of £17.8m per MHz or £0.27 per MHz/pop for 1800 MHz, and £12.7m per MHz or £0.19 per MHz/pop for 2100 MHz. The 1800 MHz amount is well above the 5G awards era average, and the 2100 MHz value is above the average of the last three years. This is further evidence that current UK 1800 MHz ALF price can no longer be considered a conservative estimate of UK value and should be reduced.

Figure 11: European lower-mid band absolute value benchmarks (2015-2024) for UK 1800 & 2100 MHz ALF lump sum value



Source: NERA. Notes: Sample consists of relevant awards for 1800 MHz and 2100 MHz (FDD) spectrum held in EU member states plus Iceland, Norway, Switzerland and the United Kingdom since 2015. Spectrum prices are reported in GBP/MHz/Pop and include award revenues and the net present value of associated annual fees. They are converted to GBP using PPP exchange rates from the World Bank and adjusted for a common license duration of 20 years. Prices are reported in nominal terms. The 4G Era Mean value is computed on the full 4G Era sample from 2010-2016.

5. Recommendations on ALFs for 900, 1800 & 2100 MHz

In Section 3, we identified the best available benchmark for the 2024 value of 900 MHz as the price paid for 700 MHz in the 2021 UK 5G auction, £14.0m per MHz. And in Section 4, we identified UK evidence as supporting a value range of £8.0m - £10.6m per MHz for a common 2024 estimate of 1800 and 2100 MHz market value. Within this range, the distance value method suggested a point value of £9.3 per MHz, although this approach comes with a non-trivial margin for error.

As a cross check on these values, it is relevant to consider the relative values of 900 MHz and 1800 / 2100 MHz. A 900 MHz lump sum value of £14.0m per MHz would be 75% above the lower end and 32% above the upper end of the proposed value range for 1800 / 2100 MHz.

We observe that the lower end premium looks high given UK and global evidence regarding the value differentials between the two bands:

- As described in Section 1.2, global and European average price data reveals an ongoing convergence in value between low-band and lower mid-band spectrum. As of 2023, the premium for the three-year moving average of low-band over lower mid-band spectrum for the global and Europe samples were 30% and 20% respectively.
- Ofcom previously set the premium for 900 MHz ALF over 1800 MHz ALF at 36%. Given evidence of value convergence, it seems unlikely that this ratio could have increased since 2018.

Against this, we recognize that European countries that have sold both low band and lower mid-band since 2015 have on average priced low band spectrum about 50% higher. The data, however, is noisy and sometimes contradictory. For example, the 2021 Portugal 5G auction reports a 1:1 ratio for the value of 700 MHz / 2100 MHz and a 4:1 ratio for the value of 900 MHz / 1800 MHz.

On balance, we put greater weight on the UK and general global and European evidence over evidence from absolute value points for a minority of European countries. Accordingly, we conclude that a premium of around 25% for the value of 900 MHz ALF over 1800 and 2100 MHz is appropriate.

Our benchmark prices are based on an analysis of nominal prices with no inflation adjustments. This is a change from Ofcom's prior methodology. We believe that this change is appropriate in the current environment of falling spectrum prices and high inflation. With falling prices, it is reasonable to anticipate that aging benchmarks will on average overstate value. Applying inflation would exaggerate this overstatement.

Ofcom is legally required to set prices based on full market value, but it is committed to adopting a conservative estimate of full market value owing to asymmetric risk. Given that nominal spectrum prices in Europe and worldwide have been falling and there is reason to expect this trend to continue, and Ofcom's benchmark methodology relies on analysing historic prices, we conclude that the values identified here are more likely to overstate than understate market value.

On this basis, we recommend that Ofcom consider setting ALF lump sum values at the following levels:

- 900 MHz: The lower of the unadjusted 700 MHz UK benchmark of £14.0m per MHz and 25% above the 1800 / 2100 MHz lump sum value; and
- 1800 and 2100 MHz: A value of around £9.3m per MHz.

6. Annual ALFs should be adjusted using CPI-CPI

In this section, we explore the impact of Ofcom's approach to date of adjusting ALF each year based on UK consumer price inflation (CPI). In recent years, this has led to significant increases in ALF at a time when the value of spectrum worldwide has been falling. Throughout this report, we have presented data that demonstrates that the CPI adjustment has contributed to a material misalignment in prices, with current ALFs for all three bands being too high. We revisit that data here.

Looking forward, the appropriate annual adjustment approach depends on the future path of spectrum prices and general inflation. If spectrum prices were projected to rise, then a CPI adjustment may be appropriate. However, the greater likelihood is that spectrum prices will continue to fall in the period to the next ALF review (which may be 5 years away), albeit with less room to decline than before. Meanwhile, the Bank of England is pursuing a 2% per annum inflation target. In this context, a zero annual adjustment of a conservatively set ALF is appropriate for the near future.

As proposed by Virgin Media O2 in their separate submission on this topic, a zero annual adjustment may be realised by applying CPI-X, with X = CPI. This approach would be compatible with Ofcom's existing methodology, preserving flexibility for the regulator to adopt a different level of X in the future if spectrum price trends and inflationary conditions change.

6.1. Background: a material misalignment in prices

In recent years, high UK inflation has led to significant increases in the levels of ALF paid by MNOs for their holdings in the 900 MHz, 1800 MHz and 2100 MHz bands. In Figure 12, we show the level of annual fees per MHz for each band subject to ALF in each year since their introduction. We observe that annual payments for 900 MHz and 1800 MHz have risen 27% since 2018, and payments for 2100 MHz have risen 21% since 2021.

These constitute significant increases in spectrum spend at a time when MNOs have experienced stagnating revenues and are under pressure to rapidly build out their 5G networks.

Figure 12: UK ALF payments and implied lump sum values, 2018-24

	2018	2019	2020	2021	2022	2023	2024
900 MHz							
Annual fee / MHz (£m)	£1.09	£1.12	£1.13	£1.16	£1.28	£1.36	£1.39
Lump sum value / MHz (£m)	£19.0	£19.5	£19.6	£20.2	£22.2	£23.7	£24.2
% increase vs 2018	**0%**	**3%**	**3%**	**6%**	**17%**	**25%**	**27%**
1800 MHz							
Annual fee / MHz (£m)	£0.81	£0.83	£0.83	£0.86	£0.94	£1.00	£1.03
Lump sum value / MHz (£m)	£14.0	£14.4	£14.4	£14.9	£16.4	£17.4	£17.8
% increase vs 2018	**0%**	**3%**	**3%**	**6%**	**17%**	**25%**	**27%**

2100 MHz				
Annual fee / MHz (£m)	£0.56	£0.58	£0.65	£0.67
Lump sum value / MHz (£m)	£10.5	£11.0	£12.2	£12.7
% increase vs 2021	**0%**	**5%**	**16%**	**21%**

Source: NERA calculations using ALF data from Ofcom, Telefonica UK, and CPI from Office of National Statistics.

In Figure 13, we also show how the implied lump sum value / MHz of each band has evolved based on the increase in annual fees. The implied lump sum value is the estimate of market value that Ofcom would need to identify to support setting ALFs at their given level in each year. For example, Ofcom set ALF for 900 MHz in 2018 at £19.0m / MHz, resulting in an annual fee of £1.09m / MHz. As of 2024, the ALF has increased to £1.39m / MHz, which is equivalent to a market value of £24.2m / MHz.

In Figure 14, we track how Ofcom's actual and implied estimates of UK market value for 900 MHz have evolved since it first consulted on ALF in 2013. We plot the values reported by Ofcom in the 2013 consultation, 2015 decision and the 2018 decision, and in between these reference points, we inflate the value annually based on the relevant UK CPI, following Ofcom's methodology. All values are expressed as an index with the 2013 value set to 100.

We observe that there was a significant downgrade in Ofcom's estimate of market value in 2015 but since then its actual and implied estimates of market value have risen with inflation. Owing to abnormally high UK inflation, prices rose significantly from 2021-22 (9.9%) and 2022-23 (6.7%). As of 2024, the ALF index has climbed to 96.7 from a low of 71.9 in 2016. Unless ALF is corrected in this review, the nominal ALF for 900 MHz is projected to exceed 100% of the 2013 value by 2026.[12]

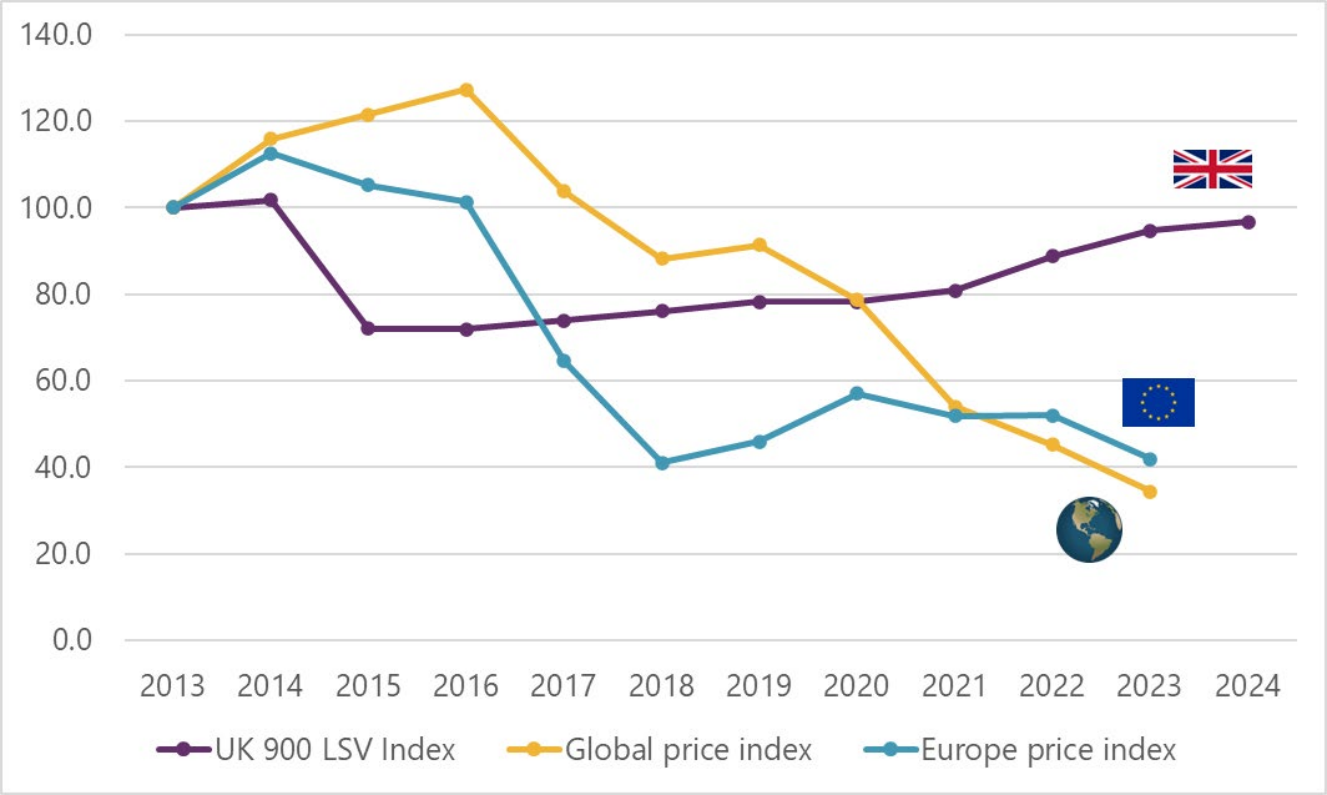
Also in Figure 14, we plot the indices of global prices and European prices (using the same 3-year moving average data as presented in Figure 2 and Figure 3. These indices have fallen substantially over the same period. As of 2024, both indices are at around 40% of their 2013 levels.

It is obvious from comparing the three lines in Figure 14 that the annual CPI adjustment applied to ALF since 2018 has contributed to a gross misalignment between 900 MHz ALFs and the market value of the spectrum. A similar misalignment has occurred with 1800 MHz and 2100 MHz ALF, as these prices have also been inflated over a period when value for lower mid-band spectrum has been falling. Simply put, this is because general prices have been rising over a period when low-band spectrum prices have been falling.

In hindsight, a zero adjustment each year to ALF for all three bands would have been more appropriate than an increase in line with CPI. This would have resulted in a smaller misalignment with spectrum price trends and annual payments today that are closer to fair market values.

[12] Assuming Bank of England target inflation of 2% per annum, the index would rise to 100.6 in 2026.

Figure 14: Indices of sub-1 GHz spectrum prices worldwide and in Europe versus Ofcom's estimate of UK 900 MHz market value



Source: NERA, using benchmark data from UK and selected countries worldwide; Notes: See figures in Section 1 for more information about methodology and source data for European and global indices.

It is also relevant to consider whether the inflation adjustment has, over time, undermined Ofcom's "*conservative approach to interpreting the evidence*" which it adopted to reduce the risk that it sets fees above market value, given associated asymmetric risk. If prices can increase over 20% in five years at the same time as market values for spectrum are falling, then the risk that annual prices move above market value before the next review is material.

6.2. A revised approach is required to prevent future misalignment

When it was first proposed in 2013, the indexing of annual fees to inflation was a less controversial aspect of Ofcom's proposals, with stakeholders broadly aligning on CPI as the preferred measure of inflation. This is unsurprising given that the period when the ALF was set, 2013-2018, was one of low inflation, with prices rising only around 7% over 5 years. There was no expectation at the time of a surge in inflation, so little thought was given to the possibility that CPI adjustment could contribute to a gross misalignment of prices.

We have presented evidence in this paper that CPI adjustment has contributed to a material misalignment of prices between the level of ALF and the market value of the spectrum. It has nevertheless been six years since the 2018 decision. This is not a criticism of Ofcom. The reality is that

the magnitude of misalignment has only recently become clear, as it is challenging to identify trends in spectrum prices given the uneven pace and scale of spectrum awards worldwide, and the UK inflationary surge is a recent event. Looking forward, now we understand this risk better, we think a revised approach is required to prevent a repeated misalignment in the next five years.

The 2024-25 review of ALF provides a unique window for Ofcom to revisit its approach to inflation indexation. No further review is likely this side of 2030, Ofcom's commitment to consider material misalignments notwithstanding. Furthermore, because Ofcom is reviewing all three bands subject to ALF at the same time, the impact of any change can be applied consistently across bands and operators.

In our view, the appropriate annual adjustment should depend primarily on projected trends in spectrum prices for relevant categories of spectrum, and secondarily on expected trends in UK inflation. These are both difficult to predict. However, we are not without information.

Broadly, current expectations are that:

- **Spectrum prices have further to fall.** The market factors that have placed downward pressure on spectrum prices, as described in Section 1.3, appear likely to persist through the rest of the decade. Given how far low-band and lower mid-band prices have already fallen, it seems unlikely that future declines will be as dramatic as in the period from 2015-23, but further modest value decline for all bands may be expected. No new demand or supply shocks are anticipated before 2030. Spectrum is a scarce commodity and historical precedent suggests prices will at some point return to a growth cycle, but there is no evidence to suggest that will happen soon.
- **Inflation is likely to be at least 2% per annum in the near term.** In its current online statement, the Bank of England says: "*We can't predict exactly what will happen to inflation, but we think it is likely to edge up to about 2.5% towards the end of the year before falling again*." [13] The possibility of a further inflationary surge in the next five years linked to disruption in global supply chains cannot be discounted.

Based on these trends, a central case scenario is that an annual inflation adjustment based on CPI would likely contribute to a gradual misalignment of prices. There is a non-negligible risk of a larger decline in spectrum value or an inflation surge that could cause a more material misalignment. The likelihood of misalignment could be reduced by adopting a zero annual adjustment.

6.3. We propose CPI-X for future annual fee adjustments

As discussed in prior sections, Ofcom can address historic price misalignments by resetting ALF prices for the three spectrum bands. For the purposes of its analysis, we proposed that it use nominal benchmark prices rather than inflating benchmarks, and then rely on qualitative analysis (such as

[13] https://www.bankofengland.co.uk/explainers/will-inflation-in-the-uk-keep-rising

putting more weight on more recent benchmarks over older ones) to address the fact that spectrum values have been falling in nominal terms.

This approach will not, however, work on a forward-looking basis, as there is no scope for qualitative judgement outside five-year reviews. Once lump sum values have been set, any annual adjustments must be formulaic and unambiguous. It would also be helpful to identify a methodology that could be easily adjusted in the future, for example, if spectrum prices enter an upward cycle.

In their separate submission on this topic, Virgin Media O2 propose that Ofcom adopt a CPI - X model for annual inflation adjustments. Under this approach, at each review, Ofcom would set a value of X that it thinks is most likely to minimize the risk of misalignment between ALF and the market value of the spectrum.

For the current review, we agree with Virgin Media O2 that it would be appropriate to set X equal to CPI. A CPI - CPI adjustment would deliver a fixed annual profile of fees in nominal terms through 2030. This approach has the same impact as making no annual adjustment while preserving a methodology that allows for future price increases (or decreases) if appropriate. Arguably, a case could be made for a value of X above CPI for the period to 2030, given the projected downward trend in spectrum prices, but owing to the uncertainty regarding the level of future price declines, we think it would be hard to define a value of X that is greater than CPI. Rather, we think that this additional risk is best addressed by Ofcom using its discretion to act conservatively when estimating 2024 market values.

NERA

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NERA
1166 Avenue of the Americas
24th Floor
New York, New York 10036
www.nera.com